Golder Associates Inc.
CONSULTING ENGINEERS

87-20

WORK PLAN FOR RI/FS ACTIVITIES AT THE YEOMAN CREEK AND EDWARDS' FIELD LANDFILLS WAUKEGAN, ILLINOIS VOLUME V OF V APPENDICES D THROUGH G

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APPENDIX D

HEALTH AND SAFETY PLAN

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APPENDIX D

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1.0 GENERAL INFORMATION AND SCOPE OF WORK

This site health and safety plan describes the general procedures that are to be implemented to protect Golder Associates' and subcontractor personnel involved with field activities at the Site during the Remedial Investigation/Feasibility Study. All operations, procedures, and equipment at the Site will meet the requirements of 29 CFR 120, Hazardous Operations and Emergency Response, and applicable subparts of 29 CFR 1926 and 29 CFR 1910. Anticipated principal activities include: fence installation, monitoring well installation, development and testing, leachate well installation and sampling, gas probe installation, groundwater sampling, surface water and sediment sampling, soil sampling, and shallow boring on and around the landfills.

1.1 Designated Safety Personnel

Golder personnel responsible for the health and safety of Golder employees on this project are:

Corporate Health and Safety Officer - William Hager

Project Health and Safety Officer - Joseph Miller

Site Safety Officer (SSO) - Joseph Miller

Project Manager - Ronald Patterson

The Corporate Health and Safety Officer has overall responsibility for establishing appropriate health and safety procedures for the project. The Project Health and Safety Officer is responsible for documenting that the designated procedures are implemented in the field. Employee cooperation is essential to the success of this health and safety program, and employee feedback is encouraged. Health and safety related

suggestions and concerns should be directed to the designated health and safety personnel specified above.

The SSO has the authority to halt work or dismiss people from the Site if they do not adhere to this plan. In addition, the SSO:

- will have received a minimum of 40 hours of hazardous waste site investigation health and safety training, be a participant in the medical surveillance program and be certified to perform first aid/CPR,
- will maintain a field logbook. Information recorded in the logbook will include such items as working hours, names of people entering and leaving the Site, instrument status, background readings, action levels reached or exceeded, and other information relevant to health and safety at the Site, and
- will maintain a list of addresses and telephone numbers of emergency assistance units (ambulance service, police, and hospitals), and will inform other members of the field team of the existence and location of this list.

1.2 Project Communications

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1.3 Personnel Training and Awareness

1.3.1 OSHA Required Training

All Golder Associates and subcontractor personnel involved in the field activities are required to be trained (in accordance with the training requirements specified in 29 CFR 1910.120e) and have baseline medical physicals including determination of serum PCB level as specified in 29 CFR Part 1910 (OSHA Regulations). They are also required to become familiar with and conform to the provisions of this plan.

All Golder Associates and subcontractor personnel who will be working on site will be required to participate in a minimum of one to four hours of site-specific training and a weekly health and safety update meeting.

1.3.2 First Aid Training

The Golder Associates Site Safety Officer should be immediately advised of any situation requiring more than minor first aid. A first aid kit shall be maintained in each of the Golder field vehicles and supplies shall be replenished by the SSO as needed. Personnel aware of accidents or injuries shall take immediate action to ensure that appropriate first aid is administered and report the incident to the SSO. The SSO will be trained in first aid/CPR.

1.4 General Guidelines

The following personal hygiene and work procedures guidelines are intended to prevent injuries and adverse health effects.

These practices establish general precautionary measures for reducing the risks associated with potentially hazardous work at site operations.

- Eating, drinking, chewing gum or tobacco, taking medications, and smoking are prohibited in the work zone.
- Avoid direct contact with potentially contaminated substances; to the extent possible do not walk through puddles, pools and mud; avoid kneeling, leaning, or sitting on the ground, drums or other working equipment. Do not place monitoring or sampling equipment on potentially contaminated surfaces.
- Be alert to potentially changing exposure conditions, including changes in wind direction, perceptible odors, unusual appearances of excavated soils, etc.
- Be alert to fatigue, heat stress and other environmental factors influencing the normal caution and efficiency of personnel.
- On-site personnel shall establish prearranged hand signals or other means of emergency communication when wearing respiratory equipment, since this equipment seriously impairs speech communications.
- Always use an appropriate level of personal protective gear. Lesser levels can result in unnecessary exposure; excessive levels of safety equipment can impair efficiency and increase the potential for accidents to occur.

1.5 Site Safety Meeting

Site safety orientation/training meetings (briefings) must be convened (1) before the field team begins work at the Site; (2) when there are modifications to the Site Health and Safety Plan that are applicable to the field personnel; and (3) when additional personnel or subcontractors begin field work. Meetings will be attended by personnel involved in carrying out the project and will be presided over by the SSO or his/her designee.

The meeting agenda must include the following minimum activities:

- Review the Site Health and Safety Plan with the attendees.
- Distribute any Site Health and Safety Plan modifications.
- Collect the attendees' signatures acknowledging receipt and understanding of the Site Health and Safety Plan and their agreement to comply (Compliance Agreement, Attachment I).

A copy of the signed Compliance Agreement will be filed in the project files.

2.0 POTENTIAL HAZARDS

Available data for the Site indicate that potential chemical hazards are present in the form of source material, contaminated surface water, groundwater, soil, and possibly gases emanating from the landfills. Table D-1 summarizes the available analytical data for the various environmental media. Detailed information on the characteristics and health effects for the target chemicals identified during previous sampling efforts are included in Attachment II. Other hazards and conditions that may be present during field investigations include heat and noise.

2.1 Contaminated Surface Water and Groundwater

Volatile organic constituents (VOCs), semi-volatiles, pesticides, and PCB compounds have been documented in the groundwater, sediment, and surface water samples at the Yeoman Creek Landfill. Some of these compounds pose potential respiratory and/or dermal threats. Although it is anticipated that the concentrations encountered during non-intrusive field activities should not exceed those detected previously, contingency plans have been made in the event that greater concentrations are encountered.

2.2 Contaminated Sediments

All sediments associated with Yeoman Creek and landfill seeps are considered potentially contaminated. Previous sediment sample analyses have detected low ppm concentrations of polynuclear aromatic hydrocarbons (PAHs), pesticides, and PCB compounds (see Table D-1). Sediment contaminants pose a potential dermal hazard. Protective clothing use will eliminate or minimize the potential for exposure to chemical contamination during sediment sampling activities.

2.3 Contaminated Soil

Little information is available about contaminants in soil on and around the Site. Soil samples collected by Warzyn from the baseball fields at the Edwards' Field Landfill showed low concentrations of pesticides and PAHs probably related to lawn care activities. The potential for exposure to compounds in the existing soil will be minimized by appropriate protective clothing. If visible airborne dust exists, or if the humidity is extremely low and ambient conditions are very dry, respiratory protection may be required.

2.4 Landfill Gases

Little information is available regarding the types of gases actually present at the Site. If methane, volatile organic compounds, or toxic gases such as H_2S and HCN are present in the landfill, they may pose a hazard if landfill intrusive activities are conducted. Air monitoring will be conducted and respiratory protection may be required during these activities. The compounds listed below represent chemicals that may be present in landfill gas. These chemicals were chosen as markers on the basis of the previous Illinois EPA site investigation and their tendency to be encountered in landfills.

Chemical	TLV(ppm)	IDLH(ppm)	Health Effects
Methane	NA	NA	Inert asphyxiant. Displaces oxygen. Primarily a combustion hazard.
H_2S	10-8 hr. TWA	300	Chemical asphyxiant. Prevents utilization of oxygen.

Chemical	TLV(ppm)	IDLH(ppm)	Health Effects
HCN	10-ceiling	50	Chemical asphyxiant. Prevents utilization of oxygen.
Benzene	0.1*-8 hr. TWA	NA	Carcinogen - causes leukemia. Central nervous system toxin.
Vinyl Chloride	5-8 hr. TWA	NA	Carcinogen - causes liver angiosarcoma. Liver Toxin. Central nervous system toxin.
Methylene Chloride	50-8 hr. TWA	NA	Carcinogen. Central nervous system toxin.

*Intended change 1990-91

2.5 Landfill Wastes and Leachate

Waste exposed by site activities, if contacted, could pose a potential dermal, respiratory, and physical threat. Consequently, dermal protection and air monitoring will be required during activities in which contact with waste or leachate is a possibility.

Previous leachate sample analyses have detected toluene, dichlorobenzene, and xylenes in significant concentrations. PAHs and PCBs were also detected (see Table D-1). Leachate may be encountered during the field investigation. Exposure to potential dermal and respiratory hazards will be minimized through the use of protective clothing, air monitoring, and respiratory protection, if necessary.

2.6 Heat

If site activities conducted during the summer months require the use of Tyvek coveralls and/or respirators, certain precautions will be required to reduce the likelihood of heat fatigue, heat exhaustion, and heat stroke. Heat stroke, in particular, is a life threatening condition. All employees must be alert to the symptoms of heat exhaustion, which include extreme fatigue, cramps, dizziness, headache, nausea, profuse sweating, and pale clammy skin.

The following are recommended minimum breaks for work performed in protective clothing during hot weather.

Temperature	Work	Rest	Comments
70 to 75 F	3 hours	5 mins	Review heat stress in a safety meeting. Schedule a beverage break every 2 hours at a minimum.
75 to 80 F	3 hours	15 mins	Seated rest. Drink at least 8 ounces at each break. Monitor daily body weight changes. Have at least 10 instant ice packs or bags of ice in first aid kit.
80 to 85 F	2 hrs	10 mins	As above, but rest area to be shaded. Take pulse before work, at beginning of lunch break and at end of day.
85 to 90 F	90 mins	10 mins	As above, and try to provide a shaded work area. More frequent breaks may be required.
above 90 F	90 mins	10 mins	As above. Try to reschedule work to avoid mid-day heat.

2.7 Heavy Machinery and Noise

Heavy machinery will be on site during drilling activities and particular care must be maintained to avoid accidents. The hazard is increased if personal protective gear that reduces mobility is required.

Drilling rigs and other heavy machinery may produce high noise levels. Hearing protection is required in the drillers' position near drill rigs or when in the immediate vicinity of other types of heavy equipment. In addition, hearing protection shall be provided at any time upon request. The effect of occupational exposure to noise is monitored by the Golder Associates' medical surveillance program. The program includes a baseline audiogram and regular audiologic examinations.

Many opportunities for accidents exist while working near drilling rigs. Site personnel should be aware of general hazards that include:

- falling objects or swinging objects suspended from winches;
- drilling hardware breaking and flying free, especially while the rig is operating near its limit;
- exploding hoses;
- slips, trips, and falls on drilling equipment (e.g., augers, etc.).

Each drilling rig and drilling method presents different specific hazards. Drilling rig and drilling method specific hazards will be discussed in the site safety meeting prior to initiating work and/or when a new method or drilling rig will be used at the Site.

3.0 SITE MONITORING AND ACTION LEVELS

3.1 Air Monitoring Procedures and Action Levels for Respiratory Protection

During activities in which atmospheric monitoring is required, an explosive gas meter, a photoionization detector (PID), and colorimetric tubes will be used. Methane is detected with an explosive gas meter and most potentially hazardous volatile organic compounds are readily detectable with a PID instrument equipped with a 10.2 to 10.6 eV lamp. In addition, H_2S and HCN will be monitored with an MSA 361 and colorimetric tubes, respectively.

Direct reading air monitoring instruments will be calibrated daily. Procedures for calibration of the air monitoring instruments are provided in the QAPP, Appendix C, Volume III of the Work Plan.

The frequency for conducting air monitoring is task specific and is indicated in Section 7.0, Task Specific Safety Requirements.

Intrinsically safe instruments will not be required at the Site during activities in which explosive gases may be encountered because personnel performing these activities will not be restricted to confined areas where explosive mixtures of gases could collect. In addition, the action limit for work stoppage and evacuation is an explosive gas concentration of 25 percent of the Lower Explosive Limit (LEL). This action level along with the fact that these activities will be conducted in a large open field will provide appropriate protection against an explosion hazard.

3.2 Action Levels

Respirators will be donned if a PID monitoring instrument calibrated to 100 ppm isobutylene shows:

- an instantaneous peak level that exceeds 25 ppm at the borehole; or
- any reading averaged over a 3.75 minute period that exceeds 10 ppm at the borehole; or
- an instantaneous peak level that exceeds 5 ppm in the breathing zone; or
- any reading averaged over a 3.75 minute period that exceeds background in the breathing zone (measured for a similar 3.75 minute period).

Respirators may be removed once air monitoring indicates respiratory protection is no longer necessary (i.e., the action levels are no longer exceeded).

The work area will be evacuated if any reading averaged over a 3.75 minute period exceeds 5 ppm or any instantaneous peak reading exceeds 15 ppm in the breathing zone.

An MSA 361 combustible gas indicator will be used to monitor for methane, other combustible gases, and hydrogen sulfide. If hydrogen sulfide concentrations exceed 10 ppm in the breathing zone, the work area will be evacuated. The alarm for hydrogen sulfide on the MSA 361 will be set for a maximum of 20 ppm. Work will also be suspended if a combustible gas meter reading greater than 25 percent of the LEL is obtained in the work zone or in the borehole. The MSA 361 will also monitor oxygen levels because combustible gas readings become less reliable if oxygen levels are less than about 19 percent.

If the action levels for donning respirators are exceeded, in addition to donning respirators, monitoring will be conducted

for hydrogen cyanide with colorimetric tubes at the borehole. If a level of hydrogen cyanide in excess of 10 ppm is measured, the work area will be evacuated. If hydrogen cyanide is detected in concentrations less than 10 ppm, employees will be alerted to the characteristic odor and the possible presence of hydrogen cyanide and monitoring will be performed at 15 minute intervals or more frequently if there is any evidence that conditions have changed. If the measurement does not indicate the presence of hydrogen cyanide, monitoring will be discontinued at this location. Monitoring for hydrogen cyanide will resume if there is reason to believe that the amount or type of landfill gases present have changed (e.g., other monitoring shows increasing levels of landfill gases or there is reason to believe that the gas constituents are different).

If the action levels for evacuation of the work area are exceeded, work will be suspended in the immediate vicinity of the borehole for 5 minutes in order to allow the excavation to vent. After the 5 minute venting period, air in the breathing zone will be monitored by a Golder Associates field supervisor wearing a respirator by approaching the hole from the upwind direction. If the PID and the CGI indicate that organic vapor concentrations and combustible gas levels are less than the action levels, work will continue; otherwise, the hole will be allowed to continue to vent for 5 additional minutes and the process will be repeated.

If air monitoring results in the breathing zone continue to exceed the evacuation action limits, supplied air may be used. Supplied air will be used if a PID monitoring instrument calibrated to 100 ppm isobutylene shows:

- any reading averaged over a 3.75 minute period that exceeds 5 ppm in the breathing zone or
- an instantaneous peak level that exceeds 15 ppm in the breathing zone.

Supplied air will also be used if an MSA 361 monitoring instrument measuring hydrogen sulfide in the breathing zone shows:

- a reading averaged over 15 minutes that exceeds 15 ppm or
- an instantaneous reading exceeds 25 ppm.

Supplied air may be discontinued once air monitoring indicates that action levels for supplied air are no longer in exceedance.

During intrusive activities (i.e., perimeter monitoring well installation, landfill gas probe installation, leachate well installation, landfill cap investigation, and waste delineation investigation), air monitoring for explosive gases, volatile organics, and hydrogen sulfide and cyanide will also be conducted downwind of the boring. Air monitoring will be conducted in the downwind direction, between the boring and the perimeter of the Site. Intrusive activities will be stopped temporarily to allow the boring to vent if air monitoring shows:

- an instantaneous peak level that exceeds 5 ppm; or
- any reading averaged over a 3.75 minute period that exceeds background (measured for a similar 3.75 minute period); or
- any hydrogen sulfide reading that exceeds 10 ppm; or
- any hydrogen cyanide reading that exceeds 10 ppm; or
- any combustible gas meter reading that is greater than 25 percent LEL.

If the Site Safety Officer determines that a hazard exists due to airborne dust, respirators will be donned by field personnel.

If significant levels of benzene, lead, and/or vinyl chloride are identified at the Site, requirements in OSHA expanded standards for vinyl chloride (29 CFR 1910. 1017), benzene (29 CFR 1910. 1028), and lead (29 CFR 1910. 1025) will be reviewed and complied with as relevant.

4.0 PERSONAL PROTECTIVE EQUIPMENT

The levels of protection required at the Site may range from Level B-2 through D-3. Figure D-1 provides descriptions of protective equipment levels. The alphabet letters ("B", "C" and "D") refer to respiratory protection. Level B includes supplied air and Level C includes respiratory protection while Level D is used when there is no respiratory hazard. The numeric designations 1, 2 and 3 refer to dermal protection. Level 1 provides the highest dermal protection. The various levels of protection which may be required are described below. The protection levels specific to each work task are specified in Section 7.0.

4.1 Level B-2

Level B-2 protection is required when a potential respiratory and skin contact hazard exists and includes the following equipment:

1. Full face respirator and supplied air (either a SCBA or airline).
2. One piece chemical resistant tyvek (woven fabric) or chemical resistant splash suit (if a splash hazard exists) taped to both the rubber safety boots and gloves.
3. Neoprene gloves - outer (chemical protective).
4. Latex gloves - inner (chemical resistent).
5. Cloth coveralls (long pants and long shirt sleeves).
6. Safety glasses or goggles.
7. Hard hat (face shield if splash hazard exists).
8. Boots (steel toed, chemical protective).
9. Outer disposable boots when required by the SSO.

4.2 Level C-2 and C-3

Level C-2 protection is required when a potential respiratory and skin contact hazard exists and includes the following equipment:

1. Half face or full face air-purifying respirator with organic vapor, acid gas, and dust filter cartridges (OSHA/NIOSH approved).
2. One piece chemical resistant tyvek (woven fabric) or chemical-resistant splash suit (if a splash hazard exists) taped to both the rubber safety boots and gloves.
3. Neoprene gloves - outer (chemical protective).
4. Latex gloves - inner (chemical resistant).
5. Cloth coveralls (long pants and long shirt sleeves).
6. Safety glasses or goggles.
7. Hard hat (face shield if splash hazard exists).
8. Boots (steel toed, chemical protective).
9. Outer disposable boots when required by the SSO.

Level C-3 is identical to Level C-2 except that tyvek coveralls and chemical resistant gloves are not required.

4.3 Level D-2

Level D-2 is to be used when there is no apparent respiratory hazard, but a potential skin contact hazard exists. It includes the following equipment:

1. One piece chemical resistant tyvek (woven fabric) or chemical-resistant splash suit (if a splash hazard exists) over cloth coveralls (long pants and long shirt sleeves) taped to both the rubber safety boots and gloves.

2. Neoprene gloves - outer (chemical protective).
3. Latex gloves - inner (chemical resistant).
4. Safety glasses or goggles.
5. Hard hat (face shield if splash hazard exists).
6. Boots (steel toed, chemical protective).
7. Outer disposable boots when required by the SSO.

4.4 Level D-3

This is the basic work uniform and should be worn only when operations are assessed as presenting no significant potential chemical hazards to personnel. It includes the following equipment.

1. Cloth coveralls (long pants and long shirt sleeves).
2. Safety glasses or goggles.
3. Hard hat.
4. Boots/shoes (steel toed, safety type).
5. Gloves.

5.0 ADDITIONAL SAFETY EQUIPMENT

5.1 Fire Extinguisher

A multipurpose dry chemical fire extinguisher shall be located within each Golder field vehicle. The SSO should be notified of any usage and shall arrange for recharging spent extinguishers.

5.2 Additional Safety Equipment

The following safety equipment will be available at the work site:

- Ear plugs, disposable;
- Medi-flush eyewash station - located within 100 feet of the work area when a splash hazard exists and accessible within 10 seconds;
- First aid kit;
- Barricades and/or barrier tape;
- Dust masks; and
- Hip boots.

6.0 ESTABLISHMENT OF SAFETY ZONES AND ACCESS CONTROL

Access will be controlled within 50 feet of a borehole, soil excavation, well, or decontamination facility when drilling, testing, monitoring, or sampling is occurring. Personnel not authorized by the Golder Associates' SSO will be restricted from entry into the controlled work zone.

When potentially contaminated areas are investigated or soil sampling, monitoring well installation, testing, monitoring and sampling are occurring, safety zones will be established around the work zone as follows:

1. The Contamination (exclusion) Zone will be the area within 10 to 25 feet around a monitoring well, drilled borehole or excavation.

2. The Decontamination (contamination reduction) Zone will be the area from the perimeter of the contamination zone to 50 feet around a monitoring well, drilled borehole or excavation, and within 50 feet of a centralized decontamination facility.

3. The Clean (support) Zone will be the area beyond 50 feet of a monitoring well, drilled borehole or excavation.

Visitors authorized to be on site will not be allowed within the Decontamination and Contamination Zones unless they comply with the safety requirements of this plan.

7.0 TASK SPECIFIC SAFETY REQUIREMENTS

Task specific health and safety requirements are described in the following sections. The Field Sampling Plan, Appendix B, Volume II, describes the activities that will be performed during the field investigation. Unless otherwise specified, action levels as described in Section 3.2 shall be followed for all work tasks. The following table outlines the frequency of air monitoring to be followed during work activities.

	Frequency of Air Monitoring				
Activities	Initially Continuous	15 min.	30 min.	60 min.	Other (see (note)
Waste Delineation	X	X			X
Seep and Sediment Sampling	X	X			X
Landfill Gas Probe Installation	X	X			X
LNAPL Investigation	X	X			X
Drilling and Monitoring Well Installation, Testing, and Sampling	X		X		X
Landfill Cover Characterization	X	X			X
Seep Mapping and Drainage Determination			X		X
Biota Survey and Wetland Investigation					X
Surface Water Sampling	X	X			X
Soil Sampling	X		X		X
Gas Monitoring	X				
Leachate Well Installation and Sampling	X	X			X

NOTE: If consecutive air monitoring results at a given field activity location (e.g., borehole, soil sampling location) indicate stable conditions with concentrations below the action levels, air monitoring will be conducted at unspecified intervals or when a change in condition occurs (i.e., presence of odors or visible evidence of contamination).

7.1 Waste Delineation

Waste delineation drilling may involve direct contact with landfill wastes. The potential for dermal contact with liquid or solid phase contaminants exists. Vapor phase volatile organics or toxic gases such as H_2S and HCN may also be encountered. Air monitoring for organic vapors and combustible gases shall be performed with a PID and MSA 361. The MSA 361 shall be used to monitor for H_2S gas. Colorimetric detector tubes shall be used to monitor for HCN gas. Initial personal protective gear requirements are Level D-2. A ribbon tape wind direction indicator shall be located in view of field personnel.

7.2 Seep and Associated Sediment Sampling

Seep and associated sediment sampling may require field personnel to stand in shallow standing water or water saturated soil. Personal protective gear requirements are Level D-2. Air monitoring for organics will be conducted with a PID and MSA 361 or equivalent combustible gas indicator.

7.3 Landfill Gas Probe Installation, Monitoring, and Sampling

During gas probe installation, personal protective gear levels shall be D-2. Air monitoring for organics shall be conducted with a PID and MSA 361. The MSA 361 shall be used to monitor for H_2S and colorimetric detector tubes will be used to monitor

for HCN. A ribbon tape wind direction indicator shall be located in view of field personnel.

During gas probe monitoring and sampling, Level D-3 personal protective gear shall be required and air monitoring action levels (see Section 3.2) will be followed.

7.4 LNAPL Investigation at Replacement Leachate Wells

Previous sampling efforts at existing IEPA leachate well L307 have indicated a floating oil layer on the leachate. Oil may be present in the replacement leachate monitoring well at L307 or other locations. Well sampling and development activities shall be conducted in Level D-2 personal protective gear. A PID and MSA 361 combustible gas indicator shall be used to monitor for organic vapors and combustible gases. H_2S will be monitored with the MSA 361 and colorimetric detector tubes will be used to monitor for HCN. A ribbon tape wind direction indicator shall be located in view of field personnel.

7.5 Drilling and Monitoring Well Installation, Testing, Monitoring and Sampling

Since many of the new wells may be located in potentially contaminated areas of the Site, Level D-2 personal protective gear and atmospheric monitoring with a PID instrument, an MSA 361 explosive gas meter or equivalent, and colorimetric tubes will be required for personnel involved in the drilling, testing, monitoring, or sampling of wells. A ribbon tape wind direction indicator shall be located in view of field personnel.

7.6 Landfill Cover Characterization

During soil sampling of landfill cover material, field personnel shall use Level D-2 personal protective gear. The PID and MSA 361 or equivalent shall be used to monitor for explosive gases and organic vapors. The MSA 361 shall also be used to monitor for H_2S. A ribbon tape wind direction indicator shall be located in view of field personnel.

7.7 Seep Mapping and Drainage Determination

This task involves walking through the Site and noting the location of seeps and drainage routes. No intrusive activities will be conducted as part of this task. Level D-3 personal protective gear shall be worn and an OVM will be used to monitor the air at seeps.

7.8 Biota Survey and Wetland Investigation

These tasks involve site walkovers and should not require landfill intrusive activities. Personal protective gear shall be Level D-3. Air monitoring shall be conducted only if the SSO deems such monitoring necessary.

7.9 Surface Water Sampling

During sampling of surface water in Yeoman Creek within the perimeter fence, contact with potentially contaminated water or sediment may occur. Level D-2 personal protective gear (hip boots shall be used if water depths are greater than 1.0 foot) and atmospheric monitoring with a PID and MSA 361 or equivalent will be required.

7.10 Soil Sampling

During soil sampling activities, Level D-2 protection will be required as described above, except that Level C protection may be used (upon the discretion of the SSO) if visible airborne dust exists. A PID shall be used for general ambient air screening during surface soil sampling activities.

7.11 Gas Monitoring

This task involves measuring concentrations of volatile organics and combustible gases in ambient air at grid node locations on the Site and possibly entering buildings in the vicinity of the Site to obtain ambient air measurements from the basements. Both ambient air monitoring on the landfill and gas monitoring in building basements will be conducted in level D-3 protective gear.

7.12 Leachate Well Installation and Sampling

This task involves drilling six borings into the Yeoman Creek and Edwards' Field Landfills and subsequently installing leachate monitoring wells. Borings will be drilled through the landfill covers and into waste to depths between 15 and 20 feet using hollow stem auger methods. Drilling borings for leachate wells may require direct contact with landfill wastes. The potential for dermal contact with liquid or solid phase contaminants exists. Vapor phase organics or toxic gases such as H_2S and HCN may also be encountered. Air monitoring for organic vapors and combustible gases shall be performed with a PID and MSA 361. The MSA 361 shall also be used to monitor for H_2S gas. Colorimetric tubes shall be used to monitor for HCN gas. Initial personal protective gear requirements are Level D-2 including splash suits. A ribbon tape wind direction indicator shall be located in view of field personnel.

During drilling and well installation activities, air monitoring will be conducted at the borehole (top of the hollow stems) and in the drillers' breathing zone. While sampling leachate and taking leachate levels, air monitoring will be conducted in the breathing zone and at the well riser. Respirators or supplied air may be required depending on the results of air monitoring.

8.0 DECONTAMINATION PROCEDURES

Decontamination activities will be conducted within the Contamination (exclusion) and Decontamination (contamination reduction) Zones as specified below. The equipment decontamination area for vehicles and drilling rigs at both the Edwards' Field Landfill and the Yeoman Creek Landfill will be covered with a layer of gravel or aggregate.

8.1 Equipment Decontamination

Drilling equipment and soil, water or sediment sampling equipment are to be decontaminated within the boundaries of the Decontamination Zone at each work site. Decontamination shall be in accordance with procedures defined in the Field Sampling Plan (Appendix B, Volume II).

8.2 Personnel Decontamination

Decontamination will be conducted in steps along a contamination reduction corridor. A typical decontamination layout for Level C protection along a corridor is illustrated in Figure D-2. After working in lower levels of dermal protective equipment (i.e., Level B or C), personnel will remove protective equipment and clothing in the following order:

- outer protective gloves (if applicable);
- tyvek or saranex suit;
- any respiratory protection;
- inner protective gloves.

Before removing rubber boots, they will be washed off in a tub of soapy water and rinsed in at tub of clean water.

Fewer steps would be required for Level D protective equipment. Disposable personal protective equipment (i.e., gloves, tyveks, saranex suits) that are not grossly contaminated will be decontaminated with soapy water and rinsed in clean water in the decontamination zone and temporarily stored in the secure storage area for subsequent disposal as general refuse. If any grossly contaminated personal protective equipment is generated, it will be drummed and stored in the secure storage compound at the respective landfill as discussed in the Field Sampling Plan, Appendix B, Volume II. Prior to entering the Clean Zone, all disposable personal safety equipment must be removed and decontaminated in the Decontamination Zone.

9.0 CONTINGENCY AND EMERGENCY RESPONSE PLANS

9.1 Emergency Procedures

The following contingency plans have been developed to deal with major incidents that might occur during field activities. Golder employees and subcontractors should familiarize themselves with the location of the nearest phone and the designated medical facilities. The location of the St. Therese Hospital is shown on Figure D-3, together with the shortest route from the Site to the hospital. The route is as follows:

1. Take Lewis Ave south to Washington St.
2. Turn right (west) onto Washington St.
3. Travel west on Washington St. approximately 6 blocks to St. Therese Hospital.

A copy of the "List of Emergency Telephone Numbers" (Section 9.6), is to be posted adjacent to the nearest phone. Contingency response plans will be reviewed with on-site personnel weekly to promote timely implementation of the contingency plan should one of the events described in the following section occur.

9.2 Medical Emergency Response Plan

Should any person visiting or working at the Site be injured or become ill, notify the SSO and initiate the following emergency response plan:

Note: The anticipated nature of chemical contamination on this project does not present an immediate threat to human health. Other than removal of outer garments and gross contamination, immediate emergency treatment of injuries should take precedence over rigorous personal decontamination.

1. If able, the injured person should proceed to the nearest available source of first aid. Remove soiled outer garments and if necessary, wash the injured area with soap and water.

   If the injury involves foreign material in the eyes, immediately flush the eyes with emergency eye wash solution, and rinse with copious amounts of water at the nearest emergency eye wash station. Obtain or administer first aid as required. If further medical treatment is required, seek medical assistance as discussed below.

2. If the victim is unable to walk, but is conscious and there is no evidence of spinal injury, escort or transport the injured person to the nearest first aid facility. If the victim cannot be moved without causing further injury, such as in the case of a severe compound fracture, take necessary emergency steps to control bleeding and immediately call for medical assistance as discussed below.

   If the victim is unconscious or unable to move, Do Not Move The Injured person Unless Absolutely Necessary to Save His Or Her Life, until the nature of the injury has been determined.

   If there is any evidence of spinal injury, do not move the victim. Administer CPR if the victim is not breathing, control severe bleeding and immediately contact the St. Therese Hospital Emergency Room (708/249-3900) and advise them of the situation. Otherwise seek medical assistance as discussed below.

3. If further medical treatment is required and

   a. The injury is not severe, contact the St. Therese Hospital and take the injured party to the hospital by private automobile.

   b. The injury is severe, immediately call paramedics (708/623-2121). In the interim, call the St. Therese Hospital Emergency Room and advise them of the situation.

4. The SSO will accompany the injured person to the hospital to ensure prompt and proper medical attention. After proper medical treatment has been obtained, the SSO should notify the Health and Safety Officer and prepare a written report.

9.3 Fire and Explosions

Prior to initiating field work at the Site, the local fire company will be informed of the contaminants that may be present at the Site to facilitate their response to an emergency situation at the Site. In the event of a fire or explosion:

1. If the situation is readily controllable with available resources, take immediate action to do so. If not:
2. Clear the area of personnel working in the immediate vicinity.
3. Immediately notify the designated SSO.

The designated SSO will initiate the following steps or procedures:

1. Make an initial assessment to determine whether the situation is controllable.
2. If the situation is controllable, dispatch fire fighting equipment to the Site of the fire and take immediate action.
3. If not controllable immediately, notify the local Fire Department (dial 708/623-2121) and evacuate all nonessential personnel from the Site.
4. Notify the Project Health and Safety Officer.
5. Notify the U.S. EPA RPM.

Under the direction of the designated SSO immediate action of the response personnel involves:

1. Isolating the fire to prevent spreading if possible.
2. Attempting to put the fire out using methods compatible with the burning material.

Golder personnel will remain at the scene of the fire until the local fire department arrives. Once professional fire fighting personnel have arrived, Golder personnel will remain at the disposal of the battalion chief. The Health and Safety Officer will function as liaison between response personnel in the incident.

9.4 Accident/Incident Reports

A health and safety incident report shall be prepared if incidents such as the following occur:

- Illness;
- Injury;
- Fire, explosion;
- Vehicular accident;
- Property damage;
- Unexpected exposure; or
- Health and safety infraction.

The report will provide a description of the incident, its possible cause, individuals involved, witnesses, and emergency or corrective actions taken. The report will be delivered to the Corporate Health and Safety Officer within one day if the incident involves medical treatment and five days for other incidents.

9.5 Unforseen Circumstances

The Health and Safety procedures specified in this plan are based on available data which suggest minimal potential for worker exposure to significant levels of hazardous substances. Should substantially higher levels of contamination be

encountered in the soil or groundwater, or should situations arise which are obviously beyond the scope of the monitoring, respiratory protection and decontamination procedures specified, work activities shall be modified or, if necessary halted pending discussion with the Golder Associates Health and Safety Officer and implementation of appropriate protective measures.

9.6 List of Emergency Telephone Numbers

Police and Fire Department	(708) 623-2121
Hospital: St. Therese Hospital, 2615 Washington, Waukegan, Illinois	(708) 249-3900
Ambulance: Ambulance Service	(708) 623-2121
Lake County Emergency Service and Disaster Agency: 24 hr number	 (708) 680-7735 (708) 680-3550
EPA Emergency Response: Region V Response Regional Office (Richard Boice)	 (201) 321-6660 (312) 886-4740
IEPA: Project Manager - Julia Carter	(217) 785-7491
Project Health and Safety: Joseph Miller	(708) 357-2066

(26010912.WP1/cap)

TABLE D-1

SAMPLE ANALYSIS, YEOMAN CREEK LANDFILL, WAUKEGAN, ILLINOIS
ORGANIC COMPOUNDS DETECTED IN SAMPLE MEDIA

SAMPLED MEDIA	LEACHATE (MG/L)	GROUNDWATER (MG/L)	STREAM WATER (UG/L)	SEDIMENT (MG/KG)
VOLATILE ORGANIC COMPOUNDS				
METHYLENE CHLORIDE	---	U	---	0.102-0.135
TOLUENE	0.65-1.7	U	---	0.046
TETRACHLOROETHENE	---	U	---	0.0032
CHLOROBENZENE	---	U	---	0.0054
DICHLOROBENZENE	0.11-15	U	---	---
TETRACHLOROBENZENE	---	U	---	0.003
STYRENE	---	U	---	0.0078
XYLENES (TOTAL)	0.28-470	U	---	0.0067
SEMI-VOLATILE ORGANIC COMPOUNDS				
PHENANTHRENE	---	---	---	0.755-1.380
ANTHRACENE	---	---	---	0.421
DI-N-BUTYL PHTHALATE	---	---	---	1.530-3.430
FLUORANTHENE	---	---	---	0.265-4.020
PYRENE	---	---	---	0.494-1.580
BUTYL BENZYL PHTHALATE	---	---	---	0.355
CHRYSENE	---	---	---	0.363-1.060
BENZO (A) ANTHRACENE	---	---	---	0.614
BIS (2-ETHYL HEXYL) PHTHALATE	---	---	---	0.189-2.280
DI-N-OCTYL PHTHALATE	---	---	---	0.377
BENZO (B & K) FLUORANTHENE	---	---	---	0.246-1.460
BENZO (A) PYRENE	---	---	---	0.61-1.12
INDENO (123-CD) PYRENE	---	---	---	0.581
NAPHTHALENE	0.02-0.11	---	---	---
METHYLNAPHTHALENE	0.065-0.28	---	---	---
DIMETHYLNAPHTHALENE	0.15	---	---	---
PESTICIDE AND PCB COMPOUNDS				
BETA-BHC	---	---	---	0.39
DELTA-BHC	---	---	---	0.02-2.01
4, 4'-DDE	---	---	---	0.018-0.112
4, 4'-DDT	---	---	---	0.16
PCB	0.087-150	<0.0001-0.0023	<0.1-23	0.763-2.620

NOTES:
--- NO INFORMATION AVAILABLE.
U INDICATES ANALYTE RESULT IS LESS THAN THE INSTRUMENT DETECTION LIMIT.

(26011429.wp1/emp)

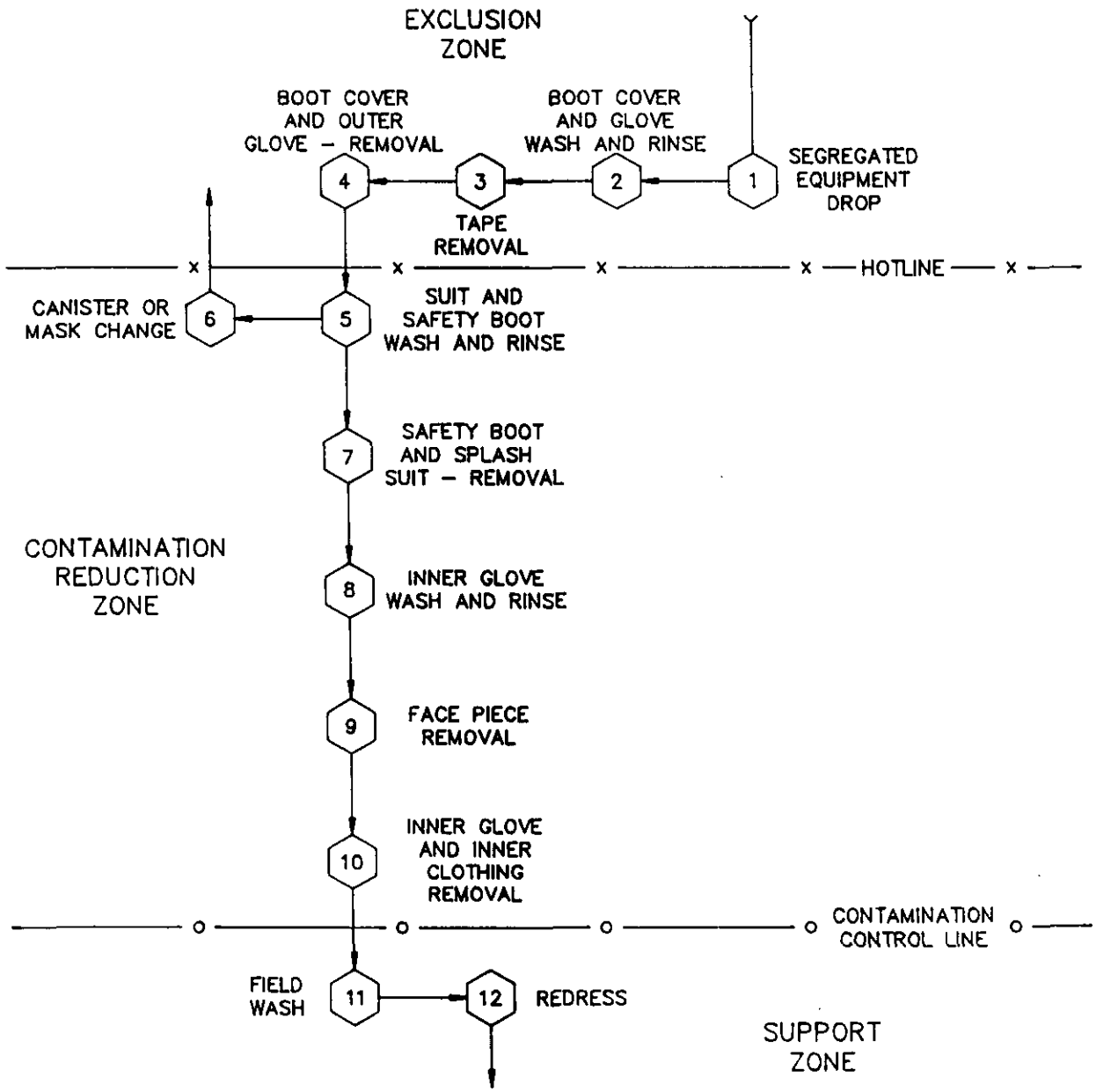
	Category 3	Category 2	Category 1
Level D	Hard Hat Safety Glasses Safety Boots Cloth Coveralls Work Gloves	Hard Hat Safety Glasses Rubber Safety Boots Outer Disposable Boots Cloth Coveralls Tyvek Coveralls Latex Inner Gloves Neoprene Outer Gloves	Hard Hat Safety Glasses Inner Rubber Safety Boots Outer Disposable Boots Cloth Coveralls Tyvek Inner Coveralls Saranex Outer Coveralls Latex Inner Gloves Neoprene Outer Gloves
Level C	Hard Hat Safety Glasses Safety Boots Cloth Coveralls Work Gloves Air Purifying Respirator	Hard Hat Safety Glasses Rubber Safety Boots Outer Disposable Boots Cloth Coveralls Tyvek Coveralls Latex Inner Gloves Neoprene Outer Gloves Air Purifying Respirator	Hard Hat Safety Glasses Inner Rubber Safety Boots Outer Disposable Boots Cloth Coveralls Tyvek Inner Coveralls Saranex Outer Coveralls Latex Inner Gloves Neoprene Outer Gloves Air Purifying Respirator
Level B	Hard Hat Safety Glasses Safety Boots Cloth Coveralls Work Gloves Supplied Air Respirator	Hard Hat Safety Glasses Rubber Safety Boots Outer Disposable Boots Cloth Coveralls Tyvek Coveralls Latex Inner Gloves Neoprene Outer Gloves Supplied Air Respirator	Hard Hat Safety Glasses Inner Rubber Safety Boots Outer Disposable Boots Cloth Coveralls Tyvek Inner Coveralls Saranex Outer Coveralls Latex Inner Gloves Neoprene Outer Gloves Supplied Air Respirator

INCREASING RESPIRATORY PROTECTION ↓

INCREASING DERMAL PROTECTION →

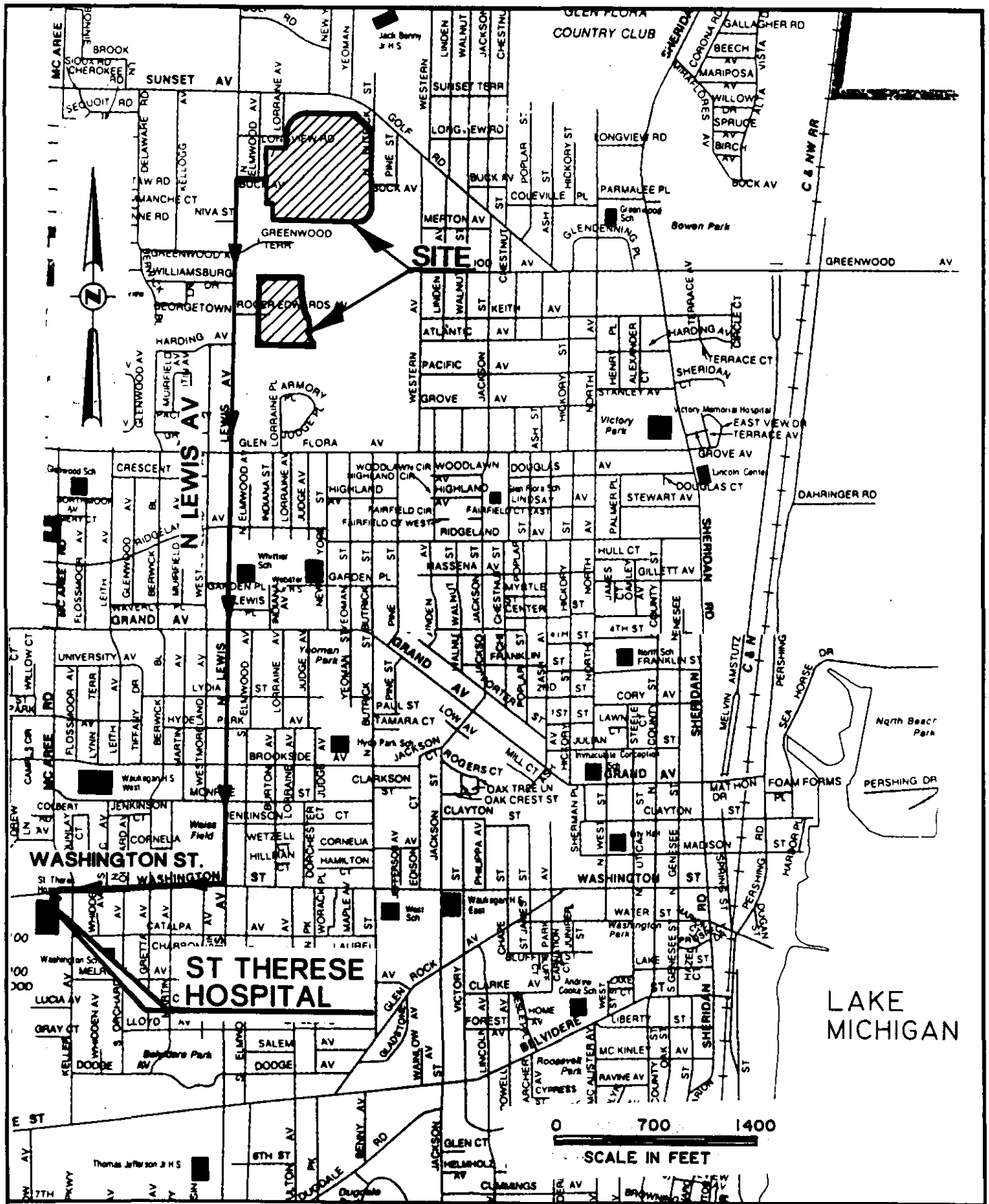
CLIENT/PROJECT			Golder Associates, Chicago, Illinois		TITLE		
PRP/YEOMAN/ILLINOIS					LEVELS OF PERSONAL PROTECTIVE EQUIPMENT		
DRAWN TPK	CHECKED ALA	REVIEWED	DATE 1-24-91	SCALE N.T.S.	JOB NO. 893-8026.01	FILE NO. 893-8026.01	DWG. NO./REV. NO. 49	FIGURE D-1

Decontamination Layout
Level C Protection



NOTE : EACH ITEM SHOULD BE WASHED, RINSED, OR REMOVED IN ORDER OF APPEARANCE IN EACH STEP.

Golder Associates Chicago, Illinois			TITLE DECONTAMINATION LAYOUT LEVEL C PROTECTION		
CLIENT/PROJECT PRP/YEOMAN/ILLINOIS			DATE 1-24-91	SCALE N.T.S.	JOB NO. 893-8026.01
DRAWN TPK	CHECKED AJA	REVIEWED JDM	FILE NO. 893-8026.01	DWG. NO / REV. NO. 42	FIGURE D-2



Golder Associates
Chicago, Illinois

CLIENT/PROJECT
PRP/YEOMAN/ILLINOIS

TITLE
EMERGENCY ROUTE TO HOSPITAL

DRAWN	CHECKED	REVIEWED
TPK	ALA	JTM

DATE	SCALE	JOB NO.
1-24-91	AS SHOWN	893-8026.01
FILE NO. 893-8026.01	DWG. NO / REV. NO.	FIGURE D-3

FDC DRAFTING AIDES 521106

ATTACHMENT I

HEALTH AND SAFETY BRIEFING AND COMPLIANCE AGREEMENT

ATTACHMENT I

HEALTH AND SAFETY COMPLIANCE AGREEMENT

Project Number: _____ Project Title: _____

Site Name: _____ Site Location: _____

Project Manager: _____ Date of Plan: _____

I, the undersigned, have received a copy of the health and safety plan prepared by Golder Associates Inc. for the project identified above. I have read the plan, understand it, have attended a safety briefing, and agree to comply with all of the health and safety requirements contained in the plan. I understand that I may be prohibited from working on the project for violating any of the requirements.

COMPANY	NAME	SIGNATURE	DATE

ATTACHMENT II

OCCUPATIONAL HEALTH GUIDELINES

Occupational Health Guideline for Ammonia

INTRODUCTION

This guideline is intended as a source of information for employees, employers, physicians, industrial hygienists, and other occupational health professionals who may have a need for such information. It does not attempt to present all data; rather, it presents pertinent information and data in summary form.

SUBSTANCE IDENTIFICATION

- Formula: NH_3
- Synonyms: Anhydrous ammonia
- Appearance and odor: Colorless gas with a penetrating, pungent, suffocating odor; it can be a liquid under pressure.

PERMISSIBLE EXPOSURE LIMIT (PEL)

The current OSHA standard for ammonia is 50 parts of ammonia per million parts of air (ppm) averaged over an eight-hour work shift. This may also be expressed as 35 milligrams of ammonia per cubic meter of air (mg/m³). NIOSH has recommended that the permissible exposure limit be changed to a ceiling of 50 ppm ammonia (35 mg/m³) averaged over a five-minute period. The NIOSH Criteria Document for Ammonia should be consulted for more detailed information.

HEALTH HAZARD INFORMATION

- **Routes of exposure**

Ammonia can affect the body if it is inhaled or if it comes in contact with the eyes or skin. It may also affect the body if it is swallowed.

- **Effects of overexposure**

1. Short-term Exposure: Ammonia is a severe irritant of the eyes, respiratory tract, and skin. It may cause burning and tearing of the eyes, runny nose, coughing, chest pain, cessation of respiration, and death. It may cause severe breathing difficulties which may be delayed in onset. Exposure of the eyes to high gas concentrations may produce temporary blindness and severe eye damage. Exposure of the skin to high concentrations of the gas may cause burning and blistering of the skin. Contact with liquid ammonia may produce severe eye and skin burns. Contact of the eyes, nose, throat, and skin with solutions of ammonia may produce severe burns.

2. Long-term Exposure: Repeated exposure to ammonia gas may cause chronic irritation of the eyes and upper respiratory tract.

3. Reporting Signs and Symptoms: A physician should be contacted if anyone develops any signs or symptoms and suspects that they are caused by exposure to ammonia.

- **Recommended medical surveillance**

The following medical procedures should be made available to each employee who is exposed to ammonia at potentially hazardous levels:

—A complete history and physical examination: The purpose is to detect pre-existing conditions that might place the exposed employee at increased risk, and to establish a baseline for future health monitoring. Examination of the eyes and respiratory tract should be stressed. The skin should be examined for evidence of chronic disorders.

—14" x 17" chest roentgenogram: Ammonia causes human lung damage. Surveillance of the lungs is indicated.

—FVC and FEV (1 sec): Ammonia is a respiratory irritant. Persons with impaired pulmonary function may be at increased risk from exposure. Periodic surveillance is indicated.

2. Periodic Medical Examinations: The above medical examinations should be repeated on an annual basis, except that an x-ray is necessary only when indicated by the results of pulmonary function testing, or by signs and symptoms of respiratory disease.

- **Summary of toxicology**

Ammonia vapor is a severe irritant of the eyes, especially the cornea, the respiratory tract, and skin. Inhalation of concentrations of 2500 to 6500 ppm causes dyspnea.

These recommendations reflect good industrial hygiene and medical surveillance practices and their implementation will assist in achieving an effective occupational health program. However, they may not be sufficient to achieve compliance with all requirements of OSHA regulations.

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Public Health Service Centers for Disease Control
National Institute for Occupational Safety and Health

U.S. DEPARTMENT OF LABOR
Occupational Safety and Health Administration

September 1978

bronchospasm, chest pain and pulmonary edema which may be fatal; production of pink frothy sputum often occurs. Consequences can include bronchitis or pneumonia; some residual reduction in pulmonary function has been reported. In a human experimental study which exposed 10 subjects to various vapor concentrations for 5 minutes, 134 ppm caused irritation of the eyes, nose, and throat in most subjects and 1 person complained of chest irritation; at 72 ppm, several reported the same symptoms; at 50 ppm, 2 reported nasal dryness and at 32 ppm only 1 reported nasal dryness. In a survey of 8 workers in a blueprint shop, ammonia concentrations of 4 to 29 ppm caused "barely noticeable" to "moderate" eye irritation; no respiratory irritation was reported. Tolerance to usually irritating concentrations of ammonia may be acquired by adaptation, a phenomenon frequently observed among workers who became inured to the effects of exposure; no data are available on concentrations that are irritating to workers who are regularly exposed to ammonia and who presumably have a higher irritation threshold. Liquid anhydrous ammonia in contact with the eyes may cause serious eye injury or blindness; on the skin it causes first- and second-degree burns which are often severe, and if extensive, may be fatal. Vapor concentrations of 10,000 ppm are mildly irritating to the moist skin, while 30,000 ppm or greater causes a stinging sensation and may produce skin burns and vesiculation. Increased cancer has been reported in workers exposed to high levels of ammonia and amines, although lack of details makes evaluation difficult.

CHEMICAL AND PHYSICAL PROPERTIES

- **Physical data**
  1. Molecular weight: 17
  2. Boiling point (760 mm Hg): −33.4 C (-28 F)
  3. Specific gravity (water = 1): Liquid 0.67 at boiling point
  4. Vapor density (air = 1 at boiling point of ammonia): 0.6
  5. Melting point: −77.7 C (-108 F)
  6. Vapor pressure at 20 C (68 F): Greater than 1 atmosphere
  7. Solubility in water, g/100 g water at 20 C (68 F): .51
  8. Evaporation rate (butyl acetate = 1): Not applicable
- **Reactivity**
  1. Conditions contributing to instability: Elevated temperatures may cause containers to explode.
  2. Incompatibilities: Contact with strong oxidizers may cause fires and explosions. Contact with calcium, hypochlorite bleaches, gold, mercury, and silver may form highly explosive products. Contact with halogens may cause violent spattering.
  3. Hazardous decomposition products: None.
  4. Special precautions: Liquid ammonia will attack some forms of plastics, rubber, and coatings.
- **Flammability**
  1. Flash point: Not applicable
  2. Autoignition temperature: 651 C (1204 F)
  3. Flammable limits in air, % by volume: Lower: 16; Upper: 25
  4. Extinguishant: Stop flow of gas.
- **Warning properties**
  1. Odor Threshold: The AIHA *Hygienic Guide* states that "ammonia is a colorless gas with a characteristic odor detectable at 1 to 5 ppm."
  2. Eye Irritation Level: Grant states that "ammonia is slightly irritant to human eyes at a concentration of 140 ppm in air and immediately irritating at 700 ppm."
  3. Other Information: The *Hygienic Guide* states that "irritation of the respiratory tract in workers inhaling 100 ppm has been found, but 55 ppm was unobjectionable."
  4. Evaluation of Warning Properties: Because of its low thresholds of odor and irritation, ammonia is treated as a material with good warning properties.

MONITORING AND MEASUREMENT PROCEDURES

- **Eight-Hour Exposure Evaluation**

Measurements to determine employee exposure are best taken so that the average eight-hour exposure is based on a single eight-hour sample or on two four-hour samples. Several short-time interval samples (up to 30 minutes) may also be used to determine the average exposure level. Air samples should be taken in the employee's breathing zone (air that would most nearly represent that inhaled by the employee).

- **Ceiling Evaluation**

Measurements to determine employee ceiling exposure are best taken during periods of maximum expected airborne concentrations of ammonia. Each measurement should consist of a fifteen (15) minute sample or series of consecutive samples totalling fifteen (15) minutes in the employee's breathing zone (air that would most nearly represent that inhaled by the employee). A minimum of three (3) measurements should be taken on one work shift and the highest of all measurements taken is an estimate of the employee's exposure.

- **Method**

Sampling and analyses may be performed by collection of vapors using an adsorption tube with a subsequent chemical analysis of the adsorption tube. Also, detector tubes certified by NIOSH under 42 CFR Part 84 or other direct-reading devices calibrated to measure ammonia may be used. An analytical method for ammonia is in the *NIOSH Manual of Analytical Methods*, 2nd Ed., Vol. 5, 1979, available from the Government Printing Office, Washington, D.C. 20402 (GPO No. 017-033-00349-1).

• Good industrial hygiene practices recommend that engineering controls be used to reduce environmental concentrations to the permissible exposure level. However, there are some exceptions where respirators may be used to control exposure. Respirators may be used when engineering and work practice controls are not technically feasible, when such controls are in the process of being installed, or when they fail and need to be supplemented. Respirators may also be used for operations which require entry into tanks or closed vessels, and in emergency situations. If the use of respirators is necessary, the only respirators permitted are those that have been approved by the Mine Safety and Health Administration (formerly Mining Enforcement and Safety Administration) or by the National Institute for Occupational Safety and Health.
• In addition to respirator selection, a complete respiratory protection program should be instituted which includes regular training, maintenance, inspection, cleaning, and evaluation.

PERSONAL PROTECTIVE EQUIPMENT

• Employees should be provided with and required to use impervious clothing, gloves, face shields (eight-inch minimum), and other appropriate protective clothing necessary to prevent any possibility of skin contact with liquid anhydrous ammonia or aqueous solutions of ammonia containing more than 10% by weight of ammonia and to prevent the skin from becoming frozen from contact with vessels containing liquid anhydrous ammonia.
• Employees should be provided with and required to use impervious clothing, gloves, face shields (eight-inch minimum), and other appropriate protective clothing necessary to prevent repeated or prolonged skin contact with solutions containing 10% or less by weight of ammonia.
• Where there is any possibility of exposure of an employee's body to liquid anhydrous ammonia or aqueous solutions containing more than 10% ammonia by weight, facilities for quick drenching of the body should be provided within the immediate work area for emergency use.
• Non-impervious clothing which becomes contaminated with anhydrous ammonia or aqueous solutions containing more than 10% ammonia by weight should be removed immediately and not reworn until the ammonia is removed from the clothing.
• Non-impervious clothing which becomes wet with solutions containing 10% ammonia by weight or less should be removed promptly and not reworn until the ammonia is removed from the clothing.
• Clothing wet with liquid anhydrous ammonia or aqueous solutions of ammonia should be placed in closed containers for storage until it can be discarded or until provision is made for the removal of ammonia otherwise cleaned to remove the ammonia, the person performing the operation should be informed of ammonia's hazardous properties.
• Employees should be provided with and required to use splash-proof safety goggles where there is any possibility of liquid anhydrous ammonia or aqueous solutions containing more than 10% ammonia by weight contacting the eyes.
• Employees should be provided with and required to use splash-proof safety goggles where solutions containing 10% ammonia by weight or less may contact the eyes.
• Where there is any possibility that employees' eyes may be exposed to liquid anhydrous ammonia or aqueous solutions containing more than 10% ammonia by weight, an eye-wash fountain should be provided within the immediate work area for emergency use.

SANITATION

• Skin that becomes contaminated with liquid anhydrous ammonia or solutions containing more than 10% ammonia by weight should be immediately washed or showered to remove any ammonia.
• Skin that becomes wet with solutions containing 10% ammonia by weight or less should be promptly washed or showered to remove any ammonia.
• Employees who handle liquid anhydrous ammonia or aqueous solutions of ammonia should wash their hands thoroughly before eating, smoking, or using toilet facilities.

COMMON OPERATIONS AND CONTROLS

The following list includes some common operations in which exposure to ammonia may occur and control methods which may be effective in each case:

Operation	Controls
Use as a chemical in manufacture of fertilizers, as solvent in manufacture of textiles, leather, and pulp and paper processing; as a stabilizer in rubber manufacture	Process enclosure; local exhaust ventilation; general dilution ventilation; personal protective equipment

Use in organic and inorganic synthesis of nitric acid, urea, plastics, fibers, synthetic resins, pharmaceuticals, pesticides, explosives, rocket fuels, cyanides, amides, dyestuffs, amines, flame retardants, and household cleaners	Process enclosure; local exhaust ventilation; personal protective equipment
Use in mining/ metallurgy ore extraction and purification, treatment of scrap metal, annealing, atomic hydrogen welding, electronics, nitriding steel	Local exhaust ventilation; general dilution ventilation; personal protective equipment
Use in petroleum refining as a neutralizing agent; manufacture and recovery of cracking catalysts; and in dewaxing of lubrication oils	Process enclosure; local exhaust ventilation; personal protective equipment
Use as a refrigerant in food installations, production of ice, cold-storage, food lockers, deicing	Local exhaust ventilation; general dilution ventilation; personal protective equipment
Use during blueprinting and photography, electroplating, and as a laboratory reagent	Local exhaust ventilation; general dilution ventilation; personal protective equipment

EMERGENCY FIRST AID PROCEDURES

In the event of an emergency, institute first aid procedures and send for first aid or medical assistance.

- **Eye Exposure**

If liquid anhydrous ammonia, solutions containing ammonia, or high concentrations of ammonia gas get into the eyes, wash eyes immediately with large amounts of water, lifting the lower and upper lids occasionally. Get medical attention immediately. Contact lenses should not be worn when working with this chemical.

- **Skin Exposure**

If liquid anhydrous ammonia, strong solutions of ammonia, or high concentrations of ammonia gas get on the skin, immediately flush the contaminated skin with water. If liquid anhydrous ammonia, strong solutions of ammonia gas penetrate through the clothing, remove the clothing immediately and flush the skin with water. If irritation or burns are present after washing, get medical attention.

- **Breathing**

If a person breathes in large amounts of ammonia, move the exposed person to fresh air at once. If breathing has stopped, perform artificial respiration. Keep the affected person warm and at rest. Get medical attention as soon as possible.

- **Swallowing**

When ammonia has been swallowed and the person is conscious, give the person large quantities of water immediately to dilute the ammonia. Do not attempt to make the exposed person vomit. Get medical attention immediately.

- **Rescue**

Move the affected person from the hazardous exposure. If the exposed person has been overcome, notify someone else and put into effect the established emergency rescue procedures. Do not become a casualty. Understand the facility's emergency rescue procedures and know the locations of rescue equipment before the need arises.

SPILL AND LEAK PROCEDURES

- Persons not wearing protective equipment and clothing should be restricted from areas of spills or leaks until cleanup has been completed.
- If ammonia is spilled or leaked, the following steps should be taken:

1. Ventilate area of spill or leak to disperse gas.
2. If in gaseous form, stop flow of gas. If source of leak is a cylinder and the leak cannot be stopped inplace, remove the leaking cylinder to a safe place in the open air, and repair the leak or allow the cylinder to empty.
3. If in liquid form, allow to vaporize.

REFERENCES

- American Conference of Governmental Industrial Hygienists: "Ammonia," *Documentation of the Threshold Limit Values for Substances in Workroom Air* (3rd ed., 2nd printing), Cincinnati, 1974.
- American Industrial Hygiene Association: "Ammonia," *Hygienic Guide Series*, Detroit, Michigan, 1971.
- Deichmann, W. B., and Gerarde, H. W.: *Toxicology of Drugs and Chemicals*, Academic Press, New York, 1969.
- Gleason, M. N., Gosselin, R. E., Hodge, H. C., and Smith, R. P.: *Clinical Toxicology of Commercial Products* (3rd ed.), Williams and Wilkins, Baltimore, 1969.
- Grant, W. M.: *Toxicology of the Eye* (2nd ed.), C. C. Thomas, Springfield, Illinois, 1974.
- "Exposure to Ammonia, Proposed Standards," *Federal Register*, 40:54684-54693, November 25, 1975.

Occupational Health Guideline for Fluoride Dust (as Fluoride)

INTRODUCTION

This guideline is intended as a source of information for employees, employers, physicians, industrial hygienists, and other occupational health professionals who may have a need for such information. It does not attempt to present all data; rather, it presents pertinent information and data in summary form.

APPLICABILITY

The general guidelines contained in this document apply to all fluoride. Physical and chemical properties of several specific compounds are provided for illustrative purposes.

SUBSTANCE IDENTIFICATION

Sodium fluoride

- Formula: NaF
- Synonyms: None
- Appearance and odor: Colorless or blue, odorless solid.

Cryolite (sodium hexafluoroaluminate)

- Formula: Na_3AlF_6
- Synonyms: Sodium hexafluoroaluminate
- Appearance and odor: Colorless to dark, odorless solid.

PERMISSIBLE EXPOSURE LIMIT (PEL)

The current OSHA standard for fluoride is 2.5 milligrams of fluoride per cubic meter of air (mg/m^3) averaged over an eight-hour work shift. NIOSH has recommended that the permissible exposure limit be changed to 2.5 mg/m^3 averaged over a work shift of up to 10 hours per day, 40 hours per week. The NIOSH Criteria Document for Inorganic Fluorides should be consulted for more detailed information.

HEALTH HAZARD INFORMATION

- **Routes of exposure**

Fluoride can affect the body if it is inhaled or if it comes in contact with the eyes or skin. It can also affect the body if it is swallowed.

- **Effects of overexposure**

1. Short-term Exposure: Fluoride containing dust may cause irritation of the eyes and respiratory tract. Swallowing fluoride may cause a salty or soapy taste, vomiting, abdominal pain, diarrhea, shortness of breath, difficulty in speaking, thirst, weakness of the pulse, disturbed color vision, muscular weakness, convulsions, loss of consciousness, and death. Kidney injury and bleeding from the stomach may occur.

2. Long-term Exposure: Repeated exposure to fluoride containing dust may cause excessive calcification of the bone and calcification of ligaments of the ribs, pelvis, and spinal column. Stiffness and limitation of motion may result. Repeated or prolonged exposure of the skin to fluoride containing dust may cause a skin rash.

3. Reporting Signs and Symptoms: A physician should be contacted if anyone develops any signs or symptoms and suspects that they are caused by exposure to fluoride.

- **Recommended medical surveillance**

The following medical procedures should be made available to each employee who is exposed to fluoride at potentially hazardous levels:

1. Initial Medical Examination:

—A complete history and physical examination: The purpose is to detect pre-existing conditions that might place the exposed employee at increased risk, and to establish a baseline for future health monitoring. Examination of the eyes, respiratory tract, central nervous system, skeletal system, and the kidneys should be stressed. The skin should be examined for evidence of chronic disorders.

—Urinalysis: Since kidney disease interferes with excretion of fluoride, thus increasing the risk from exposure to excessive fluoride, a urinalysis should be

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These recommendations reflect good industrial hygiene and medical surveillance practices and their implementation will assist in achieving an effective occupational health program. However, they may not be sufficient to achieve compliance with all requirements of OSHA regulations.

U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
Public Health Service Centers for Disease Control
National Institute for Occupational Safety and Health

U.S. DEPARTMENT OF LABOR
Occupational Safety and Health Administration

MONITORING AND MEASUREMENT PROCEDURES

• **General**

Measurements to determine employee exposure are best taken so that the average eight-hour exposure is based on a single eight-hour sample or on two four-hour samples. Several short-time interval samples (up to 30 minutes) may also be used to determine the average exposure level. Air samples should be taken in the employee's breathing zone (air that would most nearly represent that inhaled by the employee).

• **Method**

Sampling and analyses may be performed by collection of fluoride in an impinger containing sodium hydroxide, followed by dilution with a buffer, and analysis with an ion-specific electrode. An analytical method for fluoride is in the *NIOSH Manual of Analytical Methods*, 2nd Ed., Vol. 1, 1977, available from the Government Printing Office, Washington, D.C. 20402 (GPO No. 017-033-00267-3).

RESPIRATORS

• Good industrial hygiene practices recommend that engineering controls be used to reduce environmental concentrations to the permissible exposure level. However, there are some exceptions where respirators may be used to control exposure. Respirators may be used when engineering and work practice controls are not technically feasible, when such controls are in the process of being installed, or when they fail and need to be supplemented. Respirators may also be used for operations which require entry into tanks or closed vessels, and in emergency situations. If the use of respirators is necessary, the only respirators permitted are those that have been approved by the Mine Safety and Health Administration (formerly Mining Enforcement and Safety Administration) or by the National Institute for Occupational Safety and Health.

• In addition to respirator selection, a complete respiratory protection program should be instituted which includes regular training, maintenance, inspection, cleaning, and evaluation.

PERSONAL PROTECTIVE EQUIPMENT

• Employees should be provided with and required to use impervious clothing, gloves, face shields (eight-inch minimum), and other appropriate protective clothing necessary to prevent repeated or prolonged skin contact with fluoride.

• If employees' clothing has had any possibility of being contaminated with fluoride, employees should change into uncontaminated clothing before leaving the work premises.

• Clothing contaminated with fluoride should be placed in closed containers for storage until it can be discarded or until provision is made for the removal of fluoride from the clothing. If the clothing is to be laundered or otherwise cleaned to remove the fluoride, the person performing the operation should be informed of fluoride's hazardous properties.

• Employees should be provided with and required to use splash-proof safety goggles where there is any possibility of sodium fluoride or liquids containing sodium fluoride contacting the eyes.

• Non-impervious clothing which becomes contaminated with fluoride should be removed promptly and not reworn until the fluoride is removed from the clothing.

SANITATION

• Skin that becomes contaminated with fluoride should be promptly washed or showered to remove any fluoride.

• Eating and smoking should not be permitted in areas where fluoride is handled, processed, or stored.

• Employees who handle fluoride should wash their hands thoroughly with soap or mild detergent and water before eating, smoking, or using toilet facilities.

COMMON OPERATIONS AND CONTROLS

The following list includes some common operations in which exposure to fluoride dust may occur and control methods which may be effective in each case:

Operation	Controls
Liberation from mining, beneficiation, packaging, and distribution of fluorspar	Local exhaust ventilation; general dilution ventilation; personal protective equipment
Liberation from fluorides from phosphate rock treatment	Local exhaust ventilation; general dilution ventilation; personal protective equipment
Liberation from use of fluorspars as a fluxing additive for steel production	Local exhaust ventilation; general dilution ventilation; personal protective equipment
Liberation from manufacture of cryolite from phosphate rock processing; use of fluorspar and cryolite in the production of metallic aluminum by electrolysis	Local exhaust ventilation; general dilution ventilation; personal protective equipment

Operation	Controls
Use in formulations of insecticides for agricultural crops, fruits, vegetables, ornamentals, and trees	Local exhaust ventilation; general dilution ventilation; personal protective equipment
Use in chemical industry as a source of fluorine compounds; use of fluorspar and cryolite in ceramics and glass industry in manufacture of fiberglass, optical glass, lenses, and pottery; use of fluorspar in manufacture of welding rods and welding fluxes; use in electroplating	Local exhaust ventilation; general dilution ventilation; personal protective equipment
Use in treatment of water	Local exhaust ventilation; general dilution ventilation; personal protective equipment

EMERGENCY FIRST AID PROCEDURES

In the event of an emergency, institute first aid procedures and send for first aid or medical assistance.

• **Eye Exposure**

If fluoride or liquids containing fluoride get into the eyes, wash eyes immediately with large amounts of water, lifting the lower and upper lids occasionally. If irritation is present after washing, get medical attention. Contact lenses should not be worn when working with this chemical.

• **Skin Exposure**

If fluoride or liquids containing fluoride get on the skin, promptly wash the contaminated skin using soap or mild detergent and water. If fluoride or liquids containing fluoride soak through the clothing, remove the clothing promptly and wash the skin using soap or mild detergent and water. If irritation persists after washing, get medical attention.

• **Breathing**

If a person breathes in large amounts of fluoride, move the exposed person to fresh air at once. If breathing has stopped, perform artificial respiration. Keep the affected person warm and at rest. Get medical attention as soon as possible.

• **Swallowing**

When liquids containing fluoride have been swallowed and the person is conscious, give the person large quantities of water immediately. After the water has been swallowed, try to get the person to vomit by having him touch the back of his throat with his finger. Do not make an unconscious person vomit. Get medical attention immediately.

• **Rescue**

Move the affected person from the hazardous exposure. If the exposed person has been overcome, notify someone else and put into effect the established emergency rescue procedures. Do not become a casualty. Understand the facility's emergency rescue procedures and know the locations of rescue equipment before the need arises.

SPILL AND DISPOSAL PROCEDURES

• Persons not wearing protective equipment and clothing should be restricted from areas of spills or releases until cleanup has been completed.

• If fluoride is spilled or released in hazardous concentrations, the following steps should be taken:

1. Ventilate area of spill or release.
2. Collect spilled material in the most convenient and safe manner and deposit in sealed containers for reclamation or for disposal in a secured sanitary landfill. Liquid containing fluoride should be absorbed in vermiculite, dry sand, earth, or a similar material.

• Waste disposal method:

Fluoride may be disposed of in sealed containers in a secured sanitary landfill.

REFERENCES

• American Conference of Governmental Industrial Hygienists: "Fluoride Dust," *Documentation of the Threshold Limit Values for Substances in Workroom Air* (3rd ed., 2nd printing), Cincinnati, 1974.

• American Industrial Hygiene Association: "Fluoride-Bearing Dusts and Fumes (Inorganic)," *Hygienic Guide Series*, Detroit, Michigan, 1965.

• Biological Monitoring Guides: "Fluorides," *American Industrial Hygiene Association Journal*, 32:274-279, 1971.

• Committee on Biologic Effects of Atmospheric Pollutants, Division of Medical Sciences, National Research Council: *Fluorides*, Washington, D.C., 1971.

• Dinman, B. D., et al.: "Prevention of Bony Fluorosis in Aluminum Smelter Workers," *Journal of Occupational Medicine*, 18:7-25, 1976.

• Grant, W. M.: *Toxicology of the Eye* (2nd ed.), C. C. Thomas, Springfield, Illinois, 1974.

• Hodge, H. C., and Smith, F. A.: "Air Quality Criteria for the Effects of Fluorides on Man," *Journal of theAir Pollution Control Association*, 20:226-232, 1970.

• International Labour Office: *Encyclopedia of Occupational Health and Safety*, McGraw-Hill, New York, 1971.

• Largent, E. J.: "Rates of Elimination of Fluoride Stored in the Tissues of Man," *A.M.A. Archives of Industrial Hygiene and Occupational Medicine*, 6:37-42, 1952.

[illegible] specific gravity, albumin, glucose, and a microscopic examination on centrifuged sediment. An analysis for fluoride should be performed.

—Pelvic roentgenogram: Fluoride causes skeletal abnormalities. A radiologic examination of the male pelvis with proper gonadal shielding should be conducted at the time of the preplacement examination and when indicated by analysis of the results of the urinary fluoride tests.

—Eye disease: Fluoride is an eye irritant and may cause tissue damage. Those with pre-existing eye problems may be at increased risk from exposure.

—14" x 17" chest roentgenogram: Fluoride may cause respiratory system effects, such as fibrosis and asthma. Surveillance of the lungs is indicated.

—FVC and FEV (1 sec): Fluoride is a respiratory irritant. Persons with impaired pulmonary function may be at increased risk from exposure. Periodic surveillance is indicated.

—Skin disease: Fluoride can cause dermatitis on prolonged exposure. Persons with pre-existing skin disorders may be more susceptible to the effects of this agent.

2. Periodic Medical Examination: The aforementioned medical examinations should be repeated on an annual basis, except that the radiologic examination of the pelvis should be conducted only when clinically indicated.

- **Summary of toxicology**

Fluoride causes irritation of the eyes and respiratory tract; absorption of excessive amounts of fluoride over a long period of time results in increased radiographic density of bone. The lethal oral dose of sodium fluoride for humans is approximately 5 g; effects are diffuse abdominal pain, diarrhea, and vomiting; excessive salivation, thirst, and perspiration; painful spasms of the limbs; and sometimes albuminuria. Workers exposed to an airborne fluoride concentration of 5 mg/m³ complained of eye and respiratory tract irritation and nausea. A portion of absorbed fluoride is stored in bone and part is excreted promptly in the urine; with continued exposure and increasing amounts of fluoride already present in the bone, the fraction appearing in the urine increases. Some storage of fluoride occurs from the ingestion of as little as 3 mg/day. Repeated exposure to excessive concentrations of fluorides over a period of years results in increased radiographic density of bone and eventually may cause crippling fluorosis (osteosclerosis due to deposition of fluoride). The gross changes in the skeleton are quite distinctive and characteristic; as the amount of fluoride in the bone increases, exostoses may develop, especially on the long bones; the spinal and pelvic ligaments begin to calcify, occasionally vertebrae fuse together, and a typical stiffness of the spinal column develops. The absorption of 20 to 80 mg of fluoride daily may be expected to lead to crippling fluorosis in 10 to 20 years; this condition has not been reported in the United States from industrial exposure. Evidence from several sources indicates that urinary fluoride concentrations not exceeding 5 mg/l in preshift samples taken after 2 days off work are not associated with detectable osteosclerosis and that such changes are unlikely at urinary levels of 5 to 8 mg/l. Repeated or prolonged exposure of the skin to fluoride-bearing dusts and fumes may cause dermatitis. Mottled appearance and altered form of teeth are most pronounced when excessive amounts of fluoride are ingested during the period of formation and calcification of teeth, which occurs during the first 8 years of life in humans; after the teeth erupt and calcification has been completed, fluoride does not have an adverse effect on the teeth.

CHEMICAL AND PHYSICAL PROPERTIES

- **Physical data—Sodium fluoride**
  1. Molecular weight: 42
  2. Boiling point (760 mm Hg): 1702 C (3095 F)
  3. Specific gravity (water = 1): 2.8
  4. Vapor density (air = 1 at boiling point of sodium fluoride): Not applicable
  5. Melting point: 992 C (1818 F)
  6. Vapor pressure at 20 C (68 F): Essentially zero
  7. Solubility in water, g/100 g water at 20 C (68 F): 4.2
  8. Evaporation rate (butyl acetate = 1): Not applicable
- **Physical data—Cryolite (sodium hexafluoroaluminate)**
  1. Molecular weight: 209.9
  2. Boiling point (760 mm Hg): Decomposes
  3. Specific gravity (water = 1): 2.8
  4. Vapor density (air = 1 at boiling point of cryolite): Not applicable
  5. Melting point: 1009 C (1848 F)
  6. Vapor pressure at 20 C (68 F): Essentially zero
  7. Solubility in water, g/100 g water at 20 C (68 F): 0.04
  8. Evaporation rate (butyl acetate = 1): Not applicable
- **Reactivity**
  1. Conditions contributing to instability: None
  2. Incompatibilities: Contact with strong acids may cause formation of toxic and irritating hydrogen fluoride gas.
  3. Hazardous decomposition products: None
  4. Special precautions: None
- **Flammability**
  1. Not combustible
- **Warning properties**

Concerning fluorides, Grant states that "industrially, fluorides may contact the eyes in the form of fumes from fluxes in soldering, in welding, and in magnesium foundries. Irritation of the eyes and nose has been reported when fluoride concentration has reached 5 mg/m³ of air."

• National Institute for Occupational Safety and Health, U.S. Department of Health, Education, and Welfare: *Criteria for a Recommended Standard . . . . Occupational Exposure to Inorganic Fluorides*, HEW Publication No. (NIOSH) 76-103, GPO No. 017-033-00118-9, U.S. Government Printing Office, Washington, D.C., 1975.

• Patty, F. A. (ed.): *Toxicology*, Vol. II of *Industrial Hygiene and Toxicology* (2nd ed. rev.), Interscience, New York, 1963.

• Sax, N. I.: *Dangerous Properties of Industrial Materials* (3rd ed.), Van Nostrand Reinhold, New York, 1968.

• Stolman, A. (ed.): *Progress in Chemical Toxicology*, Academic Press, New York, 1965-1969.

• World Health Organization: *Fluorides and Human Health*, Geneva, 1970.

RESPIRATORY PROTECTION FOR FLUORIDE DUST (AS FLUORIDE)

Condition	Minimum Respiratory Protection* Required Above 2.5 mg/m³
Particulate Concentration	
12.5 mg/m³ or less**	A single-use dust respirator.
25 mg/m³ or less**	Any dust respirator, except single-use or quarter-mask respirator.***
	Any supplied-air respirator.
	Any self-contained breathing apparatus.
125 mg/m³ or less	A high efficiency particulate filter respirator with a full facepiece.***
	Any supplied-air respirator with a full facepiece, helmet, or hood.
	Any self-contained breathing apparatus with a full facepiece.
250 mg/m³ or less	A powered air-purifying respirator with a high efficiency particulate filter, and a full facepiece.***
	A Type C supplied-air respirator with a full facepiece operated in pressure-demand or other positive pressure mode or with a full facepiece, helmet, or hood operated in continuous-flow mode.
Greater than 250 mg/m³ or entry and escape from unknown concentrations	Self-contained breathing apparatus with a full facepiece operated in pressure-demand or other positive pressure mode.
	A combination respirator which includes a Type C supplied-air respirator with a full facepiece operated in pressure-demand or other positive pressure or continuous-flow mode and an auxiliary self-contained breathing apparatus operated in pressure-demand or other positive pressure mode.
Fire Fighting	Self-contained breathing apparatus with a full facepiece operated in pressure-demand or other positive pressure mode.
Escape	An escape gas mask with an acid gas canister.
	Any escape self-contained breathing apparatus.

*Only NIOSH-approved or MSHA-approved equipment should be used.

**If eye irritation occurs, full-facepiece respiratory protective equipment should be used.

***If acid gases are present, air-purifying elements providing protection against acid gases and including the indicated filters should be used.

• Manufacturing Chemists Association, Inc.: *Chemical Safety Data Sheet SD-8, Ammonia*, Washington, D.C., 1960.
• Matheson Company: *Anhydrous Ammonia Data Sheets*.
• National Institute for Occupational Safety and Health, U.S. Department of Health, Education, and Welfare: *Criteria for a Recommended Standard . . . . Occupational Exposure to Ammonia*, HEW Publication No. (NIOSH) 74-136, GPO No. 017-033-00036, U.S. Government Printing Office, Washington, D.C., 1974.
• Patty, F. A. (ed.): *Toxicology*, Vol. II of *Industrial Hygiene and Toxicology* (2nd ed. rev.), Interscience, New York, 1963.
• Spector, W. S. (Vols. I, II), Negherbon, W. O. (Vol. III), Grebe, R. M. (Vol. IV), and Dittmer, D. S. (Vol. V) (eds.): *Handbook of Toxicology*, Saunders, Philadelphia, 1956-1959.

RESPIRATORY PROTECTION FOR AMMONIA

Condition	Minimum Respiratory Protection* Required Above 50 ppm
Gas Concentraton	
100 ppm or less	Any chemical cartridge respirator with an ammonia cartridge(s). Any supplied-air respirator. Any self-contained breathing apparatus.
300 ppm or less	A chemical cartridge respirator with a full facepiece and an ammonia cartridge(s).
500 ppm or less	A gas mask with a chin-style or a front- or back-mounted ammonia canister. Any supplied-air respirator with a full facepiece, helmet, or hood. Any self-contained breathing apparatus with a full facepiece.
Greater than 500 ppm** or entry and escape from unknown concentrations	Self-contained breathing apparatus with a full facepiece operated in pressure-demand or other positive pressure mode. A combination respirator which includes a Type C supplied-air respirator with a full facepiece operated in pressure-demand or other positive pressure or continuous-flow mode and an auxiliary self-contained breathing apparatus operated in pressure-demand or other positive pressure mode.
Fire Fighting	Self-contained breathing apparatus with a full facepiece operated in pressure-demand or other positive pressure mode.
Escape	Any gas mask providing protection against ammonia. Any escape self-contained breathing apparatus.

*Only NIOSH-approved or MSHA-approved equipment should be used.

**Use of supplied-air suits may be necessary to prevent skin contact while providing respiratory protection from airborne concentrations of ammonia; however, this equipment should be selected, used, and maintained under the immediate supervision of trained personnel. Where supplied-air suits are used above a concentration of 500 ppm, an auxiliary self-contained breathing apparatus operated in positive pressure mode should also be worn.

Occupational Health Guideline for Soluble Barium Compounds (as Barium)

INTRODUCTION

This guideline is intended as a source of information for employees, employers, physicians, industrial hygienists, and other occupational health professionals who may have a need for such information. It does not attempt to present all data; rather, it presents pertinent information and data in summary form.

APPLICABILITY

The general guidelines contained in this document apply to all soluble barium compounds. Physical and chemical properties of several specific compounds are provided for illustrative purposes.

SUBSTANCE IDENTIFICATION

Barium nitrate

- Formula: $Ba(NO_3)_2$
- Synonyms: None
- Appearance and odor: Odorless white solid.

Barium oxide

- Formula: BaO
- Synonyms: None
- Appearance and odor: Odorless white solid.

Barium carbonate

- Formula: $BaCO_3$
- Synonyms: None
- Appearance and odor: Odorless white solid.

Barium chloride

- Formula: $BaCl_2$
- Synonyms: None
- Appearance and odor: Odorless white solid.

PERMISSIBLE EXPOSURE LIMIT (PEL)

The current OSHA standard for soluble barium compounds is 0.5 milligram of soluble barium compounds per cubic meter of air (mg/m^3) averaged over an eight-hour work shift.

HEALTH HAZARD INFORMATION

- **Routes of exposure**

Soluble barium compounds can affect the body if they are inhaled or if they come in contact with the eyes or skin. They can also affect the body if they are swallowed.

- **Effects of overexposure**

1. Short-term Exposure: Soluble barium compounds may cause local irritation of the eyes, nose, throat, bronchial tubes, and skin. Soluble barium compounds may also cause severe stomach pains, slow pulse rate, irregular heart beat, ringing of the ears, dizziness, convulsions, and muscle spasms. Death may occur.

2. Long-term Exposure: None known

3. Reporting Signs and Symptoms: A physician should be contacted if anyone develops any signs or symptoms and suspects that they are caused by exposure to soluble barium compounds.

- **Recommended medical surveillance**

The following medical procedures should be made available to each employee who is exposed to soluble barium compounds at potentially hazardous levels:

1. Initial Medical Examination:

—A complete history and physical examination: The purpose is to detect pre-existing conditions that might place the exposed employee at increased risk, and to establish a baseline for future health monitoring. Examination of the heart, lungs, and nervous system should be stressed. The skin should be examined for evidence of chronic disorders.

—14" x 17" chest roentgenogram: Soluble barium compounds cause human lung damage. Surveillance of the lungs is indicated.

These recommendations reflect good industrial hygiene and medical surveillance practices and their implementation will assist in achieving an effective occupational health program. However, they may not be sufficient to achieve compliance with all requirements of OSHA regulations.

U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
Public Health Service Centers for Disease Control
National Institute for Occupational Safety and Health

U.S. DEPARTMENT OF LABOR
Occupational Safety and Health Administration

—FVC and FEV (1 sec): Soluble barium compounds are respiratory irritants. Persons with impaired pulmonary function may be at increased risk from exposure. Periodic surveillance is indicated.

—Electrocardiogram: Barium compounds may cause cardiac arrhythmias and may have a direct effect on the cardiac muscle. Periodic surveillance of the heart is indicated.

2. Periodic Medical Examination: The aforementioned medical examinations should be repeated on an annual basis, except that an x-ray is necessary only when indicated by the results of pulmonary function testing, or by signs and symptoms of respiratory disease.

• **Summary of toxicology**

Soluble barium salts cause severe gastroenteritis and systemic effects by ingestion. Intravenous injection of barium compounds in animals causes a strong, prolonged stimulation of muscle resulting in hyperperistalsis, bladder contraction, vasoconstriction, and irregular contraction of the heart followed by arrest in systole. Animals also exhibit stimulation of the central nervous system followed by paralysis. Ingestion of barium carbonate by humans causes gastroenteritis, muscular paralysis, slow pulse rate, extrasystoles, and hypokalemia. Heavy industrial exposure to dusts of barium sulfate or barium oxides may produce a benign pneumoconiosis, termed baritosis. It results in no impairment of ventilatory function, although signs of mild bronchial irritation may occur. Characteristic x-ray changes are those of small, dense, circumscribed nodules evenly distributed throughout the lung fields, reflecting the radio-opacity of the barium dust. Bronchial irritation has been reported from the inhalation of barium carbonate dust. Barium hydroxide and barium oxide are strongly alkaline in aqueous solution, causing severe burns of the eye and irritation of the skin.

CHEMICAL AND PHYSICAL PROPERTIES

• **Physical data—Barium nitrate**

1. Molecular weight: 261.4
2. Boiling point (760 mm Hg): Greater than 592 C (greater than 1098 F) (decomposes)
3. Specific gravity (water = 1): 3.24
4. Vapor density (air = 1 at boiling point of barium nitrate): Not applicable
5. Melting point: 592 C (1098 F)
6. Vapor pressure at 20 C (68 F): Essentially zero
7. Solubility in water, g/100 g water at 20 C (68 F): 9.2
8. Evaporation rate (butyl acetate = 1): Not applicable

• **Physical data—Barium oxide**

1. Molecular weight: 153.3
2. Boiling point (760 mm Hg): 2000 C (3632 F)
3. Specific gravity (water = 1): 5.72
4. Vapor density (air = 1 at boiling point of barium oxide): Not applicable
5. Melting point: 1921 C (3490 F)
6. Vapor pressure at 20 C (68 F): Essentially zero
7. Solubility in water, g/100 g water at 20 C (68 F): Reacts
8. Evaporation rate (butyl acetate = 1): Not applicable

• **Physical data—Barium carbonate**

1. Molecular weight: 197.3
2. Boiling point (760 mm Hg): 1300 C (2372 F) (decomposes)
3. Specific gravity (water = 1): 4.25
4. Vapor density (air = 1 at boiling point of barium carbonate): Not applicable
5. Melting point: Decomposes at 1300 C (2372 F)
6. Vapor pressure at 20 C (68 F): Essentially zero
7. Solubility in water, g/100 g water at 20 C (68 F): 0.0022
8. Evaporation rate (butyl acetate = 1): Not applicable

• **Physical data—Barium chloride**

1. Molecular weight: 208.3
2. Boiling point (760 mm Hg): 1560 C (2840 F)
3. Specific gravity (water = 1): 3.86
4. Vapor density (air = 1 at boiling point of barium chloride): Not applicable
5. Melting point: 963 C (1765 F)
6. Vapor pressure at 20 C (68 F): Essentially zero
7. Solubility in water, g/100 g water at 20 C (68 F): 36
8. Evaporation rate (butyl acetate = 1): Not applicable

• **Reactivity**

1. Conditions contributing to instability: For barium nitrate, elevated temperatures may cause melting and decomposition; for the other compounds, none hazardous.
2. Incompatibilities: Contact of barium oxide with water, carbon dioxide, or hydrogen sulfide may cause fires and explosions. Contact of barium carbonate with acids causes formation of carbon dioxide gas that may cause suffocation in enclosed spaces. Contact of barium nitrate with organic matter and combustible materials may cause fires and explosions.
3. Hazardous decomposition products: Toxic gases and vapors (such as oxides of nitrogen and carbon monoxide) may be released in a fire involving barium nitrate.
4. Special precautions: None

• **Flammability**

1. Flash point: Not applicable
2. Autoignition temperature: For barium nitrate, data not available; for the the other compounds, not applicable.
3. Flammable limits in air, % by volume: Not applicable
4. Extinguishant: Large amounts of water should be used on adjacent fires.

• **Warning properties**

According to Grant, barium chloride causes "considerable iritis, which subsides in a few days" when "tested

in neutral 0.08 to 0.1 M solution on rabbit eyes by injection into the cornea or by dropping for 10 minutes on the eye after the corneal epithelium was removed to facilitate penetration." Grant states that "both the oxide and hydroxide are capable of causing severe alkali burns of the eye, similar to those produced by calcium hydroxide."

MONITORING AND MEASUREMENT PROCEDURES

• **General**

Measurements to determine employee exposure are best taken so that the average eight-hour exposure is based on a single eight-hour sample or on two four-hour samples. Several short-time interval samples (up to 30 minutes) may also be used to determine the average exposure level. Air samples should be taken in the employee's breathing zone (air that would most nearly represent that inhaled by the employee).

• **Method**

Sampling and analyses may be performed by collection on a cellulose membrane filter followed by leaching in hot water, solution of sample in acid, and analysis in an atomic absorption spectrophotometer. An analytical method for soluble barium compounds is in the *NIOSH Manual of Analytical Methods*, 2nd Ed., Vol. 3, 1977, available from the Government Printing Office, Washington, D.C. 20402 (GPO No. 017-033-00261-4).

RESPIRATORS

• Good industrial hygiene practices recommend that engineering controls be used to reduce environmental concentrations to the permissible exposure level. However, there are some exceptions where respirators may be used to control exposure. Respirators may be used when engineering and work practice controls are not technically feasible, when such controls are in the process of being installed, or when they fail and need to be supplemented. Respirators may also be used for operations which require entry into tanks or closed vessels, and in emergency situations. If the use of respirators is necessary, the only respirators permitted are those that have been approved by the Mine Safety and Health Administration (formerly Mining Enforcement and Safety Administration) or by the National Institute for Occupational Safety and Health.

• In addition to respirator selection, a complete respiratory protection program should be instituted which includes regular training, maintenance, inspection, cleaning, and evaluation.

PERSONAL PROTECTIVE EQUIPMENT

• Employees should be provided with and required to use impervious clothing, gloves, face shields (eight-inch minimum), and other appropriate protective clothing necessary to prevent repeated or prolonged skin contact with barium carbonate, barium chloride, barium nitrate or liquids containing these compounds.

• Employees should be provided with and required to use impervious clothing, gloves, face shields (eight-inch minimum), and other appropriate protective clothing necessary to prevent skin contact with barium oxide or liquids containing barium oxide, where skin contact may occur.

• If employees' clothing has had any possibility of being contaminated with barium carbonate, barium chloride, barium nitrate, barium oxide, or liquids containing these compounds, employees should change into uncontaminated clothing before leaving the work premises.

• Clothing contaminated with barium carbonate, barium chloride, barium nitrate, or barium oxide should be placed in closed containers for storage until it can be discarded or until provision is made for the removal of contaminant from the clothing. If the clothing is to be laundered or otherwise cleaned to remove the contaminant, the person performing the operation should be informed of contaminant's hazardous properties.

• Where exposure of an employee's body to barium oxide or liquids containing barium oxide may occur, facilities for quick drenching of the body should be provided within the immediate work area for emergency use.

• Non-impervious clothing which becomes contaminated with barium carbonate, barium chloride, barium nitrate, or barium oxide should be removed promptly and not reworn until the contaminant is removed from the clothing.

• Employees should be provided with and required to use dust- and splash-proof safety goggles where there is any possibility of barium oxide or liquids containing barium oxide contacting the eyes.

• Employees should be provided with and required to use dust- and splash-proof safety goggles where barium carbonate, barium chloride, barium nitrate, or liquids containing these compounds may contact the eyes.

• Where there is any possibility that employees' eyes may be exposed to barium oxide or liquids containing barium oxide, an eye-wash fountain should be provided within the immediate work area for emergency use.

SANITATION

• Workers subject to skin contact with barium oxide or liquids containing barium oxide should wash any areas of the body which may have contacted barium oxide at the end of each work day.

• Skin that becomes contaminated with barium carbonate, barium chloride, or barium nitrate should be promptly washed or showered to remove any contaminant. In the case of barium carbonate, employees should use soap or mild detergent and water for washing purposes.

• Skin that becomes contaminated with barium oxide should be promptly washed or showered to remove any barium oxide from the skin after all obvious amounts of barium oxide have been removed by other means (e.g., by use of oil or vaseline). Employees who are being burned by barium oxide should immediately utilize quick drenching facilities without first removing barium oxide by other means.

• Eating and smoking should not be permitted in areas where solid barium carbonate, barium chloride, barium nitrate, or barium oxide, or liquids containing these compounds are handled, processed, or stored.

• Employees who handle barium carbonate, barium chloride, barium nitrate, barium oxide, or liquids containing these compounds should wash their hands thoroughly before eating, smoking, or using toilet facilities. In the case of barium carbonate, employees should use soap or mild detergent and water for washing purposes.

COMMON OPERATIONS AND CONTROLS

The following list includes some common operations in which exposure to soluble barium compounds may occur and control methods which may be effective in each case:

Operation	Controls
Manufacture and distribution of soluble barium compounds	Process enclosure; local exhaust ventilation
Use in manufacture of pressed and blown glassware and flint and crown optical glass; manufacture of ceramic products; use in electronics industry in manufacture of magnets, vacuum tubes, cathodes, x-ray fluorescent screens, TV picture tubes, and dry cell depolarizers	Process enclosure; local exhaust ventilation
Use in manufacture of photographic papers, dyes, and chemicals	Process enclosure; local exhaust ventilation
Use as pesticides, rodenticides, and disinfectants; use in manufacture of explosives, matches, and pyrotechnics as igniter compositions and fireworks	Process enclosure; local exhaust ventilation
Use as an additive in manufacture of grease, and manufacture of lubricating oils; use in refining of vegetable and animal oils	Process enclosure; local exhaust ventilation
Use in case-hardening of steel in metallurgy; in welding aluminum; in electroplating; and in aluminum and sodium refining	Process enclosure; local exhaust ventilation
Use in water treatment and boiler compounds for softening water; use as catalysts, analytical reagents, and purifying agents	Process enclosure; local exhaust ventilation
Use for treatment of textiles, leather, and rubber; use in manufacture of paper and cellulose as a bleaching agent; use in manufacture of pigments, colors, and lakes	Process enclosure; local exhaust ventilation
Use as a depilatory in processing of hides; as a fire-proof and extinguishing agent; in embalming; in sugar refining; in gas and solvent drying; in marble substitutes; in valve manufacture; and as a smoke suppressant in diesel fuels	Process enclosure; local exhaust ventilation
Use in manufacture of pigments, paints, enamels, and printing inks	Process enclosure; local exhaust ventilation

EMERGENCY FIRST AID PROCEDURES

In the event of an emergency, institute first aid procedures and send for first aid or medical assistance.

• **Eye Exposure**

If solutions of barium compounds get into the eyes, wash eyes immediately with large amounts of water, lifting the lower and upper lids occasionally. Get medical attention immediately. Contact lenses should not be worn when working with these chemicals.

• Skin Exposure

If solutions of barium compounds get on the skin, immediately flush the contaminated skin with water. If solutions of barium compounds soak through the clothing, remove the clothing immediately and flush the skin with water. If irritation persists after washing, get medical attention.

• **Breathing**

If a person breathes in large amounts of soluble barium compounds, move the exposed person to fresh air at once. If breathing has stopped, perform artificial respiration. Keep the affected person warm and at rest. Get medical attention as soon as possible.

• **Swallowing**

When soluble barium compounds have been swallowed and the person is conscious, give the person large quantities of water immediately. After the water has been swallowed, try to get the person to vomit by having him touch the back of his throat with his finger. Do not make an unconscious person vomit. Get medical attention immediately.

• **Rescue**

Move the affected person from the hazardous exposure. If the exposed person has been overcome, notify someone else and put into effect the established emergency rescue procedures. Do not become a casualty. Understand the facility's emergency rescue procedures and know the locations of rescue equipment before the need arises.

SPILL AND DISPOSAL PROCEDURES

• Persons not wearing protective equipment and clothing should be restricted from areas of spills until cleanup has been completed.

• If soluble barium compounds are spilled, the following steps should be taken:

1. Ventilate area of spill.
2. Collect spilled material in the most convenient and safe manner and deposit in sealed containers for reclamation or for disposal in a secured sanitary landfill. Liquids containing soluble barium compounds should be absorbed in vermiculite, dry sand, earth, or a similar material.

• *Waste disposal method:*

Soluble barium compounds may be disposed of in sealed containers in a secured sanitary landfill.

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RESPIRATORY PROTECTION FOR SOLUBLE BARIUM COMPOUNDS (AS BARIUM)

Condition	Minimum Respiratory Protection* Required Above 0.5 mg/m³
Particulate Concentration	
2.5 mg/m³ or less	Any dust and mist respirator, except single-use.**
5 mg/m³ or less	Any dust and mist respirator, except single-use or quarter-mask respirator. Any fume respirator or high efficiency particulate filter respirator. Any supplied-air respirator. Any self-contained breathing apparatus.
25 mg/m³ or less	A high efficiency particulate filter respirator with a full facepiece. Any supplied-air respirator with a full facepiece, helmet, or hood. Any self-contained breathing apparatus with a full facepiece.
250 mg/m³ or less	A Type C supplied-air respirator operated in pressure-demand or other positive pressure mode or with a full facepiece, helmet, or hood operated in continuous-flow mode. A powered air-purifying respirator with a high efficiency particulate filter.
Greater than 250 mg/m³ or entry and escape from unknown concentrations	Self-contained breathing apparatus with a full facepiece operated in pressure-demand or other positive pressure mode. A combination respirator which includes a Type C supplied-air respirator with a full facepiece operated in pressure-demand or other positive pressure or continuous-flow mode and an auxiliary self-contained breathing apparatus operated in pressure-demand or other positive pressure mode.
Fire Fighting	Self-contained breathing apparatus with a full facepiece operated in pressure-demand or other positive pressure mode.
Escape	A high efficiency particulate filter respirator. Any escape self-contained breathing apparatus.

*Only NIOSH-approved or MSHA-approved equipment should be used.

**If eye irritation occurs, full-facepiece respiratory protective equipment should be used.

1. PUBLIC HEALTH STATEMENT

1.1 WHAT IS BENZENE?

Benzene is a naturally occurring substance produced by volcanoes and forest fires and present in many plants and animals, but benzene is also a major industrial chemical made from coal and oil. As a pure chemical, benzene is a clear, colorless liquid. In industry, benzene is used to make other intermediate chemicals, as well as some types of plastics, detergents, and pesticides. It is also a component of gasoline.

1.2 HOW MIGHT I BE EXPOSED TO BENZENE?

The three main types of exposure to benzene are environmental, consumer products, and occupational. Unquestionably, the greatest potential for high-level exposures is in the workplace. However, the greatest number of people are exposed to lower levels of benzene in cigarette smoke and automobile exhaust.

Environmental sources of benzene include: gasoline filling stations, vehicle exhaust fumes, cigarette smoke, underground storage tanks that leak, wastewater from industries that use benzene, poorly maintained toxic waste sites, chemical spills, groundwater adjacent to landfills containing benzene, and possibly some food products containing benzene as a natural constituent.

Occupational exposure to benzene can occur in the rubber industry; oil refineries; chemical plants; the shoe manufacturing industry; and gasoline storage, shipment, and retail stations.

Consumer products containing benzene include glues, adhesives, household cleaning products, paint strippers, some art supplies, cigarette smoke, and gasoline.

1.3 HOW DOES BENZENE GET INTO MY BODY?

Because benzene evaporates very quickly, the most common exposure to benzene comes from breathing air containing benzene.

Very small amounts of benzene are found in some foods, such as canned beef, and in contaminated drinking water.

Although benzene can penetrate the skin, it is rare for individuals to come into contact with liquid benzene. Exposures through the skin are not likely, except possibly through contact with benzene-containing products such as gasoline.

1.4 HOW CAN BENZENE AFFECT MY HEALTH?

Benzene is toxic, especially to the blood-cell-forming tissues. How benzene affects your health would depend on how much you are exposed to and for how long.

1.4.1 Brief Exposure at High Levels

The main effects of brief exposure to high levels of benzene are drowsiness, dizziness, and headaches. These symptoms disappear after exposure stops.

1.4.2 Long-Term Exposures at Various Levels

Long-term exposures to benzene may affect normal blood production, possibly resulting in severe anemia and internal bleeding. Some workers exposed to high levels of benzene over a long period of time have developed leukemia (cancer of the white-blood-cell-forming tissue). Benzene is regarded as a human carcinogen, because death from cancer has occurred in workers exposed to benzene for periods ranging from less than 5 to as much as 30 years. Such findings indicate that individual sensitivity as well as total dose is important in the development of benzene-induced cancer.

Benzene is also an animal carcinogen. In addition, there are human and animal data indicating that benzene is toxic to the body's natural defense system (immune system), increasing the chance for infections and impairing defense against tumors.

There are also very limited human data suggesting that benzene may be associated with spontaneous abortions and miscarriages in pregnant women. In addition, animal studies indicate adverse effects on unborn test animals such as low birth weight, delayed bone formation, and bone marrow toxicity. Some of these effects in animals occur at benzene levels as low as 10 ppm. The evidence for human reproductive effects, however, is too limited to establish a clear association.

1.5 IS THERE A MEDICAL TEST TO DETERMINE WHETHER I HAVE BEEN EXPOSED TO BENZENE?

Benzene can be measured in the blood and breath. The body changes benzene to a chemical called phenol, which can be measured in the urine. Benzene (in blood) and phenol (in urine) concentrations have not been correlated as yet with the degree of adverse health effects.

Because phenol occurs naturally in urine, urinary concentrations of phenol must be significantly above background concentrations before any measurement is meaningful. Current technology limits the interpretation and validity of blood level values generated in various laboratories. Furthermore, because benzene exposure can occur via smoking, blood levels of benzene must also be compared with background conditions before concluding that other routes of exposure have occurred. For these reasons, and until definitive body burden levels can be determined for the normal population, cautious interpretation of the levels of benzene and phenol determined in isolated cases is recommended.

1.6 WHAT LEVELS OF EXPOSURE HAVE RESULTED IN HARMFUL HEALTH EFFECTS?

The graphs on the following pages show the relationship between exposure to benzene and known health effects. In all graphs, effects in animals are shown on the left side, effects in humans on the right. The first column, called "Short Term," refers to or indicates the known health effects from exposure to benzene for 2 weeks or less. The second column, "Long Term," refers to or indicates health effects that characteristically occur following longer exposure times (more than 2 weeks to years).

In the first set of graphs, labeled "Health effects from breathing benzene" (Fig. 1.1), exposure is measured in parts of benzene per million parts of air (ppm). The numbers of cases of cancer that could occur from breathing 1 ppm benzene have been estimated to be 260 per 10,000, 2,600 per 100,000, 26,000 per 1,000,000, and 260,000 per 10,000,000 individuals. It should be noted that these risk values are plausible upper-limit estimates. Actual risk levels are unlikely to be higher and may be lower.

In the second set of graphs, the same relationship is represented for the known "Health effects from ingesting benzene" (Fig. 1.2). Exposures are measured in milligrams of benzene per kilogram of body weight (mg/kg). Information is inadequate to estimate health effects from absorbing benzene through the skin. However, this does not negate the possibility of a hazard, because benzene is known to penetrate the skin.

1.7 WHAT RECOMMENDATIONS HAS THE FEDERAL GOVERNMENT MADE TO PROTECT HUMAN HEALTH?

In terms of the number of people exposed to benzene, more individuals are exposed outside the workplace than in the workplace. However, the highest levels of benzene exposures occur in the workplace.

The National Institute for Occupational Safety and Health (NIOSH) has recommended an occupational exposure limit for benzene in air of 0.1 part of benzene per million parts of air (ppm). The Occupational Safety and Health Administration's (OSHA's) legally enforceable limit is 1.0 ppm averaged over the standard 8-hour workday.

The Environmental Protection Agency (EPA) has developed regulations setting the maximum permissible level of benzene in drinking water at 5 parts per billion parts of water (ppb). In addition, EPA has established as a guideline an ultimate goal of 0 ppb for the maximum level of benzene in drinking water and in ambient water (such as rivers and lakes), because of benzene's ability to cause leukemia. EPA recognizes that this goal may be unattainable and has estimated concentrations of benzene in ambient water that would be associated with one additional cancer case for every 100,000, every 1 million, and every 10 million individuals. These concentrations in water are 6.6 ppb, 0.66 ppb, and 0.066 ppb, respectively.

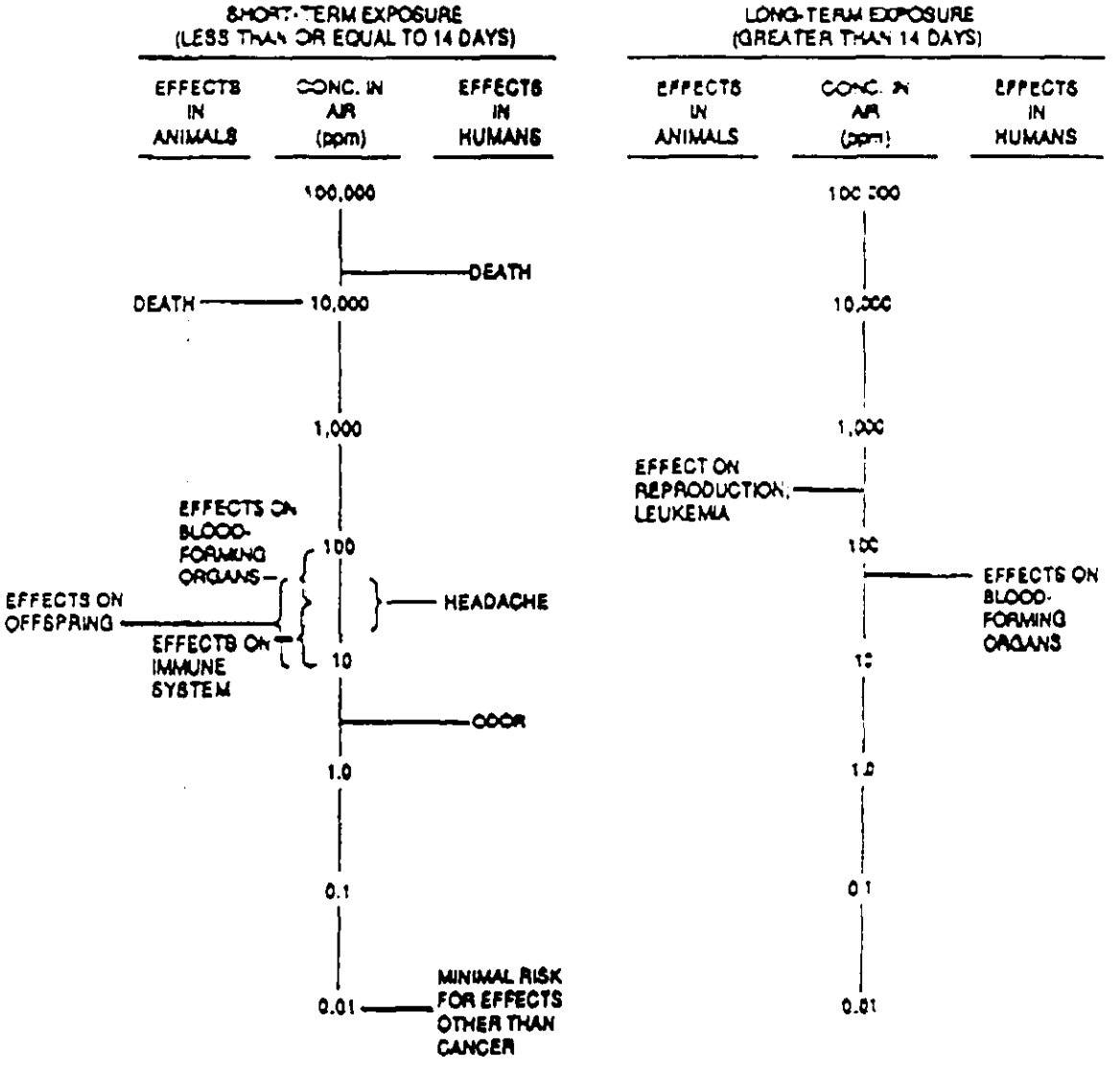


Fig. 1.1. Health effects from breathing benzene.

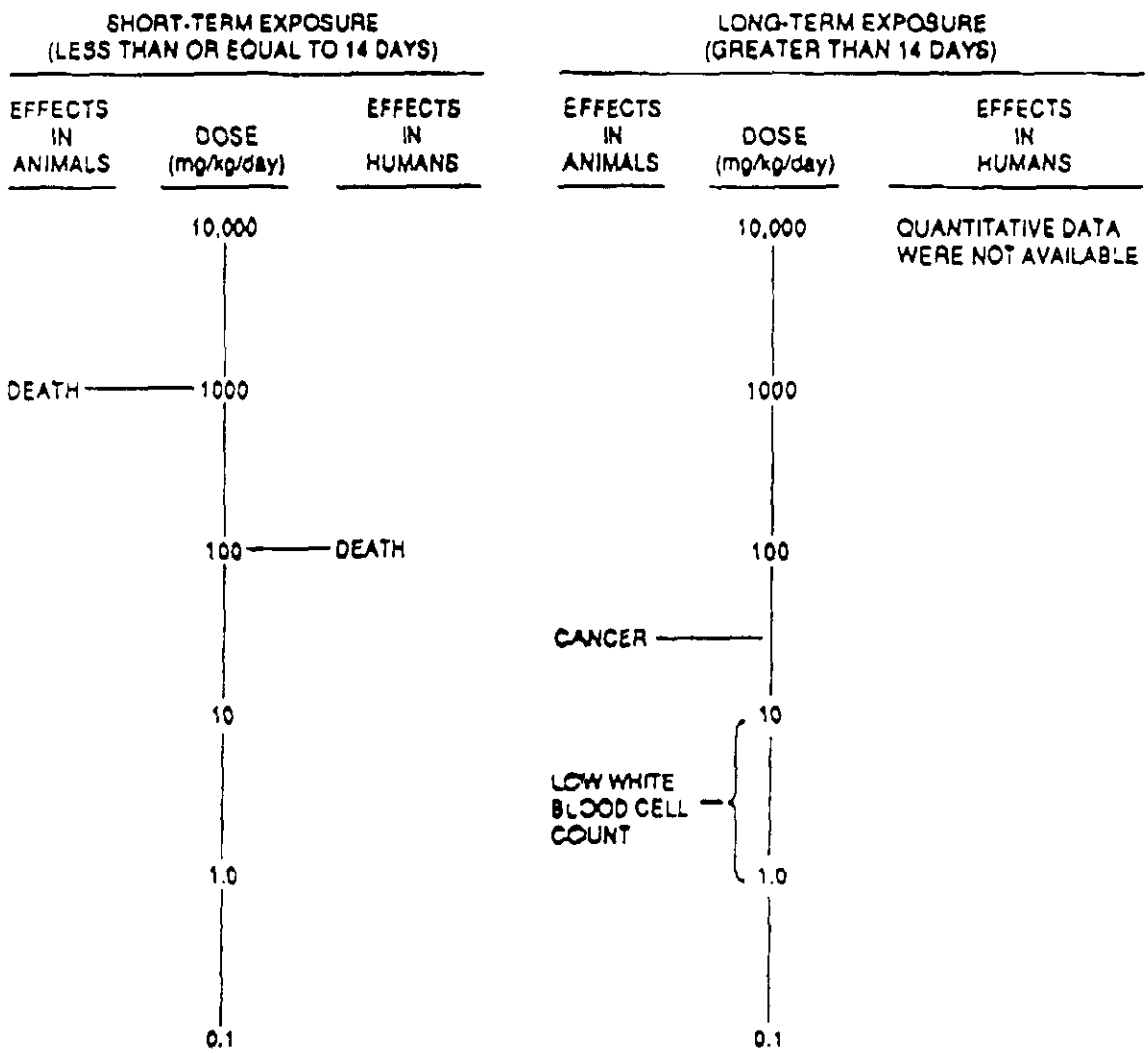


Fig. 1.2. Health effects from ingesting benzene.

3. CHEMICAL AND PHYSICAL INFORMATION

3.1 CHEMICAL IDENTITY

The chemical formula, structure, synonyms, and identification numbers for benzene are listed in Table 3.1.

3.2 PHYSICAL AND CHEMICAL PROPERTIES

The most important physical and chemical properties of benzene are given in Table 3.2.

Table 3-1. Chemical identity of benzene

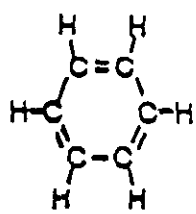
	Value	References
Chemical name	Benzene	10th C.I. Chem. Abstr.
Synonyms	Annulene, benzeen, benzen, benzin, benzine, benzol, benzole, bicarburet of hydrogen, carbon oil, coal naphtha, cyclohexatriene, fenzen, mineral naphtha, motor benzol, NCI-C55276, nitration benzene, phene, phenyl hydride, pyrobenzol, pyrobenzole	RTECS, Chemline, Merck Index, HSDB 1987
Trade name	Polycron	IARC 1982
Chemical formula	C_6H_6	
Wiswesser line notation	R	RTECS, as reported in HSDB 1987
Chemical structure		
Identification numbers		
CAS Registry No.	71-43-2	10th C.I. Chem. Abstr.
NIOSH RTECS No.	CY-1400000	Tatken and Lewis 1983
EPA RCRA Hazardous Waste No.	U019	HSDB 1987
OHM-TADS No.	7216601	HSDB 1987
DOT/UN/NA/IMCO Shipping No.	Benzene 1114	HSDB 1987
STCC No.	4908120	HSDB 1987
Hazardous Substances Data Bank No.	35	HSDB 1987

Table 3.2. Physical and chemical properties of benzene

Property	Value	References
Molecular weight	78.11	Weast et al. 1985
Physical state	Clear colorless liquid Rhombic prisms	Windholz et al. 1983 Weast et al. 1985
Odor	Aromatic	NFPA 1986
Odor threshold	4.68 ppm	Weiss 1980
Taste threshold	0.5–4.5 mg/L	EPA 1975, as reported in HSDB 1987
Melting point	5.5°C	Weast et al. 1985
Boiling point	80.1°C at 760 mm Hg	Weast et al. 1985
Density[a]	0.8765 g/cm^3	Weast et al. 1985
Conversion factors	1 ppm = 3.26 mg/m^3 at 20°C 1 mg/m^3 = 0.31 ppm	Verschueren 1983
Solubility		
Water	0.072% (wt/wt) at 22°C 820 mg/L at 22°C 1000 mg/L at 25°C 1787 mg/L at 25°C	Jackman 1975 Chiou et al. 1977 Krasnoshchekova and Gubergrits 1975, as reported in CHEMFATE 1987 Chiou et al. 1982
Nonaqueous solvents		
Alcohol	Miscible	Windholz et al. 1983
Ether	Miscible	Windholz et al. 1983
Chloroform	Miscible	Windholz et al. 1983
Carbon disulfide	Miscible	Windholz et al. 1983
Acetone	Miscible	Windholz et al. 1983
Oils	Miscible	Windholz et al. 1983
Partition coefficient (log P) (octanol/water)	1.56–2.15	Lee et al. 1971
Partition coefficient (log P) (blood/air)	7.8	Sato and Nakajima 1979
Vapor pressure	45.53 torr at 10°C 95.18 torr at 25°C 182.8 torr at 40.0°C	Zwolinski and Wilhoit 1971, as reported in CHEMFATE 1987
	0.125 atm at 25°C	Thibodeaux 1981
Viscosity	0.654 centipoise at 20°C	Jackman 1975
Heat capacity	0.2499 cal/g/°C at 25°C	Jackman 1975
Surface tension	28.9 dyn/cm at 20°C (0.0289 newton/m)	Weiss 1980
Liquid-water interfacial tension	35.0 dyn/cm at 20°C (0.0289 newton/m)	Weiss 1980
Latent heat of vaporization	169 BTU/lb	Weiss 1980
Ratio of specific heats of vapor	1.061	Weiss 1980
Critical temperature	289.5°C	Jackman 1975
Critical pressure	48.7 atm	Jackman 1975
Critical density	0.304 g/mL	Jackman 1975
Soil adsorption coefficient (K_{OC})	0.3–100 (see Sect. 2.2)	Rogers et al. 1980
Refractive index (n_D^{20})	1.5011	Weast et al. 1985

Table 3.2 (continued)

Property	Value	References
UV absorption coefficient (in water)	7000 L/mol-cm at 200 nm 220 L/mol-cm at 255 nm	Setzkorn and Huddleston 1965
Sadtler reference number	6402 (IR, prism) 136 (IR, grating) 1765 (UV) 3429 (NMR)	Weast et al. 1979, as reported in HSDB 1987
Flash point	12°F	NFPA 1986
Autoignition temperature	1044°F	NFPA 1986
Flammable limits	1.3% (lower limit) 7.1% (upper limit)	NFPA 1986
Burning rate	6.0 mm/min	Weiss 1980
Heat of combustion	−17,436 Btu/lb	Weiss 1980
Vapor-air density	1.4 at 100°F	NFPA 1986
Vapor volume	37 ft.^{3} (1 gal evapor.)	AAI 1980
Evaporation rate	2.8 (ether = 1)	AAI 1980
Evaporation halflife (from water)	2.7 h 3–5 h	Thomas 1982 Mackay and Leinonen 1975, Mackay and Yeun 1983
Henry's law constant	5.5×10^{-3} atm m^3/mol	Mackay and Leinonen 1975
Reactivity in water		
OH Radical - Rate constant	3.1×10^{10} L/mol-s	Anbar and Neta 1967
	0.78×10^{10} L/mol-s (25°C)	Dorfman and Adams 1975, as reported in CHEMFATE 1987
Halflife	0.71 year	Anbar and Neta 1967
Photodegradation in air	No direct photolysis; does not absorb at 290 nm or longer	Howard and Durkin 1975, as reported in CHEMFATE 1987
Reactivity in air		
OH Radical - Rate constant	0.8×10^{-12} cm^3/mcul-s (27°C)	Cox et al. 1980
	0.13×10^{-11} cm^3/mcul-s (25°C)	Gaffney and Levine 1979
	0.114×10^{-11} cm^3/mcul-s (25°C)	Lorenz and Zellner 1983[a]
Halflife	24.5 days	Cox et al. 1980
O_3 Radical - Rate constant	0.7×10^{-22} cm^3/mcul-s (24°C)	Pitts et al. 1979
Halflife	ca. 90 years	
Rate constant	0.7×10^{-22} cm^3/mcul-s (24°C)	Pate et al. 1976
Halflife	126 years	
O(3P) Radical - Rate constant	0.20×10^{-13} cm^3/mcul-s (27°C)	Hampson 1980, as reported in CHEMFATE 1987

[a] Relative density: Ratio of absolute density of benzene at 20°C to absolute density of water at 4°C.
[b] Data originally reported as cm^3/mol-s.

Occupational Health Guideline for Cadmium Dust (as Cadmium)*

INTRODUCTION

This guideline is intended as a source of information for employees, employers, physicians, industrial hygienists, and other occupational health professionals who may have a need for such information. It does not attempt to present all data; rather, it presents pertinent information and data in summary form.

APPLICABILITY

The general guidelines contained in this document apply to all cadmium dust. Physical and chemical properties of several specific compounds are provided for illustrative purposes.

SUBSTANCE IDENTIFICATION

Cadmium metal dust

- Formula: Cd
- Synonyms: None
- Appearance and odor: Odorless, gray powder.

Cadmium oxide dust

- Formula: CdO
- Synonyms: None
- Appearance and odor: Odorless, brown solid or blue-black solid.

Cadmium sulfide dust

- Formula: CdS
- Synonyms: Greenockite
- Appearance: Yellow-orange solid.

Cadmium chloride dust

- Formula: $CdCl_2$
- Synonyms: None
- Appearance: White solid.

PERMISSIBLE EXPOSURE LIMIT (PEL)

The current OSHA standard for cadmium dust is 0.2 milligram of cadmium dust per cubic meter of air (mg/m^3) averaged over an eight-hour work shift, with a ceiling level of 0.6 mg/m^3. NIOSH has recommended that the permissible exposure limit be reduced to 40 micrograms of cadmium per cubic meter of air ($\mu g/m^3$) averaged over a work shift of up to 10 hours per day, 40 hours per week, with a ceiling level of 200 $\mu g/m^3$ averaged over a 15-minute period. The recommendations in this guideline supplement the recommendations in the NIOSH Criteria Document for Cadmium, which should be consulted for more detailed information.

HEALTH HAZARD INFORMATION

- **Routes of exposure**

Cadmium dust can affect the body if it is inhaled. It can also affect the body if it is swallowed.

- **Effects of overexposure**

1. Short-term Exposure: Cadmium dust may cause irritation of the nose and throat. If enough has been inhaled, after a delay of several hours, a person may also develop cough, chest pain, sweating, chills, shortness of breath, and weakness. Death may occur. Ingestion of cadmium dust may cause nausea, vomiting, diarrhea, and abdominal cramps.

2. Long-term Exposure: Repeated or prolonged exposure to cadmium dust may cause loss of sense of smell, ulceration of the nose, shortness of breath (emphysema), kidney damage, and mild anemia. Exposure to cadmium has also been reported to cause an increased incidence of cancer of the prostate in man. Injections of cadmium sulfate in animals have been reported to cause malformation in their offspring.

3. Reporting Signs and Symptoms: A physician should be contacted if anyone develops any signs or symptoms and suspects that they are caused by exposure to cadmium dust.

- **Recommended medical surveillance**

These recommendations reflect good industrial hygiene and medical surveillance practices and their implementation will assist in achieving an effective occupational health program. However, they may not be sufficient to achieve compliance with all requirements of OSHA regulations.

U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
Public Health Service Centers for Disease Control
National Institute for Occupational Safety and Health

U.S. DEPARTMENT OF LABOR
Occupational Safety and Health Administration

September 1978

The following medical procedures should be made available to each employee who is exposed to cadmium dust at potentially hazardous levels:

1. Initial Medical Examination:

—A complete history and physical examination: The purpose is to detect pre-existing conditions that might place the exposed employee at increased risk, and to establish a baseline for future health monitoring. Examination of the respiratory system, liver, kidneys, prostate, and blood should be stressed.

—Urinalysis: Since kidney damage has been observed in humans exposed to cadmium, a urinalysis should be obtained to include, at a minimum, specific gravity, albumin, glucose, and a microscopic on centrifuged sediment. In addition, the urine should be examined for low molecular weight proteins by use of 3% sulfosalicylic or other acceptable techniques.

—14" x 17" chest roentgenogram: Cadmium causes human lung damage. Surveillance of the lungs is indicated.

—Liver function tests: Cadmium may cause liver damage. A profile of liver function should be obtained by utilizing a medically acceptable array of biochemical tests.

—FVC and FEV (1 sec): Cadmium is reported to cause decreased pulmonary function. Periodic surveillance is indicated.

2. Periodic Medical Examination: The aforementioned medical examinations should be repeated on an annual basis, except that an x-ray is considered necessary only when indicated by the results of pulmonary function testing, or by signs and symptoms of respiratory disease. Urine protein measurements should be made available every four months.

• Summary of toxicology

Cadmium dust causes both acute and chronic effects. It is less toxic than cadmium fume, because dust has a larger particle size than fume; at high concentrations of the dust, physiologic effects similar to those arising from fume exposure could be expected. The acute effects primarily involve the lungs but may also affect other organ systems. Most acute intoxications have been caused by inhalation of cadmium fume at concentrations which did not provide warning symptoms of irritation. The average concentrations of fume responsible for fatalities have been 40 to 50 mg/m³ for 1 hour, or 9 mg/m³ for 5 hours. Non-fatal pneumonitis has been reported from concentrations of 0.5 to 2.5 mg/m³, while relatively mild cases have been attributed to even lower concentrations. Following an asymptomatic latent period of 4 to 10 hours, there is characteristical nasopharyngeal irritation followed by a feeling of chest constriction or substernal pain, with persistent cough and dyspnea; there may also be headache, chills, muscle aches, nausea, vomiting, and diarrhea. Pulmonary edema may then develop and progress rapidly, with decreased vital capacity and markedly reduced carbon monoxide diffusing capacity. Cyanosis may be intense. In about 20% of the cases the dyspnea is progressive, accompanied by wheezing or hemoptysis, and may result in death within 7 to 10 days after exposure; at autopsy the lungs are markedly congested, and there is an intra-alveolar fibrinous exudate, as well as alveolar cell metaplasia. Among survivors, the subsequent course is unpredictable: most cases resolve slowly, but respiratory symptoms may linger for several weeks, while impairment of pulmonary function may persist for months. In experimental animals, cadmium exposure has caused pulmonary fibrosis, but this has not been documented in humans. In one fatal human case, in addition to lung abnormalities, there was renal cortical necrosis. Absorbed cadmium is retained to a large extent by the body, and excretion is very slow. Continued exposure to low levels of cadmium in air has resulted in chronic poisoning characterized by irreversible lung injury of an emphysematous type, with abnormal lung function and urinary excretion of a specific low-molecular-weight protein which may be associated with renal dysfunction. Clinical evidence of the cumulative effects of cadmium may appear after exposure has terminated; the disease then tends to be progressive. The frequency of occurrence of proteinuria increases with length of exposure: those exposed to cadmium compounds for less than 2 years had no proteinuria, whereas most of those exposed for 12 years or more had proteinuria with little other evidence of renal damage. The urinary excretion of cadmium bears no known relationship to the severity or duration of exposure and is only a confirmation of absorption. Other consequences of cadmium exposure are rhinitis, occasional ulceration of the nasal septum, damage to the olfactory nerve, and anosmia. The long-term ingestion of water, beans, and rice contaminated with cadmium has been proposed as the probable cause of a crippling condition among Japanese women who have had multiple pregnancies; severe pain in the back and joints, a waddly gait, osteomalacia, spontaneous fractures, and occasional fatal renal failure are characteristics of the disorder, which has been termed "itai-itai." Subcutaneous injection of cadmium metal suspended in fowl serum produced rhabdomyosarcomata in rats; cadmium sulfate in sterile distilled water produced sarcomata; and cadmium chloride solution produced pleomorphic sarcomata at the injection site. Increased incidence of prostatic cancer has been reported following occupational exposure to cadmium. Cadmium sulfate injected into the lingual vein of female hamsters on day 8 of pregnancy caused a high incidence of resorption and malformed offspring; acute necrosis of rat testes follows large doses orally or parenterally, but testicular effects have not been reported in humans.

CHEMICAL AND PHYSICAL PROPERTIES

- **Physical data—Cadmium metal dust**

1. Molecular weight: 112.4
2. Boiling point (760 mm Hg): 767 C (1412 F)
3. Specific gravity (water = 1): 8.642
4. Vapor density (air = 1 at boiling point of cadmium metal dust): Not applicable
5. Melting point: 321 C (609 F)
6. Vapor pressure at 20 C (68 F): Essentially zero
7. Solubility in water, g/100 g water at 20 C (68 F): Insoluble
8. Evaporation rate (butyl acetate = 1): Not applicable

- **Physical data—Cadmium oxide dust**

1. Molecular weight: 128.4
2. Boiling point (760 mm Hg): 900 C (1652 F) (sublimes and decomposes)
3. Specific gravity (water = 1): 6.95 or 8.15
4. Vapor density (air = 1 at boiling point of cadmium oxide dust): Not applicable
5. Melting point: 900 C (1652 F) (sublimes and decomposes)
6. Vapor pressure at 20 C (68 F): Essentially zero
7. Solubility in water, g/100 g water at 20 C (68 F): 0.0005
8. Evaporation rate (butyl acetate = 1): Not applicable

- **Physical data—Cadmium sulfide dust**

1. Molecular weight: 144.5
2. Boiling point (760 mm Hg): Sublimes in N_2 at 980 C (1796 F)
3. Specific gravity (water = 1): 4.82
4. Vapor density (air = 1 at boiling point of cadmium sulfide dust): Not applicable
5. Melting point: 1750 C (3182 F) at 100 atm.
6. Vapor pressure at 20 C (68 F): Essentially zero
7. Solubility in water, g/100 g water at 20 C (68 F): 0.0001
8. Evaporation rate (butyl acetate = 1): Not applicable

- **Physical data—Cadmium chloride dust**

1. Molecular weight: 183
2. Boiling point (760 mm Hg): 960 C (1760 F)
3. Specific gravity (water = 1): 4.047
4. Vapor density (air = 1 at boiling point of cadmium chloride dust): Not applicable
5. Melting point: 568 C (1054 F)
6. Vapor pressure at 20 C (68 F): Essentially zero
7. Solubility in water, g/100 g water at 20 C (68 F): 140
8. Evaporation rate (butyl acetate = 1): Not applicable

- **Reactivity**

1. Conditions contributing to instability: None hazardous
2. Incompatibilities: Contact of cadmium metal dust with strong oxidizers or with elemental sulfur, selenium, and tellurium may cause fires and explosions.
3. Hazardous decomposition products: Toxic gases and vapors (such as cadmium oxide fume) may be released in a fire involving cadmium dust.
4. Special precautions: None

- **Flammability**

1. Flash point: Not applicable
2. Autoignition temperature: 250 C (482 F) (layer) (cadmium metal dust)
3. Minimum explosive dust concentration: Data not available
4. Extinguishant: Dry powder for metal fires

- **Warning properties**

Grant states that "cadmium is a very toxic metal which gives off fumes when burned or heated strongly. Characteristically these fumes cause dryness and irritation of the throat, followed in a few hours by nausea and diarrhea. Smarting of the eyes occurs relatively infrequently, and no injury to the eyes of human beings has been reported. Neither eye nor respiratory irritation is enough to prevent exposures which may cause serious systemic poisoning and damage to the lungs."

MONITORING AND MEASUREMENT PROCEDURES

- **Eight-Hour Exposure Evaluation**

Measurements to determine employee exposure are best taken so that the average eight-hour exposure is based on a single eight-hour sample or on two four-hour samples. Several short-time interval samples (up to 30 minutes) may also be used to determine the average exposure level. Air samples should be taken in the employee's breathing zone (air that would most nearly represent that inhaled by the employee).

- **Ceiling Evaluation**

Measurements to determine employee ceiling exposure are best taken during periods of maximum expected airborne concentrations of cadmium dust. Each measurement should consist of a fifteen (15) minute sample or series of consecutive samples totalling fifteen (15) minutes in the employee's breathing zone (air that would most nearly represent that inhaled by the employee). A minimum of three (3) measurements should be taken on one work shift and the highest of all measurements taken is an estimate of the employee's exposure.

- **Method**

Sampling and analyses may be performed by collection of cadmium dust on a filter, followed by treatment with nitric acid, solution in hydrochloric acid, and atomic absorption spectrophotometric analysis. An analytical method for cadmium dust is in the *NIOSH Manual of Analytical Methods*, 2nd Ed., Vol. 3, 1977, available from the Government Printing Office, Washington D.C. 20402 (GPO No. 017-033-00261-4).

RESPIRATORS

• Good industrial hygiene practices recommend that engineering controls be used to reduce environmental concentrations to the permissible exposure level. However, there are some exceptions where respirators may be used to control exposure. Respirators may be used when engineering and work practice controls are not technically feasible, when such controls are in the process of being installed, or when they fail and need to be supplemented. Respirators may also be used for operations which require entry into tanks or closed vessels, and in emergency situations. If the use of respirators is necessary, the only respirators permitted are those that have been approved by the Mine Safety and Health Administration (formerly Mining Enforcement and Safety Administration) or by the National Institute for Occupational Safety and Health.

• In addition to respirator selection, a complete respiratory protection program should be instituted which includes regular training, maintenance, inspection, cleaning, and evaluation.

PERSONAL PROTECTIVE EQUIPMENT

• If employees' clothing has had any possibility of being contaminated with cadmium dust, employees should change into uncontaminated clothing before leaving the work premises.

• Clothing which has had any possibility of being contaminated with cadmium dust should be placed in closed containers for storage until it can be discarded or until provision is made for the removal of cadmium dust from the clothing. If the clothing is to be laundered or otherwise cleaned to remove the cadmium dust, the person performing the operation should be informed of cadmium dust's hazardous properties.

• Employees should be provided with and required to use dust-resistant safety goggles where there is any possibility of cadmium chloride dust contacting the eyes.

• Where there is any possibility that employees' eyes may be exposed to cadmium chloride dust, an eye-wash fountain should be provided within the immediate work area for emergency use.

SANITATION

• Workers subject to skin contact with cadmium dust should wash with soap or mild detergent and water any areas of the body which may have contacted cadmium dust at the end of each work day.

• Eating and smoking should not be permitted in areas where cadmium dust is handled, processed, or stored.

• Employees who handle cadmium dust should wash their hands thoroughly with soap or mild detergent and water before eating or smoking.

COMMON OPERATIONS AND CONTROLS

The following list includes some common operations in which exposure to cadmium dust may occur and control methods which may be effective in each case:

Operation	Controls
Liberation from fabrication of cadmium-plated marine, aircraft, and motor vehicle equipment for corrosion-resistant coatings	Local exhaust ventilation; personal protective equipment
Liberation during processing of cadmium metal	Process enclosure; local exhaust ventilation; personal protective equipment
Liberation in synthesis of cadmium compounds	Process enclosure; local exhaust ventilation
Liberation in manufacture and fabrication of cadmium alloys; recovery from flue dusts during smelting of lead and zinc operations	Local exhaust ventilation; personal protective equipment
Liberation during manufacture of nuclear reactor rods	Process enclosure; local exhaust ventilation

EMERGENCY FIRST AID PROCEDURES

In the event of an emergency, institute first aid procedures and send for first aid or medical assistance.

• **Eye Exposure**

If cadmium dust gets into the eyes, wash eyes immediately with large amounts of water, lifting the lower and upper lids occasionally. If irritation is present after washing, get medical attention. Contact lenses should not be worn when working with this chemical.

• **Skin Exposure**

If cadmium dust gets on the skin, wash the contaminated skin using soap or mild detergent and water. Be sure to wash the hands well before eating or smoking and at the close of work.

• **Breathing**

If a person breathes in large amounts of cadmium dust, move the exposed person to fresh air at once. If breathing has stopped, perform artificial respiration. Keep the affected person warm and at rest. Get medical attention as soon as possible.

• **Swallowing**

When cadmium dust or liquids containing cadmium dust have been swallowed and the person is conscious, give the person large quantities of water immediately. After the water has been swallowed, try to get the

person to vomit by having him touch the back of his throat with his finger. Do not make an unconscious person vomit. Get medical attention immediately.

• **Rescue**

Move the affected person from the hazardous exposure. If the exposed person has been overcome, notify someone else and put into effect the established emergency rescue procedures. Do not become a casualty. Understand the facility's emergency rescue procedures and know the locations of rescue equipment before the need arises.

SPILL AND DISPOSAL PROCEDURES

• Persons not wearing protective equipment and clothing should be restricted from areas of releases until cleanup has been completed.

• If cadmium dust is released in hazardous concentrations, the following steps should be taken:

1. Remove all ignition sources.
2. Ventilate area of release.
3. Collect released material in the most convenient and safe manner for reclamation or for disposal in sealed conainers in a secured sanitary landfill.

• Waste disposal method:

Cadmium dust may be disposed of in sealed containers in a secured sanitary landfill.

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* SPECIAL NOTE

The International Agency for Research on Cancer (IARC) has evaluated the data on these chemicals and has concluded that they cause cancer. See *IARC Monographs on the Evaluation of Carcinogenic Risk of Chemicals to Man*, Volume 2, 1973, and Volume 11, 1976.

RESPIRATORY PROTECTION FOR CADMIUM DUST (AS CADMIUM)

Condition	Minimum Respiratory Protection* Required Above 0.2 mg/m³
Dust Concentration	
1 mg/m³ or less	Any dust respirator, except single-use.
2 mg/m³ or less	Any dust respirator, except single-use or quarter-mask respirator. Any high efficiency particulate filter respirator. Any supplied-air respirator. Any self-contained breathing apparatus.
10 mg/m³ or less	A high efficiency particulate filter respirator with a full facepiece. Any supplied-air respirator with a full facepiece, helmet, or hood. Any self-contained breathing apparatus with a full facepiece.
40 mg/m³ or less	A powered air-purifying respirator with a high efficiency particulate filter. A Type C supplied-air respirator operated in pressure-demand or other positive pressure or continuous-flow mode.
Greater than 40 mg/m³ or entry and escape from unknown concentrations	Self-contained breathing apparatus with a full facepiece operated in pressure-demand or other positive pressure mode. A combination respirator which includes a Type C supplied-air respirator with a full facepiece operated in pressure-demand or other positive pressure or continuous-flow mode and an auxiliary self-contained breathing apparatus operated in pressure-demand or other positive pressure mode.
Fire Fighting	Self-contained breathing apparatus with a full facepiece operated in pressure-demand or other positive pressure mode.
Escape	Any dust respirator, except single-use. Any escape self-contained breathing apparatus.

*Only NIOSH-approved or MSHA-approved equipment should be used.

Occupational Health Guideline for Chlorobenzene

INTRODUCTION

This guideline is intended as a source of information for employees, employers, physicians, industrial hygienists, and other occupational health professionals who may have a need for such information. It does not attempt to present all data; rather, it presents pertinent information and data in summary form.

SUBSTANCE IDENTIFICATION

- Formula: C_6H_5Cl
- Synonyms: Monochlorobenzene; chlorobenzol; phenyl chloride; MCB
- Appearance and odor: Colorless liquid with a mild aromatic odor.

PERMISSIBLE EXPOSURE LIMIT (PEL)

The current OSHA standard for chlorobenzene is 75 parts of chlorobenzene per million parts of air (ppm) averaged over an eight-hour work shift. This may also be expressed as 350 milligrams of chlorobenzene per cubic meter of air (mg/m^3).

HEALTH HAZARD INFORMATION

- **Routes of exposure**

Chlorobenzene can affect the body if it is inhaled or if it comes in contact with the eyes or skin. It can also affect the body if it is swallowed.

- **Effects of overexposure**

1. Short-term Exposure: Chlorobenzene may cause drowsiness, incoordination, and unconsciousness. It may also cause irritation of the eyes, nose, and skin. Exposure to high levels might also cause liver damage.

2. Long-term Exposure: Prolonged or repeated skin contact with chlorobenzene liquid may cause skin burns. Prolonged or repeated exposure to this chemical might also result in liver, kidney, or lung damage.

3. Reporting Signs and Symptoms: A physician should be contacted if anyone develops any signs or symptoms and suspects that they are caused by exposure to chlorobenzene.

- **Recommended medical surveillance**

The following medical procedures should be made available to each employee who is exposed to chlorobenzene at potentially hazardous levels:

1. Initial Medical Screening: Employees should be screened for history of certain medical conditions (listed below) which might place the employee at increased risk from chlorobenzene exposure.

—Skin disease: Chlorobenzene can cause dermatitis on exposure. Persons with pre-existing skin disorders may be more susceptible to the effects of this agent.

—Liver disease: Chlorobenzene is known as a liver toxin in animals. The importance of this organ in the biotransformation and detoxification of foreign substances should be considered before exposing persons with impaired liver function.

—Kidney disease: Although chlorobenzene is not known as a kidney toxin in humans, the importance of this organ in the elimination of toxic substances justifies special consideration in those with impaired renal function.

—Chronic respiratory disease: In persons with impaired pulmonary function, especially those with obstructive airway diseases, the breathing of chlorobenzene might cause exacerbation of symptoms due to its irritant properties.

2. Periodic Medical Examination: Any employee developing the above-listed conditions should be referred for further medical examination.

- **Summary of toxicology**

Chlorobenzene vapor is a narcotic. Cats exposed to 8,000 ppm showed severe narcosis after ½ hour and died 2 hours after removal from exposure, but 660 ppm for 1 hour was tolerated. Exposed animals showed eye and nose irritation, drowsiness, incoordination, and coma followed by death from the most severe exposures. Several species of animals exposed to 1,000 ppm for 7 hours/day, 5 days/week over a period of 44 days showed histopathologic changes in the lungs, liver, and

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kidneys, but at 475 ppm there was only slight liver histopathology in guinea pigs. Toxicologic studies and experience indicate that chlorobenzene does not cause the type of blood changes seen with benzene exposure. In man, eye and nasal irritation begin to occur at 200 ppm, and at that level the odor is pronounced and unpleasant; industrial experience indicates that occasional short exposures are not likely to result in more than minor skin irritation, but prolonged or frequently repeated contact may result in skin burns. In one case of accidental poisoning from ingestion of the liquid by a child there was pallor, cyanosis, and coma, followed by complete recovery. Occupational intoxication has not been reported.

CHEMICAL AND PHYSICAL PROPERTIES

- **Physical data**
  1. Molecular weight: 112.5
  2. Boiling point (760 mm Hg): 132 C (270 F)
  3. Specific gravity (water = 1): 1.1
  4. Vapor density (air = 1 at boiling point of chlorobenzene): 3.9
  5. Melting point: −44 C (-47 F)
  6. Vapor pressure at 20 C (68 F): 8.8 mm Hg
  7. Solubility in water, g/100 g water at 20 C (68 F): 0.05
  8. Evaporation rate (butyl acetate = 1): 1
- **Reactivity**
  1. Conditions contributing to instability: Heat
  2. Incompatibilities: Contact with strong oxidizers may cause fires and explosions.
  3. Hazardous decomposition products: Toxic gases and vapors (such as hydrogen chloride, phosgene, and carbon monoxide) may be released in a fire involving chlorobenzene.
  4. Special precautions: Liquid chlorobenzene will attack some forms of plastics, rubber, and coatings.
- **Flammability**
  1. Flash point: 28.9 C (84 F) (closed cup)
  2. Autoignition temperature: 638 C (1180 F)
  3. Flammable limits in air, % by volume: Lower: 1.3; Upper: 7.1
  4. Extinguishant: Carbon dioxide; dry chemical, foam
- **Warning properties**

According to both Deichmann and Gerarde and the AIHA *Hygienic Guide*, the odor of chlorobenzene is "barely perceptible" at 60 ppm, a concentration below that of the permissible exposure. Chlorobenzene is considered to have good warning properties. It is an eye irritant, as stated by Patty, but the exact concentrations at which this irritation occurs are not mentioned.

MONITORING AND MEASUREMENT PROCEDURES

- **General**

Measurements to determine employee exposure are best taken so that the average eight-hour exposure is based on a single eight-hour sample or on two four-hour samples. Several short-time interval samples (up to 30 minutes) may also be used to determine the average exposure level. Air samples should be taken in the employee's breathing zone (air that would most nearly represent that inhaled by the employee).

- **Method**

Sampling and analyses may be performed by collection of vapors using an adsorption tube with subsequent desorption with carbon disulfide and gas chromatographic analysis. Also, detector tubes certified by NIOSH under 42 CFR Part 84 or other direct-reading devices calibrated to measure chlorobenzene may be used. An analytical method for chlorobenzene is in the *NIOSH Manual of Analytical Methods*, 2nd Ed., Vol. 2, 1977, available from the Government Printing Office, Washington, D.C. 20402 (GPO No. 017-033-00260-6).

RESPIRATORS

- Good industrial hygiene practices recommend that engineering controls be used to reduce environmental concentrations to the permissible exposure level. However, there are some exceptions where respirators may be used to control exposure. Respirators may be used when engineering and work practice controls are not technically feasible, when such controls are in the process of being installed, or when they fail and need to be supplemented. Respirators may also be used for operations which require entry into tanks or closed vessels, and in emergency situations. If the use of respirators is necessary, the only respirators permitted are those that have been approved by the Mine Safety and Health Administration (formerly Mining Enforcement and Safety Administration) or by the National Institute for Occupational Safety and Health.
- In addition to respirator selection, a complete respiratory protection program should be instituted which includes regular training, maintenance, inspection, cleaning, and evaluation.

PERSONAL PROTECTIVE EQUIPMENT

- Employees should be provided with and required to use impervious clothing, gloves, face shields (eight-inch minimum), and other appropriate protective clothing necessary to prevent repeated or prolonged skin contact with liquid chlorobenzene.
- Clothing wet with liquid chlorobenzene should be placed in closed containers for storage until it can be discarded or until provision is made for the removal of chlorobenzene from the clothing. If the clothing is to be laundered or otherwise cleaned to remove the chlorobenzene, the person performing the operation should be informed of chlorobenzene's hazardous properties.
- Any clothing which becomes wet with liquid chlorobenzene should be removed immediately and not

reworn until the chlorobenzene is removed from the clothing.

• Employees should be provided with and required to use splash-proof safety goggles where liquid chlorobenzene may contact the eyes.

SANITATION

• Skin that becomes wet with liquid chlorobenzene should be promptly washed or showered with soap or mild detergent and water to remove any chlorobenzene.

COMMON OPERATIONS AND CONTROLS

The following list includes some common operations in which exposure to chlorobenzene may occur and control methods which may be effective in each case:

Operation	Controls
Use in manufacture of phenol in synthesis of polymeric materials	Local exhaust ventilation
Use as an intermediate in manufacture of ortho- and para-nitrobenzenes for use in dye manufacture; manufacture of DDT, aniline, picric acid, beta-chloroanthraquinone, and other chemicals; manufacture of rubber adhesives and adhesives	Process enclosure
Use as fiber swelling agent and dye carrier in textile processing	Local exhaust ventilation
Use as tar and grease remover in cleaning and degreasing operations	Local exhaust ventilation
Use as solvent in surface coatings and surface coating removers	Process enclosure; local exhaust ventilation; personal protective equipment
Use as extractant in manufacture of diisocyanates, rubber, perfumes, and pharmaceuticals	Local exhaust ventilation

EMERGENCY FIRST AID PROCEDURES

In the event of an emergency, institute first aid procedures and send for first aid or medical assistance.

• **Eye Exposure**

If chlorobenzene gets into the eyes, wash eyes immediately with large amounts of water, lifting the lower and upper lids occasionally. Get medical attention immediately. Contact lenses should not be worn when working with this chemical.

• **Skin Exposure**

If chlorobenzene gets on the skin, promptly wash the contaminated skin using soap or mild detergent and water. If chlorobenzene soaks through the clothing, remove the clothing immediately and wash the skin using soap or mild detergent and water. If irritation persists after washing, get medical attention.

• **Breathing**

If a person breathes in large amounts of chlorobenzene, move the exposed person to fresh air at once. If breathing has stopped, perform artificial respiration. Keep the affected person warm and at rest. Get medical attention as soon as possible.

• **Swallowing**

If chlorobenzene has been swallowed, do not induce vomiting. Get medical attention immediately.

• **Rescue**

Move the affected person from the hazardous exposure. If the exposed person has been overcome, notify someone else and put into effect the established emergency rescue procedures. Do not become a casualty. Understand the facility's emergency rescue procedures and know the locations of rescue equipment before the need arises.

SPILL, LEAK, AND DISPOSAL PROCEDURES

• Persons not wearing protective equipment and clothing should be restricted from areas of spills or leaks until cleanup has been completed.

• If chlorobenzene is spilled or leaked, the following steps should be taken:

1. Remove all ignition sources.
2. Ventilate area of spill or leak.
3. For small quantities, absorb on paper towels. Evaporate in a safe place (such as a fume hood). Allow sufficient time for evaporating vapors to completely clear the hood ductwork. Burn the paper in a suitable location away from combustible materials. Large quantities can be reclaimed or collected and atomized in a suitable combustion chamber equipped with an appropriate effluent gas cleaning device. Chlorobenzene should not be allowed to enter a confined space, such as a sewer, because of the possibility of an explosion. Sewers designed to preclude the formation of explosive concentrations of chlorobenzene vapors are permitted.

• Waste disposal method:

Chlorobenzene may be disposed of by atomizing in a suitable combustion chamber equipped with an appropriate effluent gas cleaning device.

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RESPIRATORY PROTECTION FOR CHLOROBENZENE

Condition	Minimum Respiratory Protection* Required Above 75 ppm
Vapor Concentration	
1000 ppm or less	A chemical cartridge respirator with a full facepiece and an organic vapor cartridge(s).
2400 ppm or less	A gas mask with a chin-style or a front- or back-mounted organic vapor canister. Any supplied-air respirator with a full facepiece, helmet, or hood. Any self-contained breathing apparatus with a full facepiece.
Greater than 2400 ppm or entry and escape from unknown concentrations	Self-contained breathing apparatus with a full facepiece operated in pressure-demand or other positive pressure mode. A combination respirator which includes a Type C supplied-air respirator with a full facepiece operated in pressure-demand or other positive pressure or continuous-flow mode and an auxiliary self-contained breathing apparatus operated in pressure-demand or other positive pressure mode.
Fire Fighting	Self-contained breathing apparatus with a full facepiece operated in pressure-demand or other positive pressure mode.
Escape	Any gas mask providing protection against organic vapors. Any escape self-contained breathing apparatus.

*Only NIOSH-approved or MSHA-approved equipment should be used.

Occupational Health Guideline for Chromium Metal and Insoluble Chromium Salts*

INTRODUCTION

This guideline is intended as a source of information for employees, employers, physicians, industrial hygienists, and other occupational health professionals who may have a need for such information. It does not attempt to present all data; rather, it presents pertinent information and data in summary form.

APPLICABILITY

The general guidelines contained in this document apply to all chromium metal and insoluble chromium salts. Physical and chemical properties of some specific compounds are provided for illustrative purposes.

SUBSTANCE IDENTIFICATION

Metallic chromium

- Formula: Cr
- Synonyms: None
- Appearance and odor: Shiny, odorless metal.

Copper chromite

- Formula: $Cu_2Cr_2O_4$
- Synonyms: Cuprous chromite
- Appearance and odor: Greenish-blue, odorless solid.

PERMISSIBLE EXPOSURE LIMIT (PEL)

The current OSHA standard for chromium metal or insoluble chromium salts is 1 milligram of chromium metal or insoluble chromium salts per cubic meter of air (mg/m^3) averaged over an eight-hour work shift. Certain forms of chromium (VI) have been found to cause increased respiratory cancer among workers. Certain other forms of chromium (VI) are currently believed to be non-carcinogenic: The non-carcinogenic forms are the monochromates and bichromates (dichromates) of hydrogen, lithium, sodium, potassium, rubidium, cesium, and ammonium, and chromium (VI) oxide (chromium acid anhydride). NIOSH has not conducted an in-depth study of the toxicity of chromium metal or compounds containing chromium in an oxidation state other than 6. NIOSH recommends that the permissible exposure limit for carcinogenic chromium (VI) compounds be reduced to 0.001 Cr (VI) mg/m^3 and that these compounds be regulated as occupational carcinogens. NIOSH also recommends that the permissible exposure limit for non-carcinogenic chromium (VI) be reduced to 0.025 Cr (VI) mg/m^3 averaged over a work shift of up to 10 hours per day, 40 hours per week, with a ceiling level of 0.05 Cr (VI) mg/m^3 averaged over a 15-minute period. It is further recommended that chromium (VI) in the workplace be considered carcinogenic, unless it has been demonstrated that only the non-carcinogenic chromium (VI) compounds mentioned above are present. The NIOSH Criteria Documents for Chromic Acid and Chromium (VI) should be consulted for more detailed information.

HEALTH HAZARD INFORMATION

- **Routes of exposure**

Chromium metal or insoluble chromium salts can affect the body if they are inhaled. They can also affect the body if they are swallowed.

- **Effects of overexposure**

Ferro chrome alloys have been associated with lung changes in workers exposed to these alloys. Chromite dust exposure may cause minor lung changes.

- **Reporting signs and symptoms**

A physician should be contacted if anyone develops any signs or symptoms and suspects that they are caused by exposure to chromium metal or insoluble chromium salts.

- **Recommended medical surveillance**

The following medical procedures should be made available to each employee who is exposed to chromium metal or insoluble chromium salts at potentially hazardous levels:

These recommendations reflect good industrial hygiene and medical surveillance practices and their implementation will assist in achieving an effective occupational health program. However, they may not be sufficient to achieve compliance with all requirements of OSHA regulations.

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1. Initial Medical Examination:

—A complete history and physical examination: The purpose is to detect pre-existing conditions that might place the exposed employee at increased risk, and to establish a baseline for future health monitoring. Examination of the respiratory system should be stressed.

—14" x 17" chest roentgenogram: Chromium and its insoluble salts may cause human lung damage. Surveillance of the lungs is indicated.

—FVC and FEV (1 sec): Insoluble chromium salts are reported to cause decreased pulmonary function. Periodic surveillance is indicated.

2. Periodic Medical Examination: The aforementioned medical examinations should be repeated on an annual basis.

• **Summary of toxicology**

The dusts of chromium metal and its insoluble salts, chiefly the chromites, are usually reported to be relatively nontoxic; this is debatable, since exposures associated with toxic effects are usually mixed exposures involving several hexavalent chromium compounds. Ferrochrome alloys have been associated with pulmonary disease in humans. Four workers engaged in the production of ferrochrome alloys developed a nodular type of pulmonary disease with impairment of pulmonary function; air concentrations of chromium in this study averaged 0.26 mg/m^3, although other fumes and dusts were also present. This pulmonary problem may be one of hypersensitivity and thus reversible. Other reports state that chest roentgenograms have revealed only "exaggerated pulmonic markings" in workers exposed to chromite dust. The lungs of groups of workers exposed to chromite dust have been shown to be the seat of pneumoconiotic changes consisting of slight thickening of interstitial tissue and interalveolar septa, with histologic fibrosis and hyalinization. Chromite ore roast mixed with sheep fat implanted intrapleurally in rats produced squamous cell carcinomata coexisting with sarcomata of the lungs; the same material implanted in the thighs of rats produced fibrosarcomata. A refractory plant using chromite ore to make chromite brick had no excess of lung cancer deaths over a 14-year period, and it was concluded that chromite alone probably is not carcinogenic.

CHEMICAL AND PHYSICAL PROPERTIES

• **Physical data—Metallic chromium**

1. Molecular weight: 52
2. Boiling point (760 mm Hg): 2640 C (4784 F)
3. Specific gravity (water = 1): 7.2
4. Vapor density (air = 1 at boiling point of metallic chromium): Not applicable
5. Melting point: 1900 C (3452 F)
6. Vapor pressure at 20 C (68 F): Essentially zero
7. Solubility in water, g/100 g water at 20 C (68 F): Insoluble
8. Evaporation rate (butyl acetate = 1): Not applicable

• **Physical data—Copper chromite**

1. Molecular weight: 295.1
2. Boiling point (760 mm Hg): Data not available
3. Specific gravity (water = 1): 5.24
4. Vapor density (air = 1 at boiling point of copper chromite): Not applicable
5. Melting point: Data not available
6. Vapor pressure at 20 C (68 F): Essentially zero
7. Solubility in water, g/100 g water at 20 C (68 F): Insoluble
8. Evaporation rate (butyl acetate = 1): Not applicable

• **Physical data—Basic potassium zinc chromate**

1. Molecular weight: 873.8
2. Boiling point (760 mm Hg): Decomposes at red heat
3. Specific gravity (water = 1): 3.47
4. Vapor density (air = 1 at boiling point of basic potassium zinc chromate): Not applicable
5. Melting point: Loses water slowly above 100 C (212 F)
6. Vapor pressure at 20 C (68 F): Essentially zero
7. Solubility in water, g/100 g water at 20 C (68 F): Insoluble
8. Evaporation rate (butyl acetate = 1): Not applicable

• **Reactivity**

1. Conditions contributing to instability: None
2. Incompatibilities: Chromium metal in contact with strong oxidizers may cause fires and explosions.
3. Hazardous decomposition products: None listed.
4. Special precautions: None listed.

• **Flammability**

1. Flash point: Not applicable
2. Minimum ignition temperature (metal): 400 C (752 F) (layer); 580 C (1076 F) (cloud)
3. Minimum explosive dust concentration (metal): 230 grams/m^3
4. Extinguishant: Dry sand, dry dolomite, dry graphite

• **Warning properties**

Chromium metal and insoluble salts are not known to be eye irritants.

MONITORING AND MEASUREMENT PROCEDURES

• **Eight-Hour Exposure Evaluation**

Measurements to determine employee exposure are best taken so that the average eight-hour exposure is based on a single eight-hour sample or on two four-hour samples. Several short-time interval samples (up to 30 minutes) may also be used to determine the average exposure level. Air samples should be taken in the employee's breathing zone (air that would most nearly represent that inhaled by the employee).

• **Ceiling Evaluation**

Measurements to determine employee ceiling exposure are best taken during periods of maximum expected

airborne concentrations of chromium metal or insoluble chromium salts. Each measurement should consist of a fifteen (15) minute sample or series of consecutive samples totalling fifteen (15) minutes in the employee's breathing zone (air that would most nearly represent that inhaled by the employee). A minimum of three (3) measurements should be taken on one work shift and the highest of all measurements taken is an estimate of the employee's exposure.

• **Method**

Sampling and analyses may be performed by collection of chromium metal or insoluble chromium salts on a filter, followed by treatment with acid and atomic absorption spectrophotometric analysis. An analytical method for chromium metal and insoluble chromium salts is in the *NIOSH Manual of Analytical Methods*, 2nd Ed., Vol. 6, 1980, available from the Government Printing Office, Washington, D.C. 20402 (GPO No. 017-033-00369-6).

RESPIRATORS

• Good industrial hygiene practices recommend that engineering controls be used to reduce environmental concentrations to the permissible exposure level. However, there are some exceptions where respirators may be used to control exposure. Respirators may be used when engineering and work practice controls are not technically feasible, when such controls are in the process of being installed, or when they fail and need to be supplemented. Respirators may also be used for operations which require entry into tanks or closed vessels, and in emergency situations. If the use of respirators is necessary, the only respirators permitted are those that have been approved by the Mine Safety and Health Administration (formerly Mining Enforcement and Safety Administration) or by the National Institute for Occupational Safety and Health.

• In addition to respirator selection, a complete respiratory protection program should be instituted which includes regular training, maintenance, inspection, cleaning, and evaluation.

PERSONAL PROTECTIVE EQUIPMENT

• Employees should be provided with and required to use impervious clothing, gloves, face shields (eight-inch minimum), and other appropriate protective clothing necessary to prevent repeated or prolonged skin contact with solids or liquids containing insoluble chromium salts.

• Clothing contaminated with insoluble chromium salts should be placed in closed containers for storage until it can be discarded or until provision is made for the removal of insoluble chromium salts from the clothing. If the clothing is to be laundered or otherwise cleaned to remove the insoluble chromium salts, the person performing the operation should be informed of insoluble chromium salts's hazardous properties.

• Non-impervious clothing which becomes contaminated with insoluble chromium salts should be removed promptly and not reworn until the insoluble chromium salts are removed from the clothing.

• Employees should be provided with and required to use dust- and splashproof safety goggles where solids or liquids containing insoluble chromium salts may contact the eyes.

SANITATION

• Skin that becomes contaminated with insoluble chromium salts should be promptly washed or showered with soap or mild detergent and water to remove any insoluble chromium salts.

• Eating and smoking should not be permitted in areas where solids or liquids containing insoluble chromium salts are handled, processed, or stored.

• Employees who handle solids or liquids containing insoluble chromium salts should wash their hands thoroughly with soap or mild detergent and water before eating, smoking, or using toilet facilities.

COMMON OPERATIONS AND CONTROLS

The following list includes some common operations in which exposure to chromium metal or insoluble chromium salts may occur and control methods which may be effective in each case:

Operation	Controls
Use in fabrication of alloys	Local exhaust ventilation; general dilution ventilation; personal protective equipment
Use in preparation of alloy steels to enhance corrosion- and heat-resistance	Local exhaust ventilation; general dilution ventilation
Use in fabrication of plated products for decoration or increased wear-resistance	Local exhaust ventilation; general dilution ventilation; personal protective equipment
Use in production of non-ferrous alloys to impart special qualities to the alloys	Local exhaust ventilation; general dilution ventilation
Use in production and processing of insoluble salts	Local exhaust ventilation; general dilution ventilation; personal protective equipment

Operation	Controls
Use as chemical intermediates; use in textile industry in dyeing, silk treating, printing, and moth-proofing wool	Local exhaust ventilation; general dilution ventilation; personal protective equipment
Use in leather industry in tanning; use in photograhic fixing baths	Local exhaust ventilation; general dilution ventilation; personal protective equipment
Use as catalysts for halogenation, alkylation, and catalytic cracking of hydrocarbons	Local exhaust ventilation; general dilution ventilation
Use as fuel additives and propellant additives; in photogaphic fixing baths and in ceramics	Local exhaust ventilation; general dilution ventilation; personal protective equipment

EMERGENCY FIRST AID PROCEDURES

In the event of an emergency, institute first aid procedures and send for first aid or medical assistance.

• **Eye Exposure**

If chromium metal or solids or liquids containing insoluble chromium salts get into the eyes, wash eyes immediately with large amounts of water, lifting the lower and upper lids occasionally. If irritation is present after washing, get medical attention. Contact lenses should not be worn when working with these chemicals.

• **Skin Exposure**

If solids or liquids containing insoluble chromium salts get on the skin, wash the contaminated skin using soap or mild detergent and water. If solids or liquids containing insoluble chromium salts penetrate through the clothing, remove the clothing and wash the skin using soap or mild detergent and water. If irritation persists after washing, get medical attention.

• **Breathing**

If a person breathes in large amounts of chromium metal or insoluble chromium salts, move the exposed person to fresh air at once. If breathing has stopped, perform artificial respiration. Keep the affected person warm and at rest. Get medical attention as soon as possible.

• **Swallowing**

When solids or liquids containing insoluble chromium salts have been swallowed, give the person large quantities of water immediately. After the water has been swallowed, try to get the person to vomit by having him touch the back of his throat with his finger. Do not make an unconscious person vomit. Get medical attention immediately.

• **Rescue**

Move the affected person from the hazardous exposure. If the exposed person has been overcome, notify someone else and put into effect the established emergency rescue procedures. Do not become a casualty. Understand the facility's emergency rescue procedures and know the locations of rescue equipment before the need arises.

SPILL, LEAK, AND DISPOSAL PROCEDURES

• Persons not wearing protective equipment and clothing should be restricted from areas of spills until cleanup has been completed.

• If chromium metal or insoluble chromium salts are spilled, the following steps should be taken:

1. Remove all ignition sources where metallic chromium has been spilled.
2. Ventilate area of spill.
3. Collect spilled material in the most convenient and safe manner and deposit in sealed containers for reclamation or for disposal in a secured sanitary landfill. Liquid containing chromium metal or insoluble chromium salts should be absorbed in vermiculite, dry sand, earth, or a similar material.

• Waste disposal method:

Chromium metal or insoluble chromium salts may be disposed of in sealed containers in a secured sanitary landfill.

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• SPECIAL NOTE

The International Agency for Research on Cancer (IARC) has evaluated the data on these chemicals and has concluded that they cause cancer. See *IARC Monographs on the Evaluation of Carcinogenic Risk of Chemicals to Man*, Volume 2, 1973, and Volume 23, 1980.

• **Method**

Sampling and analyses may be performed by collection of chromium metal or insoluble chromium salts on a filter, followed by treatment with acid and atomic

RESPIRATORY PROTECTION FOR CHROMIUM METAL AND INSOLUBLE CHROMIUM SALTS (AS CHROMIUM)

Condition	Minimum Respiratory Protection* Required Above 1 mg/m³
Particulate Concentration	
5 mg/m³ or less	Any dust and mist respirator.
10 mg/m³ or less	Any dust and mist respirator, except single-use or quarter-mask respirator. Any fume respirator or high efficiency particulate respirator. Any supplied-air respirator. Any self-contained breathing apparatus.
50 mg/m³ or less	A high efficiency particulate filter respirator with a full facepiece. Any supplied-air respirator with a full facepiece, helmet, or hood. Any self-contained breathing apparatus with a full facepiece.
500 mg/m³ or less	A powered air-purifying respirator with a high efficiency particulate filter. A Type C supplied-air respirator operated in pressure-demand or other positive pressure or continuous-flow mode.
Greater than 500 mg/m³ or entry and escape from unknown concentrations	Self-contained breathing apparatus with a full facepiece operated in pressure-demand or other positive pressure mode. A combination respirator which includes a Type C supplied-air respirator with a full facepiece operated in pressure-demand or other positive pressure or continuous-flow mode and an auxiliary self-contained breathing apparatus operated in pressure-demand or other positive pressure mode.
Fire Fighting	Self-contained breathing apparatus with a full facepiece operated in pressure-demand or other positive pressure mode.

*Only NIOSH-approved or MSHA-approved equipment should be used.

Occupational Health Guideline for Coal Tar Pitch Volatiles

INTRODUCTION

This guideline is intended as a source of information for employees, employers, physicians, industrial hygienists, and other occupational health professionals who may have a need for such information. It does not attempt to present all data; rather, it presents pertinent information and data in summary form.

SUBSTANCE IDENTIFICATION

Anthracene

- Formula: $C_{14}H_{10}$
- Synonyms: None
- Appearance and odor: Pale green solid with a faint aromatic odor.

Phenanthrene

- Formula: $C_{14}H_{10}$
- Synonyms: None
- Appearance and odor: Colorless solid with a faint aromatic odor.

Pyrene

- Formula: $C_{16}H_{10}$
- Synonyms: None
- Appearance: Bright yellow solid

Carbazole

- Formula: $C_{12}H_9N$
- Synonyms: None
- Appearance and odor: Colorless solid with a faint aromatic odor.

Benzo(a)pyrene

- Formula: $C_{20}H_{12}$
- Synonyms: BaP, 3,4-benzopyrene
- Appearance and odor: Colorless solid with a faint aromatic odor.

PERMISSIBLE EXPOSURE LIMIT (PEL)

The current OSHA standard for coal tar pitch volatiles is 0.2 milligram of coal tar pitch volatiles per cubic meter of air (mg/m^3) averaged over an eight-hour work shift. NIOSH has recommended that the permissible exposure limit for coal tar products be reduced to 0.1 mg/m^3 (cyclohexane-extractable fraction) averaged over a work shift of up to 10 hours per day, 40 hours per week, and that coal tar products be regulated as occupational carcinogens. The NIOSH Criteria Document for Coal Tar Products and NIOSH Criteria Document for Coke Oven Emissions should be consulted for more detailed information.

HEALTH HAZARD INFORMATION

- **Routes of exposure**

Coal tar pitch volatiles can affect the body if they are inhaled or if they come in contact with the eyes or skin.

- **Effects of overexposure**

Repeated exposure to coal tar pitch volatiles has been associated with an increased risk of developing bronchitis and cancer of the lungs, skin, bladder, and kidneys. Pregnant women may be especially susceptible to exposure effects associated with coal tar pitch volatiles. Repeated exposure to these materials may also cause sunlight to have a more severe effect on a person's skin. In addition, this type of exposure may cause an allergic skin rash.

- **Reporting signs and symptoms**

A physician should be contacted if anyone develops any signs or symptoms and suspects that they are caused by exposure to coal tar pitch volatiles.

- **Recommended medical surveillance**

The following medical procedures should be made available to each employee who is exposed to coal tar pitch volatiles at potentially hazardous levels:

U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
Public Health Service Centers for Disease Control
National Institute for Occupational Safety and Health

U.S. DEPARTMENT OF LABOR
Occupational Safety and Health Administration

1. Initial Medical Examination:

—A complete history and physical examination: The purpose is to detect pre-existing conditions that might place the exposed employee at increased risk, and to establish a baseline for future health monitoring. Examination of the oral cavity, respiratory tract, bladder, and kidneys should be stressed. The skin should be examined for evidence of chronic disorders, for premalignant and malignant lesions, and evidence of hyperpigmentation or photosensitivity.

—Urinalysis: Coal tar pitch volatiles are associated with an excess of kidney and bladder cancer. A urinalysis should be obtained to include at a minimum specific gravity, albumin, glucose, and a microscopic on centrifuged sediment, as well as a test for red blood cells.

—Urinary cytology: Coal tar pitch volatiles are associated with an excess of kidney and bladder cancer. Employees having 5 or more years of exposure or who are 45 years of age or older should have a urinary cytology examination.

—Sputum cytology: Coal tar pitch volatiles are associated with an excess of lung cancer. Employees having 10 or more years of exposure or who are 45 years of age or older should have a sputum cytology examination.

—14" x 17" chest roentgenogram: Coal tar pitch volatiles are associated with an excess of lung cancer. Surveillance of the lungs is indicated.

—FVC and FEV (1 sec): Coal tar pitch volatiles are reported to cause an excess of bronchitis. Periodic surveillance is indicated.

—A complete blood count: Due to the possibility of benzene exposure associated with coal tar pitch volatiles, a complete blood count is considered necessary to search for leukemia and aplastic anemia.

—Skin disease: Coal tar pitch volatiles are defatting agents and can cause dermatitis on prolonged exposure. Persons with pre-existing skin disorders may be more susceptible to the effects of these agents.

2. Periodic Medical Examination: The aforementioned medical examinations should be repeated on an annual basis, and semi-annually for employees 45 years of age or older or with 10 or more years' exposure to coal tar pitch volatiles.

- **Summary of toxicology**

Coal tar pitch volatiles (CTPV) are products of the destructive distillation of bituminous coal and contain polynuclear aromatic hydrocarbons (PNA's). These hydrocarbons sublime readily, thereby increasing the amounts of carcinogenic compounds in working areas. Epidemiologic evidence suggests that workers intimately exposed to the products of combustion or distillation of bituminous coal are at increased risk of cancer at many sites. These include cancer of the respiratory tract, kidney, bladder, and skin. In a study of coke oven workers, the level of exposure to CTPV and the length of time exposed were related to the development of cancer. Coke oven workers with the highest risk of cancer were those employed exclusively at topside jobs for 5 or more years, for whom the increased risk of dying from lung cancer was 10-fold; all coke oven workers had a 7-½-fold increase in risk of dying from kidney cancer. Although the causative agent or agents of the cancer in coke oven workers is unidentified, it is suspected that several PNA's in the CTPV generated during the coking process are involved. Certain industrial populations exposed to coal tar products have a demonstrated risk of skin cancer. Substances containing PNA's which may produce skin cancer also produce contact dermatitis; examples are coal tar, pitch, and cutting oils. Although allergic dermatitis is readily induced by PNA's in guinea pigs, it is only rarely reported in humans from occupational contact with PNA's; these have resulted largely from the therapeutic use of coal tar preparations. Components of pitch and coal tar produce cutaneous photosensitization; skin eruptions are usually limited to areas exposed to the sun or ultraviolet light. Most of the phototoxic agents will induce hypermelanosis of the skin; if chronic photodermatitis is severe and prolonged, leukoderma may occur. Some oils containing PNA's have been associated with changes of follicular and sebaceous glands which commonly take the form of acne. There is evidence that exposures to emissions at coke ovens and gas retorts may be associated with an increased occurrence of chronic bronchitis. Coal tar pitch volatiles may be associated with benzene, an agent suspected of causing leukemia and known to cause aplastic anemia.

CHEMICAL AND PHYSICAL PROPERTIES

- **Physical data—Anthracene**
  1. Molecular weight: 178.2
  2. Boiling point (760 mm Hg): 340 C (644 F)
  3. Specific gravity (water = 1): 1.24
  4. Vapor density (air = 1 at boiling point of anthracene): 6.15
  5. Melting point: 217 C (423 F)
  6. Vapor pressure at 20 C (68 F): Less than 1 mm Hg
  7. Solubility in water, g/100 g water at 20 C (68 F): Insoluble
  8. Evaporation rate (butyl acetate = 1): Not applicable
- **Physical data—Phenanthrene**
  1. Molecular weight: 178.2
  2. Boiling point (760 mm Hg): 340 C (644 F)
  3. Specific gravity (water = 1): 1.18
  4. Vapor density (air = 1 at boiling point of phenanthrene): 6.15
  5. Melting point: 100.5 C (213 F)
  6. Vapor pressure at 20 C (68 F): Less than 1 mm Hg
  7. Solubility in water, g/100 g water at 20 C (68 F): Insoluble
  8. Evaporation rate (butyl acetate = 1): Not applicable
- **Physical data—Pyrene**
  1. Molecular weight: 202.3
  2. Boiling point (760 mm Hg): Greater than 360 C (greater than 680 F)

3. Specific gravity (water = 1): 1.28
4. Vapor density (air = 1 at boiling point of pyrene): 6.9
5. Melting point: 150.4 C (303 F)
6. Vapor pressure at 20 C (68 F): Less than 1 mm Hg
7. Solubility in water, g/100 g water at 20 C (68 F): Insoluble
8. Evaporation rate (butyl acetate = 1): Not applicable

• **Physical data—Carbazole**

1. Molecular weight: 167.2
2. Boiling point (760 mm Hg): 355 C (671 F)
3. Specific gravity (water = 1): Greater than 1
4. Vapor density (air = 1 at boiling point of carbazole): 5.8
5. Melting point: 246 C (475 F)
6. Vapor pressure at 20 C (68 F): Less than 1 mm Hg
7. Solubility in water, g/100 g water at 20 C (68 F): Insoluble
8. Evaporation rate (butyl acetate = 1): Not applicable

• **Physical data—Benzo(a)pyrene**

1. Molecular weight: 252.3
2. Boiling point (760 mm Hg): Greater than 360 C (greater than 680 F)
3. Specific gravity (water = 1): Greater than 1
4. Vapor density (air = 1 at boiling point of benzo(a)pyrene): 8.7
5. Melting point: 179 C (354 F)
6. Vapor pressure at 20 C (68 F): Less than 1 mm Hg
7. Solubility in water, g/100 g water at 20 C (68 F): Insoluble
8. Evaporation rate (butyl acetate = 1): Not applicable

• **Reactivity**

1. Conditions contributing to instability: None hazardous
2. Incompatibilities: Contact with strong oxidizers may cause fires and explosions.
3. Hazardous decomposition products: None
4. Special precautions: None

• **Flammability**

1. Flash point: Anthracene: 121 C (250 F) (closed cup); Others: Data not available
2. Autoignition temperature: Anthracene: 540 C (1004 F); Others: Data not available
3. Flammable limits in air, % by volume: Anthracene: Lower: 0.6; Others: Data not available
4. Extinguishant: Foam, dry chemical, and carbon dioxide

• **Warning properties**

Grant states that "coal tar and its various crude fractions appear principally to cause reddening and squamous eczema of the lid margins, with only small erosions of the corneal epithelium and superficial changes in the stroma, which disappear in a month following exposure. Chronic exposure of workmen to tar fumes and dust has been reported to cause conjunctivitis and discoloration of the cornea in the palpebral fissure, either near the limbus or, in extreme cases, across the whole cornea. Occasionally, epithelioma of the lid margin has been attributed to contact with coal tar."

MONITORING AND MEASUREMENT PROCEDURES

• **General**

Measurements to determine employee exposure are best taken so that the average eight-hour exposure is based on a single eight-hour sample or on two four-hour samples. Several short-time interval samples (up to 30 minutes) may also be used to determine the average exposure level. Air samples should be taken in the employee's breathing zone (air that would most nearly represent that inhaled by the employee).

• **Method**

Coal tar products may be sampled by collection on a glass fiber filter with subsequent ultrasonic extraction and weighing. An analytical method for coal tar pitch volatiles is in the *NIOSH Manual of Analytical Methods*, 2nd Ed., Vol. 1, 1977, available from the Government Printing Office, Washington, D.C. 20402 (GPO No. 017-033-00267-3).

RESPIRATORS

• Good industrial hygiene practices recommend that engineering controls be used to reduce environmental concentrations to the permissible exposure level. However, there are some exceptions where respirators may be used to control exposure. Respirators may be used when engineering and work practice controls are not technically feasible, when such controls are in the process of being installed, or when they fail and need to be supplemented. Respirators may also be used for operations which require entry into tanks or closed vessels, and in emergency situations. If the use of respirators is necessary, the only respirators permitted are those that have been approved by the Mine Safety and Health Administration (formerly Mining Enforcement and Safety Administration) or by the National Institute for Occupational Safety and Health.

• In addition to respirator selection, a complete respiratory protection program should be instituted which includes regular training, maintenance, inspection, cleaning, and evaluation.

PERSONAL PROTECTIVE EQUIPMENT

• Employees should be provided with and required to use impervious clothing, gloves, face shields (eight-inch minimum), and other appropriate protective clothing necessary to prevent skin contact with condensed coal tar pitch volatiles, where skin contact may occur.

• If employees' clothing may have become contaminated with coal tar pitch volatiles, employees should change into uncontaminated clothing before leaving the work premises.

• Clothing contaminated with coal tar pitch volatiles

should be placed in closed containers for storage until it can be discarded or until provision is made for the removal of coal tar pitch volatiles from the clothing. If the clothing is to be laundered or otherwise cleaned to remove the coal tar pitch volatiles, the person performing the operation should be informed of coal tar pitch volatiles's hazardous properties.

• Employees should be provided with and required to use splash-proof safety goggles where condensed coal tar pitch volatiles may contact the eyes.

SANITATION

• Workers subject to skin contact with coal tar pitch volatiles should wash with soap or mild detergent and water any areas of the body which may have contacted coal tar pitch volatiles at the end of each work day.

• Employees who handle coal tar pitch volatiles should wash their hands thoroughly with soap or mild detergent and water before eating, smoking, or using toilet facilities.

• Areas in which exposure to coal tar pitch volatiles may occur should be identified by signs or other appropriate means, and access to these areas should be limited to authorized persons.

COMMON OPERATIONS AND CONTROLS

The following list includes some common operations in which exposure to coal tar pitch volatiles may occur and control methods which may be effective in each case:

Operation	Controls
Liberation from extraction and packaging from coal tar fraction of coking	Process enclosure; local exhaust ventilation; general dilution ventilation; personal protective equipment
Use as a binding agent in manufacture of coal briquettes used for fuel; use as a dielectric in the manufacture of battery electrodes, electric-arc furnace electrodes, and electrodes for alumina reduction	Process enclosure; local exhaust ventilation; general dilution ventilation; personal protective equipment
Use in manufacture of roofing felts and papers and roofing	Process enclosure; local exhaust ventilation; general dilution ventilation; personal protective equipment
Use for protective coatings for pipes for underground conduits and drainage; use as a coating on concrete as waterproofing and corrosion-resistant material; use in road paving and sealing	Process enclosure; local exhaust ventilation; general dilution ventilation; personal protective equipment
Use in manufacture and repair of refractory brick; use in production of foundry cores; use in manufacture of carbon ceramic items	Process enclosure; local exhaust ventilation; general dilution ventilation; personal protective equipment

EMERGENCY FIRST AID PROCEDURES

In the event of an emergency, institute first aid procedures and send for first aid or medical assistance.

• **Eye Exposure**

If condensed coal tar pitch volatiles get into the eyes, wash eyes immediately with large amounts of water, lifting the lower and upper lids occasionally. If irritation is present after washing, get medical attention. Contact lenses should not be worn when working with these chemicals.

• **Skin Exposure**

If condensed coal tar pitch volatiles get on the skin, wash the contaminated skin using soap or mild detergent and water. Be sure to wash the hands before eating or smoking and to wash thoroughly at the close of work.

• **Breathing**

If a person breathes in large amounts of coal tar pitch volatiles, move the exposed person to fresh air at once. If breathing has stopped, perform artificial respiration. Keep the affected person warm and at rest. Get medical attention as soon as possible.

• **Rescue**

Move the affected person from the hazardous exposure. If the exposed person has been overcome, notify someone else and put into effect the established emergency rescue procedures. Do not become a casualty. Understand the facility's emergency rescue procedures and know the locations of rescue equipment before the need arises.

SPILL AND DISPOSAL PROCEDURES

• Persons not wearing protective equipment and clothing should be restricted from areas of releases until cleanup has been completed.

• If coal tar pitch volatiles are released in hazardous concentrations, the following steps should be taken:

1. Ventilate area of spill.

2. Collect released material in the most convenient and safe manner for reclamation or for disposal in sealed containers in a secured sanitary landfill.

• Waste disposal method:

Coal tar pitch volatiles may be disposed of in sealed containers in a secured sanitary landfill.

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RESPIRATORY PROTECTION FOR COAL TAR PITCH VOLATILES

Condition	Minimum Respiratory Protection* Required Above 0.2 mg/m³
Particulate and Vapor Concentration	
2 mg/m³ or less	A chemical cartridge respirator with an organic vapor cartridge(s) and with a fume or high-efficiency filter. Any supplied-air respirator. Any self-contained breathing apparatus.
10 mg/m³ or less	A chemical cartridge respirator with a full facepiece and an organic vapor cartridge(s) and with a fume or high-efficiency filter. A gas mask with a chin-style or a front- or back-mounted organic vapor canister and with a full facepiece and a fume or high-efficiency filter. Any supplied-air respirator with a full facepiece, helmet, or hood. Any self-contained breathing apparatus with a full facepiece.
200 mg/m³ or less	A Type C supplied-air respirator operated in pressure-demand or other positive pressure or continuous-flow mode. A powered air-purifying respirator with an organic vapor cartridge and a high-efficiency particulate filter.
400 mg/m³ or less	A Type C supplied-air respirator with a full facepiece operated in pressure-demand or other positive pressure mode or with a full facepiece, helmet, or hood operated in continuous-flow mode.
Greater than 400 mg/m³ or entry and escape from unknown concentrations	Self-contained breathing apparatus with a full facepiece operated in pressure-demand or other positive pressure mode. A combination respirator which includes a Type C supplied-air respirator with a full facepiece operated in pressure-demand or other positive pressure or continuous-flow mode and an auxiliary self-contained breathing apparatus operated in pressure-demand or other positive pressure mode.
Fire Fighting	Self-contained breathing apparatus with a full facepiece operated in pressure-demand or other positive pressure mode.
Escape	Any gas mask providing protection against organic vapors and particulates, including pesticide respirators which meet the requirements of this class. Any escape self-contained breathing apparatus.

*Only NIOSH-approved or MSHA-approved equipment should be used.

Occupational Health Guideline for Cyanide

INTRODUCTION

This guideline is intended as a source of information for employees, employers, physicians, industrial hygienists, and other occupational health professionals who may have a need for such information. It does not attempt to present all data; rather, it presents pertinent information and data in summary form.

APPLICABILITY

The general guidelines contained in this document apply to all cyanides. Physical and chemical properties of two specific compounds are provided for illustrative purposes.

SUBSTANCE IDENTIFICATION

Potassium cyanide

- Formula: KCN
- Synonyms: None
- Appearance and odor: White solid with a faint almond odor.

Sodium cyanide

- Formula: NaCN
- Synonyms: None
- Appearance and odor: White solid with a faint almond odor.

PERMISSIBLE EXPOSURE LIMIT (PEL)

The current OSHA standard for cyanide is 5 milligrams of cyanide per cubic meter of air (mg/m^3) averaged over an eight-hour work shift. NIOSH has recommended that the permissible exposure limit be changed to a ceiling of 5 milligrams cyanide per cubic meter of air averaged over a 10-minute period. The NIOSH Criteria Document for Hydrogen Cyanide and Cyanide Salts should be consulted for more detailed information.

HEALTH HAZARD INFORMATION

- **Routes of exposure**

Cyanide can affect the body if it is inhaled, if it comes in contact with the eyes or skin, or if it is swallowed. Sufficient cyanide may be absorbed through the skin, especially if there are cuts to cause fatal poisoning.

- **Effects of overexposure**

1. Short-term Exposure: Inhalation or ingestion of cyanide salts may be rapidly fatal. Larger doses by inhalation or swallowing may cause the person to rapidly lose consciousness, stop breathing, and die. In some cases, there are convulsions. At lower levels of exposure, the earlier symptoms include weakness, headache, confusion, nausea, and vomiting. These symptoms may be followed by unconsciousness and death. Occasionally, convulsions occur. Milder forms of intoxication may result only in weakness, dizziness, headache, and nausea. The dust of cyanide salts is irritating to the eyes. In the presence of tears, it may cause the symptoms of poisoning described above. The dust of cyanide salts may produce irritation of the nose and skin. Strong solutions of cyanide salts are corrosive and may produce ulcers.

2. Long-term Exposure: Effects from chronic exposure to cyanide are non-specific and rare.

3. Reporting Signs and Symptoms: A physician should be contacted if anyone develops any signs or symptoms and suspects that they are caused by exposure to cyanide.

- **Recommended medical surveillance**

The following medical procedures should be made available to each employee who is exposed to cyanide at potentially hazardous levels:

1. Initial Medical Examination:

—A complete history and physical examination: The purpose is to detect pre-existing conditions that might place the exposed employee at increased risk, and to establish a baseline for future health monitoring. Persons with a history of fainting spells, such as occur in various types of cardiovascular and nervous disorders,

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These recommendations reflect good industrial hygiene and medical surveillance practices and their implementation will assist in achieving an effective occupational health program. However, they may not be sufficient to achieve compliance with all requirements of OSHA regulations.

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and those unusually susceptible to effects of anoxia or with anemia would be expected to be at increased risk from exposure. Examination of the cardiovascular, nervous, and upper respiratory systems, and thyroid should be stressed. The skin should be examined for evidence of chronic disorders.

—Skin disease: Cyanide is a defatting agent and can cause dermatitis on prolonged exposure. Persons with pre-existing skin disorders may be more susceptible to the effects of this agent.

—14" x 17" chest roentgenogram: Cyanide causes human lung damage. Surveillance of the lungs is indicated.

—FVC and FEV (1 sec): Cyanide is a respiratory irritant. Persons with impaired pulmonary function may be at increased risk from exposure. Periodic surveillance is indicated.

2. Periodic Medical Examination: The aforementioned medical examinations should be repeated on an annual basis.

3. First Aid Kits: First aid kits should be readily available in workplaces where there is a potential for the release of cyanide. These kits should contain a minimum of 48 ampules, each of 0.3 ml amyl nitrate, and complete instructions for use. In addition, 2 physician's kits should be immediately available to trained medical personnel. These kits should contain the above quantity of amyl nitrate as well as sterile sodium nitrite solution (3%) and sterile sodium thiosulfate solution (25%). All of the above drugs should be replaced at least biannually to ensure their potency.

• **Summary of toxicology**

The dust of cyanide salts, a source of cyanide ion, is an asphyxiant due to an inhibitory action on metabolic enzyme systems and can be rapidly fatal. Cyanide exerts this effect because it inactivates certain enzymes by forming very stable complexes with the metal in them. Cytochrome oxidase is probably the most important of these, since it occupies a fundamental position in the respiratory process and is involved in the ultimate electron transfer to molecular oxygen. Since cytochrome oxidase is present in practically all cells that function under aerobic conditions, and since the cyanide ion diffuses easily to all parts of the body, it is capable of suddenly bringing to a halt practically all cellular respiration. In the presence of even weak acids, hydrocyanic acid (HCN) gas is liberated from cyanide salts; a few inhalations of higher concentrations of HCN may be followed by almost instantaneous collapse and cessation of respiration; 270 ppm HCN is immediately fatal to humans, 181 ppm is fatal after 10 minutes, 135 ppm after 30 minutes, and 110 ppm may be fatal in 1 hour. The ingestion by humans of 50 to 100 mg of sodium or potassium cyanide may also be fatal. At lower levels of exposure to HCN, the earliest symptoms of intoxication may include weakness, headache, confusion, and occasionally nausea and vomiting; respiratory rate and depth is usually increased initially and at later stages becomes slow and gasping; if cyanosis is present, it usually indicates that respiration has either ceased or has been very inadequate for a few minutes. Humans tolerate 45 to 54 ppm for ½ to 1 hour without immediate or delayed effects, while 18 to 36 ppm may result in some symptoms after an exposure of several hours. Sodium cyanide dust is irritating to the eyes; in the presence of tears it may liberate HCN, which can be absorbed and cause systemic intoxication. Skin contact with dust may be irritating; strong solutions on the skin produce ulcers which are slow in healing. Cyanide is one of the few toxic materials for which an antidote exists; it functions as follows: First, amyl nitrite (inhalation) and sodium nitrite (intravenously) are administered to form methemoglobin, which binds firmly with free cyanide ions. This traps any circulating cyanide ions. The formation of 10 to 20% methemoglobin usually does not involve appreciable risk, yet provides a large amount of cyanide-binding substance. Second, sodium thiosulfate is administered intravenously to increase the rate of conversion of cyanide to the less toxic thiocyanate. Methylene blue should not be administered, because it is a poor methemoglobin former and, moreover, promotes the conversion of methemoglobin back to hemoglobin.

CHEMICAL AND PHYSICAL PROPERTIES

• **Physical data—Potassium cyanide**

1. Molecular weight: 65.1
2. Boiling point (760 mm Hg): Data not available
3. Specific gravity (water = 1): 1.55
4. Vapor density (air = 1 at boiling point of potassium cyanide): Not applicable
5. Melting point: 635 C (1175 F)
6. Vapor pressure at 20 C (68 F): Essentially zero
7. Solubility in water, g/100 g water at 20 C (68 F): 71.6
8. Evaporation rate (butyl acetate = 1): Not applicable

• **Physical data—Sodium cyanide**

1. Molecular weight: 49
2. Boiling point (760 mm Hg): 1500 C (2732 F) (extrapolated)
3. Specific gravity (water = 1): 1.6
4. Vapor density (air = 1 at boiling point of sodium cyanide): Not applicable
5. Melting point: 560 C (1040 F)
6. Vapor pressure at 20 C (68 F): Essentially zero
7. Solubility in water, g/100 g water at 20 C (68 F): 58
8. Evaporation rate (butyl acetate = 1): Not applicable

• **Reactivity**

1. Conditions contributing to instability: None. Hazardous if kept in closed containers. It may form toxic concentrations of hydrogen cyanide gas when in prolonged contact with air in a closed area.
2. Incompatibilities: Contact with strong oxidizers such as nitrates and chlorates may cause fires and

explosions. Contact with acids and acid salts causes immediate formation of toxic and flammable hydrogen cyanide gas.

3. Hazardous decomposition products: Toxic gases and vapors (such as hydrogen cyanide and carbon monoxide) may be released when cyanide decomposes.

4. Special precautions: Cyanide may react with carbon dioxide in ordinary air to form toxic hydrogen cyanide gas.

- **Flammability**

1. Not combustible

- **Warning properties**

1. Odor Threshold: No quantitative information is available concerning the odor threshold of sodium or potassium cyanide. HCN, however, is evolved from these substances in the presence of moisture. The Manufacturing Chemists Association states that "although HCN has a characteristic odor, its toxic action at hazardous concentrations is so rapid that it is of no value as a warning property."

2. Eye Irritation Level: Cyanide (as CN) is not known to be an eye irritant. However, according to Grant, HCN can produce eye irritation after chronic exposures.

3. Evaluation of Warning Properties: Although cyanide (as CN) has a negligible vapor pressure, in the presence of moisture HCN can be given off. HCN does not have adequate warning properties.

MONITORING AND MEASUREMENT PROCEDURES

- **Eight-Hour Exposure Evaluation**

Measurements to determine employee exposure are best taken so that the average eight-hour exposure is based on a single eight-hour sample or on two four-hour samples. Several short-time interval samples (up to 30 minutes) may also be used to determine the average exposure level. Air samples should be taken in the employee's breathing zone (air that would most nearly represent that inhaled by the employee).

- **Ceiling Evaluation**

Measurements to determine employee ceiling exposure are best taken during periods of maximum expected airborne concentrations of cyanide. Each measurement should consist of a ten (10) minute sample or series of consecutive samples totalling ten (10) minutes in the employee's breathing zone (air that would most nearly represent that inhaled by the employee). A minimum of three (3) measurements should be taken on one work shift and the highest of all measurements taken is an estimate of the employee's exposure.

- **Method**

Sampling and analyses may be performed by collection of cyanide with a cellulose membrane filter and an impinger containing sodium hydroxide, followed by analysis by direct potentiometry. An analytical method for cyanide is in the *NIOSH Manual of Analytical Methods*, 2nd Ed., Vol. 3, 1977, available from the Government Printing Office, Washington, D.C. [illegible] (GPO No. 017-033-00261-4).

RESPIRATORS

- Good industrial hygiene practices recommend that engineering controls be used to reduce environmental concentrations to the permissible exposure level. However, there are some exceptions where respirators may be used to control exposure. Respirators may be used when engineering and work practice controls are not technically feasible, when such controls are in the process of being installed, or when they fail and need to be supplemented. Respirators may also be used for operations which require entry into tanks or closed vessels, and in emergency situations. If the use of respirators is necessary, the only respirators permitted are those that have been approved by the Mine Safety and Health Administration (formerly Mining Enforcement and Safety Administration) or by the National Institute for Occupational Safety and Health.
- In addition to respirator selection, a complete respiratory protection program should be instituted which includes regular training, maintenance, inspection, cleaning, and evaluation.

PERSONAL PROTECTIVE EQUIPMENT

- Employees should be provided with and required to use impervious clothing, gloves, face shields (eight-inch minimum), and other appropriate protective clothing necessary to prevent any possibility of skin contact with cyanide or liquids containing cyanide.
- If employees' clothing has had any possibility of being contaminated with cyanide, employees should change into uncontaminated clothing before leaving the work premises.
- Clothing which has had any possibility of being contaminated with cyanide should be placed in closed containers for storage until it can be discarded or until provision is made for the removal of cyanide from the clothing. If the clothing is to be laundered or otherwise cleaned to remove the cyanide, the person performing the operation should be informed of cyanide's hazardous properties.
- Where there is any possibility of exposure of an employee's body to cyanide or liquids containing cyanide, facilities for quick drenching of the body should be provided within the immediate work area for emergency use.
- Non-impervious clothing which becomes contaminated with cyanide should be removed immediately and not reworn until the cyanide is removed from the clothing.
- Employees should be provided with and required to use dust- and splash-proof safety goggles where there is any possibility of cyanide or liquids containing cyanide contacting the eyes.

• Where there is any possibility that employees' eyes may be exposed to cyanide or liquids containing cyanide, an eye-wash fountain should be provided within the immediate work area for emergency use.

SANITATION

• Skin that becomes contaminated with cyanide should be immediately washed or showered with soap or mild detergent and water to remove any cyanide.

• Workers subject to skin contact with cyanide should wash with soap or mild detergent and water any areas of the body which may have contacted cyanide at the end of each work day.

• Eating and smoking should not be permitted in areas where cyanide or liquids containing cyanide are handled, processed, or stored.

• Employees who handle cyanide or liquids containing cyanide should wash their hands thoroughly with soap or mild detergent and water before eating, smoking, or using toilet facilities.

COMMON OPERATIONS AND CONTROLS

The following list includes some common operations in which exposure to cyanide may occur and control methods which may be effective in each case:

Operation	Controls
Use as fumigants and pesticides in greenhouses, ships, mills, and warehouses; use of cyanogen chloride as a warning agent in fumigant gases	Local exhaust ventilation; general dilution ventilation; personal protective equipment
Use in metal treatment in nitriding, tempering, and case hardening steel; coloring of metals by chemical or electrolytic process; cleaning and coating metals; welding and cutting of heat-resistant metals; liberation during ore extraction and metal purification	Process enclosure; local exhaust ventilation; general dilution ventilation; personal protective equipment
Use of calcium cyanamid in fertilizer on soil; during chemical synthesis for manufacture of intermediates in pharmaceuticals, dyes, vitamins, plastics, and sequestering agents; preparation of nitriles, carbylamines, cyano fatty acids, and inorganic cyanides	Process enclosure; local exhaust ventilation; general dilution ventilation; personal protective equipment
Use in cellulose technology; paper manufacture; in dyeing; as cement stabilizers; use in photography as fixatives, and in blueprinting and process engraving; liberation in blast furance gases or in handling of illuminating gas	Process enclosure; local exhaust ventilation; general dilution ventilation; personal protective equipment

EMERGENCY FIRST AID PROCEDURES

In the event of an emergency, institute first aid procedures and send for first aid or medical assistance.

• **Eye Exposure**

If cyanide gets into the eyes, wash eyes immediately with large amounts of water, lifting the lower and upper lids occasionally. Get medical attention immediately. Contact lenses should not be worn when working with cyanides.

• **Skin Exposure**

If cyanide gets on the skin, immediately wash the contaminated skin using soap or mild detergent and water. If cyanide penetrates through the clothing, remove the clothing immediately and wash the skin using soap or mild detergent and water. Get medical attention immediately.

• **Breathing**

If a person breathes in large amounts of cyanide, move the exposed person to fresh air at once. If breathing has stopped, perform artificial respiration. Keep the affected person warm and at rest. Get medical attention as soon as possible.

• **Swallowing**

When cyanide has been swallowed and the person is conscious, give the person large quantities of water immediately. After the water has been swallowed, try to get the person to vomit by having him touch the back of his throat with his finger. Do not make an unconscious person vomit. Get medical attention immediately.

• **Rescue**

Move the affected person from the hazardous exposure. If the exposed person has been overcome, notify someone else and put into effect the established emergency rescue procedures. Do not become a casualty. Understand the facility's emergency rescue procedures and know the locations of rescue equipment before the need arises.

SPILL AND DISPOSAL PROCEDURES

• Persons not wearing protective equipment and clothing should be restricted from areas of spills until cleanup has been completed.

• If cyanide is spilled, the following steps should be taken:

1. Ventilate area of spill.
2. Collect spilled material in the most convenient and safe manner for reclamation, or for treatment in a cyanide disposal system.

• Waste disposal method:

After treatment as in above, cyanide may be disposed of in a secured sanitary landfill.

REFERENCES

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RESPIRATORY PROTECTION FOR CYANIDE

Condition	Minimum Respiratory Protection* Required Above 5 mg/m³
Particulate Concentration	
50 mg/m³ or less	Any supplied-air respirator. Any self-contained breathing apparatus.
Greater than 50 mg/m³ or entry and escape from unknown concentrations	Self-contained breathing apparatus with a full facepiece operated in pressure-demand or other positive pressure mode. A combination respirator which includes a Type C supplied-air respirator with a full facepiece operated in pressure-demand or other positive pressure or continuous-flow mode and an auxiliary self-contained breathing apparatus operated in pressure-demand or other positive pressure mode.
Fire Fighting	Self-contained breathing apparatus with a full facepiece operated in pressure-demand or other positive pressure mode.
Escape	Any gas mask providing protection against hydrogen cyanide and particulates. Any escape self-contained breathing apparatus.

*Only NIOSH-approved or MSHA-approved equipment should be used.

Occupational Health Guideline for Hydrogen Cyanide

INTRODUCTION

This guideline is intended as a source of information for employees, employers, physicians, industrial hygienists, and other occupational health professionals who may have a need for such information. It does not attempt to present all data; rather, it presents pertinent information and data in summary form.

SUBSTANCE IDENTIFICATION

- Formula: HCN
- Synonyms: Hydrocyanic acid; prussic acid; formonitrile
- Appearance and odor: Colorless or pale blue liquid or gas with a bitter almond odor.

PERMISSIBLE EXPOSURE LIMIT (PEL)

The current OSHA standard for hydrogen cyanide is 10 parts of hydrogen cyanide per million parts of air (ppm) averaged over an eight-hour work shift. This may also be expressed as 11 milligrams of hydrogen cyanide per cubic meter of air (mg/m³). NIOSH has recommended that the permissible exposure limit be reduced to 5 mg cyanide/m³ averaged over a 10-minute period. The NIOSH Criteria Document for Hydrogen Cyanide and Cyanide Salts should be consulted for more detailed information.

HEALTH HAZARD INFORMATION

- **Routes of exposure**

Hydrogen cyanide can affect the body if it is inhaled, comes in contact with the eyes or skin, or is swallowed. It may enter the body through the skin.

- **Effects of overexposure**

1. Short-term Exposure: Inhalation, ingestion, or skin absorption of hydrogen cyanide may be rapidly fatal. Larger doses may cause the person to rapidly lose consciousness, stop breathing, and die. At lower levels of exposure, a person may experience weakness, headache, confusion, nausea, and vomiting. These symptoms may be followed by unconsciousness and death. Hydrogen cyanide liquid may irritate the eyes.

2. Long-term Exposure: Effects from chronic exposure to hydrogen cyanide are non-specific and rare.

3. Reporting Signs and Symptoms: A physician should be contacted if anyone develops any signs or symptoms and suspects that they are caused by exposure to hydrogen cyanide.

- **Recommended medical surveillance**

The following medical procedures should be made available to each employee who is exposed to hydrogen cyanide at potentially hazardous levels:

1. Initial Medical Examination:

—A complete history and physical examination: The purpose is to detect pre-existing conditions that might place the exposed employee at increased risk, and to establish a baseline for future health monitoring. Persons with a history of fainting spells, such as occur in various types of cardiovascular and nervous disorders, and and those who are unusually susceptible to effects of anoxia or with anemia would be expected to be at increased risk from exposure. Examination of the cardiovascular, nervous, and upper respiratory systems, and thyroid should be stressed.

—Cardiovascular disease: Persons with cardiac disease may be at increased risk. An electrocardiogram should be performed on workers over 40 years of age and where indicated.

2. Periodic Medical Examination: The aforementioned medical examinations should be repeated on an annual basis.

3. First Aid Kits: First aid kits should be immediately available in workplaces where there is a potential for the release of hydrogen cyanide. These kits should contain a minimum of 48 ampules, each of 0.3 ml amyl nitrate, and complete instructions for use. In addition, 2 physician's kits should be immediately available to trained medical personnel. These kits should contain the above quantity of amyl nitrate as well as sterile sodium

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• **Ceiling Evaluation**

Measurements to determine employee ceiling exposure are best taken during periods of maximum expected airborne concentrations of hydrogen cyanide. Each measurement should consist of a ten (10) minute sample or series of consecutive samples totalling ten (10) minutes in the employee's breathing zone (air that would most nearly represent that inhaled by the employee). A minimum of three (3) measurements should be taken on one work shift and the highest of all measurements taken is an estimate of the employee's exposure.

• **Method**

Hydrogen cyanide may be monitored by collection in midget impingers containing sodium hydroxide, followed by analysis with an ion specific electrode. An analytical method for hydrogen cyanide is in the *NIOSH Manual of Analytical Methods*, 2nd Ed., Vol. 4, 1978, available from the Government Printing Office, Washington, D.C. 20402 (GPO No. 017-033-00317-3).

RESPIRATORS

• Good industrial hygiene practices recommend that engineering controls be used to reduce environmental concentrations to the permissible exposure level. However, there are some exceptions where respirators may be used to control exposure. Respirators may be used when engineering and work practice controls are not technically feasible, when such controls are in the process of being installed, or when they fail and need to be supplemented. Respirators may also be used for operations which require entry into tanks or closed vessels, and in emergency situations. If the use of respirators is necessary, the only respirators permitted are those that have been approved by the Mine Safety and Health Administration (formerly Mining Enforcement and Safety Administration) or by the National Institute for Occupational Safety and Health.

• In addition to respirator selection, a complete respiratory protection program should be instituted which includes regular training, maintenance, inspection, cleaning, and evaluation.

PERSONAL PROTECTIVE EQUIPMENT

• Employees should be provided with and required to use impervious clothing, gloves, face shields (eight-inch minimum), and other appropriate protective clothing necessary to prevent any possibility of skin contact with liquid hydrogen cyanide.

• Where there is any possibility of exposure of an employee's body to liquid hydrogen cyanide, facilities for quick drenching of the body should be provided within the immediate work area for emergency use.

• Any clothing which becomes wet with, or non-impervious clothing which becomes contaminated with, liquid hydrogen cyanide should be removed immediately and not reworn until the hydrogen cyanide is removed from the clothing.

• Clothing wet with hydrogen cyanide should be placed in closed containers for storage until it can be discarded or until provision is made for the removal of hydrogen cyanide from the clothing. If the clothing is to be laundered or otherwise cleaned to remove the hydrogen cyanide, the person performing the operation should be informed of hydrogen cyanide's hazardous properties.

• Employees should be provided with and required to use splash-proof safety goggles where there is any possibility of liquid hydrogen cyanide contacting the eyes.

• Where there is any possibility that employees' eyes may be exposed to hydrogen cyanide, an eye-wash fountain should be provided within the immediate work area for emergency use.

SANITATION

• Skin that becomes contaminated with hydrogen cyanide should be immediately washed or showered to remove any hydrogen cyanide.

• Employees who handle hydrogen cyanide should wash their hands thoroughly with soap or mild detergent and water before eating, smoking, or using toilet facilities.

COMMON OPERATIONS AND CONTROLS

The following list includes some common operations in which exposure to hydrogen cyanide may occur and control methods which may be effective in each case:

Operation	Controls
Use in fumigation of structures and agricultural crops	Process enclosure; local exhaust ventilation; personal protective equipment
Liberation during use of cyanide salts or solutions in metal treatment operations, blast furnace and coke oven operations, metal ore processing, and photoengraving operations	Process enclosure; local exhaust ventilation; personal protective equipment
Use in production of intermediates in synthesis of acrylic plastics, nylon 66, chelating agents, dyes, pharmaceuticals, and specialty chemicals	Process enclosure; local exhaust ventilation; personal protective equipment

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RESPIRATORY PROTECTION FOR HYDROGEN CYANIDE

Condition	Minimum Respiratory Protection* Required Above 5 ppm
Vapor Concentration	
50 ppm or less	Any supplied-air respirator. Any self-contained breathing apparatus.
Greater than 50 ppm** or entry and escape from unknown concentrations	Self-contained breathing apparatus with a full facepiece operated in pressure-demand or other positive pressure mode. A combination respirator which includes a Type C supplied-air respirator with a full facepiece operated in pressure-demand or other positive pressure or continuous-flow mode and an auxiliary self-contained breathing apparatus operated in pressure-demand or other positive pressure mode.
Fire Fighting	Self-contained breathing apparatus with a full facepiece operated in pressure-demand or other positive pressure mode.
Escape	Any gas mask providing protection against hydrogen cyanide. Any escape self-contained breathing apparatus.

*Only NIOSH-approved or MSHA-approved equipment should be used.

**Use of supplied-air suits may be necessary to prevent skin contact while providing respiratory protection from airborne concentrations of hydrogen cyanide; however, this equipment should be selected, used, and maintained under the immediate supervision of trained personnel. Where supplied-air suits are used above a concentration of 50 ppm, an auxiliary self-contained breathing apparatus operated in positive pressure mode should also be worn.

Occupational Health Guideline for Hydrogen Sulfide

INTRODUCTION

This guideline is intended as a source of information for employees, employers, physicians, industrial hygienists, and other occupational health professionals who may have a need for such information. It does not attempt to present all data; rather, it presents pertinent information and data in summary form.

SUBSTANCE IDENTIFICATION

- Formula: H_2S
- Synonyms: Sulfuretted hydrogen; hydrosulfuric acid; hepatic gas
- Appearance and odor: Colorless gas with a strong odor of rotten eggs. The odor of this gas should not be used as a warning, since its presence may deaden the sense of smell. Hydrogen sulfide can also exist as a liquid at low temperature and high pressure.

PERMISSIBLE EXPOSURE LIMIT (PEL)

The current OSHA standard for hydrogen sulfide is a ceiling level of 20 parts of hydrogen sulfide per million parts of air (ppm) or a maximum allowable peak of 50 ppm for 10 minutes once, if no other measurable exposure occurs. NIOSH has recommended that the permissible exposure limit be reduced to 15 mg/m³ (10 ppm) averaged over a 10-minute period, and that work areas in which the concentration of hydrogen sulfide exceeds 70 mg/m³ be evacuated. The NIOSH Criteria Document for Hydrogen Sulfide should be consulted for more detailed information.

HEALTH HAZARD INFORMATION

- **Routes of exposure**

Hydrogen sulfide can affect the body if it is inhaled or if it comes in contact with the eyes, skin, nose or throat. It can also affect the body if it is swallowed.

- **Effects of overexposure**

1. Short-term Exposure: Inhalation of high concentrations of hydrogen sulfide vapor may cause loss of consciousness and death. Inhalation of lower concentrations may cause headache, dizziness, and upset stomach. Exposure to hydrogen sulfide can cause temporary loss of the sense of smell, and irritation of the eyes, nose, or throat.

2. Long-term Exposure: Not known.

3. Reporting Signs and Symptoms: A physician should be contacted if anyone develops any signs or symptoms and suspects that they are caused by exposure to hydrogen sulfide.

- **Recommended medical surveillance**

The following medical procedures should be made available to each employee who is exposed to hydrogen sulfide at potentially hazardous levels:

1. Initial Medical Examination:

—A complete history and physical examination: The purpose is to detect pre-existing conditions that might place the exposed employee at increased risk, and to establish a baseline for future health monitoring. Examination of the eyes and lungs should be stressed.

—Eye disease: Hydrogen sulfide is a severe eye irritant and may cause tissue damage. Those with pre-existing eye problems may be at increased risk from exposure.

—14" x 17" chest roentgenogram: Hydrogen sulfide may cause human lung damage. Surveillance of the lungs is indicated.

—FVC and FEV (1 sec): Hydrogen sulfide is a respiratory irritant. Persons with impaired pulmonary function may be at increased risk from exposure. Periodic surveillance is indicated.

2. Periodic Medical Examination: The aforementioned medical examinations should be repeated on an annual basis, except that an x-ray is considered necessary only when indicated by the results of pulmonary function testing, or by signs and symptoms of respiratory disease.

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• **Summary of toxicology**

Hydrogen sulfide gas is a rapidly acting systemic poison which causes respiratory paralysis with consequent asphyxia at high concentrations. It irritates the eyes and respiratory tract at low concentrations. Inhalation of high concentrations of hydrogen sulfide, 1000 to 2000 ppm, may cause coma after a single breath and may be rapidly fatal; convulsions may also occur. Exposure to concentrations of hydrogen sulfide above 50 ppm for one hour may produce acute conjunctivitis with pain, lacrimation, and photophobia; in severe form this may progress to keratoconjunctivitis and vesiculation of the corneal epithelium. In low concentrations, hydrogen sulfide may cause headache, fatigue, irritability, insomnia, and gastrointestinal disturbances; in somewhat higher concentrations it affects the central nervous system, causing excitement and dizziness. Prolonged exposure to 250 ppm of hydrogen sulfide may cause pulmonary edema. Prolonged exposure to concentrations of hydrogen sulfide as low as 50 ppm may cause rhinitis, pharyngitis, bronchitis, and pneumonitis. Repeated exposure to hydrogen sulfide results in increased susceptibility, so that eye irritation, cough, and systemic effects may result from concentrations previously tolerated without any effect. Rapid olfactory fatigue can occur at high concentrations.

CHEMICAL AND PHYSICAL PROPERTIES

• **Physical data**

1. Molecular weight: 34.08
2. Boiling point (760 mm Hg): −60 C (−76 F)
3. Specific gravity (water = 1): Liquid = 1.54
4. Vapor density (air = 1 at 15 C (59 F)): 1.189
5. Melting point: −82.4 C (−116 F)
6. Vapor pressure at 25 C (77 F): 20 atm
7. Solubility in water, g/100 g water at 20 C (68 F): 2.9 (slight)
8. Evaporation rate (butyl acetate = 1): Not applicable

• **Reactivity**

1. Conditions contributing to instability: Elevated temperatures may cause containers to burst.
2. Incompatibilities: Contact with strong oxidizers and oxidizing materials may cause fires and explosions. Hydrogen sulfide attacks many metals, which results in the formation of sulfides.
3. Hazardous decomposition products: Toxic gases and vapors (such as sulfur oxides) may be released in a fire involving hydrogen sulfide.
4. Special precautions: Liquid hydrogen sulfide will attack some forms of plastics, rubber, and coatings.

• **Flammability**

1. Hydrogen sulfide is a flammable gas.
2. Autoignition temperature: 260 C (500 F)
3. Flammable limits in air, % by volume: Lower: 4.3; Upper: 46
4. Extinguishant: Alcohol foam, carbon dioxide

• **Warning properties**

1. Odor Threshold: According to the AIHA *Hygienic Guide*, hydrogen sulfide can be recognized by the "sense of smell at low concentrations. Odor not reliable at high concentrations, and olfactory fatigue occurs quickly . . . . Threshold is 0.13 ppm. Faint but readily perceptible at 0.77 ppm. Easily noticeable at 4.6 ppm. Strong, unpleasant, but not intolerable at 27 ppm." The *Hygienic Guide* also states that "olfactory fatigue can occur with(in) 2 to 15 minutes at 100 ppm."

2. Eye Irritation Level: Grant states that "effects of hydrogen sulfide on the eyes are notable only at sublethal concentrations, most commonly at concentrations so low that they have no discernible systemic effect . . . . Typically, workmen exposed to low concentrations of hydrogen sulfide gas . . . have no sensation of irritation or discomfort for at least several hours, or sometimes for several days while working in the presence of low concentrations. Ocular symptoms generally start after several hours of exposure and may not appear until the patient has finished his work for the day. There is then gradual onset of a scratchy, irritated sensation in the eyes, with tearing and burning . . . . Experimentally it is demonstrable that at a concentration of 100 ppm in air an immediate irritation of the eyes and respiratory tract is produced, but conditions responsible for the vast majority of cases of hydrogen sulfide keratoconjunctivitis are those in which the concentration is too low to cause immediate irritation and has toxic effect only after several hours or days of exposure. However, in industries where the concentration is regularly kept below 10 ppm in air, it is rare to have any irritation of the eyes."

The *Hygienic Guide* states that "50 to 100 ppm causes slight conjunctivitis and respiratory tract irritation after 1 hour."

3. Evaluation of Warning Properties: Since olfactory fatigue occurs at high concentrations, and since the irritant effects are delayed, hydrogen sulfide is treated as a material with poor warning properties.

MONITORING AND MEASUREMENT PROCEDURES

• **Eight-Hour Exposure Evaluation**

Measurements to determine employee exposure are best taken so that the average eight-hour exposure is based on a single eight-hour sample or on two four-hour samples. Several short-time interval samples (up to 30 minutes) may also be used to determine the average exposure level. Air samples should be taken in the employee's breathing zone (air that would most nearly represent that inhaled by the employee).

• **Ceiling Evaluation**

Measurements to determine employee ceiling exposure are best taken during periods of maximum expected airborne concentrations of hydrogen sulfide. Each measurement should consist of a fifteen (15) minute sample or series of consecutive samples totalling fifteen (15)

minutes in the employee's breathing zone (air that would most nearly represent that inhaled by the employee). A minimum of three (3) measurements should be taken on one work shift and the highest of all measurements taken is an estimate of the employee's exposure.

• **Peak Above Ceiling Evaluation**

Measurements to determine employee peak exposure should be taken during periods of maximum expected airborne concentration of hydrogen sulfide. Each measurement should consist of a 10-minute sample or a series of consecutive samples totalling 10 minutes in the employee's breathing zone (air that would most nearly represent that inhaled by the employee). A minimum of three measurements should be taken on one work shift and the highest of all measurements taken is an estimate of the employee's exposure.

• **Method**

Sampling and analyses may be performed by collection of hydrogen sulfide in an impinger containing an alkaline suspension of cadmium hydroxide, followed by chemical treatment, and spectrophotometric analysis. Also, detector tubes certified by NIOSH under 42 CFR Part 84 or other direct-reading devices calibrated to measure hydrogen sulfide may be used. An analytical method for hydrogen sulfide is in the *NIOSH Manual of Analytical Methods*, 2nd Ed., Vol. 6, 1980, available from the Government Printing Office, Washington, D.C. 20402 (GPO No. 017-033-00369-6).

RESPIRATORS

• Good industrial hygiene practices recommend that engineering controls be used to reduce environmental concentrations to the permissible exposure level. However, there are some exceptions where respirators may be used to control exposure. Respirators may be used when engineering and work practice controls are not technically feasible, when such controls are in the process of being installed, or when they fail and need to be supplemented. Respirators may also be used for operations which require entry into tanks or closed vessels, and in emergency situations. If the use of respirators is necessary, the only respirators permitted are those that have been approved by the Mine Safety and Health Administration (formerly Mining Enforcement and Safety Administration) or by the National Institute for Occupational Safety and Health.

• In addition to respirator selection, a complete respiratory protection program should be instituted which includes regular training, maintenance, inspection, cleaning, and evaluation.

PERSONAL PROTECTIVE EQUIPMENT

• Employees should be provided with and required to use impervious clothing, gloves, face shields (eight-inch minimum), and other appropriate protective clothing necessary to prevent the skin from becoming frozen from contact with liquid hydrogen sulfide or from contact with vessels containing liquid hydrogen sulfide.

• Any clothing which becomes wet with liquid hydrogen sulfide should be removed immediately and not reworn until the hydrogen sulfide has evaporated.

• Employees should be provided with and required to use splash-proof safety goggles where liquid hydrogen sulfide may contact the eyes.

COMMON OPERATIONS AND CONTROLS

The following list includes some common operations in which exposure to hydrogen sulfide may occur and control methods which may be effective in each case:

Operation	Controls
Liberation from pockets during underground mining operations near sulfide ores	Local exhaust ventilation; respiratory protective devices
Liberation during refining of high-sulfur petroleum	Concentration and recovery of H_2SO_4
Liberation from accumulations of decaying organic matter in sewers and waste waters of tanneries, glue factories, fat-rendering plants, and fertilizer plants	Provide continuous water discharge to sewer and cover and vent waste drains
Liberation as a by-product of dehairing and tanning process	Provide separate sewage lines and cover and vent waste drains; add neutralizing agents ($CaCl_2$) as appropriate; local exhaust ventilation
Liberation during manufacture of viscose rayon	Local exhaust ventilation
Liberation during production of sulfur dyes, carbon disulfide, sulfur, oleum, and thioprene	Local exhaust ventilation or process enclosure
Liberation during vulcanization of rubber; during manufacture of coke from coal having high gypsum content	Local exhaust ventilation or process enclosure
Liberation during excavation projects	Respiratory protective equipment

Liberation in closed containers containing organic matter	Respiratory protective equipment; life-support line

EMERGENCY FIRST AID PROCEDURES

In the event of an emergency, institute first aid procedures and send for first aid or medical assistance.

• **Eye Exposure**

If liquid hydrogen sulfide gets into the eyes, wash eyes immediately with large amounts of water, lifting the lower and upper lids occasionally. If irritation is present after washing, get medical attention. Contact lenses should not be worn when working with this chemical.

• **Skin Exposure**

If liquid hydrogen sulfide gets on the skin, immediately flush the contaminated skin with water. If liquid hydrogen sulfide penetrates through the clothing, remove the clothing immediately and flush the skin with water. If irritation is present after washing, get medical attention.

• **Breathing**

If a person breathes in large amounts of hydrogen sulfide, move the exposed person to fresh air at once. If breathing has stopped, perform artificial respiration. Keep the affected person warm and at rest. Get medical attention as soon as possible.

• **Rescue**

Move the affected person from the hazardous exposure. If the exposed person has been overcome, notify someone else and put into effect the established emergency rescue procedures. Do not become a casualty. Understand the facility's emergency rescue procedures and know the locations of rescue equipment before the need arises.

SPILL AND LEAK PROCEDURES

• Persons not wearing protective equipment and clothing should be restricted from areas of spills or leaks until cleanup has been completed.

• If hydrogen sulfide is spilled or leaked, the following steps should be taken:

1. Remove all ignition sources.
2. Ventilate area of spill or leak to disperse gas.
3. If in the gaseous form, stop flow of gas. If source of leak is a cylinder and the leak cannot be stopped in place, remove the leaking cylinder to a safe place in the open air, and repair the leak or allow the cylinder to empty.
4. If in the liquid form, allow to vaporize.

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RESPIRATORY PROTECTION FOR HYDROGEN SULFIDE

Condition	Minimum Respiratory Protection* Required Above 10 ppm
Gas Concentration	
300 ppm or less	Any supplied-air respirator with a full facepiece, helmet, or hood. Any self-contained breathing apparatus with a full facepiece.
Greater than 300 ppm or entry and escape from unknown concentrations	Self-contained breathing apparatus with a full facepiece operated in pressure-demand or other positive pressure mode. A combination respirator which includes a Type C supplied-air respirator with a full facepiece operated in pressure-demand or other positive pressure or continuous-flow mode and an auxiliary self-contained breathing apparatus operated in pressure-demand or other positive pressure mode.
Fire Fighting	Self-contained breathing apparatus with a full facepiece operated in pressure-demand or other positive pressure mode.
Escape	Any gas mask providing protection against acid gases or hydrogen sulfide. Any escape self-contained breathing apparatus.

*Only NIOSH-approved or MSHA-approved equipment should be used.

Occupational Health Guideline for Manganese

INTRODUCTION

This guideline is intended as a source of information for employees, employers, physicians, industrial hygienists, and other occupational health professionals who may have a need for such information. It does not attempt to present all data; rather, it presents pertinent information and data in summary form.

SUBSTANCE IDENTIFICATION

- Formula: Mn
- Synonyms: None
- Appearance: Gray solid.

PERMISSIBLE EXPOSURE LIMIT (PEL)

The current OSHA standard for manganese is a ceiling level of 5 milligrams of manganese per cubic meter of air (mg/m^3).

HEALTH HAZARD INFORMATION

- **Routes of exposure**

Manganese can affect the body if it is inhaled. Manganese can also affect the body if it is swallowed.

- **Effects of overexposure**

1. Short-term Exposure: Inhalation of fumes with high concentrations of manganese and its oxides may bring about "metal fume fever." Symptoms of metal fume fever are chills and fever, upset stomach, vomiting, dryness of the throat, cough, weakness, and aching of the head and body. Symptoms often occur several hours after exposure to fumes and usually last for only a day.

2. Long-term Exposure: Prolonged or repeated exposure to manganese may affect the nervous system with difficulty in walking and balancing, weakness or cramps in the legs, hoarseness of the voice, trouble with memory and judgment, unstable emotions or unusual irritability. If high exposure continues, a person may have poor coordination, difficulty in speaking clearly, or shaking or tremor of the arms or legs. A person may also have hallucinations or uncontrollable laughter or crying. The respiratory system may be affected by a condition known as "manganese pneumonia," which may result in symptoms and signs of coughing, fever, chills, general aching of the body, chest pain, and other common signs of pneumonia.

3. Reporting Signs and Symptoms: A physician should be contacted if anyone develops any signs or symptoms and suspects that they are caused by exposure to manganese.

- **Recommended medical surveillance**

The following medical procedures should be made available to each employee who is exposed to manganese at potentially hazardous levels:

1. Initial Medical Examination:

—A complete history and physical examination: The purpose is to detect pre-existing conditions that might place the exposed employee at increased risk, and to establish a baseline for future health monitoring. Persons with a history of alcoholism, psychiatric, neurologic, or pulmonary diseases or liver dysfunction would be expected to be at increased risk from exposure. Examination of the respiratory tract, hemopoietic system, and kidneys should be stressed.

—14" x 17" chest roentgenogram: Manganese causes pneumonitis or metal fume fever. Surveillance of the lungs is indicated.

—FVC and FEV (1 sec): Manganese is reported to cause decreased pulmonary function. Periodic surveillance is indicated.

—A complete blood count: Manganese has been reported to cause blood changes. A complete blood count should be performed including a red cell count, a white cell count, a differential count of a stained smear, as well as hemoglobin and hematocrit.

—Urinalysis: Since kidney damage has been observed in humans exposed to manganese, a urinalysis should be performed, including at a minimum specific gravity, albumin, glucose, and a microscopic on centrifuged

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sediment. Determination of manganese level in urine may be helpful in assessing exposure.

2. Periodic Medical Examination: The aforementioned medical examinations should be repeated on an annual basis, except that an x-ray is considered necessary only when indicated by the results of pulmonary function testing, or by signs and symptoms of respiratory disease.

• **Summary of toxicology**

Inhalation of manganese dust or fume primarily affects the central nervous system: high concentrations cause the influenza-like illness termed manganese pneumonitis. Manganese acts either as a direct neurotoxin, or it adversely affects certain neuroenzymes. Manganese fume causes a disease quite similar to Parkinsonism after 6 months to 2 years of exposure. Initially there is headache; asthenia; restless sleep or somnolence; change in personality with psychomotor instability associated with restlessness, irritability, and a tendency to either cry or laugh inappropriately. This is followed by an intermediate phase with visual hallucinations, double vision; impaired hearing; uncontrollable impulses; mental confusion; euphoria; and normal reaction to painful stimuli. In the advanced phase, the subject exhibits possible anemia; excessive salivation; disorders of the basal ganglia of Parkinsonian type, such as mask-like facies, muscle weakness, muscle rigidity, tremor of the uppper extremities and head, and impaired gait. High concentrations of manganese dust produce fever and chills similiar to mental fume fever. During human exposure to manganese fume there is dryness and irritation of the throat, a sweet or metallic taste followed by substernal tightness, constriction in the chest, and a dry cough. Several hours following exposure the subject develops chills, lassitude, malaise, fatigue, frontal headache, low back pain, muscle cramps, and occasionally blurred vision, nausea, and vomiting. Physical examination reveals fever, perspiration, dyspnea, rales throughout the chest, and tachycardia; in some instances there has been a reversible reduction in pulmonary vital capacity. Leukopenia has been reported in 4 out of 16 cases of manganese poisoning, although there is no convincing evidence that any changes in the blood should be regarded as specific or diagnostic of manganism.

CHEMICAL AND PHYSICAL PROPERTIES

• **Physical data**

1. Molecular weight: 54.94
2. Boiling point (760 mm Hg): 2097 C (3806 F)
3. Specific gravity (water = 1): 7.2
4. Vapor density (air = 1 at boiling point of manganese): Data not available
5. Melting point: 1245 C (2273 F)
6. Vapor pressure at 1227 C (2240 F): 1 mm Hg
7. Solubility in water, g/100 g water at 20 C (68 F): Not pertinent
8. Evaporation rate (butyl acetate = 1): Not pertinent
9. Autoignition temperature: Data not available
10. Flammable limits in air, % by volume: Data not available
11. Extinguishant: Data not available

• **Warning properties**

Grant states that "local contact of manganese with the cornea does not appear to be a problem industrially."

MONITORING AND MEASUREMENT PROCEDURES

• **Ceiling Evaluation**

Measurements to determine employee ceiling exposure are best taken during periods of maximum expected airborne concentrations of manganese. Each measurement should consist of a fifteen (15) minute sample or series of consecutive samples totalling fifteen (15) minutes in the employee's breathing zone (air that would most nearly represent that inhaled by the employee). A minimum of three (3) measurements should be taken on one work shift and the highest of all measurements taken is an estimate of the employee's exposure.

• **Method**

Sampling and analyses may be performed by collection of manganese in a filter, followed by atomic absorption spectrophotometric analysis. An analytical method for manganese is in the *NIOSH Manual of Analytical Methods*, 2nd Ed., Vol. 5, 1979, available from the Government Printing Office, Washington, D.C. 20402 (GPO No. 017-033-00349-1).

RESPIRATORS

• Good industrial hygiene practices recommend that engineering controls be used to reduce environmental concentrations to the permissible exposure level. However, there are some exceptions where respirators may be used to control exposure. Respirators may be used when engineering and work practice controls are not technically feasible, when such controls are in the process of being installed, or when they fail and need to be supplemented. Respirators may also be used for operations which require entry into tanks or closed vessels, and in emergency situations. If the use of respirators is necessary, the only respirators permitted are those that have been approved by the Mine Safety and Health Administration (formerly Mining Enforcement and Safety Administration) or by the National Institute for Occupational Safety and Health.

• In addition to respirator selection, a complete respiratory protection program should be instituted which includes regular training, maintenance, inspection, cleaning, and evaluation.

COMMON OPERATIONS AND CONTROLS

The following list includes some common operations in which exposure to manganese may occur and control methods which may be effective in each case:

Operation	Controls
Liberation during welding operations	Local exhaust ventilation; respiratory protective devices; dilution ventilation
Liberation during casting of molten ferro-manganese	Local exhaust ventilation
Liberating during bagging of manganese ore	Local exhaust ventilation; respiratory protective devices and dust suppression with water
Liberation during mixing and pressing of dry battery depolarization	Local exhaust ventilation
Liberation during grinding of ore containing manganese	Local exhaust ventilation; respiratory protective devices and dust suppression with water
Liberation during arc burning of manganese-hardened steel in repair and manufacture programs	Local exhaust ventilation; respiratory protective devices; dilution ventilation
Liberation from top of submerged arc electric furnace	General dilution ventilation and process enclosure, if possible
Liberation of dust during ore extraction	General dilution ventilation; respiratory protective devices
Liberation during metal finishing operations of high manganese steel	Local exhaust ventilation; respiratory protective equipment
Liberation of dust during crushing of ferro-manganese metal prior to shipment; during dumping, weighing, and mixing operations in ceramics and glass manufacture for pigmentation and coloration purposes	Local exhaust ventilation; respiratory protective equipment
Liberation from formulation of proprietary mixtures for paint and varnish manufacture	Local exhaust ventilation; respiratory protective equipment
Liberation of dioxide and sulfate during manufacture and application of fertilizers	Local exhaust ventilation
Liberation of dust during manufacture of manganese soap and wood preservatives; manufacture of safety matches, signal flares, fire-works, and strikers; during mixing and kiln operations of brick manufacture	Local exhaust ventilation
Liberation of dusts during manufacture and utilization of oxidation catalysts, such as hopcalite, manganese acetate, and naphthenate	Local exhaust ventilation

EMERGENCY FIRST AID PROCEDURES

In the event of an emergency, institute first aid procedures and send for first aid or medical assistance.

- **Breathing**

If a person breathes in large amounts of manganese, move the exposed person to fresh air at once. If breathing has stopped, perform artificial respiration. Keep the affected person warm and at rest. Get medical attention as soon as possible.

- **Swallowing**

When manganese has been swallowed and the person is conscious, give the person large quantities of water immediately. After the water has been swallowed, try to get the person to vomit by having him touch the back of his throat with his finger. Do not make an unconscious person vomit. Get medical attention immediately.

- **Rescue**

Move the affected person from the hazardous exposure. If the exposed person has been overcome, notify someone else and put into effect the established emergency rescue procedures. Do not become a casualty. Understand the facility's emergency rescue procedures and know the locations of rescue equipment before the need arises.

SPILL AND DISPOSAL PROCEDURES

- Persons not wearing protective equipment and clothing should be restricted from areas of spills until cleanup has been completed.
- If manganese is spilled, the following steps should be taken:

1. Remove all ignition sources.

2. Ventilate area of spill.

2. For small quantities, sweep onto paper or other suitable material, place in an appropriate container and burn in a safe place (such as a fume hood). Large quantities may be reclaimed; however, if this is not practical, dissolve in a flammable solvent (such as alcohol) and atomize in a suitable combustion chamber equipped with an appropriate effluent gas cleaning device.

• Waste disposal methods:

Manganese may be disposed of:

1. By making packages of manganese in paper or other flammable material and burning in a suitable combustion chamber equipped with an appropriate effluent gas cleaning device.

2. By dissolving manganese in a flammable solvent (such as alcohol) and atomizing in a suitable combustion chamber equipped with an appropriate effluent gas cleaning device.

ADDITIONAL INFORMATION

To find additional information on manganese, look up manganese in the following documents:

• Medical Surveillance for Chemical Hazards

• Respiratory Protection for Chemical Hazards

• Personal Protection and Sanitation for Chemical Hazards

These documents are available through the NIOSH Division of Technical Services, 4676 Columbia Parkway, Cincinnati, Ohio 45226.

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RESPIRATORY PROTECTION FOR MANGANESE

Condition	Minimum Respiratory Protection* Required Above 5 mg/m³
Dust or Mist Concentration	
25 mg/m³ or less	Any dust and mist respirator, except single-use respirators.
50 mg/m³ or less	Any dust and mist respirator, except single-use or quarter-mask respirator.
Dust, Mist, or Fume Concentration	
50 mg/m³ or less	Any fume respirator or high efficiency particulate filter respirator. Any supplied-air respirator. Any self-contained breathing apparatus.
250 mg/m³ or less	A high efficiency particulate filter respirator with a full facepiece. Any supplied-air respirator with a full facepiece, helmet, or hood. Any self-contained breathing apparatus with a full facepiece.
5000 mg/m³ or less	A powered air-purifying respirator with a high efficiency particulate filter. A Type C supplied-air respirator operated in pressure-demand or other positive pressure or continuous-flow mode.
10,000 mg/m³ or less	A Type C supplied-air respirator with a full facepiece operated in pressure-demand or other positive pressure mode or with a full facepiece, helmet, or hood operated in continuous-flow mode.
Greater than 10,000 mg/m³ or entry and escape from unknown concentrations	Self-contained breathing apparatus with a full facepiece operated in pressure-demand or other positive pressure mode. A combination respirator which includes a Type C supplied-air respirator with a full facepiece operated in pressure-demand or other positive pressure or continuous-flow mode and an auxiliary self-contained breathing apparatus operated in pressure-demand or other positive pressure mode.
Fire Fighting	Self-contained breathing apparatus with a full facepiece operated in pressure-demand or other positive pressure mode.

*Only NIOSH-approved or MSHA-approved equipment should be used.

Occupational Health Guideline for Inorganic Mercury

INTRODUCTION

This guideline is intended as a source of information for employees, employers, physicians, industrial hygienists, and other occupational health professionals who may have a need for such information. It does not attempt to present all data; rather, it presents pertinent information and data in summary form.

SUBSTANCE IDENTIFICATION

- Formula: Hg
- Synonyms: Quicksilver
- Appearance and odor: Silvery, mobile, odorless liquid.

PERMISSIBLE EXPOSURE LIMIT (PEL)

The current OSHA standard for mercury is a ceiling level of 0.1 milligram of mercury per cubic meter of air (mg/m^3). NIOSH has recommended that the permissible exposure limit be changed to 0.05 mg/m^3 averaged over an eight-hour work shift. The NIOSH Criteria Document for Inorganic Mercury should be consulted for more detailed information.

HEALTH HAZARD INFORMATION

- **Routes of exposure**

Mercury can affect the body if it is inhaled or if it comes in contact with the eyes or skin. It may enter the body through the skin.

- **Effects of overexposure**

1. Short-term Exposure: Inhaled mercury vapor may cause headaches, cough, chest pains, chest tightness, and difficulty in breathing. It may also cause chemical pneumanitis. In addition, it may cause soreness of the mouth, loss of teeth, nausea, and diarrhea. Liquid mercury may irritate the skin.

2. Long-term Exposure: Repeated or prolonged exposure to mercury liquid or vapor causes effects which develop gradually. The first effects to occur are often fine shaking of the hands, eyelids, lips, tongue, or jaw. Other effects are allergic skin rash, headache, sores in the mouth, sore and swollen gums, loose teeth, insomnia, excess salivation, personality change, irritability, indecision, loss of memory, and intellectual deterioration.

3. Reporting Signs and Symptoms: A physician should be contacted if anyone develops any signs or symptoms and suspects that they are caused by exposure to mercury.

- **Recommended medical surveillance**

The following medical procedures should be made available to each employee who is exposed to mercury at potentially hazardous levels:

1. Initial Medical Examination:

—A complete history and physical examination: The purpose is to detect pre-existing conditions that might place the exposed employee at increased risk, and to establish a baseline for future health monitoring. Persons with a history of allergies or known sensitization to mercury, chronic respiratory disease, nervous system disorders, or kidney disease would be expected to be at increased risk from exposure. Examination for any signs or symptoms of unacceptable mercury absorption such as weight loss, insomnia, tremors, personality changes, or other evidence of central nervous system involvement, as well as evidence of kidney damage, should be stressed. The skin should be examined for evidence of chronic disorders.

—Urinalysis: Since kidney damage has been observed in humans exposed to mercury, a urinalysis should be obtained to include, at a minimum, specific gravity, albumin, glucose, and a microscopic on centrifuged sediment. Determination of mercury level in urine may be helpful in assessing extent of absorption.

2. Periodic Medical Examination: The aforementioned medical examinations should be repeated on an annual basis.

These recommendations reflect good industrial hygiene and medical surveillance practices and their implementation will assist in achieving an effective occupational health program. However, they may not be sufficient to achieve compliance with all requirements of OSHA regulations.

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Summary of Toxicology

Acute exposure to mercury at high levels causes severe respiratory irritation, digestive disturbances, and marked renal damage; chronic mercurialism, the form of intoxication most frequently caused by occupational exposure, is characterized by neurologic and psychic disturbances, anorexia, weight loss, and stomatitis. Skin absorption of inorganic mercury probably adds to the toxic effects of vapor inhalation. Intraperitoneal injection of metallic mercury in rats has produced sarcomas. Exposure of humans to mercury vapor in concentrations of 1.2 to 8.5 mg/m^3 causes cough, chest pain and dyspnea, leading to bronchitis and pneumonitis. Metallic mercury readily vaporizes at room temperature, and the vapor has no warning properties. At low levels, the onset of symptoms resulting from chronic exposure is insidious; fine tremors of the hands, eyelids, lips and tongue are often the presenting complaint. Coarse jerky movements and incoordination may interfere with the fine movements considered necessary for writing and eating. Psychic disturbances such as insomnia, irritability, and indecision occur; headache, excessive fatigue, anorexia, digestive disturbances, and weight loss are common; stomatitis with excessive salivation is sometimes severe; muscle weakness has been reported. Proteinuria may occur, but is relatively infrequent. Mercury has been reported to be capable of causing sensitization dermatitis. Examination of urine for mercury may be of value. There is no "critical" level of mercury in urine above or below which poisoning cannot be seen. Various observers have suggested from 0.1 to 0.5 mg of Hg/l of urine as having clinical significance. Mercury, particularly organic forms, is known to adversely affect the fetus if the mother is exposed during pregnancy.

CHEMICAL AND PHYSICAL PROPERTIES

- **Physical data**
  1. Molecular weight: 200.6
  2. Boiling point (760 mm Hg): 357 C (674 F)
  3. Specific gravity (water = 1): 13.5
  4. Vapor density (air = 1 at boiling point of mercury): Not applicable
  5. Melting point: −39 C (-38 F)
  6. Vapor pressure at 20 C (68 F): 0.0012 mm Hg
  7. Solubility in water, g/100 g water at 20 C (68 F): 0.002
  8. Evaporation rate (butyl acetate = 1): Not applicable
- **Reactivity**
  1. Conditions contributing to instability: None
  2. Incompatibilities: Contact with acetylene, acetylene products, or ammonia gases may form solid products that are sensitive to shock and which can initiate fires of combustible materials.
  3. Hazardous decomposition products: None
  4. Special precautions: Mercury can attack copper and copper alloy materials.
- **Flammability**
  1. Not combustible
- **Warning properties**
  1. Odor Threshold: Mercury is odorless.
  2. Eye Irritation Level: Grant states that "when mercury metal droplets are in the epithelium, rather than the corneal stroma or anterior chamber, they are extruded rapidly with little reaction, as was reported in a patient who was sprayed forcefully with metallic mercury and was observed to have many fine silvery globules beneath the epithelium of the cornea . . . .

"Mercury metal in contact with the conjunctiva has been shown in rabbits to be absorbed and ultimately to be detectable in the urine. While in contact with the conjunctiva, metallic mercury produced no clinical signs of conjunctivitis, but histologically an inflammatory reaction has been demonstrable. External contact with mercury vapor has repeatedly been observed to induce a characteristic discoloration of the crystalline lens (mercurialentis)." Mercurialentis also is caused by systemic poisoning "from absorption of mercury vapor through the respiratory tract, the skin, and the gastrointestinal tract."

For the purposes of this guideline, mercury is not treated as an eye irritant.

3. Evaluation of Warning Properties: Mercury has no warning properties, according to the *Hygienic Guide*.

MONITORING AND MEASUREMENT PROCEDURES

- **Ceiling Evaluation**

Measurements to determine employee ceiling exposure are best taken during periods of maximum expected airborne concentrations of mercury. Each measurement should consist of a fifteen (15) minute sample or series of consecutive samples totalling fifteen (15) minutes in the employee's breathing zone (air that would most nearly represent that inhaled by the employee). A minimum of three (3) measurements should be taken on one work shift and the highest of all measurements taken is an estimate of the employee's exposure.

- **Method**

Sampling and analyses may be performed by collection of mercury with a three-section solid phase sampler, followed by analysis with an atomic absorption spectrophotometer. An analytical method for mercury is in the *NIOSH Manual of Analytical Methods*, 2nd Ed., Vol. 6, 1980, available from the Government Printing Office, Washington, D.C. 20402 (GPO No. 017-033-00369-6).

RESPIRATORS

- Good industrial hygiene practices recommend that engineering controls be used to reduce environmental concentrations to the permissible exposure level. However, there are some exceptions where respirators may

be used to control exposure. Respirators may be used when engineering and work practice controls are not technically feasible, when such controls are in the process of being installed, or when they fail and need to be supplemented. Respirators may also be used for operations which require entry into tanks or closed vessels, and in emergency situations. If the use of respirators is necessary, the only respirators permitted are those that have been approved by the Mine Safety and Health Administration (formerly Mining Enforcement and Safety Administration) or by the National Institute for Occupational Safety and Health.

- In addition to respirator selection, a complete respiratory protection program should be instituted which includes regular training, maintenance, inspection, cleaning, and evaluation.

PERSONAL PROTECTIVE EQUIPMENT

- Employees should be provided with and required to use impervious clothing, gloves, face shields (eight-inch minimum), and other appropriate protective clothing necessary to prevent repeated or prolonged skin contact with liquid mercury.
- If employees' clothing may have become contaminated with mercury, employees should change into uncontaminated clothing before leaving the work premises.
- Clothing contaminated with mercury should be placed in closed containers for storage until it can be discarded or until provision is made for the removal of mercury from the clothing. If the clothing is to be laundered or otherwise cleaned to remove the mercury, the person performing the operation should be informed of mercury's hazardous properties.
- Non-impervious clothing which becomes contaminated with mercury should be removed promptly and not reworn until the mercury is removed from the clothing.

SANITATION

- Workers subject to skin contact with liquid mercury should wash with soap or mild detergent and water any areas of the body which may have contacted mercury at the end of each work day.
- Skin that becomes contaminated with mercury should be promptly washed or showered with soap or mild detergent and water to remove any mercury.
- Eating and smoking should not be permitted in areas where mercury is handled, processed, or stored.
- Employees who handle mercury should wash their hands thoroughly with soap or mild detergent and water before eating, smoking, or using toilet facilities.

COMMON OPERATIONS AND CONTROLS

The following list includes some common operations in which exposure to mercury may occur and control methods which may be effective in each case:

Operation	Controls
Use as a liquid cathode in electrolytic production of chlorine and caustic soda from brine	General dilution ventilation; process enclosure; local exhaust ventilation; personal protective equipment; meticulous housekeeping
Use during manufacture and repair of industrial and medical apparatus; use during manufacture of inorganic and organic compounds for use as pesticides, antiseptics, germicides, and skin preparations, and miscellaneous applications as chemical intermediates, preservatives, and pigments	General dilution ventilation; process enclosure; local exhaust ventilation; personal protective equipment; meticulous housekeeping
Use in preparation of amalgams for use in tooth restorations, chemical processing, and molding operations; use during manufacture of mildew-proof paints and marine antifouling agents	General dilution ventilation; process enclosure; local exhaust ventilation; personal protective equipment
Use in manufacture of organic mercurials; use in manufacture of batteries, lamps, and power tubes; manufacture of tungsten-molybdenum wire and rods; use in manufacture of inorganic salts for use as catalysts in production of urethanes, vinyl chloride monomers, anthraquinone derivatives, and other miscellaneous chemicals	General dilution ventilation; process enclosure; local exhaust ventilation; personal protective equipment; meticulous housekeeping

Use as a chemical intermediate and in the manufacture of felt; as a flotation agent in manufacture of bowling balls; use as a laboratory reagent or as a working fluid in instruments	General dilution ventilation; process enclosure; local exhaust ventilation; personal protective equipment; meticulous housekeeping
Use as a conductor during construction and maintenance of military and nuclear power systems, in mercury-stem boilers, and in air-rectifiers	General dilution ventilation; personal protective equipment; meticulous housekeeping
Liberation during roasting and smelting operations	General dilution ventilation; local exhaust ventilation
Use in manufacture of explosives; in preparation of amalgams for use in artificial jewelry	General dilution ventilation; process enclosure; local exhaust ventilation; personal protective equipment; meticulous housekeeping
Use in manufacture of compounds for pulp and paper industry as controls for biological growths	General dilution ventilation; process enclosure; local exhaust ventilation; personal protective equipment
Liberation during mining and subsequent refining of ore containing cinnabar	General dilution ventilation; personal protective equipment; meticulous housekeeping

EMERGENCY FIRST AID PROCEDURES

In the event of an emergency, institute first aid procedures and send for first aid or medical assistance.

- **Eye Exposure**

If liquid mercury gets into the eyes, wash eyes immediately with large amounts of water, lifting the lower and upper lids occasionally. If irritation is present after washing, get medical attention. Contact lenses should not be worn when working with this chemical.

- **Skin Exposure**

If liquid mercury gets on the skin, promptly wash the contaminated skin using soap or mild detergent and water. If liquid mercury penetrates through the clothing, remove the clothing promptly and wash the skin using soap or mild detergent and water. If irritation persists after washing, get medical attention.

If a person breathes in large amounts of mercury, move the exposed person to fresh air at once. If breathing has stopped, perform artificial respiration. Keep the affected person warm and at rest. Get medical attention as soon as possible.

- **Swallowing**

When large quantities of mercury have been swallowed or mercury has been swallowed repeatedly and the person is conscious, give the person large quantities of water immediately. After the water has been swallowed, try to get the person to vomit by having him touch the back of his throat with his finger. Do not make an unconscious person vomit. Get medical attention immediately.

- **Rescue**

Move the affected person from the hazardous exposure. If the exposed person has been overcome, notify someone else and put into effect the established emergency rescue procedures. Do not become a casualty. Understand the facility's emergency rescue procedures and know the locations of rescue equipment before the need arises.

SPILL PROCEDURES

- Persons not wearing protective equipment and clothing should be restricted from areas of spills until cleanup has been completed.
- If mercury is spilled, the following steps should be taken:

1. Ventilate area of spill.
2. Collect spilled material for reclamation using commercially available mercury vapor depressants or specialized vacuum cleaners.

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RESPIRATORY PROTECTION FOR INORGANIC MERCURY

Condition	Minimum Respiratory Protection* Required Above 0.1 mg/m³
Particulate or Vapor Concentration	
1 mg/m³ or less	Any supplied-air respirator. Any self-contained breathing apparatus.
5 mg/m³ or less	Any supplied-air respirator with a full facepiece, helmet, or hood. Any self-contained breathing apparatus with a full facepiece.
28 mg/m³ or less	A Type C supplied-air respirator operated in pressure-demand or other positive pressure or continuous-flow mode.
Greater than 28 mg/m³ or entry and escape from unknown concentrations	Self-contained breathing apparatus with a full facepiece operated in pressure-demand or other positive pressure mode. A combination respirator which includes a Type C supplied-air respirator with a full facepiece operated in pressure-demand or other positive pressure or continuous-flow mode and an auxiliary self-contained breathing apparatus operated in pressure-demand or other positive pressure mode.
Fire Fighting	Self-contained breathing apparatus with a full facepiece operated in pressure-demand or other positive pressure mode.
Escape	Any gas mask providing protection against mercury. Any escape self-contained breathing apparatus.

*Only NIOSH-approved or MSHA-approved equipment should be used.

Occupational Health Guideline for Methylene Chloride

INTRODUCTION

This guideline is intended as a source of information for employees, employers, physicians, industrial hygienists, and other occupational health professionals who may have a need for such information. It does not attempt to present all data; rather, it presents pertinent information and data in summary form.

SUBSTANCE IDENTIFICATION

- Formula: CH_2Cl_2
- Synonyms: Dichloromethane; methylene dichloride
- Appearance and odor: Colorless liquid with an odor like chloroform.

PERMISSIBLE EXPOSURE LIMIT (PEL)

The current OSHA standard for methylene chloride is 500 parts of methylene chloride per million parts of air (ppm) averaged over an eight-hour work shift, with an acceptable ceiling level of 1000 ppm and a maximum peak concentration of 2000 ppm for 5 minutes in any two-hour period. NIOSH has recommended that the permissible exposure limit be reduced to 75 ppm averaged over a work shift of up to 10 hours per day, 40 hours per week, with a ceiling level of 500 ppm averaged over a 15-minute period. NIOSH further recommends that permissible levels of methylene chloride be reduced where carbon monoxide is present. The NIOSH Criteria Document for Methylene Chloride should be consulted for more detailed information.

HEALTH HAZARD INFORMATION

- **Routes of exposure**

Methylene chloride can affect the body if it is inhaled or if it comes in contact with the eyes or skin. It can also affect the body if it is swallowed.

- **Effects of overexposure**

1. Short-term Exposure: Methylene chloride is an anesthetic. Inhaling the vapor may cause mental confusion, light-headedness, nausea, vomiting, and headache. Continued exposure may cause increased light-headedness, staggering, unconsciousness, and death. High vapor concentrations may also cause irritation of the eyes and respiratory tract. Exposure to this chemical may make the symptoms of angina worse. Skin exposure to the liquid may cause irritation. If the liquid is held in contact with the skin, it may cause skin burns. Splashes of the liquid into the eyes may cause irritation.

2. Long-term Exposure: Prolonged or repeated exposure to methylene chloride may cause irritation of the skin.

3. Reporting Signs and Symptoms: A physician should be contacted if anyone develops any signs or symptoms and suspects that they are caused by exposure to methylene chloride.

- **Recommended medical surveillance**

The following medical procedures should be made available to each employee who is exposed to methylene chloride at potentially hazardous levels:

1. Initial Medical Examination:

—A complete history and physical examination: The purpose is to detect pre-existing conditions that might place the employee at increased risk, and to establish a baseline for future health monitoring. Examination of the skin, liver, kidneys, cardiovascular system, and blood should be stressed. Clinical impressions of the autonomic nervous system and pulmonary function should be made, with additional tests conducted where indicated.

—Skin disease: Methylene chloride can cause dermatitis on prolonged exposure. Persons with pre-existing skin disorders may be more susceptible to the effects of this agent.

—Liver function test: Methylene chloride causes liver damage in animals and this justifies consideration before exposing persons with impaired liver function. A profile of liver function should be obtained by utilizing a medically acceptable array of biochemical tests.

—Kidney disease: Methylene chloride causes kidney damage in animals and this justifies special considera-

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tion before exposing persons with impaired renal function.

—Cardiovascular disease: Because of reports of excessive carbon monoxide levels following exposure to methylene chloride, persons with cardiac disease may be at increased risk.

—A complete blood count: A complete blood count should be performed, including a red cell count, a white cell count, a differential count of a stained smear, as well as hemoglobin and hematocrit. Carboxyhemoglobin values should also be determined periodically, and any level above 5% should prompt an investigation of the worker and his workplace.

2. *Periodic Medical Examination:* The aforementioned medical examinations should be repeated on an annual basis.

• **Summary of toxicology**

Methylene chloride vapor is a mild narcotic. Exposure of animals to 15,000 ppm for 7 hours was fatal. Animal experiments have shown that continuous exposure to 1,000 ppm can be lethal in 5 to 7 weeks for dogs and that fatty livers, icterus, pneumonia, and splenic atrophy developed in dogs. Cardiac arrhytmias attributed to sensitization of the myocardium have been observed following exposure to high concentrations of some chlorinated hydrocarbons, but dogs exposed to 10,000 and 20,000 ppm of methylene chloride did not show this phenomenon. In human experiments, inhalation of 500 to 1000 ppm for 1 to 2 hours resulted in lightheadedness; there was sustained elevation of carboxyhemoglobin level. High exposures have resulted in deaths in industrial situations. Lower but unknown concentrations have caused such symptoms as lightheadedness, weakness, nausea, and "drunken behavior," resulting in mistakes and accidental falls. Phosgene poisoning has been reported to occur in several cases where methylene chloride was used in the presence of an open fire. Liquid methylene chloride is irritating to the skin on repeated contact. Splashed in the eye, it is painfully irritating, but is not likely to cause serious injury.

CHEMICAL AND PHYSICAL PROPERTIES

• **Physical data**

1. Molecular weight: 84.9
2. Boiling point (760 mm Hg): 39.8 C (104 F)
3. Specific gravity (water = 1): 1.3
4. Vapor density (air = 1 at boiling point of methylene chloride): 2.9
5. Melting point: −97 C (−142 F)
6. Vapor pressure at 20 C (68 F): 350 mm Hg
7. Solubility in water, g/100 g water at 20 C (68 F): 1.32
8. Evaporation rate (butyl acetate = 1): 27.5

• **Reactivity**

1. Conditions contributing to instability: Heat and moisture
2. Incompatibilities: Contact with strong oxidizers, strong caustics, and chemically active metals such as aluminum or magnesium powder, sodium and potassium may cause fires and explosions.
3. Hazardous decomposition products: Toxic gases and vapors (such as hydrogen chloride, phosgene, and carbon monoxide) may be released in a fire involving methylene chloride.
4. Special precautions: Liquid methylene chloride will attack some forms of plastics, rubber, and coatings.

• **Flammability**

1. Flash point: None with normal test method
2. Autoignition temperature: 556 C (1033 F)
3. Flammable limits in air, % by volume: (at elevated temperatures) Lower: 12; Upper: 19
4. Extinguishant: Dry chemical, carbon dioxide, foam

• **Warning properties**

1. Odor Threshold: Different authors have reported varying odor thresholds for methylene chloride. Summer and May both report 150 ppm; Kirk-Othmer and Sax both report 25 to 50 ppm; Spector reports 320 ppm. Patty, however, states that since one can become adapted to the odor, it cannot be considered an adequate warning property.
2. Eye Irritation Level: Grant reports that methylene chloride "presents no particular hazard to the eyes." Kirk-Othmer, however, reports that "methylene chloride vapor is seriously damaging to the eyes." Sax agrees with Kirk-Othmer's statement.

The *Documentation of TLV's* states that irritation of the eyes has been observed in workers who had been exposed to concentrations up to 5000 ppm, but that neurasthenic disorders were found in 50% and digestive disturbances in 30% of the persons exposed.

3. Other Information: Gleason reports that methylene chloride may be "irritating to the respiratory tract and may produce pulmonary edema" but gives no quantitative information. The *Documentation of TLV's* reports that in one investigation, irritation of the respiratory passages was observed in workers who had been exposed to concentrations up to 5000 ppm.
4. Evaluation of Warning Properties: Since no detailed information is available relating the irritant effects of methylene chloride to air concentrations and since adaptation to the odor occurs, methylene chloride is treated as a material with poor warning properties.

MONITORING AND MEASUREMENT PROCEDURES

• **Eight-Hour Exposure Evaluation**

Measurements to determine employee exposure are best taken so that the average eight-hour exposure is based on a single eight-hour sample or on two four-hour samples. Several short-time interval samples (up to 30 minutes) may also be used to determine the average exposure level. Air samples should be taken in the employee's breathing zone (air that would most nearly represent that inhaled by the employee).

• **Ceiling Evaluation**

Measurements to determine employee ceiling exposure are best taken during periods of maximum expected airborne concentrations of methylene chloride. Each measurement should consist of a fifteen (15) minute sample or series of consecutive samples totalling fifteen (15) minutes in the employee's breathing zone (air that would most nearly represent that inhaled by the employee). A minimum of three (3) measurements should be taken on one work shift and the highest of all measurements taken is an estimate of the employee's exposure.

• **Peak Above Ceiling Evaluation**

Measurements to determine employee peak exposure should be taken during periods of maximum expected airborne concentration of methylene chloride. Each measurement should consist of a 30-minute sample or a series of consecutive samples totalling 30 minutes in the employee's breathing zone (air that would most nearly represent that inhaled by the employee). A minimum of three measurements should be taken on one work shift and the highest of all measurements taken is an estimate of the employee's exposure.

• **Method**

Sampling and analyses may be performed by collection of vapors using an adsorption tube with subsequent desorption with carbon disulfide and gas chromatographic analysis. Also, detector tubes certified by NIOSH under 42 CFR Part 84 or other direct-reading devices calibrated to measure methylene chloride may be used. An analytical method for methylene chloride is in the *NIOSH Manual of Analytical Methods*, 2nd Ed., Vol. 3, 1977, available from the Government Printing Office, Washington, D.C. 20402 (GPO No. 017-033-00261-4).

RESPIRATORS

• Good industrial hygiene practices recommend that engineering controls be used to reduce environmental concentrations to the permissible exposure level. However, there are some exceptions where respirators may be used to control exposure. Respirators may be used when engineering and work practice controls are not technically feasible, when such controls are in the process of being installed, or when they fail and need to be supplemented. Respirators may also be used for operations which require entry into tanks or closed vessels, and in emergency situations. If the use of respirators is necessary, the only respirators permitted are those that have been approved by the Mine Safety and Health Administration (formerly Mining Enforcement and Safety Administration) or by the National Institute for Occupational Safety and Health.

• In addition to respirator selection, a complete respiratory protection program should be instituted which includes regular training, maintenance, inspection, cleaning, and evaluation.

PERSONAL PROTECTIVE EQUIPMENT

• Employees should be provided with and required to use impervious clothing, gloves, face shields (eight-inch minimum), and other appropriate protective clothing necessary to prevent repeated or prolonged skin contact with liquid methylene chloride.

• Non-impervious clothing which becomes wet with liquid methylene chloride should be removed promptly and not reworn until the methylene chloride is removed from the clothing.

• Employees should be provided with and required to use splash-proof safety goggles where liquid methylene chloride may contact the eyes.

SANITATION

• Skin that becomes wet with liquid methylene chloride should be promptly washed or showered with soap or mild detergent and water to remove any methylene chloride.

COMMON OPERATIONS AND CONTROLS

The following list includes some common operations in which exposure to methylene chloride may occur and control methods which may be effective in each case.

Operation	Controls
Use as a solvent in paint and varnish removers; manufacture of aerosols; cold cleaning and ultrasonic cleaning; and as an extraction solvent for foods and furniture processing	General dilution ventilation; local exhaust ventilation; personal protective equipment
Use as a cooling solvent in manufacture of cellulose acetate; in organic synthesis; and in plastics processing	Process enclosure; local exhaust ventilation
Use as a solvent in vapor degreasing of thermal switches and thermometers	Process enclosure; local exhaust ventilation
Use as a secondary refrigerant in air conditioning and scientific testing	General dilution ventilation; local exhaust ventilation; personal protective equipment

Operation	Controls
Use as an extraction solvent for edible fats, coca, butter, beer flavoring in hops, decaffeinated coffee, oleoresin manufacture, oils, waxes, perfumes, flavorings, and drugs	General dilution ventilation; local exhaust ventilation; personal protective equipment
Use as a solvent for paints, lacquers, varnishes, enamels, adhesives, rubber cements, manufacture of printed circuit boards, as a carrier for pharmaceutical tablet coatings, shrink-fitting of synthetic rubber covers, and dyeing of synthetic fibers	General dilution ventilation; local exhaust ventilation; personal protective equipment

EMERGENCY FIRST AID PROCEDURES

In the event of an emergency, institute first aid procedures and send for first aid or medical assistance.

- **Eye Exposure**

If methylene chloride gets into the eyes, wash eyes immediately with large amounts of water, lifting the lower and upper lids occasionally. If irritation is present after washing, get medical attention. Contact lenses should not be worn when working with this chemical.

- **Skin Exposure**

If methylene chloride gets on the skin, promptly wash the contaminated skin using soap or mild detergent and water if the methylene chloride has not already evaporated. If methylene chloride soaks through the clothing, remove the clothing promptly and wash the skin using soap or mild detergent and water. If irritation persists after washing, get medical attention.

- **Breathing**

If a person breathes in large amounts of methylene chloride, move the exposed person to fresh air at once. If breathing has stopped, perform artificial respiration. Keep the affected person warm and at rest. Get medical attention as soon as possible.

- **Swallowing**

When methylene chloride has been swallowed, get medical attention immediately. If medical attention is not immediately available, get the afflicted person to vomit by having him touch the back of his throat with his finger or by giving him syrup of ipecac as directed on the package. This non-prescription drug is available at most drug stores and drug counters and should be kept with emergency medical supplies in the workplace. Do not make an unconscious person vomit.

- *Rescue*

Move the affected person from the hazardous exposure. If the exposed person has been overcome, notify someone else and put into effect the established emergency rescue procedures. Do not become a casualty. Understand the facility's emergency rescue procedures and know the locations of rescue equipment before the need arises.

SPILL AND LEAK PROCEDURES

- Persons not wearing protective equipment and clothing should be restricted from areas of spills or leaks until cleanup has been completed.
- If methylene chloride is spilled or leaked, the following steps should be taken:

1. Remove all ignition sources.
2. Ventilate area of spill or leak.
3. Collect for reclamation or absorb in vermiculite, dry sand, earth, or a similar material.

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RESPIRATORY PROTECTION FOR METHYLENE CHLORIDE

Condition	Minimum Respiratory Protection* Required Above 500 ppm
Vapor Concentration	
5000 ppm or less	Any supplied-air respirator with a full facepiece, helmet, or hood. Any self-contained breathing apparatus with a full facepiece.
Greater than 5000 ppm or entry and escape from unknown concentrations	Self-contained breathing apparatus with a full facepiece operated in pressure-demand or other positive pressure mode. A combination respirator which includes a Type C supplied-air respirator with a full facepiece operated in pressure-demand or other positive pressure or continuous-flow mode and an auxiliary self-contained breathing apparatus operated in pressure-demand or other positive pressure mode.
Fire Fighting	Self-contained breathing apparatus with a full facepiece operated in pressure-demand or other positive pressure mode.
Escape	Any gas mask providing protection against organic vapors. Any escape self-contained breathing apparatus.

*Only NIOSH-approved or MSHA-approved equipment should be used.

Occupational Health Guideline for Naphthalene

INTRODUCTION

This guideline is intended as a source of information for employees, employers, physicians, industrial hygienists, and other occupational health professionals who may have a need for such information. It does not attempt to present all data; rather, it presents pertinent information and data in summary form.

SUBSTANCE IDENTIFICATION

- Formula: $C_{10}H_8$
- Synonyms: White tar; naphthalin
- Appearance and odor: Colorless to brown solid with the odor of mothballs.

PERMISSIBLE EXPOSURE LIMIT (PEL)

The current OSHA standard for naphthalene is 10 parts of naphthalene per million parts of air (ppm) averaged over an eight-hour work shift. This may also be expressed as 50 milligrams of naphthalene per cubic meter of air (mg/m³).

HEALTH HAZARD INFORMATION

- **Routes of exposure**

Naphthalene can affect the body if it is inhaled, if it comes in contact with the eyes or skin, or if it is swallowed. It may enter the body through the skin.

- **Effects of overexposure**

1. Short-term Exposure: Inhalation or ingestion of naphthalene may cause abdominal cramps, nausea, vomiting, diarrhea, headache, tiredness, confusion, painful urination, and bloody or dark urine. Swallowing large amounts may cause convulsions or coma. Inhalation, ingestion, and possibly skin absorption of naphthalene may cause destruction of red blood cells with anemia, fever, yellow jaundice, bloody urine, kidney and liver damage. Naphthalene, on contact with the eyes, has produced irritation. Naphthalene, on contact with the skin, has produced skin irritation.

2. Long-term Exposure: Repeated skin exposure to naphthalene may cause an allergic rash. Repeated exposure may cause cataracts.

3. Reporting Signs and Symptoms: A physician should be contacted if anyone develops any signs or symptoms and suspects that they are caused by exposure to naphthalene.

- **Recommended medical surveillance**

The following medical procedures should be made available to each employee who is exposed to naphthalene at potentially hazardous levels:

1. Initial Medical Examination:

—A complete history and physical examination: The purpose is to detect pre-existing conditions that might place the exposed employee at increased risk, and to establish a baseline for future health monitoring. Persons with a deficiency of glucose-6-phosphate dehydrogenase in erythrocytes may be at increased risk from exposure. Examination of the eyes, blood, liver and kidneys should be stressed. The skin should be examined for evidence of chronic disorders.

—A complete blood count: Naphthalene has been shown to cause red blood cell hemolysis. A complete blood count should be performed, including a red cell count, a white cell count, and a differential count of a stained smear, as well as hemoglobin and hematocrit.

—Urinalysis: Since kidney damage may also occur from exposure to naphthalene, a urinalysis should be performed, including at a minimum specific gravity, albumin, glucose, and a microscopic on centrifuged sediment.

2. Periodic Medical Examination: The aforementioned medical examinations should be repeated on an annual basis.

- **Summary of toxicology**

Naphthalene vapor causes hemolysis and eye irritation; it may cause cataracts. Severe intoxication from ingestion of the solid results in characteristic manifestations of marked intravascular hemolysis and its consequences, including potentially fatal hyperkalemia. Initial symptoms include eye irritation, headache, confu-

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sion, excitement, malaise, profuse sweating, nausea, vomiting, abdominal pain, and irritation of the bladder; there may be progression to jaundice, hematuria, hemoglobinuria, renal tubular blockage, and acute renal shutdown. Hematologic features include red cell fragmentation, icterus, severe anemia with nucleated red cells, leukocytosis, and dramatic decreases in hemoglobin, hematocrit, and red cell count; sometimes there is formation of Heinz bodies and methemoglobin. Individuals with a deficiency of glucose-6-phosphate dehydrogenase in erythrocytes may be more susceptible to hemolysis by naphthalene. Cataracts and ocular irritation have been produced experimentally in animals and have been described in humans; of 21 workers exposed to high concentrations of fume or vapor for 5 years, 8 had peripheral lens opacities; in other studies no abnormalities of the eyes have been detected in workers exposed to naphthalene for several years. The vapor causes eye irritation at 15 ppm; eye contact with the solid may result in conjunctivitis, superficial injury to the cornea, chorioretinitis, scotoma, and diminished visual acuity. Naphthalene on the skin may cause hypersensitivity dermatitis; chronic dermatitis is rare.

CHEMICAL AND PHYSICAL PROPERTIES

- **Physical data**

1. Molecular weight: 128.2
2. Boiling point (760 mm Hg): 218 C (424 F)
3. Specific gravity (water = 1): 1.14
4. Vapor density (air = 1 at boiling point of naphthalene): 4.4
5. Melting point: 74 – 80 C (165 – 176 F)
6. Vapor pressure at 20 C (68 F): 0.05 mm Hg
7. Solubility in water, g/100 g water at 20 C (68 F): 0.003
8. Evaporation rate (butyl acetate = 1): Much less than 1

- **Reactivity**

1. Conditions contributing to instability: None.
2. Incompatibilities: Contact with strong oxidizers may cause fires and explosions.
3. Hazardous decomposition products: Toxic gases and vapors (such as dense acrid smoke and carbon monoxide) may be released in a fire involving naphthalene.
4. Special precautions: Melted naphthalene will attack some forms of plastics, rubber, and coatings.

- **Flammability**

1. Flash point: 79 C (174 F) (closed cup)
2. Autoignition temperature: 526 C (979 F)
3. Flammable limits in air, % by volume: Lower: 0.9; Upper: 5.9
4. Extinguishant: Carbon dioxide, dry chemical, foam

- **Warning properties**

1. Odor Threshold: The AIHA *Hygienic Guide* reports that the odor threshold of naphthalene is "at least as low as 0.3 ppm."
2. Eye Irritation Level: The *Hygienic Guide* states that "naphthalene vapor is reported to cause eye irritation at 15 ppm or above in air."
3. Evaluation of Warning Properties: Through its odor and irritant effects, naphthalene can be detected at or below the permissible exposure limit. Naphthalene, therefore, is treated as a material with good warning properties.

MONITORING AND MEASUREMENT PROCEDURES

- **General**

Measurements to determine employee exposure are best taken so that the average eight-hour exposure is based on a single eight-hour sample or on two four-hour samples. Several short-time interval samples (up to 30 minutes) may also be used to determine the average exposure level. Air samples should be taken in the employee's breathing zone (air that would most nearly represent that inhaled by the employee).

- **Method**

Sampling and analyses may be performed by collection of vapors using an adsorption tube with subsequent desorption with carbon disulfide and gas chromatographic analysis. Also, detector tubes certified by NIOSH under 42 CFR Part 84 or other direct-reading devices calibrated to measure naphthalene may be used. An analytical method for naphthalene is in the *NIOSH Manual of Analytical Methods*, 2nd Ed., Vol. 4, 1978, available from the Government Printing Office, Washington, D.C. 20402 (GPO No. 017-033-00317-3).

RESPIRATORS

- Good industrial hygiene practices recommend that engineering controls be used to reduce environmental concentrations to the permissible exposure level. However, there are some exceptions where respirators may be used to control exposure. Respirators may be used when engineering and work practice controls are not technically feasible, when such controls are in the process of being installed, or when they fail and need to be supplemented. Respirators may also be used for operations which require entry into tanks or closed vessels, and in emergency situations. If the use of respirators is necessary, the only respirators permitted are those that have been approved by the Mine Safety and Health Administration (formerly Mining Enforcement and Safety Administration) or by the National Institute for Occupational Safety and Health.
- In addition to respirator selection, a complete respiratory protection program should be instituted which includes regular training, maintenance, inspection, cleaning, and evaluation.

PERSONAL PROTECTIVE EQUIPMENT

- Employees should be provided with and required to use impervious clothing, gloves, face shields (eight-inch minimum), and other appropriate protective clothing necessary to prevent repeated or prolonged skin contact with naphthalene or liquids containing naphthalene.
- If employees' clothing may have become contaminated with solid naphthalene, employees should change into uncontaminated clothing before leaving the work premises.
- Clothing contaminated with naphthalene should be placed in closed containers for storage until it can be discarded or until provision is made for the removal of naphthalene from the clothing. If the clothing is to be laundered or otherwise cleaned to remove the naphthalene, the person performing the operation should be informed of naphthalene's hazardous properties.
- Non-impervious clothing which becomes contaminated with naphthalene should be removed promptly and not reworn until the naphthalene is removed from the clothing.
- Employees should be provided with and required to use dust- and splash-proof safety goggles where solid naphthalene or liquids containing naphthalene may contact the eyes.

SANITATION

- Skin that becomes contaminated with naphthalene should be promptly washed or showered with soap or mild detergent and water to remove any naphthalene.
- Eating and smoking should not be permitted in areas where solid naphthalene is handled, processed, or stored.
- Employees who handle naphthalene or liquids containing naphthalene should wash their hands thoroughly with soap or mild detergent and water before eating, smoking, or using toilet facilities.

COMMON OPERATIONS AND CONTROLS

The following list includes some common operations in which exposure to naphthalene may occur and control methods which may be effective in each case:

Operation	Controls
Formulation of insecticide and moth repellant as flakes, powder, balls, or cakes	Local exhaust ventilation; general dilution ventilation; personal protective equipment
Use as a fumigant for moth repellant and insecticide	General dilution ventilation; personal protective equipment
Use in manufacture of chemical intermediates for production of pharmaceuticals, resins, dyes, plasticizers, solvents, coatings, insecticides, pigments, rubber chemicals, tanning agents, surfactants, waxes, cable coatings, textile spinning lubricants, rodenticides, and in storage batteries	Local exhaust ventilation; general dilution ventilation; personal protective equipment
Manufacture of naphthalene	Local exhaust ventilation; process enclosure; general dilution ventilation; personal protective equipment

EMERGENCY FIRST AID PROCEDURES

In the event of an emergency, institute first aid procedures and send for first aid or medical assistance.

- **Eye Exposure**

If naphthalene or liquids containing naphthalene get into the eyes, wash eyes immediately with large amounts of water, lifting the lower and upper lids occasionally. If irritation is present after washing, get medical attention. Contact lenses should not be worn when working with this chemical.

- **Skin Exposure**

If molten naphthalene gets on the skin, immediately flush the skin with large amounts of water. Get medical attention immediately. If naphthalene or liquids containing naphthalene get on the skin, promptly wash the contaminated skin using soap or mild detergent and water. If naphthalene or liquids containing naphthalene penetrate through the clothing, remove the clothing immediately and wash the skin using soap or mild detergent and water. If irritation persists after washing, get medical attention.

- **Breathing**

If a person breathes in large amounts of naphthalene, move the exposed person to fresh air at once.

- **Swallowing**

When naphthalene has been swallowed and the person is conscious, give the person large quantities of water immediately. After the water has been swallowed, try to get the person to vomit by having him touch the back of his throat with his finger. Do not make an unconscious person vomit. Get medical attention immediately.

- **Rescue**

Move the affected person from the hazardous exposure. If the exposed person has been overcome, notify some-

one else and put into effect the established emergency rescue procedures. Do not become a casualty. Understand the facility's emergency rescue procedures and know the locations of rescue equipment before the need arises.

SPILL AND DISPOSAL PROCEDURES

• Persons not wearing protective equipment and clothing should be restricted from areas of spills until cleanup has been completed.

• If naphthalene is spilled, the following steps should be taken:

1. Ventilate area of spill.
2. For small quantities, sweep onto paper or other suitable material, place in an appropriate container and burn in a safe place (such as a fume hood). Large quantities may be reclaimed; however, if this is not practical, dissolve in a flammable solvent (such as alcohol) and atomize in a suitable combustion chamber.

• Waste disposal methods:

Naphthalene may be disposed of:

1. By making packages of naphthalene in paper or other flammable material and burning in a suitable combustion chamber.
2. By dissolving naphthalene in a flammable solvent (such as alcohol) and atomizing in a suitable combustion chamber.

ADDITIONAL INFORMATION

To find additional information on naphthalene, look up naphthalene in the following documents:

• Medical Surveillance for Chemical Hazards
• Respiratory Protection for Chemical Hazards
• Personal Protection and Sanitation for Chemical Hazards

These documents are available through the NIOSH Division of Technical Services, 4676 Columbia Parkway, Cincinnati, Ohio 45226.

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RESPIRATORY PROTECTION FOR NAPHTHALENE

Condition	Minimum Respiratory Protection* Required Above 10 ppm
Particulate and Vapor Concentration	
500 ppm or less	A chemical cartridge respirator with a full facepiece, organic vapor cartridge(s) and dust filter. A gas mask with a chin-style or a front- or back-mounted organic vapor canister and dust filter. Any supplied-air respirator with a full facepiece, helmet, or hood. Any self-contained breathing apparatus with a full facepiece.
Greater than 500 ppm or entry and escape from unknown concentrations	Self-contained breathing apparatus with a full facepiece operated in pressure-demand or other positive pressure mode. A combination respirator which includes a Type C supplied-air respirator with a full facepiece operated in pressure-demand or other positive pressure or continuous-flow mode and an auxiliary self-contained breathing apparatus operated in pressure-demand or other positive pressure mode.
Fire Fighting	Self-contained breathing apparatus with a full facepiece operated in pressure-demand or other positive pressure mode.
Escape	Any gas mask providing protection against organic vapors and particulates. Any escape self-contained breathing apparatus.

*Only NIOSH-approved or MSHA-approved equipment should be used.

Occupational Health Guideline for Nickel Metal and Soluble Nickel Compounds

INTRODUCTION

This guideline is intended as a source of information for employees, employers, physicians, industrial hygienists, and other occupational health professionals who may have a need for such information. It does not attempt to present all data; rather, it presents pertinent information and data in summary form.

APPLICABILITY

The general guidelines contained in this document apply to all soluble nickel compounds. Physical and chemical properties of several specific compounds are provided for illustrative purposes.

SUBSTANCE IDENTIFICATION

Nickel, metallic

- Formula: Ni
- Synonyms: Nickel catalyst; Raney nickel
- Appearance and odor: Silvery gray, metallic (or darker), odorless powder.

Nickel nitrate hexahydrate

- Formula: $Ni(NO_3)_2 \cdot 6H_2O$
- Synonyms: None
- Appearance and odor: Green, odorless solid.

Nickel sulfate hexahydrate

- Formula: $NiSO_4 \cdot 6H_2O$
- Synonyms: None
- Appearance and odor: Green, odorless solid.

PERMISSIBLE EXPOSURE LIMIT (PEL)

The current OSHA standard for nickel metal and soluble nickel compounds is 1 milligram of nickel metal and soluble nickel compounds per cubic meter of air (mg/m^3) averaged over an eight-hour work shift. NIOSH has recommended that the permissible exposure limit for nickel be reduced to 0.015 mg/m^3 averaged over a work shift of up to 10 hours per day, 40 hours per week, and that nickel be regulated as an occupational carcinogen. The NIOSH Criteria Document for Inorganic Nickel and the Special Occupational Hazard Review for Nickel Carbonyl should be consulted for more detailed information.

HEALTH HAZARD INFORMATION

- **Routes of exposure**

Metallic nickel or soluble nickel compounds can affect the body if they are inhaled or if they come in contact with the eyes or skin. They can also affect the body if they are swallowed.

- **Effects of overexposure**

Nickel fumes are respiratory irritants and may cause pneumonitis. Skin contact may cause an allergic skin rash. Nickel and its compounds have been reported to cause cancer of the lungs and sinuses. Nickel itself is not very toxic if swallowed, but its soluble salts are quite toxic and, if swallowed, may cause giddiness and nausea. Exposure to nickel carbonyl (by inhalation or skin absorption) may cause both initial and delayed symptoms. Initial symptoms include headache, dizziness, shortness of breath, and vomiting. These symptoms generally disappear when the worker is exposed to fresh air. The delayed symptoms may develop 12 to 36 hours after exposure. The shortness of breath returns, a blue color of the skin may appear, and a fever may develop. The exposed person may become delirious. In some cases the symptoms may run together. Death may occur.

- **Reporting signs and symptoms**

A physician should be contacted if anyone develops any signs or symptoms and suspects that they are caused by exposure to nickel metal and soluble nickel compounds.

These recommendations reflect good industrial hygiene and medical surveillance practices and their implementation will assist in achieving an effective occupational health program. However, they may not be sufficient to achieve compliance with all requirements of OSHA regulations.

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• Recommended medical surveillance

The following medical procedures should be made available to each employee who is exposed to nickel metal and soluble nickel compounds at potentially hazardous levels:

1. Initial Medical Examination:

—A complete history and physical examination: The purpose is to detect pre-existing conditions that might place the exposed employee at increased risk, and to establish a baseline for future health monitoring. Persons with a history of asthma, allergies, or known sensitization to nickel metal and soluble nickel compounds would be expected to be at increased risk from exposure. Examination of the nasal cavities and lungs should be stressed. The skin should be examined for evidence of chronic disorders.

—14" x 17" chest roentgenogram: Nickel metal and soluble nickel compounds cause human lung damage and cancer of the lung. Surveillance of the lungs is indicated.

—FVC and FEV (1 sec): Nickel metal and soluble nickel compounds are respiratory irritants. Persons with impaired pulmonary function may be at increased risk from exposure. Periodic surveillance is indicated.

—Skin disease: Nickel metal and soluble compounds are defatting agents and can cause dermatitis on prolonged exposure. Persons with pre-existing skin disorders may be more susceptible to the effects of these agents.

2. Periodic Medical Examination: The aforementioned medical examinations should be repeated on an annual basis.

• **Summary of toxicology**

Metallic nickel and certain soluble nickel compounds as dust or fume cause sensitization dermatitis and probably produce cancer of the paranasal sinuses and the lung; nickel fume in high concentrations is a respiratory irritant. Severe but transient pneumonitis in two workers resulted from exposure to nickel fume; in one case, exposure was for 6 hours, and post-incident sampling suggested a nickel concentration of 0.26 mg/m^3. "Nickel itch" is a dermatitis resulting from sensitization to nickel; the first symptom is usually itching, which occurs up to 7 days before skin eruption appears. The primary skin eruption is erythematous, or follicular; it may be followed by superficial discrete ulcers, which discharge and become crusted, or by eczema; in the chronic stages, pigmented or depigmented plaques may be formed. Nickel sensitivity, once acquired, is apparently not lost; recovery from the dermatitis usually occurs within 7 days of cessation of exposure, but may take several weeks. A worker who had developed cutaneous sensitization also developed apparent asthma from inhalation of nickel sulfate; immunologic studies showed circulating antibodies to the salt, and controlled exposure to a solution of nickel sulfate resulted in decreased pulmonary function and progressive dyspnea; the possibility of developing hypersensitivity pneumonitis could not be excluded. In animals, finely divided metallic nickel was carcinogenic when introduced into the pleural cavity, muscle tissue, and subcutaneous tissues; rats and guinea pigs exposed to a concentration of 15 mg/m^3 of powdered metallic nickel developed malignant pulmonary neoplasms. Several epidemiologic studies have shown an increased incidence of cancer of the paranasal sinuses and lungs among workers in nickel refineries and factories; suspicion of carcinogenicity has been focused primarily on respirable particles of nickel, nickel subsulfide, nickel oxide, and on nickel carbonyl vapor. Many of the studies also included exposures to other suspected carcinogens.

CHEMICAL AND PHYSICAL PROPERTIES

• **Physical data—Nickel, metallic**

1. Molecular weight: 58.7
2. Boiling point (760 mm Hg): 2730 C (4946 F)
3. Specific gravity (water = 1): 8.9
4. Vapor density (air = 1 at boiling point of metallic nickel): Not applicable
5. Melting point: 1453 C (2648 F)
6. Vapor pressure at 20 C (68 F): Essentially zero
7. Solubility in water, g/100 g water at 20 C (68 F): Insoluble
8. Evaporation rate (butyl acetate = 1): Not applicable

• **Physical data—Nickel nitrate hexahydrate**

1. Molecular weight: 290.8
2. Boiling point (760 mm Hg): 137 C (278 F) (loses water)
3. Specific gravity (water = 1): 2.05
4. Vapor density (air = 1 at boiling point of nickel nitrate hexahydrate): Not applicable
5. Melting point: 57 C (135 F)
6. Vapor pressure at 20 C (68 F): Essentially zero
7. Solubility in water, g/100 g water at 20 C (68 F): 60
8. Evaporation rate (butyl acetate = 1): Not applicable

• **Physical data—Nickel sulfate hexahydrate**

1. Molecular weight: 262.8
2. Boiling point (760 mm Hg): 103 C (217 F) (loses water)
3. Specific gravity (water = 1): 2.07
4. Vapor density (air = 1 at boiling point of nickel sulfate hexahydrate): Not applicable
5. Melting point: 53 C (127 F)
6. Vapor pressure at 20 C (68 F): Essentially zero
7. Solubility in water, g/100 g water at 20 C (68 F): 40
8. Evaporation rate (butyl acetate = 1): Not applicable

• **Reactivity**

1. Conditions contributing to instability: Heat (nickel only)
2. Incompatibilities: Contact of nickel with strong acids may form flammable and explosive hydrogen gas.

Contact with sulfur may cause evolution of heat. Contact of nickel nitrate with wood and other combustibles may cause fire.

3. Hazardous decomposition products: Toxic gases and vapors (such as nickel carbonyl and oxides of nitrogen) may be released in a fire involving nickel or in the decompostion of nickel compounds.

4. Special precautions: None

• **Flammability**

1. Flash point: Not applicable

2. Minimum ignition temperature: Not available

3. Minimum explosive concentration: Not available, but nickel sponge catalyst may ignite spontaneously in air.

4. Extinguishant: Dry powder, dry sand, dry dolomite, dry graphite

• **Warning properties**

Grant states that "workers employed in nickel plating involving nickel sulfate, sulfuric acid, and chlorine are said to have developed conjunctivitis and epiphora when ventilation was poor." Since, according to Grant, "both sulfuric acid mist and chlorine gas are known to cause burning and stinging of the eyes," and since the AIHA *Hygienic Guide* states that eye contact "does not present any problem peculiar to nickel," nickel metal and soluble compounds are not treated as eye irritants.

MONITORING AND MEASUREMENT PROCEDURES

• **General**

Measurements to determine employee exposure are best taken so that the average eight-hour exposure is based on a single eight-hour sample or on two four-hour samples. Several short-time interval samples (up to 30 minutes) may also be used to determine the average exposure level. Air samples should be taken in the employee's breathing zone (air that would most nearly represent that inhaled by the employee).

• **Method**

Sampling and analyses may be performed by collection on a cellulose membrane filter followed by treatment with nitric and perchloric acids, solution in nitric acid, and analysis with an atomic absorption spectrophotometer. An analytical method for nickel metal and soluble nickel compounds is in the *NIOSH Manual of Analytical Methods*, 2nd Ed., Vol. 5, 1979, available from the Government Printing Office, Washington, D.C. 20402 (GPO No. 017-033-00349-1).
number PB 258 433).

RESPIRATORS

• Good industrial hygiene practices recommend that engineering controls be used to reduce environmental concentrations to the permissible exposure level. However, there are some exceptions where respirators may be used to control exposure. Respirators may be used when engineering and work practice controls are not technically feasible, when such controls are in the process of being installed, or when they fail and need to be supplemented. Respirators may also be used for operations which require entry into tanks or closed vessels, and in emergency situations. If the use of respirators is necessary, the only respirators permitted are those that have been approved by the Mine Safety and Health Administration (formerly Mining Enforcement and Safety Administration) or by the National Institute for Occupational Safety and Health.

• In addition to respirator selection, a complete respiratory protection program should be instituted which includes regular training, maintenance, inspection, cleaning, and evaluation.

PERSONAL PROTECTIVE EQUIPMENT

• Employees should be provided with and required to use impervious clothing, gloves, face shields (eight-inch minimum), and other appropriate protective clothing necessary to prevent repeated or prolonged skin contact with powdered metallic nickel or solids or liquids containing soluble nickel compounds.

• If employees' clothing may have become contaminated with powdered metallic nickel or solid soluble nickel compounds, employees should change into uncontaminated clothing before leaving the work premises.

• Clothing contaminated with metallic nickel or soluble nickel compounds should be placed in closed containers for storage until it can be discarded or until provision is made for the removal of metallic nickel or soluble nickel compounds from the clothing. If the clothing is to be laundered or otherwise cleaned to remove the metallic nickel or soluble nickel compounds, the person performing the operation should be informed of these substances's hazardous properties.

• Non-impervious clothing which becomes contaminated with metallic nickel or soluble nickel compounds should be removed promptly and not reworn until the metallic nickel or soluble nickel compounds are removed from the clothing.

SANITATION

• Skin that becomes contaminated with metallic nickel or soluble nickel compounds should be promptly washed or showered with soap or mild detergent and water to remove any metallic nickel or soluble nickel compounds.

• Eating and smoking should not be permitted in areas where solids or liquids containing soluble nickel compounds are handled, processed, or stored.

• Employees who handle powdered metallic nickel or solids or liquids containing soluble nickel compounds should wash their hands thoroughly with soap or mild detergent and water before eating, smoking, or using toilet facilities.

• Areas in which exposure to nickel metal and soluble nickel compounds may occur should be identified by

signs or appropriate means, and access to these areas should be limited to authorized persons.

COMMON OPERATIONS AND CONTROLS

The following list includes some common operations in which exposure to nickel metal and soluble nickel compounds may occur and control methods which may be effective in each case:

Operation	Controls
Use during manufacture and fabricating of more than 3000 alloys; use in electronic tube parts, coins heavy machinery, tools, instrument parts, magnets, food and chemical processing equipment, flatware, jet engines, automotive parts, zippers, nickel anodes, surgical and dental instruments, and cooking utensils (they aid in corrosion- and heat-resistance, enhance ductibility, and increase thermal conductivity)	General dilution ventilation; local exhaust ventilation; personal protective equipment
Liberation during processing and refining of ore	General dilution ventilation; local exhaust ventilation; personal protective equipment
Use in manufacture of nickel-iron alloys, and non-ferrous-nickel alloys	Local exhaust ventilation; general dilution ventilation
Use during fabrication of nickel-plated materials	General dilution ventilation; local exhaust ventilation; personal protective equipment
Use in chemical synthesis as starting material of complex compounds; use as catalysts in hydrogenation of fats/ oils	General dilution ventilation
Use in textile industry in dyeing and printing; and in ceramic industry in coloring	General dilution ventilation; local exhaust ventilation
Use of metal and salts during electroplating and electroless plating	General dilution ventilation; local exhaust ventilation; personal protective equipment
Use in manufacture of nickel-iron alloys and non-ferrous-nickel alloys	Local exhaust ventilation; general dilution ventilation

EMERGENCY FIRST AID PROCEDURES

In the event of an emergency, institute first aid procedures and send for first aid or medical assistance.

• **Skin Exposure**

If solids or liquids containing soluble nickel compounds get on the skin, immediately flush the contaminated skin with water. If solids of liquids containing soluble nickel compounds penetrate through the clothing, remove the clothing immediately and flush the skin with water. If irritation persists after washing, get medical attention. Metallic nickel should be removed from the skin by washing with soap or mild detergent and water.

• **Breathing**

If a person breathes in large amounts of metallic nickel of soluble nickel compounds, move the exposed person to fresh air at once. If breathing has stopped, perform artificial respiration. Keep the affected person warm and at rest. Get medical attention as soon as possible. If any nickel carbonyl has been inhaled, get medical attention promptly.

• **Swallowing**

When metallic nickel or solids or liquids containing soluble nickel compounds have been swallowed and the person is conscious, give the person large quantities of water immediately. After the water has been swallowed, try to get the person to vomit by having him touch the back of his throat with his finger. Do not make an unconscious person vomit. Get medical attention immediately.

• **Rescue**

Move the affected person from the hazardous exposure. If the exposed person has been overcome, notify someone else and put into effect the established emergency rescue procedures. Do not become a casualty. Understand the facility's emergency rescue procedures and know the locations of rescue equipment before the need arises.

SPILL AND DISPOSAL PROCEDURES

• Persons not wearing protective equipment and clothing should be restricted from areas of spills until cleanup has been completed.

• If nickel metal and soluble nickel compounds are spilled, the following steps should be taken:

1. Ventilate area of spill.

2. Collect spilled material in the most convenient and safe manner for reclamation or for disposal in a secured sanitary landfill. Liquid containing nickel should be absorbed in vermiculite, dry sand, earth, or a similar material.

• Waste disposal method:

Nickel metal and soluble nickel compounds may be disposed of in sealed containers in a secured sanitary landfill.

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• SPECIAL NOTE

Nickel metal and soluble nickel compounds appear on the OSHA "Candidate List" of chemicals being considered for further scientific review regarding their carcinogenicity (*Federal Register*, Vol. 45, No. 157, pp 5372-5379, 12 August 1980).

The International Agency for Research on Cancer (IARC) has evaluated the data on these chemicals and has concluded that they cause cancer. See *IARC Monographs on the Evaluation of Carcinogenic Risk of Chemicals to Man*, Volume 11, 1976.

RESPIRATORY PROTECTION FOR NICKEL METAL AND SOLUBLE COMPOUNDS

Condition	Minimum Respiratory Protection* Required Above 1 mg/m³
Dust or Mist Concentration	
5 mg/m³ or less	Any dust and mist respirator.
10 mg/m³ or less	Any dust and mist respirator, except single-use or quarter-mask respirator.
50 mg/m³ or less	A high efficiency particulate filter respirator with a full facepiece. Any supplied-air respirator with a full facepiece, helmet, or hood. Any self-contained breathing apparatus with a full facepiece.
1000 mg/m³ or less	A powered air-purifying respirator with a high efficiency particulate filter. A Type C supplied-air respirator operated in pressure-demand or other positive pressure or continuous-flow mode.
2000 mg/m³ or less	A Type C supplied-air respirator with a full facepiece operated in pressure-demand or other positive pressure mode or with a full facepiece, helmet, or hood operated in continuous-flow mode.
Greater than 2000 mg/m³ or entry and escape from unknown concentrations	Self-contained breathing apparatus with a full facepiece operated in pressure-demand or other positive pressure mode. A combination respirator which includes a Type C supplied-air respirator with a full facepiece operated in pressure-demand or other positive pressure or continuous-flow mode and an auxiliary self-contained breathing apparatus operated in pressure-demand or other positive pressure mode.
Fire Fighting	Self-contained breathing apparatus with a full facepiece operated in pressure-demand or other positive pressure mode.

*Only NIOSH-approved or MSHA-approved equipment should be used.

RESPIRATORY PROTECTION FOR NICKEL METAL AND SOLUBLE COMPOUNDS

Condition	Minimum Respiratory Protection* Required Above 1 mg/m³
Dust, Mist, or Fume Concentration	
10 mg/m³ or less	Any fume respirator or high efficiency particulate respirator. Any supplied-air respirator. Any self-contained breathing apparatus.
50 mg/m³ or less	A high efficiency particulate filter respirator with a full facepiece. Any supplied-air respirator with a full facepiece, helmet, or hood. Any self-contained breathing apparatus with a full facepiece.
1000 mg/m³ or less	A powered air-purifying respirator with a high efficiency particulate filter. A Type C supplied-air respirator operated in pressure-demand or other positive pressure or continuous-flow mode.
2000 mg/m³ or less	A Type C supplied-air respirator with a full facepiece operated in pressure-demand or other positive pressure mode or with a full facepiece, helmet, or hood operated in continuous-flow mode.
Greater than 2000 mg/m³ or entry and escape from unknown concentrations	Self-contained breathing apparatus with a full facepiece operated in pressure-demand or other positive pressure mode. A combination respirator which includes a Type C supplied-air respirator with a full facepiece operated in pressure-demand or other positive pressure or continuous-flow mode and an auxiliary self-contained breathing apparatus operated in pressure-demand or other positive pressure mode.
Fire Fighting	Self-contained breathing apparatus with a full facepiece operated in pressure-demand or other positive pressure mode.

*Only NIOSH-approved or MSHA-approved equipment should be used.

Occupational Health Guideline for Phenol

INTRODUCTION

This guideline is intended as a source of information for employees, employers, physicians, industrial hygienists, and other occupational health professionals who may have a need for such information. It does not attempt to present all data; rather, it presents pertinent information and data in summary form.

SUBSTANCE IDENTIFICATION

- Formula: C_6H_5OH
- Synonyms: Carbolic acid; monohydroxybenzene
- Appearance and odor: Colorless to pink solid or thick liquid with a characteristic, sweet, tarry odor.

PERMISSIBLE EXPOSURE LIMIT (PEL)

The current OSHA standard for phenol is 5 parts of phenol per million parts of air (ppm) averaged over an eight-hour work shift. This may also be expressed as 19 milligrams of phenol per cubic meter of air (mg/m^3). NIOSH has recommended that the permissible exposure limit be changed to 20 mg/m^3 averaged over a work shift of up to 10 hours per day, 40 hours per week, with a ceiling of 60 mg/m^3 averaged over a 15-minute period. The NIOSH Criteria Document for Phenol should be consulted for more detailed information.

HEALTH HAZARD INFORMATION

- **Routes of exposure**

Phenol can affect the body if it is inhaled, comes in contact with the eyes or skin, or is swallowed. It may enter the body through the skin.

- **Effects of overexposure**

1. Short-term Exposure: Phenol has a marked corrosive effect on any tissue. When it comes in contact with the eyes, it may cause severe damage and blindness. On contact with the skin, it does not cause pain but causes a whitening of the exposed area. If the chemical is not removed promptly, it may cause a severe burn or systemic poisoning. Systemic effects may occur from any route of exposure, especially after skin contact.

2. Long-term Exposure: Repeated or prolonged exposure to phenol may cause chronic phenol poisoning. The symptoms of chronic poisoning include vomiting, difficulty in swallowing, diarrhea, lack of appetite, headache, fainting, dizziness, dark urine, mental disturbances, and possibly a skin rash. Liver damage and discoloration of the skin may occur.

3. Reporting Signs and Symptoms: A physician should be contacted if anyone develops any signs or symptoms and suspects that they are caused by exposure to phenol.

- **Recommended medical surveillance**

The following medical procedures should be made available to each employee who is exposed to phenol at potentially hazardous levels:

1. Initial Medical Examination:

—A complete history and physical examination: The purpose is to detect pre-existing conditions that might place the exposed employee at increased risk, and to establish a baseline for future health monitoring. Persons with a history of convulsive disorders or abnormalities of the skin, respiratory tract, liver, or kidneys would be expected to be at increased risk from exposure. Examination of the liver, kidneys, and respiratory tract should be stressed. The skin should be examined for evidence of chronic disorders.

—Urinalysis: Darkening of the urine has occurred in persons exposed to phenol after accidental ingestion or skin contact. A urinalysis should be performed, including at a minimum specific gravity, albumin, glucose, and a microscopic on centrifuged sediment. Urinary phenol is useful if good individual background levels are available.

—Liver function tests: Since liver damage has been observed in humans exposed to phenol, a profile of liver function should be performed by using a medically acceptable array of biochemical tests.

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2. Periodic Medical Examination: The aforementioned medical examinations should be repeated on an annual basis.

• **Summary of toxicology**

Phenol in the vapor form or in solution is an irritant to the eyes, mucous membranes, and skin; systemic absorption causes central nervous system effects as well as liver and kidney damage. Sudden collapse is characteristic of gross overexposure. In animals, prolonged inhalation of the vapor at 30 to 60 ppm induced respiratory difficulty, lung damage, and paralysis. Systemic absorption by animals caused muscle twitching and severe convulsions. There are no reports of human fatalities from inhalation of the vapor, although one case of severe poisoning has been reported. Ingestion of lethal amounts (as little as 1 g) cause severe burns of the mouth and throat, marked abdominal pain, cyanosis, muscular weakness, collapse, coma, and death; tremors, convulsions, or muscle twitching were occasionally observed but were not severe. A laboratory technician repeatedly exposed to unknown vapor concentrations and liquid spilled on the skin developed anorexia, weight loss, weakness, muscle aches and pain, and dark urine; during several months of nonexposure there was gradual improvement in his condition, but after brief reexposure he suffered an immediate worsening of symptoms with prompt darkening of the urine and tender enlargement of the liver. Brief intermittent industrial exposures to vapor concentrations of 48 ppm of phenol (accompanied by 8 ppm of formaldehyde) caused marked irritation of eyes, nose, and throat. Concentrated phenol solutions are severely irritating to the human eye and cause conjunctival swelling; the cornea becomes white and hypesthetic; loss of vision has occurred in some cases. Solutions of phenol have a marked corrosive action on any tissue on contact; on skin, there is local anesthesia and a white discoloration, and the area may subsequently become gangrenous; severe dermatitis will result from contact with dilute solutions, and prolonged exposure may result in ochronosis. In workers making phenol-formaldehyde plastic, the urinary level of total phenol, free plus conjugated, was proportional to the air concentration of phenol up to 12.5 mg/m^3 of workroom air. Mice were treated twice weekly for 72 weeks by application of 1 drop of a 10% solution of phenol in benzene to the shaved dorsal skin; after 52 weeks of treatment there were papillomas in 5 of 14 mice, and 1 fibrosarcoma appeared at 58 weeks.

CHEMICAL AND PHYSICAL PROPERTIES

• **Physical data**

1. Molecular weight: 94.11
2. Boiling point (760 mm Hg): 182 C (359 F)
3. Specific gravity (water = 1): 107 (solid); 1.05 (liquid)
4. Vapor density (air = 1 at boiling point of phenol): 3.24
5. Melting point: 41 C (106 F)
6. Vapor pressure at 20 C (68 F): 0.36 mm Hg
7. Solubility in water, g/100 g water at 20 C (68 F): 8.4
8. Evaporation rate (butyl acetate = 1): Less than 0.01

• **Reactivity**

1. Conditions contributing to instability: Heat
2. Incompatibilities: Contact with strong oxidizers (especially calcium hypochlorite) may cause fires and explosions.
3. Hazardous decomposition products: Toxic gases and vapors (such as carbon monoxide) may be released in a fire involving phenol.
4. Special precautions: Liquid phenol will attack some forms of plastics, rubber, and coatings. Hot liquid phenol will attack aluminum, magnesium, lead, and zinc metals.

• **Flammability**

1. Flash point: 79 C (174 F) (closed cup)
2. Autoignition temperature: 715 C (1319 F)
3. Flammable limits in air, % by volume: Lower: 1.7; Upper: 8.6
4. Extinguishant: Alcohol foam, carbon dioxide, dry chemical

• **Warning properties**

1. Odor Threshold: Summer reports that the odor threshold of phenol is 3 ppm; the Manufacturing Chemists Association reports 0.3 ppm; Thienes and Haley report 5 ppm.
2. Irritation Levels: The *Documentation of TLV's* reports that intermittent exposures to 48 ppm phenol have been observed to produce eye, nose, and throat irritation. Formaldehyde was also present in this atmosphere at a concentration of 8 ppm. The Respirator Review Committee considers the source of the eye irritation to be the 8 ppm formaldehyde rather than the phenol.
3. Evaluation of Warning Properties: Since the odor threshold of phenol is at or below the permissible exposure limit, phenol is treated as a material with good warning properties.

MONITORING AND MEASUREMENT PROCEDURES

• **Eight-Hour Exposure Evaluation**

Measurements to determine employee exposure are best taken so that the average eight-hour exposure is based on a single eight-hour sample or on two four-hour samples. Several short-time interval samples (up to 30 minutes) may also be used to determine the average exposure level. Air samples should be taken in the employee's breathing zone (air that would most nearly represent that inhaled by the employee).

• **Ceiling Evaluation**

Measurements to determine employee ceiling exposure are best taken during periods of maximum expected airborne concentrations of phenol. Each measurement

should consist of a fifteen (15) minute sample or series of consecutive samples totalling fifteen (15) minutes in the employee's breathing zone (air that would most nearly represent that inhaled by the employee). A minimum of three (3) measurements should be taken on one work shift and the highest of all measurements taken is an estimate of the employee's exposure.

• **Method**

Sampling and analyses may be performed by collection of phenol in a bubbler containing sodium hydroxide, followed by treatment with sulfuric acid, and gas chromatographic analysis. Also, detector tubes certified by NIOSH under 42 CFR Part 84 or other direct-reading devices calibrated to measure phenol may be used. An analytical method for phenol is in the *NIOSH Manual of Analytical Methods*, 2nd Ed., Vol. 6, 1980, available from the Government Printing Office, Washington, D.C. 20402 (GPO No. 017-033-00369-6).

RESPIRATORS

• Good industrial hygiene practices recommend that engineering controls be used to reduce environmental concentrations to the permissible exposure level. However, there are some exceptions where respirators may be used to control exposure. Respirators may be used when engineering and work practice controls are not technically feasible, when such controls are in the process of being installed, or when they fail and need to be supplemented. Respirators may also be used for operations which require entry into tanks or closed vessels, and in emergency situations. If the use of respirators is necessary, the only respirators permitted are those that have been approved by the Mine Safety and Health Administration (formerly Mining Enforcement and Safety Administration) or by the National Institute for Occupational Safety and Health.

• In addition to respirator selection, a complete respiratory protection program should be instituted which includes regular training, maintenance, inspection, cleaning, and evaluation.

PERSONAL PROTECTIVE EQUIPMENT

• Employees should be provided with and required to use impervious clothing, gloves, face shields (eight-inch minimum), and other appropriate protective clothing necessary to prevent any possibility of skin contact with solid or liquid phenol or liquids containing phenol.

• If employees' clothing has had any possibility of being contaminated with solid or liquid phenol or liquids containing phenol, employees should change into uncontaminated clothing before leaving the work premises.

• Clothing which has had any possibility of being contaminated with solid or liquid phenol or liquids containing phenol should be placed in closed containers for storage until it can be discarded or until provision is made for the removal of phenol from the clothing. If the clothing is to be laundered or otherwise cleaned to remove the phenol, the person performing the operation should be informed of phenol's hazardous properties.

• Where there is any possibility of exposure of an employee's body to solid or liquid phenol or liquids containing phenol, facilities for quick drenching of the body should be provided within the immediate work area for emergency use.

• Non-impervious clothing which becomes contaminated with phenol should be removed immediately and not reworn until the phenol is removed from the clothing.

• Employees should be provided with and required to use dust- and splash-proof safety goggles where there is any possibility of solid or liquid phenol or liquids containing phenol contacting the eyes.

• Where there is any possibility that employees' eyes may be exposed to solid or liquid phenol or liquids containing phenol, an eye-wash fountain should be provided within the immediate work area for emergency use.

SANITATION

• Skin that becomes contaminated with phenol should be immediately washed or showered with soap or mild detergent and water to remove any phenol.

• Any clothing which becomes wet with liquid phenol or liquids containing phenol should be removed immediately and not reworn until the phenol is removed from the clothing.

• Eating and smoking should not be permitted in areas where solid or liquid phenol or liquids containing phenol are handled, processed, or stored.

• Employees who handle solid or liquid phenol or liquids containing phenol should wash their hands thoroughly with soap or mild detergent and water before eating, smoking, or using toilet facilities.

COMMON OPERATIONS AND CONTROLS

The following list includes some common operations in which exposure to phenol may occur and control methods which may be effective in each case:

Operation	Controls
Application and curing of bonding resin in plywood manufacture; application and curing of molding resins in manufacture of molded articles, such as	Process enclosure; local exhaust ventilation; personal protective equipment

electrical appliances, automotive parts, foundry sand molds, and utensil handles; manufacture of friction materials, bonded abrasives, coated abrasives, wood particle board, and insulation materials	
Use in industnal coatings in drum and can linings, milk and beer-processing equipment, water tanks and air-conditioning equipment, decorative laminates, and textile coatings	Process enclosure; local exhaust ventilation; personal protective equipment
Use in synthesis of thermosetting phenolic resins, epoxy, polycarbonate, phenoxy, and polysulfone; synthesis of aprolactam for use in nylon 6 fibers, plastics, and films	Process enclosure; local exhaust ventilation; personal protective equipment
Use in synthesis of agricultural chemicals and intermediates; synthesis of pharmaceuticals, rubber and plastic plasticizers, antioxidants, curing agents, and intermediates	Process enclosure; local exhaust ventilation; personal protective equipment
Use in synthesis of stabilizers and preservatives for dyes, perfumes, and fungicides	Process enclosure; local exhaust ventilation; personal protective equipment
Use during solvent refining of lubrication oil and wax; use in synthesis of additives for gasoline and lubricating fluids and intermediates	Process enclosure; local exhaust ventilation; personal protective equipment
Use in synthesis of intermediates in polyester production; production of corrosion-resistant polyester and polyester polyols; use in synthesis of dye intermediates	Process enclosure; local exhaust ventilation; personal protective equipment
Use in synthesis of surface-active agents and detergent intermediates; in synthesis of explosives	Process enclosure; local exhaust ventilation; personal protective equipment
Use in manufacture of disinfectant agents and products for industrial and household use	Process enclosure; local exhaust ventilation; personal protective equipment
Use in synthesis of synthetic cresols and xylenols	Process enclosure; local exhaust ventilation; personal protective equipment

EMERGENCY FIRST AID PROCEDURES

In the event of an emergency, institute first aid procedures and send for first aid or medical assistance.

- **Eye Exposure**

If solid or liquid phenol or liquids containing phenol get into the eyes, wash eyes immediately with large amounts of water, lifting the lower and upper lids occasionally. Get medical attention immediately. Contact lenses should not be worn when working with this chemical.

- **Skin Exposure**

If solid or liquid phenol or liquids containing phenol get on the skin, promptly wash the contaminated skin using soap or mild detergent and water. If solid or liquid phenol or liquids containing phenol penetrate through the clothing, remove the clothing immediately and wash the skin using soap or mild detergent and water. Get medical attention immediately.

- **Breathing**

If a person breathes in large amounts of phenol, move the exposed person to fresh air at once. If breathing has stopped, perform artificial respiration. Keep the affected person warm and at rest. Get medical attention as soon as possible.

- **Swallowing**

When solid or liquid phenol or liquids containing phenol have been swallowed and the person is conscious, give the person large quantities of water immediately. After the water has been swallowed, try to get the person to vomit by having him touch the back of his throat with his finger. Do not make an unconscious person vomit. Get medical attention immediately.

• **Rescue**

Move the affected person from the hazardous exposure. If the exposed person has been overcome, notify someone else and put into effect the established emergency rescue procedures. Do not become a casualty. Understand the facility's emergency rescue procedures and know the locations of rescue equipment before the need arises.

SPILL, LEAK, AND DISPOSAL PROCEDURES

• Persons not wearing protective equipment and clothing should be restricted from areas of spills or leaks until cleanup has been completed.

• If phenol is spilled or leaked, the following steps should be taken:

1. Ventilate area of spill.

2. If in the solid form, for small quantities, sweep onto paper or other suitable material, place in an appropriate container and burn in a safe place (such as a fume hood). Large quantities may be reclaimed; however, if this is not practical, dissolve in a flammable solvent (such as alcohol) and atomize in a suitable combustion chamber.

3. If in the liquid form, for small quantities, absorb on paper towels. Evaporate in a safe place (such as a fume hood). Allow sufficient time for evaporating vapors to completely clear the hood ductwork. Burn the paper in a suitable location away from combustible materials. Large quantities can be collected and atomized in a suitable combustion chamber.

• Waste disposal methods:

Phenol may be disposed of:

1. If in the solid form, by making packages of phenol in paper or other flammable material and burning in a suitable combustion chamber, or by dissolving phenol in a flammable solvent (such as alcohol) and atomizing in a suitable combustion chamber.

2. If in the liquid form, by absorbing it in vermiculite, dry sand, earth or a similar material and disposing in a secured sanitary landfill, or by atomizing the liquid in a suitable combustion chamber.

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RESPIRATORY PROTECTION FOR PHENOL

Condition	Minimum Respiratory Protection* Required Above 5 ppm
Vapor or Particulate Concentration	
50 ppm or less	Any chemical cartridge respirator with an organic vapor cartridge(s) and dust and mist filter(s). Any supplied-air respirator. Any self-contained breathing apparatus.
100 ppm or less	A chemical cartridge respirator with a full facepiece, organic vapor cartridge(s), and dust and mist filter(s). A gas mask with a chin-style or a front- or back-mounted organic vapor canister and dust and mist filter. Any supplied-air respirator with a full facepiece, helmet, or hood. Any self-contained breathing apparatus with a full facepiece.
Greater than 100 ppm** or entry and escape from unknown concentrations	Self-contained breathing apparatus with a full facepiece operated in pressure-demand or other positive pressure mode. A combination respirator which includes a Type C supplied-air respirator with a full facepiece operated in pressure-demand or other positive pressure or continuous-flow mode and an auxiliary self-contained breathing apparatus operated in pressure-demand or other positive pressure mode.
Fire Fighting	Self-contained breathing apparatus with a full facepiece operated in pressure-demand or other positive pressure mode.
Escape	Any gas mask providing protection against organic vapors and particulates. Any escape self-contained breathing apparatus.

*Only NIOSH-approved or MSHA-approved equipment should be used.

**Use of supplied-air suits may be necessary to prevent skin contact while providing respiratory protection from airborne concentrations of phenol; however, this equipment should be selected, used, and maintained under the immediate supervision of trained personnel. Where supplied-air suits are used above a concentration of 100 ppm, an auxiliary self-contained breathing apparatus operated in positive pressure mode should also be worn.

Occupational Health Guideline for Phosphorus (Yellow)

INTRODUCTION

This guideline is intended as a source of information for employees, employers, physicians, industrial hygienists, and other occupational health professionals who may have a need for such information. It does not attempt to present all data; rather, it presents pertinent information and data in summary form.

SUBSTANCE IDENTIFICATION

- Formula: P_4
- Synonyms: White phosphorus; WP; phosphorus, elemental, white
- Appearance and odor: White to yellow, soft, waxy solid which gives off acrid fumes on exposure to air.

PERMISSIBLE EXPOSURE LIMIT (PEL)

The current OSHA standard for phosphorus (yellow) is 0.1 milligram of phosphorus (yellow) per cubic meter of air (mg/m^3) averaged over an eight-hour work shift.

HEALTH HAZARD INFORMATION

- **Routes of exposure**

Phosphorus (yellow) can affect the body if it is inhaled or if it comes in contact with the eyes or skin. It can also affect the body if it is swallowed.

- **Effects of overexposure**

1. Short-term Exposure: The vapors of burning phosphorus (yellow) are irritating to the nose, throat, and lungs. Severe breathing difficulties may occur. The onset of these difficulties may be delayed for several hours. Phosphorus (yellow) on contact with the skin may ignite and produce severe skin burns with blistering. Phosphorus (yellow) is especially hazardous to the eyes and may produce severe damage. When phosphorus (yellow) is swallowed, after a delay of a few hours, nausea, vomiting, and abdominal pain may occur. The vomit may smell like garlic and glow in the dark. After 24 to 36 hours, the symptoms may go away. In a few hours or 2 or 3 days, the nausea, vomiting, and abdominal pain may reappear with diarrhea and a yellow color to the skin. Death may occur.

2. Long-term Exposure: Repeated or prolonged exposure to phosphorus (yellow) can cause "phossy jaw" with pain and swelling of the jaw, toothaches, loosening of the teeth and destruction of the jawbone. Chronic exposure to phosphorus (yellow) can also cause weakness, anemia, loss of appetite, stomach complaints, cough, and paleness. In addition, chronic exposure to phosphorus (yellow) may cause bones to become brittle and break.

3. Reporting Signs and Symptoms: A physician should be contacted if anyone develops any signs or symptoms and suspects that they are caused by exposure to phosphorus (yellow).

- **Recommended medical surveillance**

The following medical procedures should be made available to each employee who is exposed to phosphorus (yellow) at potentially hazardous levels:

1. Initial Medical Examination:

—A complete history and physical examination: The purpose is to detect pre-existing conditions that might place the exposed employee at increased risk, and to establish a baseline for future health monitoring. Examination of the eyes, respiratory tract, liver, and kidneys should be stressed. Particular attention should be given to the jaw and teeth. The skin should be examined for evidence of chronic disorders.

—Dental examination: Phosphorus exposure may aggravate existing dental disorders such as caries, periodontal disease, retained roots, and cysts which may predispose to toxic necrosis of the jaw. Dental examination including x-rays should be performed.

—Liver function tests: Since liver damage has been observed in humans exposed to phosphorus, a profile of liver function should be obtained by using a medically acceptable array of biochemical tests.

—Complete blood count: Phosphorus exposure may cause anemia. A complete blood count should be per-

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formed including red and white blood cell count, a differential count of a stained blood smear, as well as hemoglobin and hematocrit.

2. Periodic Medical Examination: The aforementioned medical examinations should be repeated on an semi-annual basis.

• **Summary of toxicology**

Yellow phosphorus fume irritates the respiratory tract and eyes; the solid in contact with the skin produces deep thermal burns; prolonged absorption of phosphorus causes necrosis of facial bones. Yellow phosphorus spontaneously burns in air, and the vapors released are irritating to the respiratory tract. The early signs of systemic intoxication by phosphorus are abdominal pain, jaundice, and a garlic odor of the breath; prolonged intake may cause anemia, cachexia, and necrosis of bone, typically the maxilla and mandible. Complaints of possible overexposure among phosphorus workers may be toothache and excessive salivation; there may be dull red appearance of the oral mucosa; one or more teeth may loosen, followed by pain and swelling of the jaw; healing may be delayed following dental procedures such as extractions; with necrosis of bone, sequestra may develop with sinus tract formation. In a series of 10 cases, the shortest period of exposure to phosphorus fume leading to bone necrosis was 10 months (2 cases) and the longest was 18 years. Yellow phosphorus fume causes severe eye irritation with blepharospasm, photophobia, and lacrimation; the solid in the eye produces severe injury. Phosphorus burns on the skin are deep and painful; a firm eschar is produced and is surrounded by vesiculation.

CHEMICAL AND PHYSICAL PROPERTIES

• **Physical data**

1. Molecular weight: 123.9
2. Boiling point (760 mm Hg): 279 C (535 F)
3. Specific gravity (water = 1): 1.82
4. Vapor density (air = 1 at boiling point of phosphorus (yellow)): 4.4
5. Melting point: 44 C (111 F)
6. Vapor pressure at 20 C (68 F): 0.026 mm Hg
7. Solubility in water, g/100 g water at 20 C (68 F): 0.0003
8. Evaporation rate (butyl acetate = 1): Not applicable

• **Reactivity**

1. Conditions contributing to instability: Light causes formation of yellow or red color.
2. Incompatibilities: Contact with air and all oxidizing agents (including elemental sulfur) will cause fires and explosions. Contact with strong caustics will cause formation of poisonous and flammable phosphine gas.
3. Hazardous decomposition products: Toxic gases and vapors (such as phosphoric acid fume) may be released in a fire involving phosphorus (yellow).
4. Special precautions: Liquid phosphorus (yellow) will attack some forms of plastics, rubber, and coatings.

• **Flammability**

1. Flash point: Ignites spontaneously in air at or above 30 C (86 F)
2. Autoignition temperature: 30 C (86 F)
3. Flammable limits in air, % by volume: Not applicable
4. Extinguishant: Water, carbon dioxide, sand, warth, dry chemical

• **Warning properties**

Grant states that yellow phosphorus fumes are "irritating to the respiratory tract and cause severe ocular irritation with blepharospasm, photophobia, and lacrimation. Particles of white phosphorus (yellow phosphorus) are caustic and seriously damaging in contact with tissues."

No quantitative information is available concerning the concentrations that produce eye irritation, however.

MONITORING AND MEASUREMENT PROCEDURES

• **General**

Measurements to determine employee exposure are best taken so that the average eight-hour exposure is based on a single eight-hour sample or on two four-hour samples. Several short-time interval samples (up to 30 minutes) may also be used to determine the average exposure level. Air samples should be taken in the employee's breathing zone (air that would most nearly represent that inhaled by the employee).

• **Method**

An analytical method for phosphorus (yellow) is in the *NIOSH Manual of Analytical Methods*, 2nd Ed., Vol. 4, 1978, available from the Government Printing Office; Washington, D.C. 20402 (GPO No. 017-033-00317-3).

RESPIRATORS

• Good industrial hygiene practices recommend that engineering controls be used to reduce environmental concentrations to the permissible exposure level. However, there are some exceptions where respirators may be used to control exposure. Respirators may be used when engineering and work practice controls are not technically feasible, when such controls are in the process of being installed, or when they fail and need to be supplemented. Respirators may also be used for operations which require entry into tanks or closed vessels, and in emergency situations. If the use of respirators is necessary, the only respirators permitted are those that have been approved by the Mine Safety and Health Administration (formerly Mining Enforcement and Safety Administration) or by the National Institute for Occupational Safety and Health.

• In addition to respirator selection, a complete respiratory protection program should be instituted which includes regular training, maintenance, inspection, cleaning, and evaluation.

PERSONAL PROTECTIVE EQUIPMENT

- Employees should be provided with and required to use flame-retardant clothing, gloves, face shields (eight-inch minimum), and other appropriate protective clothing necessary to prevent any possibility of skin contact with solid or liquid phosphorus (yellow).
- Clothing contaminated with phosphorus (yellow) should be placed underwater in closed containers for storage until it can be discarded or until provision is made for the removal of phosphorus (yellow) from the clothing. If the clothing is to be laundered or otherwise cleaned to remove the phosphorus (yellow), the person performing the operation should be informed of phosphorus (yellow)'s hazardous properties.
- Where there is any possibility of exposure of an employee's body to solid or liquid phosphorus (yellow), facilities for quick drenching of the body should be provided within the immediate work area for emergency use.
- Any clothing which becomes contaminated with phosphorus (yellow) should be removed immediately and not reworn until the phosphorus (yellow) is removed from the clothing.
- Employees should be provided with and required to use dust- and splash-proof safety goggles where there is any possibility of solid or liquid phosphorus (yellow) contacting the eyes.
- Where there is any possibility that employees' eyes may be exposed to solid or liquid phosphorus (yellow), an eye-wash fountain should be provided within the immediate work area for emergency use.

SANITATION

- Skin that becomes contaminated with phosphorus (yellow) should be immediately washed or showered with soap or mild detergent and water to remove any phosphorus (yellow).
- Workers subject to skin contact with solid or liquid phosphorus (yellow) should wash with soap or mild detergent and water any areas of the body which may have contacted phosphorus (yellow) at the end of each work day.
- Eating and smoking should not be permitted in areas where solid or liquid phosphorus (yellow) are handled, processed, or stored.
- Employees who handle solid or liquid phosphorus (yellow) should wash their hands thoroughly with soap or mild detergent and water before eating, smoking, or using toilet facilities.

COMMON OPERATIONS AND CONTROLS

The following list includes some common operations in which exposure to phosphorus (yellow) may occur and control methods which may be effective in each case:

Operation	Controls
Use in synthesis of high purity phosphoric acid salts for use as fertilizers, water treatment chemicals, food products, beverages, and dentrifices; use in synthesis of inorganic phosphorus compounds for use as pesticides, flame retardants for plastics and fibers, and gasoline and lube oil additives; use in synthesis of inorganic and organic compounds	Process enclosure; local exhaust ventilation; general dilution ventilation
Use in manufacture of phosphorus alloys for introduction into low carbon steel, copper alloys, copper pipe, and bronze	Process enclosure; local exhaust ventilation; general dilution ventilation
Use in manufacture of explosives, munitions, and pyrotechnics for military use	Local exhaust ventilation; general dilution ventilation; personal protective equipment
Use as a catalyst in synthesis of acrylonitrile and organic bromine compounds	Local exhaust ventilation; general dilution ventilation; personal protective equipment
Use during conversion of yellow phosphorus to red phosphorus for manufacture of wood and paper safety matches	Process enclosure; local exhaust ventilation; general dilution ventilation
Use as an ingredient of rat poison and roach powders	Material substitution

EMERGENCY FIRST AID PROCEDURES

In the event of an emergency, institute first aid procedures and send for first aid or medical assistance.

- **Eye Exposure**

If phosphorus (yellow) gets into the eyes, wash eyes immediately with large amounts of water, lifting the lower and upper lids occasionally. Get medical attention immediately. Contact lenses should not be worn when working with this chemical.

• **Skin Exposure**

If phosphorus (yellow) gets on the skin, immediately flush the contaminated skin with water. If phosphorus (yellow) penetrates through the clothing, remove the clothing immediately and flush the skin with water. Get medical attention immediately. The skin should be kept wet until medical attention is obtained to prevent any remaining phosphorus (yellow) from burning.

• **Breathing**

If a person breathes in large amounts of phosphorus (yellow), move the exposed person to fresh air at once. If breathing has stopped, perform artificial respiration. Keep the affected person warm and at rest. Get medical attention as soon as possible.

• **Swallowing**

When phosphorus (yellow) has been swallowed and the person is conscious, give the person large quantities of water immediately. After the water has been swallowed, try to get the person to vomit by having him touch the back of his throat with his finger. Do not make an unconscious person vomit. Get medical attention immediately.

• **Rescue**

Move the affected person from the hazardous exposure. If the exposed person has been overcome, notify someone else and put into effect the established emergency rescue procedures. Do not become a casualty. Understand the facility's emergency rescue procedures and know the locations of rescue equipment before the need arises.

SPILL AND DISPOSAL PROCEDURES

• Persons not wearing protective equipment and clothing should be restricted from areas of spills until cleanup has been completed.

• If phosphorus (yellow) is spilled, the following step should be taken:

1. Immediately douse the spill with water and cover with wet sand or dirt.

• Waste disposal method:

Phosphorus (yellow), after solidification and covering with wet sand or dirt, may be disposed of in a secured sanitary landfill.

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RESPIRATORY PROTECTION FOR PHOSPHORUS (YELLOW)

Condition	Minimum Respiratory Protection* Required Above 0.1 mg/m³
Particulate Concentration	
5 mg/m³ or less	A high efficiency particulate filter respirator with a full facepiece. Any supplied-air respirator with a full facepiece, helmet, or hood. Any self-contained breathing apparatus with a full facepiece.
200 mg/m³ or less	A Type C supplied-air respirator with a full facepiece operated in pressure-demand or other positive pressure mode or with a full facepiece, helmet, or hood operated in continuous-flow mode.
Greater than 200 mg/m³ or entry and escape from unknown concentrations	Self-contained breathing apparatus with a full facepiece operated in pressure-demand or other positive pressure mode. A combination respirator which includes a Type C supplied-air respirator with a full facepiece operated in pressure-demand or other positive pressure or continuous-flow mode and an auxiliary self-contained breathing apparatus operated in pressure-demand or other positive pressure mode.
Fire Fighting	Self-contained breathing apparatus with a full facepiece operated in pressure-demand or other positive pressure mode.

*Only NIOSH-approved or MSHA-approved equipment should be used.

Occupational Health Guideline for Selenium and Its Inorganic Compounds (as Selenium)*

INTRODUCTION

This guideline is intended as a source of information for employees, employers, physicians, industrial hygienists, and other occupational health professionals who may have a need for such information. It does not attempt to present all data; rather, it presents pertinent information and data in summary form.

APPLICABILITY

The general guidelines contained in this document apply to all selenium and its inorganic compounds. Physical and chemical properties of several specific compounds are provided for illustrative purposes.

SUBSTANCE IDENTIFICATION

Selenium

- Formula: Se
- Synonyms: Selenium, metallic; selenium, elemental
- Appearance and odor: Black, gray, or red odorless solid.

Sodium selenite

- Formula: Na_2SeO_3
- Synonyms: None
- Appearance and odor: Colorless and odorless solid.

Sodium selenate

- Formula: Na_2SeO_4
- Synonyms: None
- Appearance and odor: Colorless and odorless solid.

Selenium dioxide

- Formula: SeO_2
- Synonyms: None
- Appearance and odor: Colorless and odorless solid.

Selenium oxychloride

- Formula: $SeOCl_2$
- Synonyms: None
- Appearance: Colorless to yellow liquid.

PERMISSIBLE EXPOSURE LIMIT (PEL)

The current OSHA standard for selenium and its inorganic compounds is 0.2 milligram of selenium and its inorganic compounds (as selenium) per cubic meter of air (mg/m^3) averaged over an eight-hour work shift.

HEALTH HAZARD INFORMATION

- **Routes of exposure**

Selenium, sodium selenite, sodium selenate, or selenium dioxide can affect the body if they are inhaled, if they come in contact with the eyes or skin, or if they are swallowed. Selenium oxychloride and selenium dioxide may enter the body through the skin.

- **Effects of overexposure**

1. Short-term Exposure: Inhalation of large quantities of selenium dioxide or selenium oxychloride may cause severe breathing difficulties which may not appear for several hours after exposure. Skin contact with selenium dioxide or selenium oxychloride may cause skin burns. Skin exposure to selenium dioxide dust may cause a skin rash. Splashes of selenium dioxide may cause eye irritation. Selenium dioxide dust may cause "rose eye," an allergy of the eyelids in which they may become puffy.

2. Long-term Exposure: Prolonged exposure to selenium, sodium selenite, sodium selenate, or selenium dioxide may cause paleness, coated tongue, stomach disorders, nervousness, metallic taste and a garlic odor of the breath. Fluid in the abdominal cavity, damage to the liver and spleen, and anemia have been reported in animals. Prolonged skin contact with selenium oxide or selenium oxychloride may cause skin sensitization.

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3. Reporting Signs and Symptoms: A physician should be contacted if anyone develops any signs or symptoms and suspects that they are caused by exposure to selenium and its inorganic compounds.

• **Recommended medical surveillance**

The following medical procedures should be made available to each employee who is exposed to selenium and its inorganic compounds at potentially hazardous levels:

1. Initial Medical Examination:

—A complete history and physical examination: The purpose is to detect pre-existing conditions that might place the exposed employee at increased risk, and to establish a baseline for future health monitoring. Persons with a history of asthma, allergies, or known sensitization to selenium, or with a history of other chronic respiratory disease, gastrointestinal disturbances, disorders of liver or kidneys, or recurrent dermatitis would be expected to be at increased risk from exposure. Examination of the eyes, respiratory system, liver, kidneys, and blood should be stressed. The skin should be examined for evidence of chronic disorders. Special consideration should be given to women of childbearing age since the possibility that selenium may be teratogenic might place these women in a high risk group.

—Urinalysis: Proper function of the kidneys is necessary to validate levels of selenium in the urine. A urinalysis should be obtained to include at a minimum specific gravity, albumin, glucose, and a microscopic on centrifuged sediment.

—Liver function tests: Selenium causes liver damage and tumors in animals. A profile of liver function should be obtained by using a medically acceptable array of biochemical tests.

2. Periodic Medical Examination: The aforementioned medical examinations should be repeated on an annual basis.

• **Summary of toxicology**

Elemental selenium and certain selenium compounds as dusts, vapors, and fumes irritate the eyes, upper respiratory tract, and skin. Animals exposed to selenium anhydride at a concentration of 150 mg/m³ for 4 hours developed conjunctivitis, pulmonary edema, and convulsions preceding death; there were degenerative changes in the liver, kidneys, spleen, and heart. Prolonged feeding of animals with diets containing selenium in amounts of 5 to 15 ppm caused hepatic necrosis, hemorrhage, and cirrhosis; marked and progressive anemia occurred in some species. The possibility of teratogenic effects from exposure to selenium has been raised, based upon observations in animals, but it has not been established in man. Eleven of 53 rats developed adenoma or low-grade carcinoma in cirrhotic livers, and four others had advanced adenomatoid hyperplasia, after having survived for 18 to 24 months on diets containing 5, 7, or 10 ppm of selenium; no tumors occurred in 73 rats surviving less than 18 months, although after 3 months cirrhosis was frequent. In control rats 18 to 24 months of age, the incidence of spontaneous hepatic tumors was less than 1%. A group of workers briefly exposed to high concentrations of selenium fume developed severe irritation of the eyes, nose, and throat, followed by headaches; transient dyspnea occurred in one case. In workers exposed to an undetermined concentration of selenium oxide there was bronchospasm and dyspnea, followed within 12 hours by chills, fever, headache, and bronchitis, leading to pneumonitis in a few cases; all were asymptomatic within a week. In a study of workers in a selenium plant, workroom air levels ranged from 0.2 to 3.6 mg/m³, while urinary levels ranged from below 0.10 to 0.43 mg/l; the chief complaints were garlic odor of the breath, metallic taste, gastrointestinal disturbances, and skin eruptions. An accidental spray of selenium dioxide, in unspecified form and concentration, into the eyes of a chemist caused superficial burns of the skin and immediate irritation of the eyes; within 16 hours vision was blurred, and the lower portions of both corneas appeared dulled; 16 days after the accident the corneas were normal. Acute burns of the skin can be caused by selenium oxychloride and selenium oxide, which are highly vesicant. Contact with the fume of heated selenium dioxide caused an acute, weeping dermatitis, with the development of hypersensitivity in some cases.

CHEMICAL AND PHYSICAL PROPERTIES

• **Physical data—Selenium**

1. Molecular weight: 78.96
2. Boiling point (760 mm Hg): 685 C (1265 F)
3. Specific gravity (water = 1): 4.45 to 4.8
4. Vapor density (air = 1 at boiling point of selenium): Not applicable
5. Melting point: 150 C (302 F)
6. Vapor pressure at 20 C (68 F): Less than 0.001 mm Hg
7. Solubility in water, g/100 g water at 20 C (68 F): Insoluble
8. Evaporation rate (butyl acetate = 1): Not applicable

• **Physical data—Sodium selenite**

1. Molecular weight: 173
2. Boiling point (760 mm Hg): Decomposes
3. Specific gravity (water = 1): 3.1
4. Vapor density (air = 1 at boiling point of sodium selenite): Not applicable
5. Melting point: 710 C (1310 F) (decomposes)
6. Vapor pressure at 20 C (68 F): Less than 0.001 mg Hg
7. Solubility in water, g/100 g water at 20 C (68 F): 85
8. Evaporation rate (butyl acetate = 1): Not applicable

• **Physical data—Sodium selenate**

1. Molecular weight: 188.9
2. Boiling point (760 mm Hg): Decomposes
3. Specific gravity (water = 1): 3.1

4. Vapor density (air = 1 at boiling point of sodium selenate): Not applicable
5. Melting point: Decomposes
6. Vapor pressure at 20 C (68 F): Less than 0.001 mm Hg
7. Solubility in water, g/200 g water at 20 C (68 F): 83
8. Evaporation rate (butyl acetate = 1): Not applicable

• **Physical data—Selenium dioxide**

1. Molecular weight: 110.9
2. Boiling point (760 mm Hg): 315 C (599 F) (sublimes)
3. Specific gravity (water = 1): 3.95
4. Vapor density (air = 1 at boiling point of selenium dioxide): Not applicable
5. Melting point: 340 C (644 F)
6. Vapor pressure at 20 C (68 F): 0.001 mm Hg
7. Solubility in water, g/100 g water at 20 C (68 F): 257
8. Evaporation rate (butyl acetate = 1): Not applicable

• **Physical data—Selenium oxychloride**

1. Molecular weight: 165.9
2. Boiling point (760 mm Hg): 176 C (349 F)
3. Specific gravity (water = 1): 2.42
4. Vapor density (air = 1 at boiling point of selenium oxychloride): 5.7
5. Melting point: 10.8 C (51 F)
6. Vapor pressure at 20 C (68 F): 0.35 mm approximately
7. Solubility in water, g/100 g water at 20 C (68 F): Decomposes
8. Evaporation rate (butyl acetate = 1): Not applicable

• **Reactivity**

1. Conditions contributing to instability: None hazardous
2. Incompatibilities: Contact of selenium with acids may cause formation of poisonous hydrogen selenide gas. Contact of selenium with strong oxidizing agents may cause fires and explosions.
3. Hazardous decomposition products: Toxic gases and vapors may be released in a fire involving selenium, sodium selenite, sodium selenate, selenium dioxide, and selenium oxychloride.
4. Special precautions: None

• **Flammability**

1. Flash point: Not applicable
2. Autoignition temperature: Selenium: Data not available; sodium selenite, sodium selenate, selenium dioxide, and selenium oxychloride: Not applicable
3. Flammable limits in air, % by volume: Not applicable
4. Extinguishant: For selenium, water

• **Warning properties**

The *Documentation of TLV's* notes that "Clinton reported intense irritation of eyes, nose, and throat, followed by headache, in a group of workers briefly exposed to high concentrations of selenium fume." The ILO reports that "persons who work in atmospheres containing selenium dioxide dust may develop a condition known among the workers as 'rose eye,' a pink allergy of the eyelids, which often become puffy. There is usually also a conjunctivitis of the palpebral conjunctiva but rarely of the bulbar conjunctiva." The *Hygienic Information Guide* for selenium states that "in contact with the eye, selenium compounds exert a rapid irritant action leading to inflammation." Grant reports that both selenium dioxide and selenium sulfide can produce toxic effects on the eye. Quantitative information concerning air concentrations of selenium compounds which cause eye irritation is not available.

MONITORING AND MEASUREMENT PROCEDURES

• **General**

Measurements to determine employee exposure are best taken so that the average eight-hour exposure is based on a single eight-hour sample or on two four-hour samples. Several short-time interval samples (up to 30 minutes) may also be used to determine the average exposure level. Air samples should be taken in the employee's breathing zone (air that would most nearly represent that inhaled by the employee).

• **Method**

Sampling and analyses may be performed by collection of selenium and its inorganic compounds on a filter, followed by treatment with acid and atomic absorption spectrophotometric analysis. An analytical method for selenium and its inorganic compounds is in the *NIOSH Manual of Analytical Methods*, 2nd Ed., Vol. 3, 1977, available from the Government Printing Office, Washington, D.C. 20402 (GPO No. 017-033-00261-4).

RESPIRATORS

• Good industrial hygiene practices recommend that engineering controls be used to reduce environmental concentrations to the permissible exposure level. However, there are some exceptions where respirators may be used to control exposure. Respirators may be used when engineering and work practice controls are not technically feasible, when such controls are in the process of being installed, or when they fail and need to be supplemented. Respirators may also be used for operations which require entry into tanks or closed vessels, and in emergency situations. If the use of respirators is necessary, the only respirators permitted are those that have been approved by the Mine Safety and Health Administration (formerly Mining Enforcement and Safety Administration) or by the National Institute for Occupational Safety and Health.

• In addition to respirator selection, a complete respiratory protection program should be instituted which

includes regular training, maintenance, inspection, cleaning, and evaluation.

PERSONAL PROTECTIVE EQUIPMENT

- Employees should be provided with and required to use impervious clothing, gloves, face shields (eight-inch minimum), and other appropriate protective clothing necessary to prevent any possibility of skin contact with selenium oxychloride or liquids containing selenium oxychloride.
- Employees should be provided with and required to use impervious clothing, gloves, face shields (eight-inch minimum), and other appropriate protective clothing necessary to prevent repeated or prolonged skin contact with selenium, sodium selenite, sodium selenate, or liquids containing these compounds.
- Employees should be provided with and required to use impervious clothing, gloves, face shields (eight-inch minimum), and other appropriate protective clothing necessary to prevent skin contact with selenium dioxide or liquids containing selenium dioxide, where skin contact may occur.
- If employees' clothing has had any possibility of being contaminated with selenium oxychloride, sodium selenite,sodium selenate, selenium dioxide, or liquids containing these compounds, employees should change into uncontaminated clothing before leaving the work premises.
- Clothing which has had any possibility of being contaminated with selenium oxychloride, sodium selenite, sodium selenate, or selenium dioxide should be placed in closed containers for storage until it can be discarded or until provision is made for the removal of contaminant from the clothing. If the clothing is to be laundered or otherwise cleaned to remove the contaminant, the person performing the operation should be informed of contaminant's hazardous properties.
- Where there is any possibility of exposure of an employee's body to selenium, selenium oxychloride, sodium selenite, sodium selenate, selenium dioxide, or liquids containing these compounds, facilities for quick drenching of the body should be provided within the immediate work area for emergency use.
- Non-impervious clothing which becomes contaminated with selenium, sodium selenite, sodium selenate, selenium dioxide or liquids containing these compounds should be removed promptly and not reworn until the contaminant is removed from the clothing.
- Non-impervious clothing which becomes contaminated with selenium oxychloride should be removed immediately and not reworn until the selenium oxychloride is removed from the clothing.
- Employees should be provided with and required to use dust- and splash-proof safety goggles where there is any possibility of selenium dioxide, selenium oxychloride, or liquids containing these compounds contacting the eyes.
- Employees should be provided with and required to use dust- and splash-proof safety goggles where sodium selenite, sodium selenate, or liquids containing these compounds may contact the eyes.
- Where there is any possibility that employees' eyes may be exposed to selenium oxychloride, selenium dioxide, or liquids containing these compounds, an eye-wash fountain should be provided within the immediate work area for emergency use.

SANITATION

- Workers subject to skin contact with selenium oxychloride, sodium selenite, sodium selenate, selenium dioxide, or liquids containing these compounds should wash any areas of the body which may have contacted selenium oxychloride, sodium selenite, sodium selenate, selenium dioxide, or liquids containing these compounds at the end of each work day.
- Skin that becomes contaminated with selenium, sodium selenite, sodium selenate, selenium dioxide, or liquids containing these substances should be promptly washed or showered to remove any contaminant.
- Skin that becomes contaminated with selenium oxychloride should be immediately washed or showered to remove any selenium oxychloride.
- Eating and smoking should not be permitted in areas where selenium oxychloride, sodium selenite, sodium selenate, selenium dioxide, or liquids containing these compounds are handled, processed, or stored.
- Employees who handle selenium oxychloride, sodium selenite, sodium selenate, selenium dioxide, or liquids containing these compounds should wash their hands thoroughly before eating, smoking, or using toilet facilities.

COMMON OPERATIONS AND CONTROLS

The following list includes some common operations in which exposure to selenium and its inorganic compounds may occur and control methods which may be effective in each case:

Operation	Controls
Liberation during mining recovery, and purification and manufacture of selenium compounds	Local exhaust ventilation; general dilution ventilation; personal protective equipment

Operation	Controls
Use in glassware industry for decolorization of fiberglass, scientific glassware, vehicular tail lights, traffic and other signal lenses, and infrared equipment; use in manufacture of electrical components in welding, transformers, semiconductors, photoelectric cells, etc.	Local exhaust ventilation; general dilution ventilation; personal protective equipment
Use in manufacture of photography and photocopy devices; manufacture of dyes, pigments, and colored glazes for metal etching and for printing on glass	Local exhaust ventilation; general dilution ventilation; personal protective equipment
Use in manufacture of lubricating oils and extreme pressure lubricants as antioxidants and detergency improvers	Local exhaust ventilation; general dilution ventilation; personal protective equipment
Use in rubber industry for manufacture and use as vulcanization accelerators and antioxidants; use in manufacture of pharmaceuticals, fungicides, and dermatitis control	Local exhaust ventilation; general dilution ventilation; personal protective equipment
Use as a catalyst for hardening fats for soaps, waxes, edible fats, and plastics	Local exhaust ventilation; general dilution ventilation; personal protective equipment
Use in manufacture of insecticides, parasiticides, bactericides, and herbicides for agricultural and citrus crops	Local exhaust ventilation; general dilution ventilation; personal protective equipment
Use in manufacture of flame-proofing agents on textiles and electric cables	Local exhaust ventilation; general dilution ventilation; personal protective equipment
Use in manufacture of delayed action blasting caps	Local exhaust ventilation; general dilution ventilation; personal protective equipment
Use as solvents in paint and varnish removers; rubber, resin, and glue solvent; use for organic synthesis in oxidation, hydrogenation, and dehyrogenation	Local exhaust ventilation; general dilution ventilation; personal protective equipment
Use in refining of copper, silver, gold, or nickel ores or during recycling of scrap metal	Local exhaust ventilation; general dilution ventilation; personal protective equipment
Use in miscellaneous operations in manufacture of insect repellants, activators, hardeners, special ceramic materials, plasticizers, and mercury vapor detectors	Local exhaust ventilation; general dilution ventilation; personal protective equipment
Use for preparation of feed additives for poultry and swine	Local exhaust ventilation; general dilution ventilation; personal protective equipment

EMERGENCY FIRST AID PROCEDURES

In the event of an emergency, institute first aid procedures and send for first aid or medical assistance.

- **Eye Exposure**

If selenium or its inorganic compounds get into the eyes, wash eyes immediately with large amounts of water, lifting the lower and upper lids occasionally. Get medical attention immediately. Contact lenses should not be worn when working with these chemicals.

- **Skin Exposure**

If selenium or its inorganic compounds get on the skin, immediately wash the contaminated skin. If selenium, sodium selenite, sodium selenate, or selenium dioxide soak through the clothing, remove the clothing immediately and wash the skin. If irritation persists after washing, get medical attention.

- **Breathing**

If a person breathes in large amounts of selenium sodium selenite, sodium selenate, or selenium dioxide, move the exposed person to fresh air at once. If breathing has stopped, perform artificial respiration.

Keep the affected person warm and at rest. Get medical attention as soon as possible.

• **Swallowing**

When selenium, sodium selenite, sodium selenate, selenium oxychloride, or selenium dioxide have been swallowed and the person is conscious, give the person large quantities of water immediately. After the water has been swallowed, try to get the person to vomit by having him touch the back of his throat with his finger. Do not make an unconscious person vomit. Get medical attention immediately.

• **Rescue**

Move the affected person from the hazardous exposure. If the exposed person has been overcome, notify someone else and put into effect the established emergency rescue procedures. Do not become a casualty. Understand the facility's emergency rescue procedures and know the locations of rescue equipment before the need arises.

SPILL AND DISPOSAL PROCEDURES

• Persons not wearing protective equipment and clothing should be restricted from areas of spills until cleanup has been completed.

• If selenium or its inorganic compounds are spilled, the following steps should be taken:

1. Ventilate area of spill.
2. Collect spilled material in the most convenient and safe manner and deposit in sealed containers for reclamation or for disposal in a secured sanitary landfill. Liquid containing selenium and its inorganic compounds should be absorbed in vermiculite, dry sand, earth, or a similar material.

• Waste disposal method:

Selenium and its inorganic compounds may be disposed of in sealed containers in a secured sanitary landfill.

REFERENCES

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* SPECIAL NOTE

Selenium and its inorganic compounds (as selenium) appear on the OSHA "Candidate List" of chemicals being considered for further scientific review regarding their carcinogenicity (*Federal Register*, Vol. 45, No. 157, pp. 5372-5379, 12 August 1980).

RESPIRATORY PROTECTION FOR SELENIUM AND ITS INORGANIC COMPOUNDS (AS SELENIUM)

Condition	Minimum Respiratory Protection* Required Above 0.2 mg/m³
Particulate Concentration	
10 mg/m³ or less	A high efficiency particulate filter respirator with a full facepiece. Any supplied-air respirator with a full facepiece, helmet, or hood. Any self-contained breathing apparatus with a full facepiece.
100 mg/m³ or less	A Type C supplied-air respirator with a full facepiece operated in pressure-demand or other positive pressure mode or with a full facepiece, helmet, or hood operated in continuous-flow mode. A powered air-purifying respirator with a high efficiency particulate filter and a full facepiece, helmet, or hood.
Greater than 100 mg/m³ or entry and escape from unknown concentrations	Self-contained breathing apparatus with a full facepiece operated in pressure-demand or other positive pressure mode. A combination respirator which includes a Type C supplied-air respirator with a full facepiece operated in pressure-demand or other positive pressure or continuous-flow mode and an auxiliary self-contained breathing apparatus operated in pressure-demand or other positive pressure mode.
Fire Fighting	Self-contained breathing apparatus with a full facepiece operated in pressure-demand or other positive pressure mode.
Escape	A high efficiency particulate filter respirator with a full facepiece. Any escape self-contained breathing apparatus with a full facepiece.

*Only NIOSH-approved or MSHA-approved equipment should be used.

Occupational Health Guideline for Silver Metal and Soluble Silver Compounds

INTRODUCTION

This guideline is intended as a source of information for employees, employers, physicians, industrial hygienists, and other occupational health professionals who may have a need for such information. It does not attempt to present all data; rather, it presents pertinent information and data in summary form.

APPLICABILITY

The general guidelines contained in this document apply to metallic silver and all soluble silver compounds. Physical and chemical properties of several specific compounds are provided for illustrative purposes.

SUBSTANCE IDENTIFICATION

Silver, metallic

- Formula: Ag
- Synonyms: None
- Appearance and odor: Characteristic white metallic solid with no odor.

Silver nitrate

- Formula: $AgNO_3$
- Synonyms: Argerol; lunar caustic
- Appearance and odor: Colorless and odorless solid which may become gray on storage.

Silver fluoride

- Formula: AgF
- Synonyms: None
- Appearance and odor: Yellow-white, odorless solid.

PERMISSIBLE EXPOSURE LIMIT (PEL)

The current OSHA standard for silver metal and soluble silver compounds is 0.01 milligram of silver metal and soluble silver compounds per cubic meter of air (mg/m^3) averaged over an eight-hour work shift. The American Conference of Governmental Industrial Hygienists has issued a Notice of Intended Changes of its recommended Threshold Limit Value for silver metal and soluble silver compounds from 0.01 mg/m^3 to 0.1 mg/m^3.

HEALTH HAZARD INFORMATION

- **Routes of exposure**

Silver or soluble silver compounds can affect the body if they are inhaled or if they come in contact with the eyes or skin. They can also affect the body if they are swallowed.

- **Effects of overexposure**

Silver or soluble silver compounds can cause discoloration or blue-gray darkening of the eyes, nose, throat, and skin. Silver nitrate is strongly corrosive and can cause burns and permanent damage to the eyes and can burn the skin.

- **Reporting signs and symptoms**

A physician should be contacted if anyone develops any signs or symptoms and suspects that they are caused by exposure to silver metal or soluble silver compounds.

- **Recommended medical surveillance**

The following medical procedures should be made available to each employee who is exposed to silver metal and soluble silver compounds at potentially hazardous levels:

1. Initial Medical Examination:

—Examination of the nasal septum, eyes, and skin for evidence of pigmentation: The purpose is to establish a baseline for future observations of silver deposition in tissues.

2. Periodic Medical Examination: The aforementioned

These recommendations reflect good industrial hygiene and medical surveillance practices and their implementation will assist in achieving an effective occupational health program. However, they may not be sufficient to achieve compliance with all requirements of OSHA regulations.

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medical examinations should be repeated on an annual basis.

• **Summary of toxicology**

The dust of silver and its soluble compounds cause argyria, the local or generalized impregnation of the mucous membranes, skin, and eyes with silver. Localized argyria occurs in the skin, eyes, nasal septum and throat, where gray-blue patches of pigmentation are formed without evidence of tissue reaction. Generalized argyria is recognized by the widespread pigmentation of the skin and may be seen first in the conjunctiva, with some localization in the inner canthus. Argyrosis of the respiratory tract has been described in two workers involved in the manufacture of silver nitrate; their only symptom was mild, chronic bronchitis; bronchoscopy revealed tracheobronchial pigmentation; biopsy of the nasal mucous membrane showed silver deposition in the subepithelial area. A total body burden from 1 to 5 g of silver will lead to generalized argyria. Silver, once deposited in the body, is poorly excreted in the urine in amounts detectable by spectrochemical methods. Silver nitrate (lunar caustic) may cause irritation, ulcers, and discoloration of skin; if ingested, it may cause abdominal pain and gastroenteritis.

CHEMICAL AND PHYSICAL PROPERTIES

• **Physical data—Silver, metallic**

1. Molecular weight: 107.9
2. Boiling point (760 mm Hg): 2200 C (3992 F)
3. Specific gravity (water = 1): 10.4
4. Vapor density (air = 1 at boiling point of metallic silver): Not applicable
5. Melting point: 966 C (1771 F)
6. Vapor pressure at 20 C (68 F): Negligible
7. Solubility in water, g/100 g water at 20 C (68 F): Insoluble
8. Evaporation rate (butyl acetate = 1): Not applicable

• **Physical data—Silver nitrate**

1. Molecular weight: 169.9
2. Boiling point (760 mm Hg): 444 C (831 F) (decomposes)
3. Specific gravity (water = 1): 4.4
4. Vapor density (air = 1 at boiling point of silver nitrate): Not applicable
5. Melting point: 209 C (408 F)
6. Vapor pressure at 20 C (68 F): Negligible
7. Solubility in water, g/100 g water at 20 C (68 F): 245
8. Evaporation rate (butyl acetate = 1): Not applicable

• **Physical data—Silver fluoride**

1. Molecular weight: 126.9
2. Boiling point (760 mm Hg): 1159 C (2119 F) (approximately)
3. Specific gravity (water = 1): 5.8
4. Vapor density (air = 1 at boiling point of silver fluoride): Not applicable
5. Melting point: 435 C (815 F)
6. Vapor pressure at 20 C (68 F): Negligible
7. Solubility in water, g/100 g water at 20 C (68 F): 64
8. Evaporation rate (butyl acetate = 1): Not applicable

• **Reactivity**

1. Conditions contributing to instability: Heat
2. Incompatibilities: Contact of metallic silver and soluble silver compounds with acetylene may cause formation of silver acetylide that is sensitive to shock. Contact with ammonia may cause formation of compounds that are explosive when dry. Contact with strong hydrogen peroxide solutions will cause violent decomposition to oxygen gas.
3. Hazardous decomposition products: Toxic gases and vapors (such as oxides of nitrogen) may be released when some soluble silver compounds decompose.
4. Special precautions: Soluble silver compounds will attack some forms of plastics, rubber, and coatings.

• **Flammability**

1. Most soluble silver compounds are not combustible. However, silver nitrate is a strong oxidizing material capable of increasing the flammability of combustible, organic, or other readily oxidizable materials. The following soluble silver compounds are explosives and should be stored and handled in accordance with 29 CFR 1910.109: silver acetylide, silver azide, silver fulminate, silver oxalate mixtures, silver styphnate, silver tartarate mixtures, and silver tetrazene.

• **Warning properties**

According to Stecher "many silver salts are irritating . . . to mucous membranes." Grant notes that many simple silver salts and silver ammonium compounds are injurious to the eye. According to Grant, "a great many reports have been published describing argyrosis of the eye, either from local contact with silver compounds or as a part of a generalized argyrosis from systemic absorption of silver or its compounds." Since there are inadequate data to assess the effects on the eye at or near the permissible exposure limit, for the purposes of this guideline, silver metal and soluble silver compounds are considered to have poor warning properties.

MONITORING AND MEASUREMENT PROCEDURES

• **General**

Measurements to determine employee exposure are best taken so that the average eight-hour exposure is based on a single eight-hour sample or on two four-hour samples. Several short-time interval samples (up to 30 minutes) may also be used to determine the average exposure level. Air samples should be taken in the employee's breathing zone (air that would most nearly represent that inhaled by the employee).

• **Method**

An analytical method for silver metal and soluble silver

compounds is in the *NIOSH Manual of Analytical Methods*. 2nd Ed., Vol. 3, 1977, available from the Government Printing Office, Washington, D.C. 20402 (GPO No. 017-033-00261-4).

technically feasible, when such controls are in the process of being installed, or when they fail and need to be supplemented. Respirators may also be used for operations which require entry into tanks or closed vessels, and in emergency situations. If the use of respirators is necessary, the only respirators permitted are those that have been approved by the Mine Safety and Health Administration (formerly Mining Enforcement and Safety Administration) or by the National Institute for Occupational Safety and Health.

- In addition to respirator selection, a complete respiratory protection program should be instituted which includes regular training, maintenance, inspection, cleaning, and evaluation.

PERSONAL PROTECTIVE EQUIPMENT

- Employees should be provided with and required to use impervious clothing, gloves, face shields (eight-inch minimum), and other appropriate protective clothing necessary to prevent skin contact with powdered metallic silver or solids or liquids containing soluble silver compounds, where skin contact may occur.
- If employees' clothing may have become contaminated with solids or liquids containing soluble silver compounds, employees should change into uncontaminated clothing before leaving the work premises.
- Clothing contaminated with metallic silver or soluble silver compounds should be placed in closed containers for storage until it can be discarded or until provision is made for the removal of substances from the clothing. If the clothing is to be laundered or otherwise cleaned to remove the substances, the person performing the operation should be informed of substances' hazardous properties.
- Non-impervious clothing which becomes contaminated with metallic silver or soluble silver compounds should be removed promptly and not reworn until the metallic silver or soluble silver compounds are removed from the clothing.
- Employees should be provided with and required to use dust- and splash-proof safety goggles where there is any possibility of powdered metallic silver or solids or liquids containing soluble silver compounds contacting the eyes.
- Where there is any possibility that employees' eyes may be exposed to silver nitrate or solutions containing 5 percent or more silver nitrate by weight, an eye-wash fountain should be provided within the immediate work area for emergency use.

SANITATION

- Skin that becomes contaminated with metallic silver or soluble silver compounds should be promptly washed or showered to remove any metallic silver or soluble silver compounds.
- Eating and smoking should not be permitted in areas where metallic silver or solids or liquids containing soluble silver compounds are handled, processed, or stored.
- Employees who handle powdered metallic silver or solids or liquids containing soluble silver compounds should wash their hands thoroughly before eating, smoking, or using toilet facilities.

COMMON OPERATIONS AND CONTROLS

The following list includes some common operations in which exposure to silver metal and soluble silver compounds may occur and control methods which may be effective in each case:

Operation	Controls
Liberation during mining and purification from ore; during refining from secondary sources	Local exhaust ventilation; general dilution ventilation; personal protective equipment
Use in manufacture of silver nitrate for use in photography, mirrors, plating, inks, dyes, and porcelain; and as germicides, antiseptics, caustics, and analytical reagents	Process enclosure; local exhaust ventilation; personal protective equipment
Use in manufacture of silver salts as catalysts in oxidation-reduction and polymerization reactions; in chemical synthesis; in glass manufacture, in silver-plating, in photography, as laboratory reagents, and in medicine	Process enclosure; local exhaust ventilation; personal protective equipment

Operation	Controls
Liberation from manufacture and casting of alloys; during fabrication of silver metal, alloys, and bi-metals for electrical uses; and during electroplating operations and fabrication of solders and brazing alloys; during manufacture and use of photographic chemicals and materials; during manufacture of mirrors, and during manufacture of silver powder pigments and paints	Local exhaust ventilation; general dilution ventilation; personal protective equipment
Use during manufacture of silver powder pigments and paints; during manufacture of mirrors; during manufacture of photographic chemicals and materials	Local exhaust ventilation; general dilution ventilation; personal protective equipment

EMERGENCY FIRST AID PROCEDURES

In the event of an emergency, institute first aid procedures and send for first aid or medical assistance.

• **Eye Exposure**

If powdered metallic silver or solids or liquids containing soluble silver compounds get into the eyes, wash eyes immediately with large amounts of water, lifting the lower and upper lids occasionally. Get medical attention immediately. Contact lenses should not be worn when working with this chemical.

• **Skin Exposure**

If powdered metallic silver or solids or liquids containing soluble silver compounds get on the skin, flush the contaminated skin with water. If powdered metallic silver or solids or liquids containing soluble silver compounds penetrate through the clothing, remove the clothing immediately and flush the skin with water. If irritation is present after washing, get medical attention. Other silver compounds should be removed by promptly flushing the skin with water.

• **Breathing**

If a person breathes in large amounts of silver metal or soluble silver compounds, move the exposed person to fresh air at once. If breathing has stopped, perform artificial respiration. Keep the affected person warm and at rest. Get medical attention as soon as possible.

• **Swallowing**

If silver nitrate or other corrosive soluble silver compounds have been swallowed and the person is conscious, give him large quantities of water immediately to dilute the silver nitrate or other corrosive silver compounds. Do not attempt to make the exposed person vomit. Get medical attention immediately. When non-corrosive soluble silver compounds have been swallowed, give the person large quantities of water immediately. After the water has been swallowed, try to get the person to vomit by having him touch the back of his throat with his finger. Do not make an unconscious person vomit. Get medical attention immediately.

• **Rescue**

Move the affected person from the hazardous exposure. If the exposed person has been overcome, notify someone else and put into effect the established emergency rescue procedures. Do not become a casualty. Understand the facility's emergency rescue procedures and know the locations of rescue equipment before the need arises.

SPILL, LEAK, AND DISPOSAL PROCEDURES

• Persons not wearing protective equipment and clothing should be restricted from areas of spills or leaks until cleanup has been completed.

• If powdered silver metal or soluble silver compounds are spilled or leaked, the following steps should be taken:

1. Ventilate area of spill or leak.
2. Collect spilled material in the most convenient and safe manner and deposit in sealed containers for reclamation or for disposal in a secured sanitary landfill. Liquid containing silver metal or soluble silver compounds should be absorbed in vermiculite, dry sand, earth, or a similar material.

• Waste disposal method:

Silver metal and soluble silver compounds may be disposed of in sealed containers in a secured sanitary landfill.

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• American Conference of Governmental Industrial Hygienists: "Silver," *Documentation of the Threshold Limit Values for Substances in Workroom Air* (3rd ed., 2nd printing), Cincinnati, 1974.

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RESPIRATORY PROTECTION FOR SILVER METAL AND SOLUBLE SILVER COMPOUNDS

Condition	Minimum Respiratory Protection* Required Above 0.01 mg/m³
Particulate Concentration	
0.5 mg/m³ or less	A high efficiency particulate filter respirator with a full facepiece. Any supplied-air respirator with a full facepiece, helmet, or hood. Any self-contained breathing apparatus with a full facepiece.
10 mg/m³ or less	A powered air-purifying respirator with a full facepiece and a high efficiency particulate filter.
20 mg/m³ or less	A Type C supplied-air respirator with a full facepiece operated in pressure-demand or other positive pressure mode or with a full facepiece, helmet, or hood operated in continuous-flow mode.
Greater than 20 mg/m³ or entry and escape from unknown concentrations	Self-contained breathing apparatus with a full facepiece operated in pressure-demand or other positive pressure mode. A combination respirator which includes a Type C supplied-air respirator with a full facepiece operated in pressure-demand or other positive pressure or continuous-flow mode and an auxiliary self-contained breathing apparatus operated in pressure-demand or other positive pressure mode.
Fire Fighting	Self-contained breathing apparatus with a full facepiece operated in pressure-demand or other positive pressure mode.

*Only NIOSH-approved or MSHA-approved equipment should be used.

Occupational Health Guideline for Styrene

INTRODUCTION

This guideline is intended as a source of information for employees, employers, physicians, industrial hygienists, and other occupational health professionals who may have a need for such information. It does not attempt to present all data; rather, it presents pertinent information and data in summary form.

SUBSTANCE IDENTIFICATION

- Formula: $C_6H_5CH=CH_2$
- Synonyms: Phenylethylene; vinylbenzene; cinnamene; styrene monomer
- Appearance and odor: Colorless liquid with a sweet aromatic odor at low concentrations. Sharp, penetrating, and disagreeable odor at higher concentrations.

PERMISSIBLE EXPOSURE LIMIT (PEL)

The current OSHA standard for styrene is 100 parts of styrene per million parts of air (ppm) averaged over an eight-hour work shift, with a ceiling level of 200 ppm and an acceptable peak of 600 ppm for 5 minutes in any three-hour period. The American Conference of Governmental Industrial Hygienists has issued a Notice of Intended Changes of its recommended Threshold Limit Value for styrene from 100 ppm to 50 ppm.

HEALTH HAZARD INFORMATION

- **Routes of exposure**

Styrene can affect the body if it is inhaled, is swallowed, or comes in contact with the eyes or skin.

- **Effects of overexposure**

1. Short-term Exposure: Styrene may irritate the eyes, nose, throat, and skin. High concentrations may cause a person to become sleepy or to become unconscious.
2. Long-term Exposure: Repeated skin contact with styrene may produce a skin rash.
3. Reporting Signs and Symptoms: A physician should be contacted if anyone develops any signs or symptoms and suspects that they are caused by exposure to styrene

- **Recommended medical surveillance**

The following medical procedures should be made available to each employee who is exposed to styrene at potentially hazardous levels:
1. Initial Medical Screening: Employees should be screened for history of certain medical conditions (listed below) which might place the employee at increased risk from styrene exposure.

—Central nervous system disorders: Since exposure to styrene vapor or liquid on the skin has been observed to result in central nervous system depression and occasional abnormalities in the electroencephalogram, persons with pre-existing disorders may be unusually susceptible to these effects.

—Chronic respiratory disease: In persons with impaired pulmonary function, especially those with obstructive airway diseases, the breathing of styrene might cause exacerbation of symptoms due to its irritant properties or psychic reflex bronchospasm.

—Skin disease: Styrene is a defatting agent and can cause dermatitis on prolonged exposure. Persons with pre-existing skin disorders may be more susceptible to the effects of this agent.

—Kidney disease: Although styrene is not known as a kidney toxin in humans, the importance of this organ in the elimination of toxic substances justifies special consideration in those with possible impairment of renal function.

—Liver disease: Although styrene is not known as a liver toxin in humans, the importance of this organ in the biotransformation and detoxification of foreign substances should be considered before exposing persons with impaired liver function.

2. Periodic Medical Examination: Any employee developing the above-listed conditions should be referred for further medical examination.

- **Summary of toxicology**

Exposure to concentrations of styrene above 200 ppm

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causes irritation of the eyes and upper respiratory tract. There is cracking and inflammation of the skin due to defatting. Higher exposures depress the central nervous system. Electroencephalographic changes have been reported. Styrene is excreted fairly rapidly in the urine, largely as hippuric acid.

CHEMICAL AND PHYSICAL PROPERTIES

- **Physical data**
  1. Molecular weight: 104
  2. Boiling point (760 mm Hg): 145 C (293 F)
  3. Specific gravity (water = 1): 0.90
  4. Vapor density (air = 1 at boiling point of styrene): 3.6
  5. Melting point: −30.6 C (−23 F)
  6. Vapor pressure at 20 C (68 F): 4.5 mm Hg
  7. Solubility in water, g/100 g water at 20 C (68 F): 0.03
  8. Evaporation rate (butyl acetate = 1): 0.49
- **Reactivity**

1. Conditions contributing to instability: Styrene is stabilized by a polymerization inhibitor (often tert-butylcatechol). If this is not present in adequate concentrations, styrene can polymerize and explode its container. The polymerization is also speeded up by temperatures above 66 C (150 F).

2. Incompatibilities: Avoid contact with oxidizing agents and catalysts for vinyl polymerization, such as peroxides, strong acids, and aluminum chloride.

3. Hazardous decomposition products: Toxic gases and vapors (such as carbon monoxide) may be released in a fire involving styrene. Styrene fumes are very acrid.

4. Special precautions: Styrene will corrode copper and copper alloys and dissolve rubber.

- **Flammability**
  1. Flash point: 32 C (90 F) (closed cup)
  2. Autoignition temperature: 490 C (914 F)
  3. Flammable limits in air, % by volume: Lower: 1.1; Upper: 6.1
  4. Extinguishant: Dry cemical, foam, or carbon dioxide
- **Warning properties**

1. Odor Threshold: May reports that the odor threshold of styrene is 0.08 ppm.

2. Eye Irritation Level: The AIHA *Hygienic Guide* reports that "styrene vapor at concentrations of 200 to 400 ppm was found to have transient irritant effects on the eyes."

4. Evaluation of Warning Properties: Since the odor threshold of styrene is below the permissible exposure limit, it is treated as a material with adequate warning properties.

MONITORING AND MEASUREMENT PROCEDURES

- **Eight-Hour Exposure Evaluation**

Measurements to determine employee exposure are best taken so that the average eight-hour exposure is based on a single eight-hour sample or on two four-hour samples. Several short-time interval samples (up to 30 minutes) may also be used to determine the average exposure level. Air samples should be taken in the employee's breathing zone (air that would most nearly represent that inhaled by the employee).

- **Ceiling Evaluation**

Measurements to determine employee ceiling exposure are best taken during periods of maximum expected airborne concentrations of styrene. Each measurement should consist of a fifteen (15) minute sample or series of consecutive samples totalling fifteen (15) minutes in the employee's breathing zone (air that would most nearly represent that inhaled by the employee). A minimum of three (3) measurements should be taken on one work shift and the highest of all measurements taken is an estimate of the employee's exposure.

- **Peak Above Ceiling Evaluation**

Measurements to determine employee peak exposure should be taken during periods of maximum expected airborne concentration of styrene. Each measurement should consist of a 30-minute sample or a series of consecutive samples totalling 30 minutes in the employee's breathing zone (air that would most nearly represent that inhaled by the employee). A minimum of three measurements should be taken on one work shift and the highest of all measurements taken is an estimate of the employee's exposure.

- **Method**

Sampling and analyses may be performed by collection of styrene vapors using an adsorption tube with subsequent desorption with carbon disulfide and gas chromatographic analysis. Also, detector tubes certified by NIOSH under 42 CFR Part 84 or other direct-reading devices calibrated to measure styrene may be used. An analytical method for styrene is in the *NIOSH Manual of Analytical Methods*, 2nd Ed., Vol. 2, 1977, available from the Government Printing Office, Washington, D.C. 20402 (GPO No. 017-033-00260-6).

RESPIRATORS

• Good industrial hygiene practices recommend that engineering controls be used to reduce environmental concentrations to the permissible exposure level. However, there are some exceptions where respirators may be used to control exposure. Respirators may be used when engineering and work practice controls are not technically feasible, when such controls are in the process of being installed, or when they fail and need to be supplemented. Respirators may also be used for operations which require entry into tanks or closed vessels, and in emergency situations. If the use of respirators is necessary, the only respirators permitted are those that have been approved by the Mine Safety and Health Administration (formerly Mining Enforcement and Safety Administration) or by the National

Institute for Occupational Safety and Health.

• In addition to respirator selection, a complete respiratory protection program should be instituted which includes regular training, maintenance, inspection, cleaning, and evaluation.

PERSONAL PROTECTIVE EQUIPMENT

• Employees should be provided with and required to use impervious clothing, gloves, face shields (eight-inch minimum), and other appropriate protective clothing necessary to prevent repeated or prolonged skin contact with liquid styrene.

• Clothing wet with liquid styrene should be placed in closed containers for storage until it can be discarded or until provision is made for the removal of styrene from the clothing. If the clothing is to be laundered or otherwise cleaned to remove the styrene, the person performing the operation should be informed of styrene's hazardous properties.

• Non-impervious clothing which becomes contaminated with liquid styrene should be removed promptly and not reworn until the styrene is removed from the clothing.

• Any clothing which becomes wet with liquid styrene should be removed immediately and not reworn until the styrene is removed from the clothing.

• Employees should be provided with and required to use splash-proof safety goggles where liquid styrene may contact the eyes.

SANITATION

• Skin that becomes contaminated with liquid styrene should be promptly washed or showered with soap or mild detergent and water to remove any styrene.

COMMON OPERATIONS AND CONTROLS

The following list includes some common operations in which exposure to styrene may occur and control methods which may be effective in each case:

Operation	Controls
Liberation during spray-up manufacture of glass fiber, reinforced styrene-polyester articles	Local exhaust ventilation; general dilution ventilation; personal protective equipment
Use during spray application of styrene polyester surface coatings	Process enclosure; local exhaust ventilation; personal protective equipment
Use during hand lay-up of glass fibers, reinforced styrene-polyester articles	Local exhaust ventilation; general dilution ventilation; personal protective equipment
Use during molding of articles or potting electrical components with polystyrene	Local exhaust ventilation; general dilution ventilation; personal protective equipment
Use during manufacture of tires and other rubber goods using styrene-butadiene elastomers (SBR)	General dilution ventilation
Use in manufacture of concretes	General dilution ventilation; personal protective equipment
Use during bag lay-up manufacture of glass fiber, reinforced styrene-polyester articles; during use of surface coatings containing styrene-butadiene copolymer resins	Local exhaust ventilation; general dilution ventilation; personal protective equipment
Liberation during die molding of articles made from styrene-polyester resins; during brush application of surface coatings	Local exhaust ventilation; general dilution ventilation; personal protective equipment
Use in process operations for production of polystyrene, acrylonitrile-butadiene styrene (ABS), styrene-acrylonitrile (SAN), and styrene-butadiene copolymers	Local exhaust ventilation; personal protective equipment
Use in manufacture of surface coatings; use in miscellaneous processes as an elastomer, intermediate, or starting material; use during manufacture of ion-exchange resins (styrene-divinylbenzene copolymer)	Local exhaust ventilation; personal protective equipment

EMERGENCY FIRST AID PROCEDURES

In the event of an emergency, institute first aid procedures and send for first aid or medical assistance.

• **Eye Exposure**

If styrene gets into the eyes, wash eyes immediately with large amounts of water, lifting the lower and upper lids occasionally. Get medical attention as soon as possible. Contact lenses should not be worn when working with this chemical.

• **Skin Exposure**

If styrene gets on the skin, promptly flush the contaminated skin with water. If styrene soaks through the clothing, remove the clothing immediately and flush the skin with water. When there is skin irritation, get medical attention.

• **Breathing**

If a person breathes in large amounts of styrene, move the exposed person to fresh air at once. If breathing has stopped, perform artificial respiration. Keep the affected person warm and at rest. Get medical attention as soon as possible.

• **Swallowing**

If styrene has been swallowed, do not induce vomiting. Get medical attention immediately.

• **Rescue**

Move the affected person from the hazardous exposure. If the exposed person has been overcome, notify someone else and put into effect the established emergency rescue procedures. Do not become a casualty. Understand the facility's emergency rescue procedures and know the locations of rescue equipment before the need arises.

SPILL, LEAK, AND DISPOSAL PROCEDURES

• Persons not wearing protective equipment and clothing should be restricted from areas of spills or leaks until cleanup has been completed.

• If styrene is spilled or leaked, the following steps should be taken:

1. Remove all ignition sources.
2. Ventilate area of spill or leak.
3. For small quantities, absorb on paper towels. Evaporate in a safe place (such as a fume hood). Allow sufficient time for evaporating vapors to completely clear the hood ductwork. Burn the paper in a suitable location away from combustible materials. Large quantities can be collected and atomized in a suitable combustion chamber. Combustion may be improved by mixing with a more flammable liquid.

• Waste disposal methods:

Styrene may be disposed of:

1. By absorbing it in vermiculite, dry sand, earth or a similar material and disposing in a secured sanitary landfill.
2. By atomizing in a suitable combustion chamber. Combustion may be improved by mixing with a more flammable liquid.

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RESPIRATORY PROTECTION FOR STYRENE

Condition	Minimum Respiratory Protection* Required Above 100 ppm
Vapor Concentration	
400 ppm or less	Any chemical cartridge respirator with an organic vapor cartridge(s).**
	Any supplied-air respirator.**
	Any self-contained breathing apparatus.**
1000 ppm or less	A chemical cartridge respirator with a full facepiece and an organic vapor cartridge(s).
5000 ppm or less	A gas mask with a chin-style or a front- or back-mounted organic vapor canister.
	Any supplied-air respirator with a full facepiece, helmet, or hood.
	Any self-contained breathing apparatus with a full facepiece.
Greater than 5000 ppm or entry and escape from unknown concentrations	Self-contained breathing apparatus with a full facepiece operated in pressure-demand or other positive pressure mode.
	A combination respirator which includes a Type C supplied-air respirator with a full facepiece operated in pressure-demand or other positive pressure or continuous-flow mode and an auxiliary self-contained breathing apparatus operated in pressure-demand or other positive pressure mode.
Fire Fighting	Self-contained breathing apparatus with a full facepiece operated in pressure-demand or other positive pressure mode.
Escape	Any gas mask providing protection against organic vapors.
	Any escape self-contained breathing apparatus.

*Only NIOSH-approved or MSHA-approved equipment should be used.

**If eye irritation occurs, full-facepiece respiratory protective equipment should be used.

Occupational Health Guideline for Toluene

INTRODUCTION

This guideline is intended as a source of information for employees, employers, physicians, industrial hygienists, and other occupational health professionals who may have a need for such information. It does not attempt to present all data; rather, it presents pertinent information and data in summary form.

SUBSTANCE IDENTIFICATION

- Formula: $C_6H_5CH_3$
- Synonyms: Toluol; phenylmethane; methylbenzene
- Appearance and odor: Colorless liquid with an aromatic odor, like benzene.

PERMISSIBLE EXPOSURE LIMIT (PEL)

The current OSHA standard for toluene is 200 parts of toluene per million parts of air (ppm) averaged over an eight-hour work shift, and during any such work shift, 300 ppm toluene may not be exceeded except that a peak of 500 ppm toluene is permitted for 10 minutes during the eight-hour work shift. NIOSH has recommended that the permissible exposure limit be reduced to 100 ppm toluene averaged over an eight-hour work shift with a ceiling level of 200 ppm averaged over a ten-minute period. The NIOSH Criteria Document for Toluene should be consulted for more detailed information.

HEALTH HAZARD INFORMATION

- **Routes of exposure**

Toluene can affect the body if it is inhaled, if it comes in contact with the eyes or skin, or if it is swallowed. It may enter the body through the skin.

- **Effects of overexposure**

1. Short-term Exposure: Toluene may cause irritation of the eyes, respiratory tract, and skin. It may also cause fatigue, weakness, confusion, headache, dizziness, and drowsiness. Peculiar skin sensation may be produced such as a "pins and needles feeling" or numbness. Very high concentrations may cause unconsciousness and death. The liquid splashed in the eye may cause irritation and temporary damage. Inhalation may also cause difficulty in seeing in bright light. If liquid toluene is splashed in the eyes, it will cause temporary irritation.

2. Long-term Exposure: Repeated or prolonged exposure to liquid toluene may cause drying and cracking of the skin.

3. Reporting Signs and Symptoms: A physician should be contacted if anyone develops any signs or symptoms and suspects that they are caused by exposure to toluene.

- **Recommended medical surveillance**

The following medical procedures should be made available to each employee who is exposed to toluene at potentially hazardous levels:

1. Initial Medical Examination:

—A complete history and physical examination: The purpose is to detect pre-existing conditions that might place the exposed employee at increased risk, and to establish a baseline for future health monitoring. Examination of the central nervous system, liver and kidneys should be stressed. The skin should be examined for evidence of chronic disorders.

—Urinalysis: Since proper kidney function is necessary for biologic monitoring, a urinalysis should be obtained to include at a minimum specific gravity, albumin, glucose, and a microscopic on centrifuged sediment. The urine should be analyzed for hippuric acid to obtain a background level.

2. Periodic Medical Examination: The aforementioned medical examinations should be repeated on an annual basis. Hippuric acid level in urine may be an indicator of the level of toluene exposure.

- **Summary of toxicology**

Toluene vapor causes narcosis. Controlled exposure of human subjects to 200 ppm for 8 hours produced mild fatigue, weakness, confusion, lacrimation, and paresthesia; at 600 ppm for 8 hours there were also euphoria, headache, dizziness, dilated pupils and nausea; at 800

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ppm for 8 hours, symptoms were more pronounced, and after-effects included nervousness, muscular fatigue, and insomnia persisting for several days. Severe but reversible liver and kidney injury occurred in a person who was a glue-sniffer for 3 years; the chief component of the inhaled solvent was toluene (80% V/V); other ingredients were not listed. In workers exposed for many years to concentrations in the range of 80 to 300 ppm, there was no clinical or laboratory evidence of altered liver function. Toluene exposure does not result in the hematopoietic effects caused by benzene; the myelotoxic effects previously attributed to toluene are judged by more recent investigations to be the result of concurrent exposure to benzene present as a contaminant in the commercial toluene used. Most of the toluene absorbed from inhalation is metabolized to benzoic acid, conjugated with glycine in the liver to form hippuric acid, and excreted in the urine; the average amount of hippuric acid excreted in the urine by individuals not exposed to toluene is approximately 0.7 to 1.0 g/l of urine. The liquid splashed in the eyes of two workers caused transient corneal damage and conjunctival irritation; complete recovery occurred within 48 hours. Repeated or prolonged skin contact with liquid toluene has a defatting action, causing drying, fissuring, and dermatitis.

CHEMICAL AND PHYSICAL PROPERTIES

- **Physical data**
  1. Molecular weight: 92.1
  2. Boiling point (760 mm Hg): 111 C (231 F)
  3. Specific gravity (water = 1): 0.86
  4. Vapor density (air = 1 at boiling point of toluene): 3.14
  5. Melting point: −95 C (−139 F)
  6. Vapor pressure at 20 C (68 F): 22 mm Hg
  7. Solubility in water, g/100 g water at 20 C (68 F): 0.05
  8. Evaporation rate (butyl acetate = 1): 2.24
- **Reactivity**
  1. Conditions contributing to instability: Containers may burst at elevated temperatures.
  2. Incompatibilities: Contact with strong oxidizers may cause fires and explosions.
  3. Hazardous decomposition products: Toxic gases and vapors (such as carbon dioxide and carbon monoxide) may be released in a fire involving toluene.
  4. Special precautions: Toluene will attack some forms of plastics, rubber, and coatings.
- **Flammability**
  1. Flash point: 4 C (40 F) (closed cup)
  2. Autoignition temperature: 480 C (896 F)
  3. Flammable limits in air, % by volume: Lower: 1.27; Upper: 7.1
  4. Extinguishant: Carbon dioxide, dry chemical, foam
- **Warning properties**
  1. Odor Threshold: The American National Standards Institute (ANSI) states that "the odor of toluene is detectable by most people at concentrations in the range of 10 to 15 ppm. The odor has little value as a warning property."

  Patty points out that olfactory fatigue occurs rapidly upon exposure to toluene.

  2. Eye Irritation Level: Grant states that "the vapors of toluene cause noticeable sensation of irritation to human eyes at 300 to 400 ppm in air, but even at 800 ppm irritation is slight."

  ANSI reports that "irritation of eyes, mucous membranes, and upper respiratory tract may occur while workers are exposed to low concentrations of toluene. There is a considerable range of variation (100 to 500 ppm) between individuals, some finding any concentration of toluene objectionable. Commercial grades of toluene vary in irritant properties."

  3. Evaluation of Warning Properties: Because of its irritant effects, toluene is judged to have good warning properties.

MONITORING AND MEASUREMENT PROCEDURES

- **Eight-Hour Exposure Evaluation**

Measurements to determine employee exposure are best taken so that the average eight-hour exposure is based on a single eight-hour sample or on two four-hour samples. Several short-time interval samples (up to 30 minutes) may also be used to determine the average exposure level. Air samples should be taken in the employee's breathing zone (air that would most nearly represent that inhaled by the employee).

- **Ceiling Evaluation**

Measurements to determine employee ceiling exposure are best taken during periods of maximum expected airborne concentrations of toluene. Each measurement should consist of a ten (10) minute sample or series of consecutive samples totalling ten (10) minutes in the employee's breathing zone (air that would most nearly represent that inhaled by the employee). A minimum of three (3) measurements should be taken on one work shift and the highest of all measurements taken is an estimate of the employee's exposure.

- **Peak Above Ceiling Evaluation**

Measurements to determine employee peak exposure should be taken during periods of maximum expected airborne concentration of toluene. Each measurement should consist of a 10-minute sample or a series of consecutive samples totalling 10 minutes in the employee's breathing zone (air that would most nearly represent that inhaled by the employee). A minimum of three measurements should be taken on one work shift and the highest of all measurements taken is an estimate of the employee's exposure.

- **Method**

Sampling and analyses may be performed by collection of vapors using an adsorption tube with a subsequent desorption of toluene with carbon disulfide and gas

chromatographic analysis. Also, detector tubes certified by NIOSH under 42 CFR Part 84 or other direct-reading devices calibrated to measure toluene may be used. An analytical method for toluene is in the *NIOSH Manual of Analytical Methods*, 2nd Ed., Vol. 3, 1977, available from the Government Printing Office, Washington, D.C. 20402 (GPO No. 017-033-00261-4).

Methods for Set V" (order number PB 262 524).

RESPIRATORS

- Good industrial hygiene practices recommend that engineering controls be used to reduce environmental concentrations to the permissible exposure level. However, there are some exceptions where respirators may be used to control exposure. Respirators may be used when engineering and work practice controls are not technically feasible, when such controls are in the process of being installed, or when they fail and need to be supplemented. Respirators may also be used for operations which require entry into tanks or closed vessels, and in emergency situations. If the use of respirators is necessary, the only respirators permitted are those that have been approved by the Mine Safety and Health Administration (formerly Mining Enforcement and Safety Administration) or by the National Institute for Occupational Safety and Health.
- In addition to respirator selection, a complete respiratory protection program should be instituted which includes regular training, maintenance, inspection, cleaning, and evaluation.

PERSONAL PROTECTIVE EQUIPMENT

- Employees should be provided with and required to use impervious clothing, gloves, face shields (eight-inch minimum), and other appropriate protective clothing necessary to prevent repeated or prolonged skin contact with liquid toluene.
- Any clothing which becomes wet with liquid toluene should be removed immediately and not reworn until the toluene is removed from the clothing.
- Clothing wet with toluene should be placed in closed containers for storage until it can be discarded or until provision is made for the removal of toluene from the clothing. If the clothing is to be laundered or otherwise cleaned to remove the toluene, the person performing the operation should be informed of toluene's hazardous properties.
- Employees should be provided with and required to use splash-proof safety goggles where liquid toluene may contact the eyes.
- Where there is any possibility that employees' eyes may be exposed to toluene, an eye-wash fountain should be provided within the immediate work area for emergency use.

SANITATION

- Skin that becomes wet with liquid toluene should be promptly washed or showered with soap or mild detergent and water to remove any toluene.
- Employees who handle liquid toluene should wash their hands thoroughly with soap or mild detergent and water before eating or smoking.

COMMON OPERATIONS AND CONTROLS

The following list includes some common operations in which exposure to toluene may occur and control methods which may be effective in each case:

Operation	Controls
Use as a solvent in pharmaceutical, chemical, rubber, and plastics industries; as a thinner for paints, lacquer, coatings, and dyes; as a paint remover; insecticides	Process enclosure; general dilution ventilation; local exhaust ventilation; personal protective equipment
Use as starting material and intermediate in organic chemical and chemical synthesis industries	Process enclosure; general dilution ventilation; local exhaust ventilation; personal protective equipment
Use in manufacture of artificial leather; fabric and paper coatings; photogravure ink production; spray surface coating; as a diluent (cellulose ester lacquers)	Process enclosure; general dilution ventilation; local exhaust ventilation; personal protective equipment
Use as constituent in formulation of automotive and aviation fuels	Process enclosure; general dilution ventilation; local exhaust ventilation; personal protective equipment

EMERGENCY FIRST AID PROCEDURES

In the event of an emergency, institute first aid procedures and send for first aid or medical assistance.

- **Eye Exposure**

If liquid toluene gets into the eyes, wash eyes immediately with large amounts of water, lifting the lower and upper lids occasionally. If irritation is present after washing, get medical attention. Contact lenses should not be worn when working with this chemical.

- **Skin Exposure**

If liquid toluene gets on the skin, promptly wash the contaminated skin using soap or mild detergent and

water. If liquid toluene soaks through the clothing, remove the clothing immediately and wash the skin using soap or mild detergent and water. If irritation persists after washing, get medical attention.

• **Breathing**

If a person breathes in large amounts of toluene, move the exposed person to fresh air at once. If breathing has stopped, perform artificial respiration. Keep the affected person warm and at rest. Get medical attention as soon as possible.

• **Swallowing**

When toluene has been swallowed, get medical attention immediately. Do not attempt to make the exposed person vomit.

• **Rescue**

Move the affected person from the hazardous exposure. If the exposed person has been overcome, notify someone else and put into effect the established emergency rescue procedures. Do not become a casualty. Understand the facility's emergency rescue procedures and know the locations of rescue equipment before the need arises.

SPILL, LEAK, AND DISPOSAL PROCEDURES

• Persons not wearing protective equipment and clothing should be restricted from areas of spills or leaks until cleanup has been completed.

• If toluene is spilled or leaked, the following steps should be taken:

1. Remove all ignition sources.
2. Ventilate area of spill or leak.
3. For small quantities, absorb on paper towels. Evaporate in a safe place (such as a fume hood). Allow sufficient time for evaporating vapors to completely clear the hood ductwork. Burn the paper in a suitable location away from combustible materials. Large quantities can be reclaimed or collected and atomized in a suitable combustion chamber. Toluene should not be allowed to enter a confined space, such as a sewer, because of the possibility of an explosion. Sewers designed to preclude the formation of explosive concentrations of toluene vapors are permitted.

• Waste disposal method:

Toluene may be disposed of by atomizing in a suitable combustion chamber.

ADDITIONAL INFORMATION

To find additional information on toluene, look up toluene in the following documents:

• Medical Surveillance for Chemical Hazards
• Respiratory Protection for Chemical Hazards
• Personal Protection and Sanitation for Chemical Hazards
• NIOSH Criteria Document for Toluene (July 1973)

These documents are available through the NIOSH Division of Technical Services, 4676 Columbia Parkway, Cincinnati, Ohio 45226.

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RESPIRATORY PROTECTION FOR TOLUENE

Condition	Minimum Respiratory Protection* Required Above 200 ppm
Vapor Concentration	
500 ppm or less	Any chemical cartridge respirator with an organic vapor cartridge(s). Any supplied-air respirator. Any self-contained breathing apparatus.
1000 ppm or less	A chemical cartridge respirator with a full facepiece and an organic vapor cartridge(s).
2000 ppm or less	A gas mask with a chin-style or a front- or back-mounted organic vapor canister. Any supplied-air respirator with a full facepiece, helmet, or hood. Any self-contained breathing apparatus with a full facepiece.
Greater than 2000 ppm or entry and escape from unknown concentrations	Self-contained breathing apparatus with a full facepiece operated in pressure-demand or other positive pressure mode. A combination respirator which includes a Type C supplied-air respirator with a full facepiece operated in pressure-demand or other positive pressure or continuous-flow mode and an auxiliary self-contained breathing apparatus operated in pressure-demand or other positive pressure mode.
Fire Fighting	Self-contained breathing apparatus with a full facepiece operated in pressure-demand or other positive pressure mode.
Escape	Any gas mask providing protection against organic vapors. Any escape self-contained breathing apparatus.

*Only NIOSH-approved or MSHA-approved equipment should be used.

1. PUBLIC HEALTH STATEMENT

1.1 WHAT IS VINYL CHLORIDE?

Vinyl chloride is a colorless gas with a mild, sweet odor. Most of the vinyl chloride produced in the United States is used to make polyvinyl chloride (PVC), a material used to manufacture a variety of plastic and vinyl products including pipes, wire and cable coatings, packaging materials, furniture and automobile upholstery, wall coverings, housewares, and automotive parts. Much smaller amounts of vinyl chloride are used as a refrigerant gas and in the manufacture of other chlorinated compounds. The major sources of release of vinyl chloride to the environment are atmospheric emissions and wastewater discharges from the plastics industries (primarily vinyl chloride and PVC manufacturers). Most of the vinyl chloride released to the environment eventually ends up in air.

1.2 HOW MIGHT I BE EXPOSED TO VINYL CHLORIDE?

Humans are exposed to vinyl chloride from environmental and occupational sources. The low levels of vinyl chloride found in the environment (often called background levels) are usually more than a thousand times lower than levels found in occupational locations. Background levels in the environment are usually expressed in terms of parts of vinyl chloride present in a billion parts of air or water (ppb). Background levels found in the air we breathe result from the discharge of exhaust gasses from factories that manufacture or process vinyl chloride, or evaporation from areas where chemical wastes are stored. Highest background levels have been measured in air near vinyl chloride factories or over chemical waste storage areas. Air inside new cars may contain levels of vinyl chloride higher than expected background levels, because vinyl chloride may seep into the air from the new plastic parts.

Background levels in drinking water come from factories that release wastes into rivers and lakes, from seepage into water in areas where chemical wastes are stored, or from contact with polyvinyl chloride pipes. In the past, concentrations exceeding expected background levels were present in foods packaged in plastic that contained vinyl chloride.

Occupational sources, such as what might be experienced in vinyl chloride manufacturing or processing factories, may result in exposure to levels in the air much higher than those from environmental sources. Levels in the air in occupational locations are usually expressed in terms of parts of vinyl chloride per million parts of air (ppm).

1.3 HOW DOES VINYL CHLORIDE GET INTO MY BODY?

The most likely route for vinyl chloride to enter the body is by breathing contaminated air containing the vapor. This route of exposure may be important for persons employed in vinyl chloride manufacturing or processing, but may also be of concern for those living in a community where vinyl chloride plants are located, or those living near hazardous waste disposal sites. Vinyl chloride can also enter the body by eating food or drinking water containing the compound. Insignificant amounts of vinyl chloride can enter foods that are packaged in plastic made from polyvinyl chloride and insignificant amounts can enter drinking water transported in polyvinyl chloride pipes. In addition, vinyl chloride may be present in drinking water contaminated with hazardous waste. Levels of vinyl chloride present in drinking water and packaged foods and beverages are far below those expected to have an effect on health. Absorption of vinyl chloride through the skin is not likely to be important.

1.4 HOW CAN VINYL CHLORIDE AFFECT MY HEALTH?

Short-term exposures to very high levels in contaminated air can cause dizziness, giddiness, stumbling and incoordination, headache, unconsciousness, and death. Long-term exposure to lower concentrations, for example, in factories where vinyl chloride was made or processed, has caused "vinyl chloride disease," which is characterized by severe damage to the liver, effects on the lungs, poor circulation in the fingers, changes in the bones at the end of the fingers, thickening of the skin, and changes in the blood. Increased risk of cancer of the liver, brain, lungs, and possibly other organs, and increased risk of miscarriage have been associated with breathing air in factories containing vinyl chloride.

Health effects have not been associated with the very low levels of vinyl chloride measured in drinking water or foods.

1.5 IS THERE A MEDICAL TEST TO DETERMINE WHETHER I HAVE BEEN EXPOSED TO VINYL CHLORIDE?

Vinyl chloride can be detected in urine and body tissues, but the tests are not a reliable indicator of exposure. Measuring the amount of the predominant breakdown product of vinyl chloride in the urine may give some indication of recent exposure; however, people differ in the quantity of excretion of this breakdown product. This method, therefore, is not a reliable indicator of either the level or the duration of exposure, particularly at low exposure levels. The laboratory tests commonly used by doctors to evaluate liver damage and liver function generally are not reliable for monitoring liver damage from vinyl chloride exposure.

1.6 WHAT LEVELS OF EXPOSURE HAVE RESULTED IN HARMFUL HEALTH EFFECTS?

The graphs on the following pages show the relationship between exposure to vinyl chloride and known health effects. In the first set of graphs labeled "Health effects from breathing vinyl chloride" (Fig. 1.1), exposure is expressed in parts of vinyl chloride per million parts

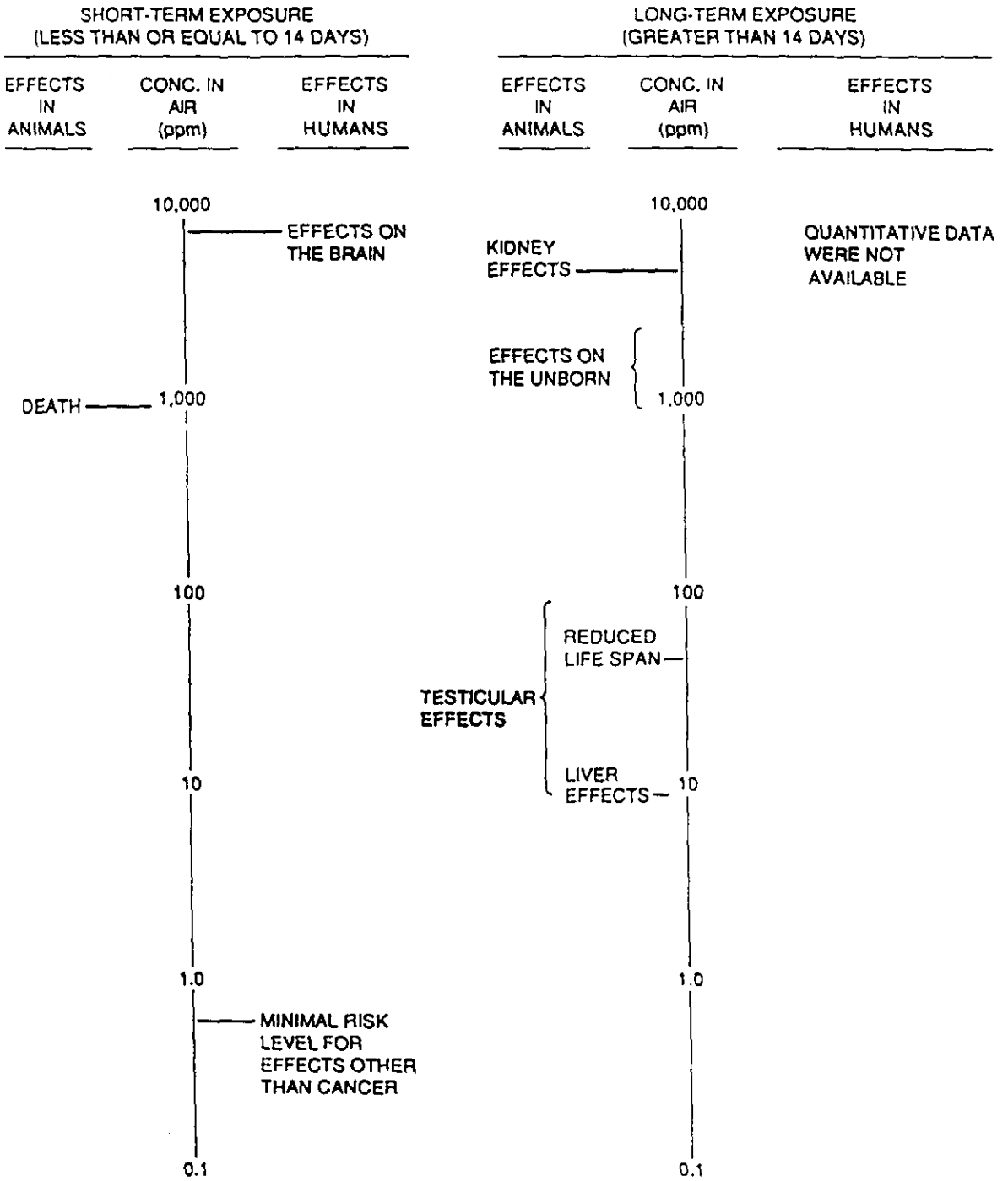


Fig. 1.1. Health effects from breathing vinyl chloride.

of air (ppm). In the second set of graphs, the same relationship is shown for the known "Health effects from ingesting vinyl chloride" (Fig. 1.2). Exposures are expressed in milligrams of vinyl chloride per kilogram of body weight per day (mg/kg/day). In both graphs, effects in animals are shown on the left, effects in humans on the right.

The first column, labeled "Short-term exposure," refers to effects associated with exposure durations of 14 days or less. The column labeled "Long-term exposure" refers to exposures lasting longer than 14 days. The levels marked on the graphs as "Minimal risk for effects other than cancer" are estimates based on data obtained from laboratory animals, and hence are subject to the uncertainties involved in using animal data to predict effects in humans. This data extrapolation is necessary, however, because quantitative exposure data were not available for humans.

1.6.1 Toxic Effects Other Than Cancer

For breathing vinyl chloride, animal data were sufficient to estimate that short-term exposure to 0.7 ppm would result in minimal risk from effects other than cancer. The data did not provide sufficient information to estimate with confidence a level that would be safe for long-term exposure.

For ingesting vinyl chloride, minimal risk of effects other than cancer is expected for lifetime "doses" of 0.0013 mg/kg/day, based on data from laboratory animals.

1.6.2 Cancer

From available data in animals, the Environmental Protection Agency (EPA) has estimated that breathing air containing 1 ppm vinyl chloride every day, all day, for 70 years, increases, at the most, risk of 1100 persons in a population of 10,000 (or 1,100,000 persons in a population of 10,000,000) developing cancer. Consuming 1.0 μg/kg/day vinyl chloride from food and water every day for 70 years increases, at the most, risk of 23 persons in a population of 10,000 (or 23,000 persons in a population of 10,000,000) developing cancer. It should be noted that these risk values are plausible upper-limit estimates. Actual risk levels are unlikely to be higher and may be lower.

1.7 WHAT RECOMMENDATIONS HAS THE FEDERAL GOVERNMENT MADE TO PROTECT HUMAN HEALTH?

The Occupational Safety and Health Administration (OSHA) regulations state that a worker must not be exposed to a concentration of vinyl chloride in air that exceeds 1 ppm over any 8-hour work period, and that the concentration must not exceed 5 ppm for more than 15 minutes. The National Institute for Occupational Safety and Health (NIOSH) recommends that workers exposed to any measurable amount of vinyl chloride wear an air-supplied respirator. EPA has determined that factories must limit air emission of vinyl chloride to 10 ppm.

Pursuant to the Safe Drinking Water Act, EPA established that community drinking water systems that regularly serve the same 25 persons for at least 8 months of the year must limit vinyl chloride in

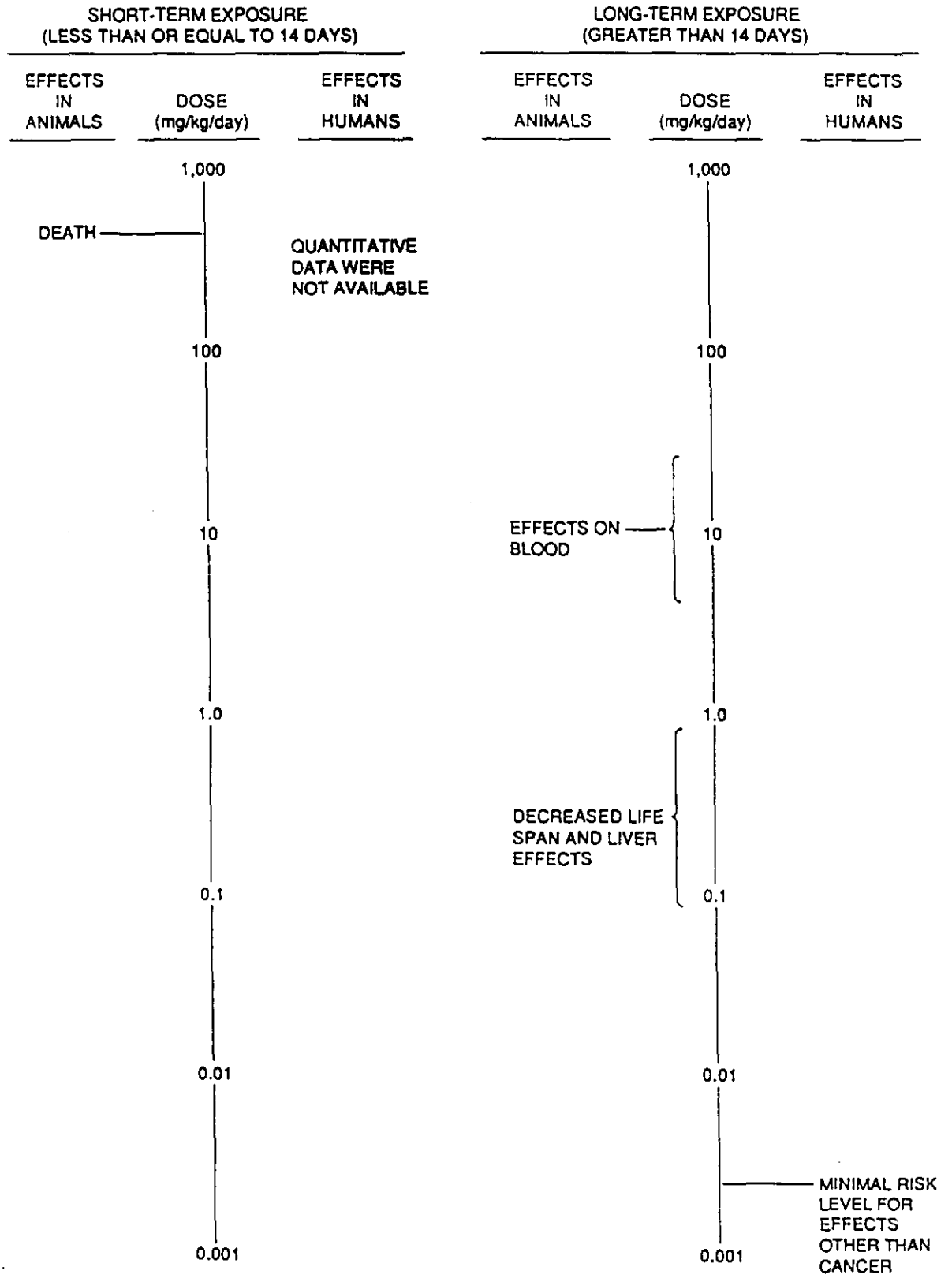


Fig. 1.2. Health effects from ingesting vinyl chloride.

the drinking water to 0.002 mg/L, starting January 9, 1989. In order to limit ingestion of vinyl chloride in food, the Food and Drug Administration (FDA) recently amended its regulations regarding the vinyl chloride content of various plastics used for food packaging. Limits range from 5 to 50 ppm, depending on the nature of the plastic and its use.

In order to exercise control over the handling of vinyl chloride, EPA has designated the chemical as a hazardous constituent of solid waste. If quantities greater than 1 pound are released to the environment, the National Response Center must be notified immediately.

Table 3.1. Chemical identity of vinyl chloride

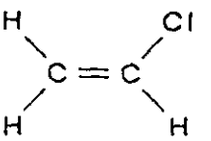
Parameter	Value	References
Chemical name	Chloroethene	SANSS 1987
Synonyms and trade names	Vinyl chloride, chloroethylene, ethylene monochloride, monochloroethylene, VC, VCM, vinyl C monomer	SANSS 1987
Chemical formula	C_2H_3Cl	HSDB 1987
Wiswesser line notation	G1U1	HSDB 1987
Chemical structure		
Identification numbers		
CAS Registry No.	75-01-4	HSDB 1987
NIOSH RTECS No.	KU9625000	HSDB 1987
EPA Hazardous Waste No.	U043	HSDB 1987
OHM-TADS No.	7216947	HSDB 1987
DOT/UN/NA/IMCO Shipping No.	1086	HSDB 1987
STCC No.	49 057 92	HSDB 1987
Hazardous Substances Data Bank No.	169	HSDB 1987
National Cancer Institute No.	None available	

Table 3.2. Physical and chemical properties of vinyl chloride

Property	Value	References
Molecular weight	62.5	Cowfer and Magistro 1983
Color	Colorless	Cowfer and Magistro 1983
Physical state	Gas	Cowfer and Magistro 1983
Odor	Mild, sweet	Verschueren 1983
Odor threshold		
Water	3.4 ppm (w/v)	Amoore and Hautula 1983
Air	3000 ppm (v/v)	Amoore and Hautula 1983
Melting point	−153.8°C	Cowfer and Magistro 1983
Boiling point	−13.4°C	Cowfer and Magistro 1983
Autoignition temperature	472°C	Cowfer and Magistro 1983
Solubility		
Water	2763 mg/L at 25°C	EPA 1985b
	1100 mg/L at 25°C	Cowfer and Magistro 1983
Organic solvents	Soluble in hydrocarbons, oil, alcohol, chlorinated solvents, and most common organic liquids	Cowfer and Magistro 1983
Density, g/cm^3	0.969 (−14.2°C)	Cowfer and Magistro 1983
Vapor density (air = 1)	2.15	Verschueren 1983
Log octanol-water partition coefficients	1.36	EPA 1987b
Vapor pressure	2660 mm Hg at 25°C	Verschueren 1983
Henry's Law constant	1.2 (atm-m^3)/mol at 10°C	EPA 1985b
Refractive index	1.3700 at 20°C	EPA 1985b
Flashpoint	−77.75 (open cup)	Cowfer and Magistro 1983
Flammability limits	4–22 vol %	Cowfer and Magistro 1983
Conversion factors		
ppm (v/v) to mg/m^3 in air	ppm (v/v) = 2.60 mg/m^3	
mg/m^3 to ppm (v/v) in air	mg/m^3 = 0.39 ppm (v/v)	
ppm (w/v) to mg/L in water	ppm (w/v) = mg/L = μg/mL	
ppm (w/w) to mg/kg in solid matrices	ppm (w/w) = mg/kg = μg/g	

Occupational Health Guideline for Xylene

INTRODUCTION

This guideline is intended as a source of information for employees, employers, physicians, industrial hygienists, and other occupational health professionals who may have a need for such information. It does not attempt to present all data; rather, it presents pertinent information and data in summary form.

SUBSTANCE IDENTIFICATION

- Formula: $C_6H_4(CH_3)_2$
- Synonyms: Commercial xylene (xylol) is a mixture, mostly the meta-isomer. 1) O-xylene, ortho-xylene, 1,2-dimethylbenzene; 2) m-xylene, meta-xylene, 1,3-dimethylbenzene; 3) p-xylene, para-xylene, 1,4-dimethylbenzene
- Appearance and odor: Colorless liquids with aromatic odors (pure p-xylene is a solid below 12.7 C (55 F)).

PERMISSIBLE EXPOSURE LIMIT (PEL)

The current OSHA standard for xylene is 100 parts of xylene per million parts of air (ppm) averaged over an eight-hour work shift. This may also be expressed as 435 milligrams of xylene per cubic meter of air (mg/m^3). NIOSH has recommended that the permissible exposure limit be changed to 100 ppm averaged over a work shift of up to ten hours per day, forty hours per week, with an acceptable ceiling level of 200 ppm averaged over a 10-minute period. The NIOSH Criteria Document for Xylene should be consulted for more detailed information.

HEALTH HAZARD INFORMATION

- **Routes of exposure**

Xylene can affect the body if it is inhaled, if it comes in contact with the eyes or skin, or if it is swallowed. It may enter the body through the skin.

- **Effects of overexposure**

1. Short-term Exposure: Xylene vapor may cause irritation of the eyes, nose, and throat. At high concentrations, xylene vapor may cause severe breathing difficulties which may be delayed in onset. At high concentrations, it may also cause dizziness, staggering, drowsiness, and unconsciousness. In addition, breathing high concentrations may cause loss of appetite, nausea, vomiting, and abdominal pain. Liquid xylene may be irritating to the eyes and skin. Exposure to high concentrations of xylene vapor may cause reversible damage to the kidneys and liver.

2. Long-term Exposure: Repeated or prolonged exposure to xylene may cause a skin rash. Repeated exposure of the eyes to high concentrations of xylene vapor may cause reversible eye damage.

3. Reporting Signs and Symptoms: A physician should be contacted if anyone develops any signs or symptoms and suspects that they are caused by exposure to xylene.

- **Recommended medical surveillance**

The following medical procedures should be made available to each employee who is exposed to xylene at potentially hazardous levels:

1. Initial Medical Examination:

—A complete history and physical examination: The purpose is to detect pre-existing conditions that might place the exposed employee at increased risk, and to establish a baseline for future health monitoring. Examination of the central nervous system, eyes, gastrointestinal tract, blood, liver, and kidneys should be stressed. The skin should be examined for evidence of chronic disorders.

—A complete blood count: Xylene has been shown to cause reversible hematopoietic depression in animals. A complete blood count should be performed, including a red cell count, a white cell count, a differential count of a stained smear, as well as hemoglobin and hematocrit.

—Liver function tests: Since liver damage has been observed in humans exposed to xylene, a profile of liver

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These recommendations reflect good industrial hygiene and medical surveillance practices and their implementation will assist in achieving an effective occupational health program. However, they may not be sufficient to achieve compliance with all requirements of OSHA regulations.

U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
Public Health Service Centers for Disease Control
National Institute for Occupational Safety and Health

U.S. DEPARTMENT OF LABOR
Occupational Safety and Health Administration

function should be obtained by using a medically acceptable array of biochemical tests.

—Urinalysis: Since kidney damage has been observed in humans exposed to xylene, a urinalysis should be obtained to include at a minimum specific gravity, albumin, glucose, and a microscopic on centrifuged sediment.

2. Periodic Medical Examination: The aforementioned medical examinations should be repeated on a biannual basis.

• **Summary of toxicology**

Xylene vapor irritates the eyes, mucous membranes, and skin; at high concentrations it causes narcosis. In animals, xylene causes blood changes reflecting mild toxicity to the hematopoietic system. Repeated exposure of rabbits to 1150 ppm of a mixture of isomers of xylene for 40 to 55 days caused a reversible decrease in red and white cell count and an increase in thrombocytes; exposure to 690 ppm for the same time period caused only a slight decrease in the white cell count. Three painters working in a confined space of a fuel tank were overcome by xylene vapors estimated to be 10,000 ppm; they were not found until 18.5 hours after entering the tank, and one died from pulmonary edema shortly thereafter; the other two recovered completely in 2 days; both had temporary hepatic impairment (inferred from elevated serum transaminase levels) and one of them had evidence of temporary renal impairment (increased blood urea and reduced creatinine clearance). In humans, exposure to undetermined but high concentrations caused dizziness, excitement, drowsiness, incoordination and a staggering gait. Workers exposed to concentrations above 200 ppm complain of anorexia, nausea, vomiting, and abdominal pain. Brief exposure of humans to 200 ppm caused irritation of the eyes, nose, and throat. There are reports of reversible corneal vacuolation in workers exposed to xylene, or to xylene plus other volatile solvents. The liquid is a skin irritant and causes erythema, dryness, and defatting; prolonged contact may cause the formation of vesicles.

CHEMICAL AND PHYSICAL PROPERTIES

Data in the following section are presented for xylene's three isomers: 1) ortho, 2) meta, and 3) para.

• **Physical data**

1. Molecular weight: 106.2
2. Boiling point (760 mm Hg): 1) 144.4 C (292 F); 2) 138.9 C (282 F); 3) 138.3 C (281 F)
3. Specific gravity (water = 1): 1) 0.88; 2) 0.86; 3) 0.86
4. Vapor density (air = 1 at boiling point of xylene): 3.7
5. Melting point: 1) −25 C (−12 F); 2) −48 C (−54 F); 3) 13 C (55 F)
6. Vapor pressure at 20 C (68 F): 1) 7 mm Hg; 2) 9 mm Hg; 3) 9 mm Hg
7. Solubility in water, g/100 g water at 20 C (68 F): 1) 0.00003; 2) 0.00003; 3) 0.00003
8. Evaporation rate (butyl acetate = 1): 1) 0.7; 2) 0.7; 3) 0.7

• **Reactivity**

1. Conditions contributing to instability: Elevated temperatures may cause containers to burst.
2. Incompatibilities: Contact with strong oxidizers may cause fires and explosions.
3. Hazardous decomposition products: Toxic gases and vapors (such as carbon monoxide) may be released in a fire involving xylene.
4. Special precautions: Xylene will attack some forms of plastics, rubber, and coatings.

• **Flammability**

1. Flash point: 1) 32 C (90 F) (closed cup); 2) 28.9 C (84 F); 3) 27.2 C (81 F)
2. Autoignition temperature: 1) 465 C (869 F); 2) 530 C (986 F); 3) 530 C (986 F)
3. Flammable limits in air, % by volume: Lower: 1) 1.0; 2) 1.1; 3) 1.1; Upper: 1) 6.0; 2) 7.0; 3) 7.0
4. Extinguishant: Foam, carbon dioxide, dry chemical

• **Warning properties**

1. Odor Threshold: Patty states that "the initial odor of 200 ppm has an intensity of approximately 3 and an irritation value of 1. As in most other instances, olfactory fatigue occurs rapidly and the odor is no longer detected at this concentration."
2. Eye Irritation Level: The AIHA *Hygienic Guide* states that "exposure to vapors at 200 ppm caused eye irritation in most of the persons tested. Lesions in the form of fine vacuoles in the cornea of cats exposed to commercial xylene vapors have been observed."
3. Other Information: The *Handbook of Industrial Organic Chemicals* states that xylene "may be irritating to eyes, nose and throat as exposure exceeds threshold limit." The *Hygienic Guide* notes that 200 ppm causes irritation of the nose and throat.
4. Evaluation of Warning Properties: Through its irritant effects, xylene can be detected within three times the permissible exposure limit. For the purposes of this guideline, therefore, xylene is treated as a material with good warning properties.

MONITORING AND MEASUREMENT PROCEDURES

• **Eight-Hour Exposure Evaluation**

Measurements to determine employee exposure are best taken so that the average eight-hour exposure is based on a single eight-hour sample or on two four-hour samples. Several short-time interval samples (up to 30 minutes) may also be used to determine the average exposure level. Air samples should be taken in the employee's breathing zone (air that would most nearly represent that inhaled by the employee).

• **Ceiling Evaluation**

Measurements to determine employee ceiling exposure are best taken during periods of maximum expected airborne concentrations of xylene. Each measurement

should consist of a ten (10) minute sample or series of consecutive samples totalling ten (10) minutes in the employee's breathing zone (air that would most nearly represent that inhaled by the employee). A minimum of three (3) measurements should be taken on one work shift and the highest of all measurements taken is an estimate of the employee's exposure.

• **Method**

Sampling and analyses may be performed by collection of vapors using an adsorption tube with subsequent desorption with carbon disulfide and gas chromatographic analysis. Also, detector tubes certified by NIOSH under 42 CFR Part 84 or other direct-reading devices calibrated to measure xylene may be used. An analytical method for xylene is in the *NIOSH Manual of Analytical Methods*, 2nd Ed., Vol. 3, 1977, available from the Government Printing Office, Washington, D.C. 20402 (GPO No. 017-033-00261-4).

RESPIRATORS

• Good industrial hygiene practices recommend that engineering controls be used to reduce environmental concentrations to the permissible exposure level. However, there are some exceptions where respirators may be used to control exposure. Respirators may be used when engineering and work practice controls are not technically feasible, when such controls are in the process of being installed, or when they fail and need to be supplemented. Respirators may also be used for operations which require entry into tanks or closed vessels, and in emergency situations. If the use of respirators is necessary, the only respirators permitted are those that have been approved by the Mine Safety and Health Administration (formerly Mining Enforcement and Safety Administration) or by the National Institute for Occupational Safety and Health.

• In addition to respirator selection, a complete respiratory protection program should be instituted which includes regular training, maintenance, inspection, cleaning, and evaluation.

PERSONAL PROTECTIVE EQUIPMENT

• Employees should be provided with and required to use impervious clothing, gloves, face shields (eight-inch minimum), and other appropriate protective clothing necessary to prevent repeated or prolonged skin contact with liquid or solid xylene.

• Clothing contaminated with xylene should be placed in closed containers for storage until it can be discarded or until provision is made for the removal of xylene from the clothing. If the clothing is to be laundered or otherwise cleaned to remove the xylene, the person performing the operation should be informed of xylene's hazardous properties.

• Any clothing which becomes wet with liquid xylene should be removed immediately and non-impervious clothing which becomes contaminated with xylene should be removed promptly and not reworn until the xylene is removed from the clothing.

• Employees should be provided with and required to use splash-proof safety goggles where liquid or solid xylene may contact the eyes.

SANITATION

• Skin that becomes contaminated with xylene should be promptly washed or showered with soap or mild detergent and water to remove any xylene.

• Employees who handle liquid or solid xylene should wash their hands thoroughly with soap or mild detergent and water before eating, smoking, or using toilet facilities.

COMMON OPERATIONS AND CONTROLS

The following list includes some common operations in which exposure to xylene may occur and control methods which may be effective in each case:

Operation	Controls
Use as an intermediate during manufacture of plastics, synthetic fibers, and mixed/pure isomers	Process enclosure; local exhaust ventilation; general mechanical ventilation; personal protective equipment
Use as diluent or solvent in surface coatings, printing operations, and manufacture of rubber; degreasing agent in plastics and electronics manufacture; in organic synthesis reactions and manufacture of epoxy resins	Process enclosure; local exhaust ventilation; general mechanical ventilation; personal protective equipment
Use in formulation of insecticides	Process enclosure; local exhaust ventilation; general mechanical ventilation; personal protective equipment
Use in manufacture of xylene-formaldehyde resins; pharmaceuticals, vitamins, leather; and as a sterilizing agent for cat-gut and in microscopy	Process enclosure; local exhaust ventilation; general mechanical ventilation; personal protective equipment

Operation	Controls
Use during blending of motor and aviation fuels	Process enclosure; local exhaust ventilation; general mechanical ventilation; personal protective equipment

EMERGENCY FIRST AID PROCEDURES

In the event of an emergency, institute first aid procedures and send for first aid or medical assistance.

• **Eye Exposure**

If liquid or solid xylene gets into the eyes, wash eyes immediately with large amounts of water, lifting the lower and upper lids occasionally. Get medical attention immediately. Contact lenses should not be worn when working with this chemical.

• **Skin Exposure**

If liquid or solid xylene gets on the skin, promptly wash the contaminated skin using soap or mild detergent and water. If liquid or solid xylene penetrates through the clothing, remove the clothing immediately and wash the skin using soap or mild detergent and water. If irritation is present after washing, get medical attention.

• **Breathing**

If a person breathes in large amounts of xylene, move the exposed person to fresh air at once. If breathing has stopped, perform artificial respiration. Keep the affected person warm and at rest. Get medical attention as soon as possible.

• **Swallowing**

When xylene has been swallowed, do not induce vomiting. Get medical attention immediately.

• **Rescue**

Move the affected person from the hazardous exposure. If the exposed person has been overcome, notify someone else and put into effect the established emergency rescue procedures. Do not become a casualty. Understand the facility's emergency rescue procedures and know the locations of rescue equipment before the need arises.

SPILL, LEAK, AND DISPOSAL PROCEDURES

• Persons not wearing protective equipment and clothing should be restricted from areas of spills or leaks until cleanup has been completed.

• If xylene is spilled or leaked, the following steps should be taken:

1. Remove all ignition sources.
2. Ventilate area of spill or leak.
3. For small quantities, absorb on paper towels. Evaporate in a safe place (such as a fume hood). Allow sufficient time for evaporating vapors to completely clear the hood ductwork. Burn the paper in a suitable location away from combustible materials. Large quantities can be reclaimed or collected and atomized in a suitable combustion chamber. Xylene should not be allowed to enter a confined space, such as a sewer, because of the possibility of an explosion. Sewers designed to preclude the formation of explosive concentrations of xylene vapors are permitted.
4. If the solid form, allow to melt and treat as in (3) above.

• Waste disposal method:

Xylene may be disposed of by atomizing in a suitable combustion chamber.

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RESPIRATORY PROTECTION FOR XYLENE (XYLOL)

Condition	Minimum Respiratory Protection* Required Above 100 ppm
Vapor Concentration	
1000 ppm or less	A chemical cartridge respirator with a full facepiece and an organic vapor cartridge(s).
5000 ppm or less	A gas mask with a chin-style or a front- or back-mounted organic vapor canister. Any supplied-air respirator with a full facepiece, helmet, or hood. Any self-contained breathing apparatus with a full facepiece.
10,000 ppm or less	A Type C supplied-air respirator with a full facepiece operated in pressure-demand or other positive pressure mode or with a full facepiece, helmet, or hood operated in continuous-flow mode.
Greater than 10,000 ppm or entry and escape from unknown concentrations	Self-contained breathing apparatus with a full facepiece operated in pressure-demand or other positive pressure mode. A combination respirator which includes a Type C supplied-air respirator with a full facepiece operated in pressure-demand or other positive pressure or continuous-flow mode and an auxiliary self-contained breathing apparatus operated in pressure-demand or other positive pressure mode.
Fire Fighting	Self-contained breathing apparatus with a full facepiece operated in pressure-demand or other positive pressure mode.
Escape	Any gas mask providing protection against organic vapors. Any escape self-contained breathing apparatus.

*Only NIOSH-approved or MSHA-approved equipment should be used.

ATTACHMENT III

GOLDER ASSOCIATES RESPIRATORY PROTECTION PLAN

Golder Associates Inc.
CONSULTING ENGINEERS

GOLDER ASSOCIATES INC.

RESPIRATORY PROTECTION PROGRAM

Revision Level 2
June 1990

William L Hager
Corporate Health and Safety Officer

Date: 7-13-90

Daniel A Grutzo
Office Health and Safety Officer

Date: 7-23-90

Richard D Wells
Office Manager

Date: 7-23-90

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1. RESPIRATORY PROTECTION POLICY STATEMENT

The purpose of this policy statement is to establish the existence of a corporate respiratory protection program and to reaffirm the commitment of Golder Associates Inc., to protecting the health of its employees. This program defines the responsibilities of management and employees and specific procedures to implement, administer, and maintain a respiratory protection program. The respiratory protection program has been developed to meet applicable federal safety and health regulations and recommendations including 29 CFR 1910.134, Appendix C to CFR 1910.1001, ANSI (American National Standard Institute) Z88.2-1980, and ANSI Z88.6-1984.

The management of Golder Associates Inc. believes that every employee is entitled to a safe work place. To that end, Golder Associates Inc. endeavors to provide each employee, including those engaged in field activities, with a place of employment free from hazards likely to cause work related illness, injury, or death.

Field operations may present situations in which employees encounter oxygen deficient atmospheres or the presence of potentially harmful airborne contaminants such as gasses, vapors, dusts, mists, sprays, smokes, and/or fumes. Effective engineering controls to limit the exposure to or concentration of hazardous contaminants in field operations may not always be feasible. Consequently, the employee may need to rely on the use of respiratory protective devices to protect his or her health.

Golder Associates Inc. will train the employee in the selection and use of respiratory protective devices. Respirators which are applicable and suitable for the purposes intended will be provided, where such equipment is necessary to protect the health of the employee. In addition, Golder Associates Inc. will provide baseline physicals and follow-up medical surveillance at no expense to the employee.

The employee must use the provided respiratory protection in accordance with the established procedures and training received. It is the responsibility of the employee to guard against damage to the respirator and to immediately inform a designated responsible person of any respirator defects, or any perceived deficiencies in the respiratory protection program in general.

The Corporate Health and Safety Officer shall be responsible for the overall implementation, administration, and evaluation of the respiratory protection program. The designated Health and Safety Officer at each Golder Associates Inc. office will assist and support the Corporate Health and Safety Officer in these activities.

2. LIST OF TERMS

ANSI	American National Standard Institute
CFR	Code of Federal Regulations
EPA	Environmental Protection Agency
HCN	Hydrogen Cyanide
H_2S	Hydrogen Sulfide
IDLH	Immediately Dangerous to Life and Health
MSHA	Mine Safety and Health Administration
MUC	Maximum Use Concentration
NIOSH	National Institute for Occupational Safety and Health
OSHA	Occupational Safety and Health Administration
OVA	Organic Vapor Analyzer
PEL	Permissible Exposure Limit
PF	Protection Factor
PSI	Pounds Per Square Inch (Gauge)
REL	NIOSH Recommended Exposure Limit
SCBA	Self-Contained Breathing Apparatus
STEL	Short Term Exposure Limit
TLV	Threshold Limit Value
TWA	Time Weighted Average

3. GENERAL CONSIDERATIONS

The purpose of this document is to establish written standard operating procedures for a corporate respiratory protection program. Because Golder Associates Inc. is involved in a wide variety of projects, it is not possible to identify specific respiratory hazards, select appropriate respirators, and indicate the type of respirator to be issued to each employee for every conceivable situation in a "standard" operating procedure. This information shall be addressed in a site-specific health and safety plan for each project that has the potential for employee exposure to hazardous airborne contaminants.

This document addresses those issues which can be addressed at the program level such as respiratory program administration, personnel training, respirator fit testing, medical surveillance, etc. In addition, this document establishes protocols to address those issues regarding respiratory protection that must be considered on a site specific basis.

Personal respiratory protection devices, when required as a primary means of limiting employee exposure to potentially harmful concentrations of airborne contaminants or IDLH atmospheres, shall be used only in accordance with the standard operating procedures established herein.

4. PROGRAM ADMINISTRATION, IMPLEMENTATION, AND EVALUATION

4.1 Program Administration and Implementation

The Corporate Health and Safety Officer for Golder Associates Inc. shall have overall responsibility and authority for establishing and implementing the respiratory protection program at an administrative level. Each office, permanent or temporary, shall have a designated Health and Safety officer who shall be responsible for the implementation of the program at the office level.

Each Project Manager shall be responsible for recognizing the potential need for respiratory protection at the planning stage of a project and shall indicate this need when filling out the Project Information Sheet. The Project Manager must either act as or designate a Site Health and Safety Coordinator for the project.

The office Health and Safety Officer is responsible for evaluating the appropriate level of respiratory protection and will prepare the Site Specific Health and Safety Plan in conjunction with the Project Manager or Site Health and Safety Coordinator. The site specific plan shall include the type of respiratory protection necessary, the action levels to be observed, and other appropriate information.

The Site Health and Safety Coordinator shall work closely with the Health and Safety Officer and will be responsible for implementing applicable standard operating procedures in the field. Whenever respiratory protection equipment is utilized, the Site Health and Safety Coordinator shall record who wore respiratory protective equipment, when the equipment was worn, where the individual was working at the site, and any other relevant information in the comment section of the air monitoring data sheet.

4.2 Program Evaluation

The effectiveness of the respiratory protection program shall be evaluated at least annually under the direction of the Corporate Health and Safety Officer to identify and correct deficiencies in the program.

The evaluation shall include consulting individuals who have worn respiratory protection to determine wearer acceptance and to address any suggestions, complaints, or other concerns. Employees who have worn respiratory protection are encouraged to provide feedback to the office Health and Safety Officer and/or the Corporate Health and Safety Officer regarding the use of personal respiratory protective equipment. This feedback should include information such as respirator comfort, effect of respirator use on communication, work performance, vision, breathing, and the individual's level of personal confidence in the effectiveness of the program.

The operation of the program shall be periodically audited to ensure that appropriate respirators are issued, that respirators are properly used, and that all equipment is maintained in good operating condition. The Site Health and Safety Coordinator and the Health and Safety Officer shall monitor the use of respirators where employees have been required to use the equipment. Appropriate entries shall be made in the comment section of the air monitoring data sheet to monitor the overall applicability of and adherence to the site safety plans.

The respiratory program evaluation shall also include an appraisal of the level of protection afforded through review of air monitoring data sheets, periodic employee physical examination results, and specific bioassay surveillance of respirator users as necessary. The purpose of such reviews is to determine that adequate respiratory protection is being provided.

The results of the above evaluations shall be documented, and shall include plans and target dates to correct identified program deficiencies.

5. PROGRAM REQUIREMENTS RELATING TO PERSONNEL

5.1 Physical Qualifications of Personnel

An employee shall be assigned to a task requiring the use of a respirator only after he or she has been examined and determined to be physically qualified to use respiratory protective equipment by a licensed physician. At a minimum, employee evaluations shall meet the requirements of ANSI Z88.6-1984 "American National Standard for Respiratory Protection - Physical Qualifications for Personnel". A copy of the physician's written evaluation shall be retained in the employee's confidential personnel file.

5.2 Medical Surveillance of Personnel

A baseline physical will be required for all personnel prior to assignment to a project requiring respiratory protection. All employees who are or may be exposed to hazardous substances at a level in excess of an established PEL, TLV, or REL for 30 days or more a year, and any employees who may have been exposed to hazardous substances at concentrations above the applicable PEL or TLV in an emergency situation will receive follow-up medical examinations at least once a year, or as may be deemed prudent under the circumstances.

A physician shall determine the requirements of each follow-up examination with the complete cooperation of Golder Associates Inc. At a minimum, Golder Associates Inc. shall provide the physician with a description of the employee's duties as they relate to the employee's potential exposure, the employee's exposure levels or anticipated exposure levels, and a description of any personal protection equipment used, or to be used. Furthermore, any information from previous medical examinations of the employee which is not readily available to the examining physician shall be made available to Golder Associates Inc., the employee, or the employee's personal physician.

All employee medical records and available exposure records shall be retained in a confidential personnel file for at least the duration of employment plus thirty years.

5.3 Special Considerations for Respirator Use by Personnel

Employees shall not use any air purifying or air supplying respirator if hair comes between the sealing periphery of the face piece and the face, or if facial hair interferes with valve function. This requirement effectively prohibits the use of respirators by persons wearing beards (even if only several days growth), large sideburns, and large mustaches.

Eyeglasses with temple bars shall not be worn with any respirator having a full face piece. An employee who wears gas permeable or soft contact lenses may wear these lenses within the provision of the OSHA memorandum to modify current enforcement procedures regarding the use of contact lenses with respirators (See Appendix A).

Employees with uncorrected vision poorer than 20/40 with both eyes shall not wear a full face respirator in any irritating or IDLH atmosphere, unless the face piece is fitted with corrective lenses or the individual wears gas permeable or soft contact lenses. Corrective lenses will be provided by Golder Associates Inc., if required, for the particular respirator used.

No employee shall wear any spectacles (including sunglasses), goggle, face shield, welding shield, or other eye and face protective device which interferes with the seal of a respirator.

Head coverings which pass between the sealing surface of a respirator facepiece and the wearer's face shall not be used.

5.4 Personnel Training

Every employee required to wear a respirator shall be given training such that he or she is knowledgeable concerning the characteristics and recognition of respiratory hazards, and proficient in the use of the respirator(s) that might be worn. The training shall address:

A. Classification of respiratory hazards according to their physical characteristics and biological effects;

B. Respirator selection;

C. Proper wearing of a respirator;

D. Limitations of respirators and restrictions on use;

E. Respirator Inspection;

F. IDLH, oxygen deficient atmospheres, and confined spaces;

G. Recognition and coping with emergency situations;

H. Maintenance and storage of respirators;

I. Fit testing; and

J. Regulations concerning respirator use.

Refresher training for respirator use shall be provided at least annually. If respirators are intended for emergency use or in potentially IDLH atmospheres, then the respirator training shall be conducted quarterly or on a project specific basis as needed.

Initial respirator training of all employees and all respirator refresher training of Office Health and Safety Officers shall be administered by or under the direction of the Corporate Health and Safety Officer. Otherwise, the Office Health and Safety Officers and Site Health and Safety Coordinators may administer employee refresher training in respirator use.

A written outline of the training program will be maintained and updated annually under the direction of the Corporate Health and Safety Officer (See Appendix B).

Written records of training will be retained in the employee's personnel files for at least the duration of employment plus 5 years.

5.5 Respirator Fit Testing of Personnel

An employee shall wear a respirator, other than a pressure-demand supplied air respirator, only after being qualitatively fit tested and achieving a satisfactory fit for that particular brand, model and size respirator. The fit test shall be performed by a trained individual using isoamyl acetate (banana oil) and stannic oxychloride (irritant smoke) according to the procedures set forth in Appendix C of 29 CFR 1910.1001 asbestos regulations. (See Appendix C of this document for Golder Associates Inc. Respirator Fit Test Instructions and current regulatory procedures).

The employee shall be allowed to pick the most comfortable respirator from a selection of respirators. The selection shall include (a total of) at least five sizes of elastomeric half face respirators, from at least two manufacturers. The employee shall then be fit tested with the selected respirator. Should the selected respirator not seal properly, thus failing the fit test, the employee shall select another respirator and be fit tested with that respirator. If necessary, Golder Associates Inc. will order alternate respirators to provide a properly fitting respirator.

For those situations that the Health and Safety Officer or his designee has determined that air purifying respirators offer an adequate level of protection, the employee shall be allowed to use only the specific make(s), model(s), and size(s) of respirator for which he or she obtained a satisfactory fit. Fit testing shall be repeated at least once per year or whenever an employee loses or gains in excess of fifteen pounds, or has major dental or cosmetic surgery which may effect the respirator fit.

A record of respirator fit test results shall be retained in the employees confidential personnel file with medical records for the duration of employment plus five years. An additional wallet sized record shall be provided to the employee as shown in Figure 1, Appendix C. These records shall include:

A. Name of person tested;
B. Date of test;
C. Type of fit test procedure used;
D. Specific make, model, and size of respirator tested;
E. Name of person performing test;
F. Results of fit test, including success or failure to obtain a satisfactory seal.

6. RESPIRATORY PROTECTION EQUIPMENT

6.1 Use of Approved Respirators

Only gas masks approved by the Bureau of Mines under BM Schedule 14F or respirators approved by MSHA and NIOSH under provisions of 30 CFR 11 may be used. Any modifications of an approved respirator, or use of any component that is not specifically approved for use with an approved respirator by the authorizing agencies voids the approval.

6.2 Respirator Selection

The following factors must be considered in the selection of appropriate respiratory protection:

- Type of airborne contaminant;
- Nature of exposure risk (toxic, carcinogenic, etc.);
- Substances present and concentrations (both peak and average levels);
- Mechanism for toxic effects (asphyxiant, neurological, etc.);
- Physical and chemical properties of contaminants;
- Health effects at varying exposure levels without proper respiratory protection;
- Nature and level of warning properties (color, odor threshold, etc.);
- Escape routes, distances, and times; and
- Limiting atmospheric conditions - IDLH and/or oxygen deficient.

The overall working environment must also be considered in the respiratory selection, including:

- Anticipated temperature and humidity;
- Anticipated period of work with respirator protection;
- Expected level of physical exertion, both with and without respirator protection;
- Type of additional protective stresses, such as tyvek or encapsulating gear;
- Obstructions and terrain restrictions; and
- Emergency/escape uses.

It would not be desirable, for instance, to select a respirator that is heavy, or offers substantial breathing resistance if the task requires a high-level of physical exertion or requires the use of respiratory protection for prolonged periods. Closed or confining areas may restrict SCBA use, while rough terrain or heavy equipment may restrict air line use.

Respiratory selection must also be based upon:

- Physical characteristics of the respirator type;
- Functional capabilities and limitations of the respirator; and
- Respirator protection factors.

6.3 Respirator Protection Factor

The protection factor (PF) is defined as the ratio of the concentration of a contaminant in the ambient air to the concentration inside the respirator in the worker's breathing zone. This factor reflects reductions in the concentration of an airborne contaminant and is a measure of the degree of protection provided to a particular wearer by a particular respirator. ANSI Z88.2 - 1980, the American National Standard "Practices for Respiratory Protection" and OSHA assign the following protection factors for various types of respirators when fitted by the qualitative method:

Type of Respirator	ANSI Protection Factor	OSHA Protection Factor
Half-face air purifying	10	10
Full-face air purifying	100	50
Powered air purifying respirator	100	50
Demand air supplied respirator	100	50
Pressure demand air supplied respirator w/escape provisions.	10,000+	10,000+

Pressure demand airline respirators without escape provisions do not require a fit test since they are pressure demand devices but are limited to use in atmospheres below IDLH concentrations.

Golder Associates Inc. projects will rarely require the use of respiratory protection on a continuous basis, or a protection factor greater than 10. Consequently, the Golder Associates Inc. respiratory protection program will rely heavily on the use of half-face air purifying respirators. Air purifying respirators may be used only when all four of the criteria set forth in 6.4 below are met.

6.4 Air Purifying Respirator Criteria

The following restrictions apply to the use of half-face or full-face air purifying respirators:

A. The atmosphere is not IDLH;

B. The atmosphere is not oxygen deficient (i.e., less than 19.5 percent oxygen);

C. The airborne contaminants exhibit good warning properties or the atmosphere is monitored continuously; and

D. The concentration of airborne contaminants is known and is below the product of the PEL or TLV times the PF (Maximum Concentration = TLV x PF) or the maximum approved capability of the cartridge, whichever is lower.

The Project Manager and the Site Health and Safety Coordinator have the responsibility to verify that all of the above criteria for the use of air purifying respirators, particularly Item D, are met. In those instances where it has been determined that an air purifying respirator will provide an adequate level of protection, the employee shall be allowed to use an air purifying respirator only after receiving a physician's approval, adequate training and proper fit-testing as indicated in Section 5. The Site Health and Safety Coordinator shall ensure that each employee is provided with approved fresh cartridges appropriate for the (presumably) known respiratory hazard(s).

6.5 SCBA Criteria

Pressure demand SCBA or pressure demand air line respirator with escape bottle must be used in the following situations:

A. IDLH atmosphere;
B. Oxygen deficient atmosphere;
C. Unknown concentration of unknown airborne contaminants; and
D. Emergency rescue in contaminated or oxygen deficient atmosphere.

Only "Grade D" or better breathing quality air may be used with supplied air respirators.

6.6 Respiratory Selection Decision Logic

An appropriate respirator shall be selected based on the criteria presented in 6.4 and 6.5 and the decision logic presented in Figure 2, Appendix D. The ergonomics and logistics of the specific task at hand should also be considered.

6.7 Issuance of Respirators

Any employee assigned to a project that may require the use of respiratory protection may be issued an appropriate respirator only after the employee has received a baseline physical, respirator training, and fit testing for the specific respirator. The Project Manager or the Site Health and Safety Coordinator shall ensure that each employee is provided with appropriate cartridges.

The person issuing respirators to persons who must wear respirators for protection against harmful atmospheres shall be given adequate training to ensure that the correct respirator is issued.

6.8 Respirator Inspection and Maintenance

Each employee assigned to a task which may require the use of respiratory protection shall be trained in proper inspection and maintenance procedures for his or her respirator.

The respirator shall be inspected by the wearer prior to each use to determine that it is in proper working condition. In the case of an air purifying respirator, this will include inspection of the inhalation and exhalation valves for creases, tears, poor seating, foreign material, (dirt and dust) etc., examination of all rubber or elastomeric parts for signs of deterioration, verification that the respirator is equipped with appropriate cartridges and that they are not expired, and evaluation of the overall condition of the respirator.

In the case of a self-contained breathing apparatus, the employee will follow the inspection and donning procedures specified by the manufacturer and the training received.

Each respirator wearer shall check the seal of the respirator by appropriate means prior to entering a harmful atmosphere. In the case of "negative pressure" air purifying respirators, this will consist of creating a negative pressure (inhaling) while covering the cartridge(s), and creating a positive pressure (exhaling) while covering the exhalation valve. The employee should be able to achieve and maintain a slight negative and positive pressure with no obvious leaks with a properly fitted mask.

Each employee shall be responsible for the proper cleaning and routine maintenance of his or her respirator. Each employee shall inspect his or her respirator for missing, worn or deteriorated parts, or any other defects and return the respirator to the Site Health and Safety Coordinator for repair or replacement. Repairs to air supplying respirators other than routine maintenance, are to be performed only by certified technicians.

6.9 Respirator Storage

Respirators shall be stored in a manner that will protect them against dust, sunlight, heat, extreme cold, excessive moisture, or damaging chemicals. Respirators shall be stored to prevent distortion of rubber or other elastomeric parts. Respirators shall not be stored in such places as foot lockers or tool boxes unless they are protected from contamination, distortion, and damage. Self contained breathing apparatus which are in work areas for emergency use must be "full" i.e., at least 1800 psi and quickly accessible at all times, and the storage cabinet or container in which they are stored shall be clearly marked. Each SCBA stored for emergency or rescue use shall be inspected at least once a month. The date and results of the inspection shall be recorded and maintained with the respirator.

7. RESPIRATORY HAZARD RECOGNITION AND EVALUATION

7.1 General Hazard Identification

Golder Associates Inc. has the responsibility to evaluate the hazards associated with any and all field activities associated with its work. The Project Manager or his designee shall investigate the history of a site to the extent necessary to assess and/or characterize potential hazards. The identity and relative concentration of the constituents must be determined, to the extent possible, whenever the presence of chemical contaminant is suspected in the air, soil or groundwater under investigation.

7.2 Site-Specific Health and Safety Plan

The nature of the potential hazard (constituent makeup, concentration and exposure periods) shall be considered in order to establish employee protection procedures. The identified hazards and protection procedures will be incorporated into the site-specific health and safety plan. This plan will include, at a minimum:

- Site Characterization;
- Nature of the hazard;
- Exposures expected;
- Appropriate protective equipment;
- Appropriate monitoring equipment and action levels;
- Escape procedures and contingency measures; and
- Contacts, i.e., appropriate response agencies.

7.3 Protection Criteria

In those instances where existing data or a detailed site history indicate that chemical concentrations are very low, or there are only a few potential contaminants, the Health and Safety Officer may be able to establish an appropriate respiratory protection strategy based on the relative toxicity of contaminants, comparison of odor thresholds to PELs or TLVs, etc.

When contamination is known or expected to exist in significant (but below IDLH) concentrations, when the contaminants are unknown, or when there are many possible contaminants, only two possible respiratory protection alternatives are permissible until the respiratory hazard is positively identified and characterized:

A. The use of pressure demand air supplied respiratory protection, or

B. The use of air purifying respirator, while continuously monitoring workers breathing zones with an appropriate direct reading instrument such as an HNu PI-101, a Photovac "Microtip" or a Foxboro OVA (organic vapor analyzer) for organics, an MSA 361 for H_2S, or Draeger tubes for specific compounds such as HCN. This option is permissible only where allowable exposure limits, instrument response factors, and/or designated action levels are sufficient to adequately protect employee health.

Where the site history or nature of potential airborne contaminants is unknown, the action level for the use of an air purifying respirator shall be any consistent reading in the worker's breathing zone above the upwind background level. Readings in excess of 5 ppm above background shall require a full face pressure demand air supplying respirator or pressure demand SCBA. These are generally accepted action levels as specified in the EPA Standard Operating Safety Guides but they should not be applied blindly nor adhered to in deference to observed site conditions and/or good judgement. These guidelines should be adjusted (either higher or lower as appropriate) based on available information and observed site conditions ie. the presence or absence of visible waste/contamination, perceptible odors, etc.

Air purifying respirators equipped with organic vapor/acid gas cartridges are quite effective in removing certain highly toxic gases such as H_2S and HCN, but are not approved for such use due to the potential for IDLH conditions. In such cases, the use of cartridge type air purifying respirators at concentrations in excess of the eight hour TLV, STEL or TLV ceiling value is permitted only for escape. Continuous exposure to the H_2S, HCN, or other acutely toxic substances at concentrations in excess of the respective allowable exposure limits require the use of pressure demand air supplying respirators.

7.4 Air Monitoring and Action Levels

When the contaminants are known, or have been positively identified by an appropriate sampling strategy, the Health and Safety Officer or the Site Health and Safety Coordinator shall select appropriate air monitoring instrumentation and implement an air monitoring regimen commensurate with the perceived degree of respiratory hazard.

The action level for the use of respiratory protection shall be determined as follows:

A. Identify the "critical" contaminant(s). This will depend on a number of factors including relative concentration, relative toxicity, vapor pressure, odor threshold, etc.

B. Identify the instrument response (in percent) to the critical contaminant(s).

C. Multiply the instrument response times the TLV or PEL of the critical contaminant (whichever is lower).

For example, assuming that trichloroethylene (TCE) is identified as the critical contaminant (TLV-50 ppm) and the OVA response to TCE is 70 percent, the action level for the use of respiratory protection will be 0.7 x 50 ppm = 35 ppm as measured on an OVA. Good industrial hygiene practice however, requires that a reasonable safety factor (such as "2") be applied to allow for any possible synergistic effects of mixtures of contaminants. In the above case, this results in an action level of 35 ppm/2 = 17.5 ppm (rounded to 15 or 20 ppm).

The maximum allowable concentration for the use of a particular type of respirator shall be the action level determined according to the procedures specified above, times the protection factor for the particular respirator. Using the example above, the maximum allowable concentration for a half-face respirator as determined on an OVA will be

17.5 ppm x 10 (PF) = 175 ppm.

These maximum allowable concentrations may be adjusted based on the professional judgement of a qualified health and safety professional. If there is any question, consult a designated Health and Safety Officer.

Air monitoring equipment shall be dedicated to projects on an "as available" basis in the following order of priority:

A. Sites falling under the requirements of 29 CFR 1910.120 (RCRA clean-ups, CERCLA remedial actions, hazardous materials spills, etc.); and Sites where there are known high-levels of contamination or where high levels may be reasonably anticipated (abandoned municipal landfills, etc.);

B. Sites where unanticipated contamination is discovered; and

C. All other sites.

When existing data or a preliminary site characterization indicates the need for air monitoring instrumentation, and Golder Associates Inc. equipment is not available, it shall be the responsibility of the Project Manager to secure the necessary instrument(s) prior to starting site work.

8. EMERGENCY AND CONTINGENCY USE OF RESPIRATORY PROTECTION EQUIPMENT

Continuous use of respiratory protection, or a need for a protection factor greater than 10, is rarely required on projects involving Golder Associates Inc. Consequently, the Golder Associates Inc. respiratory program will frequently involve the use of air purifying respirators. Because respiratory protection will not be required continuously on most projects, in many situations, the use of a half-face respirator may in itself represent the "contingency plan". Occasionally, air purifying respirators may actually be required to bring employee exposures within allowable TLVs or PELS on a continuous basis. It is this type of intermittent or occasional use that typically results in the greatest potential for improper use and/or abuse of air purifying respirators.

On those sites where the possibility of chemical contamination has been recognized, a preliminary site characterization must be prepared and, if justified, a monitoring instrument must be available on-site. Under these circumstances, if chemical contamination is indeed encountered, work may proceed and air purifying respirators may be employed within the limits discussed under Respirator Selection Criteria, and Hazard Recognition and Evaluation.

In the event that chemical contamination is encountered on a site where it had been completely unanticipated, and air monitoring equipment is not available, work activities shall be modified (moved to another location) or halted. Appropriate changes to the program will be developed in concert with the site personnel, the Project Manager, the Golder Associates Inc. Health and Safety Officer, and the client. Implementation of an appropriate air monitoring strategy will be required prior to restarting the project.

Should air contamination levels exceed the maximum allowable concentrations of the available respiratory protection, or should a situation arise which is obviously beyond the scope of the specified respiratory protection strategy (such as a sudden release), workers shall don their respirators if they have not done so already, and immediately leave the area.

At a minimum, "5 minute" self contained escape packs shall be issued whenever there is any recognized possibility of a sudden release exceeding the capabilities of cartridge type air purifying respirators.

No employee shall enter an IDLH atmosphere or attempt any emergency repair or rescue requiring the use of an SCBA unless a back-up person, also equipped with an SCBA, is standing by and is in constant visual or voice communication with that employee. No back-up person shall enter any IDLH atmosphere and attempt any emergency response before notifying a second back-up person or persons. Under no circumstances shall a Golder Associates Inc. employee deliberately enter a confined space without a backup person equipped with a pressure demand SCBA or airline respirator with escape provisions unless it is in accordance with written site specific confined space entry procedures addressed in the Health and Safety plan.

APPENDIX A

CONTACT LENSES USED WITH RESPIRATORS

U.S. Department of Labor

Occupational Safety and Health Administration
Washington, D.C. 20210

Reply to the Attention of:

Feb. 8, 1988

MEMORANDUM FOR: REGIONAL ADMINISTRATORS

THROUGH: Leo Carey, Director
Office of Field Programs

FROM: Thomas Shepich, Director
Directorate of Compliance Programs

SUBJECT: Contact Lenses Used With Respirators
(29 CFR 1910.34(e)(5)(ii))

Section 1910.134(e)(5)(ii), in part, reads, "... Wearing of contact lenses in contaminated atmospheres with a respirator shall not be allowed...." This wording was adopted in 1971 into OSHA's standards without change from the American National Standard "Practices for Respiratory Protection," ANSI Z88.2-1969, in accordance with Section 6(a) of the Occupational Safety and Health Act of 1970. The current ANSI Z88.2-1980 standard also includes this restriction on the wearing of contact lenses.

OSHA has frequently been asked why the prohibition on contact lenses is included in our requirements and, as a result, the matter has been investigated, including the funding of a research project on the wearing of contact lenses by firefighters using full facepiece respirators. Current members of the ANSI Z88.2 Committee have suggested hypothetical scenarios which they believe would have supported the prohibition. However, actual incidents resulting in employee exposure to inhalation hazards or to eye hazards which were aggravated by the use of contact lenses were not forthcoming from the ANSI Committee members contacted. The uncertainty of reasons for the prohibition on contact lens use prompted funding of the research project conducted by Lawrence Livermore National Laboratories (LLNL). A copy of the final LLNL report is attached for your information.

Recommendations contained in the LLNL report read, "Based on a numerical analysis of the responses to the questionnaire, our follow-up interviews with those indicating the worst problems, and reading the 829 comments on positive or negative experiences

with contacts, we believe the pronibition against wearing contacts while using a full-facepiece respirator should be revoked or withdrawn. Wearers of corrective lenses would have the option of wearing either contacts or eyeglasses with their full facepiece respirators. One must keep in mind, however, that some people do not adapt well to contacts.

If the person cannot comfortably wear contacts in everyday non-work situations, then he will probably not adapt well to using them with a full-facepiece respirator. Also, a person's facial shape and eyeglass prescription may be such that he cannot obtain and retain a proper alignment of his eyeglasses inside the full-facepiece. In this case, he would have to wear contacts, or no corrective lenses at all.... Considering the severe conditions under which firefighters must work, we believe it is unlikely that the working conditions of any other SCBA users would preclude the similar use of contact lenses. This would also include negative-pressure air-purifying respirators." Other reports and articles (list attached) have been reviewed which further support that the pronibition in the current standards is unwaranted.

Although, the LLNL report deals specifically with firefighters and full-facepiece SCBA's, OSHA knows of no reason why other work situations and types of respirators would present greater hazards relevant to wearing contact lenses. Therefore, this memorandum applies to all respirator use in all workplaces unless specific information should become available which indicates a hazard which has not been considered.

Even though much of the material mentioned above applies to all types of contact lenses, OSHA staff wishes to further investigate the issue of non gas permeable hard contact lenses before completely suspending the prohibition, since the original prohibition in ANSI 287.1 was adopted when the use of this type of hard lens was prevalent.

In consideration of the results of our investigation, and in accordance with the Agency's intent to modify the rule, an interim enforcement policy is appropriate. Accordingly, this memorandum modifies current enforcement procedures as follows:

1. Violations of the respirator standard involving the use of gas permeable and soft contact lenses shall continue to be documented in the case file and recorded as de minimis; citations shall not be issued.

2. Evidence indicating any negative effect associated with the use of contact lenses with respirators should be provided to this office. Benefits associated with the use of contact lenses with respirators would also be useful to this office.

The issue with non gas permeable hard contact lenses will be resolved in the revision effort for §1910.134 which is now underway.

Attachments

1. Giroux, Arthur R., "Time to Reconsider Contact Lens Policies?" Occupational Hazards, November 1985.

2. Nilsson, Sven Erik G., et al, (a) "The Use of Contact Lens in Environments with Organic Solvents, Acids or Alkalis," ACTA Opnthalmologica, Vol. 60, 1982.

   (b) "The Use of Contact Lenses in Wet or Damp Environments," ACTA Opntnalmologica, Vol. 58, 1980;

   (c) "Contact Lenses and Mechanical Trauma to the Eye," ACTA Opntnalmologica, Vol. 59, 1981;

   (d) "Contact Lens Wear in an Environmental Contaminated with Metal Particles," ACTA Opntnalmologica, Vol. 61, 1983.

3. Da Roza, Robert A., "Is it Safe to Wear Contact Lenses?" Lawrence Livermore National Laboratory, UCRL-53653, August 16, 1985.

4. Guthrie, John W., et al, "An Investigation of the Chemical Contact Lens Problem," Journal of Occupational Medicine, March 1975.

5. Aalphen, C. C. Kok-van, et al, "Protection of the Police Against Tear Gas with Soft Lenses," Military Medicine, Vol. 150, August 1985.

6. Kartchner, Mark N., "Fight Fires with Contacts?" Contact Lens Forum, March 1985.

7. Hirschfelder, Dennis, "Contact Lenses in the Workplace: The Dilemma," Sightsaving, Vol. 52, No. 1, 1983, National Society to Prevent Blindness.

APPENDIX B

RESPIRATOR TRAINING PROGRAM

RESPIRATORY PROTECTION TRAINING PROGRAM

I SLIDE PRESENTATION

Slide No.	Topic
1.	Title - Respiratory Protection Respiratory protection is probably the most important method of "controlling" health hazards on a hazardous waste site.
2.	Applicable standards and regulations: ANSI Z88.2-1980 Consensus standards for use of respiratory protection ANSI Z88.6-1984 - Z88.2 requires "physician's approval" so Z88.6 was developed to establish criteria for physical qualifications OSHA 29CFR1910.134 - OSHA standards for general industry - respiratory protection - adopted directory from ANSI Z88.2-1969
3.	Acceptable methods of compliance with allowable exposure limits, in order of preference. By law, the employer must implement "feasible engineering controls" prior to resorting to respiratory protection. - What <u>are</u> some examples of engineering controls on a hazardous waste investigation?
4.	Permissible use of respirators Respiratory protection may be used before engineering controls are installed (on an interim basis), after engineering controls are installed if levels are still in excess of PELs, during periodic maintenance procedures, and in emergencies for escape and/or rescue.
5.	ANSI Z88.2-1969 -revised in 1980

6. Employer's Responsibilities

7. Employees' responsibilities

8.,9.,10.,11. Regulations require employers to implement an "effective" respiratory protective program. The following elements are required in an "effective" program.

1. Must have a written respiratory protection program.

2. Program management must be assigned to one person with sufficient knowledge of respiratory protection to implement an effective program.

3. An employee may use respiratory protection only after being examined by a licensed physician (according to criteria established in Z88.6) and found to be physically qualified to use such equipment.

4. Only respirators grandfathered under the Bureau of Mines or approved by NIOSH and MSHA may be used. Only parts that have been approved specifically for the particular make and model respirator in which they are to be used are permitted.

5. An effective program must designate specific criteria for selecting appropriate respiratory protection including:

   a) the nature of the hazardous operation

   b) type of hazard - oxygen deficiency, toxic gases and vapors, radionuclides, etc.

   c) location relative to clean air - Why is this important?

   d) temporal properties of exposure - Are the exposure levels relatively constant, or are there wide excursions over time?

e) worker activities - does the work require a great deal of mobility? Does the work require a great deal of physical exertion? etc.

f) the respirator protection factor (more about this later)

g) and finally, the physical characteristics and functional capabilities of the respirator itself.

6. Training - All personnel required to use respiratory protection must receive training in the selection, limitations, use, and care and maintenance of the equipment they may be using.

7. Fit testing - All personnel using "negative pressure" respirators must be fit tested in a test atmosphere according to prescribed procedures, for the specific size, make and model that they will be using.

8. Policy on facial hair, eyeglasses, use of contact lenses, etc.

   - No facial hair which may compromise the face mask seal is a allowed.
   - Eyeglasses with temple bars that break the face mask seal are not allowed. For those who must wear glasses, only spectacles approved for the particular make and model (full-face) respirator may be used.
   - Historically, industrial hygiene "lore" has maintained that you can't use contact lenses with respiratory protection. There is no basis for this in fact - Refer to OSHA February 8, 1988 enforcement directive.

9. Program must establish procedures for issuing respirators. You don't just go grab one when you think you may need it.

10. Respirators must be inspected prior to use - straps, face piece, inhalation valves, exhalation valves, required gaskets, etc.

11. Program managers or designees must monitor employees' use of respirators.

12. Whenever air purifying respirators are used, you must perform sufficient air monitoring to verify that conditions are not changing to the extent that the capabilities of the respirator are being exceeded.

13. Medical Surveillance - Employees who use respiratory protection on a regular basis or for protection against specific toxic substances (eg. pesticides) must be included in an appropriate medical surveillance program.

14. There must be established procedures for maintenance.

15. Finally, the program manager must periodically evaluate the effectiveness of the program and correct recognized deficiencies.

12. Types of Respiratory Hazards

13. Physiological impairment does not typically begin to occur until you get down to approximately 16% (120mm Hg) O_2. OSHA's definition of an oxygen deficient atmosphere is more stringent - anything below 19.5%.

14. Types of Particulate Hazards - has direct bearing on type of filter required

1. Dust - typically formed by mechanical processes - grinding, crushing, erosion, etc.

2. Mist - liquid aerosol such as atomized spray.

3. Fume - extremely small particulate formed by condensation of vaporized metal i.e. welding "fumes".

15. Gas and Vapor Hazards

1. Inert (simple asphyxiant)

2. Acid

3. Alkaline

4. Organic

Don't forget chemical asphyxiants such as HCN and CO.

16. Definition of IDLH

- Note: IDLH conditions are not limited to those which will result in immediate effects. IDLH conditions also include situations which may pose an immediate hazard of delayed health effects such as exposure to radionuclides.

17. Two basic categories of respirators.

Air purifying respirators - which filter or clean ambient air

Air supplying respirators - which provide an air supply independent of the (contaminated) atmosphere

18. Examples of each -

Half face air purifying respirator
Open circuit SCBA

19. Air purifying respirators may be categorized by the type of contaminant they are designed for, whether they are disposable or non disposable, or the type of face piece. Powered air purifying respirators (PAPRs) are a special case. They are basically the same thing as an air purifying respirator with the addition of a pump which forces air under positive pressure to the face mask. PAPRs are typically used for particulate hazards and find wide applications in the asbestos industry.

20. Half-face, air purifying respirator.

21. Examples of "gas masks" or canister air purifying respirators with full face pieces.

22. Powered air purifying respirator. Take a good look because this is the only time you'll ever see a welder wearing a respirator.

23. Color codes for cartridges and gas mask canisters. - There are specific cartridges for specific hazards and you have to know which is which. Remember black (organic vapors), yellow (organic vapor, acid gases), green (ammonia and amines), and purple (HEPA -high efficiency particulate air filters).

24. Air purifying respirator with acid gas cartridges and "snap-on" dust and mist (not fume) filters.

25. Air purifying respirator with combination organic vapor (black) HEPA filter (purple) cartridges.

26. There are two basic categories of air supplying respirators: Air line, and self-contained (BYOA - bring your own air)

27. Example of air line - lightweight, comfortable and indefinite supply of air, but you're attached to a hose and limited to 300 feet (by regulations) of travel.

28. Self-contained breathing apparatus - You're independent of any fixed air supply, but they are heavy (28-35 pounds) and cumbersome, and only provide about 30 minutes of air.

29. Two types of self contained breathing apparatus: Open circuit (classic SCBA) and closed circuit (rebreathers).

30. Examples of each - Closed circuit SCBAs find wide application in mine rescue. They provide a 2 to 3 hour air "supply" (you actually breath the same slug of air over and over again) but there is really no such thing as a positive pressure (pressure demand) closed circuit SCBA.

31. Types of Open Circuit SCBAs.

1. Demand - provides air only when you create a negative pressure in mask by inhaling.

2. Pressure-demand - provides air only when you demand it by inhaling, but always maintains a positive pressure in the face piece.

3. Combination - Some units have a demand - pressure demand switch or lever. Demand mode is convenient for donning respirator.

32. Demand type apparatus - The green hose at the bottom left is the air hose to your face mask. When you inhale, you create a negative pressure and "suck up" the rubber diaphragm in the regulator which opens the admission valve and gives you a shot of air - "upon demand". A momentary negative pressure is created when you inhale. Note: by-pass valve by passes regulator entirely and introduces air directly form SCBA cylinder. What would happen if you opened the by-pass and covered the outlet?

33. The only difference between the demand and pressure demand units are these two 10 cent springs. The spring behind the diaphragm fools the diaphragm into thinking you are always demanding air. The spring behind the exhalation valve tends to hold the exhalation valve shut, which creates a slight back (positive) pressure in the mask. The back pressure balances the spring behind the diaphragm. So once the equilibrium positive pressure is established, there is no air flow unless you inhale and demand it. If there are any leaks, it will be impossible to establish the back pressure required to push the diaphragm down and there will be air flow <u>out</u> of the mask.

34. Air-line respirators may be demand, pressure-demand, or constant-flow. Constant-flow air-lines are typically only used with compressors supplying a continuous unlimited supply of air (for obvious reasons). What are considerations regarding the location of the compressor?

35. Graphical illustration of available air supplying respirators. It's not as complicated as it looks. Note "combination" air-line, SCBAs at bottom. (See next slide)

36. Air line systems used in IDLH atmospheres must be equipped with 5 minute self-contained escape bottles as shown here. So if a front-end loader operator parks his rig on your air-line, you can turn on your 5 minute escape bottle and get out. Note: 5 minute escape bottles may be used only for escape.

Combination SCBA-airline is shown on the right. It's an SCBA with a connection for an airline on the regulator. You can have the airlines laid out through pipes, over rafters, etc., walk into the work area on the SCBA, hook up to the airline, and work for three hours. When you're done, you disconnect the airline and walk-out by any convenient route on the SCBA. It's the best of both worlds except that you have a 30 pound SCBA on your back the whole time.

37. The "Respirator Protection Factor" is an important concept.

38. It is the concentration of a contaminant in the air relative to the concentration inside of the mask. So if there's 100ppm of xylene in the air and 1ppm inside of your mask, the protection factor is 100.

39. Prior to using any respirator other than a pressure-demand supplied air respirator, employees must pass a fit test for the exact make, model, and size respirator they will be using. There are two types of fit tests: qualitative and quantitative.

40. In a quantitative fit test as shown here, they actually measure the concentration of a test substance in the test atmosphere and inside of the mask, and calculate the actual protection factor for that person and that respirator.

41. This is the NIOSH respirator fit testing institute for the deaf.

42. When you are trying to determine whether or not an air purifying respirator will provide an adequate level of protection for a given contaminant, you have to consider the protection factor, and the limitations of the cartridge or canister. Organic vapor cartridges contain less than 200 ccs of activated carbon. If you read the label it says "Not to be used in atmospheres exceeding .1% (1000 ppm) total organic vapor by volume.

43. "Super Size" canisters contain over ten times more adsorbent material and can be used in much higher concentrations of contaminants.

44. Regardless of the quantitative fit test results i.e. the measured "protection factor", the concentration of airborne contaminants cannot exceed the stated maximum use concentration of the filter cartridge or canister.

45. In other words, the maximum concentration in which you can use a particular respirator is equal to the allowable exposure limit such as the PEL, TLV or REL as applicable, times the protection factor - or the MUC stated on the cartridge - whichever is lower.

For example, if the TLV of carbon tetrachloride is 5 ppm, and a respirator has a protection factor of "10", the maximum concentration in which you can use that respirator is 5 ppm x 10 or 50 ppm. The TLV of 1,1,1, TCA is 350 ppm. Ten times 350 equals 3500 ppm but the cartridge says "Not to be used in atmospheres exceeding .1% total organic vapor by volume" so the limit in this case is 1000 ppm.

46. In the case of a hazardous waste site you have to check the OSHA PELs, the ACGIH TLVs, and the NIOSH RELs.

47. Not many respiratory protection programs provide for quantitative fit testing. So OSHA assigns allowable protection factors for different respirators provided the employee passes a qualitative fit performed according to specific procedures spelled out in the OSHA lead and asbestos standards. The qualitative fit test protection factor for a half face air purifying respirator is "10". It is "50" for a full face APR just because full face masks don't have to negotiate the bridge of the nose, and tend to offer a better fit. Full face respirators are still limited by the same cartridges as a half face respirator (unless it's a canister "gas mask").

48. Look at the difference in the allowable protection factors between otherwise identical demand and pressure-demand SCBAs. The demand SCBA is 50 - the same as a full face air purifying respirator. The pressure demand SCBA is 10,000+. I think OSHA is trying to tell us something.

49. Pressure demand airline with escape provisions is the same as the pressure demand SCBA; 10,000+. What do you suppose the limit is on pressure demand air line respirators without escape provisions? - No fit test is required because of pressure demand, but they are restricted to use in atmospheres below the IDLH concentration of the contaminants of concern.

50. Employees must have documentation of fit test results on their person when wearing any respirator which requires such a test.

51. Respirator selection is the most important, and unfortunately the most complex aspect of the respiratory protection program.

52.,53. When determining the appropriate respirator for a given situation you must consider:

1. The allowable exposure limit of the contaminant(s).
2. The maximum (worst case) concentrations expected.
3. Is the atmosphere oxygen deficient?
4. Or IDLH?
5. Does the contaminant have adequate warning properties? What do we mean by warning properties and why is that important? Refer to and discuss Appendix F in course manual - Appendix II Warning Concentration of Various Chemicals, pages 2-17 - 2-34
6. What are the cartridge/canister limitations? Refer to and discuss Appendix F in course manual - Table 2-2 Effect of Solvent Vapor on Respirator Cartridge Efficiency, pages 2-8 - 2-10.
7. What is the allowable "protection factor"?
8. What are the task mobility requirements?
9. What is the intended use?

54. An air purifying respirator may be used only when <u>all four</u> of the criteria shown here are met. We can buy ourselves a little slack on 3 and 4 if we are monitoring continuously with direct reading instruments and establish appropriate action levels for upgrading to supplied air.

55. Pressure demand SCBAs or pressure demand airlines with escape provisions must be worn if any <u>one</u> of these conditions are present.

Note: Airlines must be pressure demand but escape provisions are not required in atmospheres that are oxygen deficient but not otherwise IDLH.

56. Otherwise any demand or pressure demand respirator with an adequate protection factor for the anticipated hazards may be used.

57. Lets go through this exercise:

Based on the information given, what type of respirator would be appropriate in each of these situations?

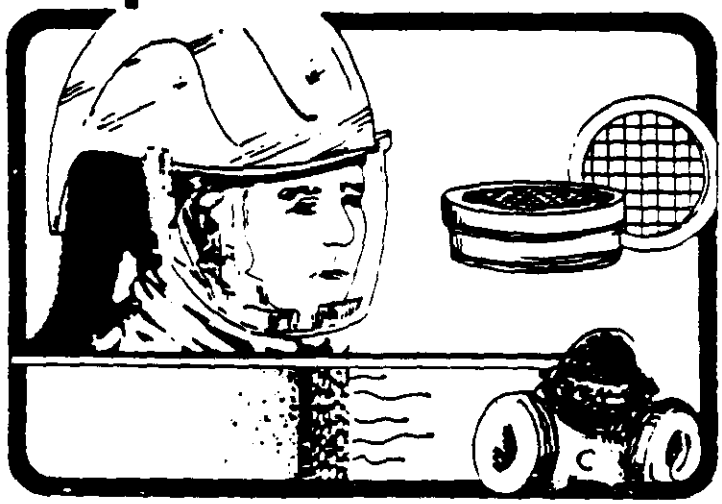
1500 ppm TCA	Pressure demand SCBA or pressure demand airline with escape provisions - Why?
500 ppm TCA	Half Face APR with organic vapor cartridges.
40 ppm 1,1,DCE	Look at the TLV and the odor threshold. If you were monitoring continuously with a direct reading instrument and the 40 ppm was a brief peak you could use an air purifying respirator, otherwise some type of supplied air would be required.
200 ppm TCE re. 50 ppm TLV	Half face APR
200 ppm TCE re. 25 ppm REL	Half face APR might consider full face APR (PF=50)
20 ppm H_2S	Must use pressure demand supplied air if concentrations are greater than TLV. Remember?
12 ppm Cl_2	Why not a full face air purifying respirator? Look at the cartridge - Not to be used in atmospheres containing more than 10 ppm chlorine. Must be supplied air.

II VIEW AND DISCUSS AIR PURIFYING RESPIRATOR VIDEO TAPE

III SCBA CHECK OUT AND DONNING PROCEDURES AND HANDS ON EXERCISE

II VIEW AND DISCUSS AIR PURIFYING
RESPIRATOR VIDEO TAPE

Air Purifying Respirators



AUDIOVISUAL PROGRAM OUTLINE (118 Frames; length 24:00)

I. Introduction (Frames 1 - 11)

II. Respiratory Protective Equipment (Frames 12 - 49)

- A Selection factors
  1. Oxygen deficiency
  2. Specific air contaminant
  3. Concentration
  4. Warning properties
- B Service life
- C. Facepiece styles
  1. Disposable
  2. Half-mask
  3. Full-mask
  4. Escape-only respirator

III. Three Basic Categories of Air-Purifying Respirators (Frames 50 - 65)

- A Filter respirators
- B Chemical-cartridge respirators
- C. Combination filter-chemical-cartridge respirators

IV. Important Usage Guidelines (Frames 66 - 71)

V. Respirator Components (Frames 72 - 77)

VI. Donning Procedures (Frames 78 - 96)

- A. Fit checks
- B Positive pressure test
- C. Negative pressure test
- D Qualitative fit test

III SCBA HANDS-ON

CHECKOUT AND DONNING PROCEDURE

Purpose of Exercise

1. To familiarize you with the equipment - including the different types of SCBAs.
2. To use air:
   a. To become comfortable and confident with using supplied air respirators.
   b. To become familiar with your limitations when using an SCBA.
   c. To become familiar with your time of use.
3. To set up and use a cascade system to fill SCBAs.
4. To become familiar with the differences and limitations of the equipment.

SCBA CHECK OUT

1) Remove the unit from the case. Check the integrity of all straps, buckles (male and female ends), back pack (screws and rivets). Check that bottle is securely fastened to back pack.

2) Check the Mask to see if it is:

- Intact
- Seal soft and pliable - so it conforms to your face.

Then check:

- Hoses for breaks, cracks, cuts, inspect the corrugations between accordion hoses for cracks.
- Pull on the hose attached to the mask to see if it comes off. If it comes off, good, better now than later.

3) Check Diaphragm

The diaphragm is located in the regulator assembly.

- Blow and then suck (inhale) on the regulator outlet - a popping sound should be heard and the ability to blow or suck air through the regulatory should stop abruptly.

If there is no pop or if you can continue to blow air through the regulator - DO NOT USE THE SCBA.

a. Drager diaphragm connects to the face piece.

b. Scott diaphragm is on the chest harness with the gage (cover entire opening and blow).

c. MSA diaphragm is in the regulator located on the belt with the gage.

4) Check "O" Ring

All SCBAs have an "O" ring in the high pressure line at the connection to the tank (including air line escape bottles). Conical fitting into tank requires an O ring. If the O ring is present and intact, the high pressure connection to the SCBA bottle should require tightening only by hand.

If the O ring is missing, cracked or chipped, replace it. Do not use without O ring. Do not use a wrench to tighten.

O-ring location:

a. Drager - on frame where the SCBA bottle connects to the back-pack.
b. Scott - at SCBA tank end of the high pressure air line.
c. MSA - at SCBA tank end of the high pressure air line.

The SCBA must be filled with air to complete the check-out procedure. Check SCBA tank pressure. Emergency SCBAs must be stored "full".

Normal pressure tanks - 1800 - 2400 psi.
With normal pressure at 2200 psi.
1800 psi is minimum legal pressure for emergency use.

High pressure SCBAs hold around 4500 psi.

We do not have any of these because there have been numerous problems with high pressure SCBAs and it is hard to get a 4500 psi air supply.

If tank does not have at least 1800 psi - disconnect the tank from the back pack/frame and fill.

Tank filling - Cascade System

The cascade system is a number of air cylinders (usually 4 or 6) connected in series by high pressure charging lines. If all of the cylinders are full, the first air cylinder (simply for convenience) or the cylinder having the lowest psi will be used first to fill the SCBA tank.

To fill SCBA tank:

- Ensure that all valves are closed (i.e. air cylinders, SCBA tank, bleed valve, and the main valve)
- Open the air cylinder at the end of the cascade and let a little air flow through the charging lines. Then close the air cylinder. By letting air flow through the charging lines before you fill up the SCBA, you have taken out any potential contaminants or moisture that may have condensed in the lines. This prevents moisturized air from getting into your SCBA tank and rusting it.
- Connect the SCBA bottle to the cascade filler line. Place the SCBA bottle on the ground and stand clear of it. .
- Open the air cylinder with the lowest psi, open the main valve in the charging line (if present), and open the SCBA tank.
- Allow the air cylinder to fill the SCBA tank, slowly. The SCBA tank should not become hot during the filling process. If it does, slow down your rate of filling the tank. This should not be a problem if there is 500-800 psi differential between the supply cylinder and the SCBA tank. However if the supply cylinder is full (2200 psi) and the SCBA is empty (0 psi) fill slowly until the "cascade" or lower to higher pressure system of supply cylinders is established. Allow the SCBA tank to come to equilibrium with the air cylinder. Once this has been accomplished, close the air cylinder valve.
- Open the next highest pressure air cylinder. Ensure that only one air cylinder is open at a time because if more than one is open the pressures in the cascade system air cylinders will equalize. Fill the SCBA tank until both the cylinder and the tank are at equilibrium.
- Continue to use the air cylinders from longest to highest pressure until either the SCBA tank is full (legally at least 1800 psi) or until all air cylinders have pressures below 1800 psi. Once all air cylinders have pressures below 1800 psi, remove the air cylinder with the lowest pressure and replace it with a full air cylinder. Remember this new air cylinder will be used last since the lowest air cylinder is used to fill the tank first.
- Before removing the SCBA tank from the cascade system, ensure that all valves are closed and open and bleed valve to bleed off the pressure in the charging line. Before removing an air cylinder from the cascade system, you must bleed off all pressure in the charging lines.

With full tank check:

a. Gage on the SCBA to see if it is similar to the gage reading on the tank.

b. Low pressure alarm. Note! The low pressure alarm may be checked more conveniently after donning the SCBA.

(The Instructor will go through each SCBA and then each person will do their own.)

MSA

MSA is a pressure-demand system - it is always in the positive pressure or pressure demand mode.

- Start with all valves closed.
- Open SCBA tank valve. Alarm bell will ring as pressure in line passes "up" through 500 psi.
- Close SCBA tank valve.
- Cover the breathing air outlet from the regulator with your hand and open main line valve (round and gold). Gage on SCBA will show "0" - before the mainline valve is opened. Afterwards, pressure gage should jump to approximately pressure in tank. The pressures should be close; however, they are never the same.
- The pressure reading on the gauge should hold steady. If the pressure reading drops it is indicative of a leak somewhere in the regulator.

Testing - Low Pressure Alarm

Need to bleed the pressure to approximately 500 psi (400 - 700).

- Slowly remove hand over air outlet.
- Watch pressure gage reading drop.
- Note the pressure when the alarm sounds. This tells you that the alarm works, and how much air (not time) left to egress, decon etc.

It is very important to know how long a tank of air lasts for each person for each SCBA.

SCOTT AIR-PAK

Pressure-Demand or Demand System

Put switch to "off" for Demand mode to get air when you inhale.

Put switch to "on" for pressure-demand as on MSA. There is a positive pressure in the mask and air (flow) is supplied when you inhale.

To check gage:

- Turn switch on regulator to "off" position.
- Open tank.
- Close tank.

To check the low pressure alarm:

Now bleed line as with MSA.

- Cover entire outlet with surgical glove, cellophane, etc. and open main line valve (yellow knob).
- Compare pressure on gage to pressure on tank. If they are similar, it means tank and high pressure lines are okay.
- Turn switch to ON slowly, releasing air in line.
- Watch gage as pressure drops.
- Note the pressure when the Alarm goes off. (Should ring around 500 psi)

DRAGER

Pressure-Demand or Demand as with Scott

Demand Mode is "-" on regulator Pressure-Demand is "+".

To check gage:

- Put on "-".
- Open tank.
- Check pressure on gage with tank to ensure that they are similar.

To check low pressure alarm:

- Close tank.
- Cover outlet on diaphragm unit with hand
- Switch from - to +.
- Slowly release air from line by removing hand from outlet.
- Watch gage as air releases.
- Note pressure when alarm sounds.

Ready to don equipment.

- Turn tanks over.

- Lay out straps - untangle.
  Straighten out.
  Loosen so easy to don and adjust.

- Put tanks on back.
  Help each other (Buddy System - no need to make it more difficult).

- Be sure "main line" valves are closed on MSA and Scott, and Scott is in "demand" mode (switch "off"). Be sure Drager is in demand mode "-".

- Reach down on right hand side and open tank.
  (All SCBAs same on this item).
  (SCUBA has valve at top to minimize air hose length).
  (SCBA for rescue to protect valve and to avoid choking as entering work areas.

- With Drager and Scott you can connect face-piece hose, open mainline valve and take your time donning mask. Air will not flow until you create a negative pressure in mask. MSA is always pressure demand so as soon as you open mainline, air will flow until the face-piece hose is connected to the regulator and the mask is on snug.

- Now put on face mask - Scott and Drager face-mask hoses should already be connected and Scott mainline valve may be open with switch off. MSA face-piece hose should not be connected to regulator at this point and mainline valve should be closed.
  Open mask.
  Loosen straps on mask
  Put mask on
  Tighten temple, chin, forehead.

- Drager and Scott should be giving you air as soon as you put on mask. Switch Scott to "on" and Drager to "+" to be in pressure demand mode. Once MSA mask is on, simultaneously connect face-piece hose to regulator and open the mainline. Check operation of by-pass valve briefly on each unit (red knobs on Scott and MSA, button on diaphragm assembly on Drager). You are now on pressure demand supplied air.

- NOW USE FULL TANK OF AIR - WALK AND TALK, RUN, DO CALISTHENICS, ETC.

APPENDIX C

QUALITATIVE FIT TEST INSTRUCTIONS AND REGULATIONS

QUALITATIVE FIT TEST INSTRUCTIONS

I. Isoamyl Acetate Protocol

A. Odor Threshold Screening - Equipment

1. Obtain 3 - 1 quart mason jars with lids. Fill one with 800 ml clean odorless water. Fill each of the other two with 500 ml clean water.

2. Obtain 2 eyedroppers or medicine syringes with ml or cc graduations. Use one only for pure isoamyl acetate. Use the other only for "stock" solution.

3. Obtain bulk (i.e., 1 pint jar etc.) of isoamyl acetate (banana oil). You will also need MSA Part #5645 smoke tubes and aspirator bulb.

B. Odor Threshold Screening - Procedure
(Section I.A 1-8 in Appendix C to 29 CFR 1910.1001)

1. Add 1 ml (1 cc) of isoamyl acetate (IAA) to 800 ml jar of water and shake well. This is your "stock" solution and it may be kept (sealed) for up to one week.

2. Add .4 ml of stock solution to one of the 500 ml jars of water. Note which jar contains IAA but do not label jar as such. Shake well and allow jar to sit for several minutes (sealed).

3. Have test subject open and smell both 500 ml jars and indicate which one contains banana oil. Subject must correctly identify IAA to continue with banana oil fit test.

C. Isoamyl Acetate Fit Test
(Section I.C 5-8 in Appendix C to 29 CFR 1910.1001)

1. Cut a standard size sheet of paper towel in half and wet with .75 ml (cc) of pure IAA. Hang towel inside at top of fit test chamber such that the total is approximately six inches above the test subjects head. Allow chamber to "equilibrate" for a minute or two.

2. Have subject select and don a suitable respirator (i.e., one that is comfortable and appears to fit properly). Have subject perform positive and negative pressure tests.

a. Negative-Pressure Sealing Test - After donning the respirator, the subject should cover the inlet opening of the respirator's cartridge(s) by covering it with the palm of the hand(s). Then, the subject should inhale gently and hold his/her breath for at least 10 seconds. The facepiece should collapse slightly with no inward leakage of air into the facepiece. If leakage is obvious that the fit of the respirator to the wearer is unsatisfactory.

b. Positive-Pressure Sealing Test - The exhalation valve is closed off and then the subject exhales gently. The fit of a respirator equipped with a facepiece is considered to be satisfactory if a slight positive pressure can be built up inside the facepiece without the detection of any outward leakage of air between the sealing surface of the facepiece and the subject's face.

3. Use organic vapor (black) or combination organic vapor/acid gas (yellow) cartridges with snap on dust/mist/fume filters, or use combination organic vapor-HEPA (black and purple) or organic vapor/acid gas - HEPA (yellow and purple) cartridges. Cartridges used for fit testing should not be left open or used for more than a month. Be aware of possible "break through," due to using old cartridges.

4. Cut a standard size sheet of paper towel in half, then fold the half sheet in half. Wet the folded towel with .75 cc of isoamyl acetate. Hang the paper towel in the fit test chamber approximately six inches above the test subjects head.

5. Have subject get in fit test bag. Have subject move head around, side to side, up and down through normal range of motions. Have subject jump up and down and jog in place.

   If subject cannot smell "bananas" have him or her recite the rainbow passage clearly and articulately.

   If the subject can smell bananas have them leave the test area and adjust respirator straps, check tightness of cartridges, reseal mask and repeat the test. If subject still fails IAA test, have them leave the test area and try a different brand and/or size of respirator.

At the end of a successful IAA test, have the subject break the seal of the mask and take a slight whiff of the IAA atmosphere in the bag - just to convince them that the respirator works.

II. Irritant Fume Test
(Section III.B 7-8 in Appendix C to CFR 1910.1001)

A. Have subject close eyes. Then, repeat above procedures (#4 for IAA test) while directing irritant smoke around edges of mask, under chin, etc.

B. Repeat IAA and irritant fume test procedures until subject finds a mask which passes both tests. **Do not break the respirator seal in the presence of the irritant smoke.**

C. Upon successful completion of IAA and irritant fume tests, record:

- date
- employee name and number
- size, brand, model of respirator i.e., "North medium half face"
- types of test "1910.1001 Appendix C qualitative fit test procedures IAA, irritant smoke."

Place in employee's personal health and safety file and keep a running record (notebook, database, etc.) of employee fit testing.

D. Issue employee a signed completed "fit testing card" as shown in Figure 1.

Rainbow Passage

When the sunlight strikes raindrops in the air, they act like a prism and form a rainbow. The rainbow is a division of white light into many beautiful colors. These take the shape of a long round arch with its patch high above, and its two ends apparently beyond the horizon. There is, according to legend, a boiling pot of gold at one end. People look, but no one ever finds it. When a man looks for something beyond reach, his friends say he is looking for the pot of gold at the end of the rainbow.

RESPIRATOR FITTING CARD

Appendix C to 290FR1910.1001
Qualitative Fit Test Protocols

Name: _____

Date Fitted _____

Employee No. _____

Fitted By _____

Satisfactory Respiratory Fit Achieved for:

Make	Model or Type	Size	Isoamyl Acetate	Irritant Smoke

FIGURE 1
FIT TEST RECORD
HEALTH AND SAFETY

PROJECT NO. 993-1014 DWG. NO. 22670 DATE 7/12/90 DRAWN DC

Golder Associates

$$C = \frac{(E)(Ac)}{V(10^9)}$$

Note.—Periodically check and adjust the value of A_c if necessary.

Appendix C to § 1910.1001—Qualitative and Quantitative Fit Testing Procedures—Mandatory

Qualitative Fit Test Protocols

I. Isoamyl Acetate Protocol.

A. Odor Threshold Screening

1. Three 1-liter glass jars with metal lids (e.g. Mason or Ball jars) are required.

2. Odor-free water (e.g. distilled or spring water) at approximately 25°C shall be used for the solutions.

3. The isoamyl acetate (IAA) (also known as isopentyl acetate) stock solution is prepared by adding 1 cc of pure IAA to 800 cc of odor free water in a 1-liter jar and shaking for 30 seconds. This solution shall be prepared new at least weekly.

4. The screening test shall be conducted in a room separate from the room used for actual fit testing. The two rooms shall be well ventilated but shall not be connected to the same recirculating ventilation system.

5. The odor test solution is prepared in a second jar by placing 0.4 cc of the stock solution into 500 cc of odor free water using a clean dropper or pipette. Shake for 30 seconds and allow to stand for two to three minutes so that the IAA concentration above the liquid may reach equilibrium. This solution may be used for only one day.

6. A test blank is prepared in a third jar by adding 500 cc of odor free water.

7. The odor test and test blank jars shall be labelled 1 and 2 for jar identification. If the labels are put on the lids they can be periodically peeled, dried off and switched to maintain the integrity of the test.

8. The following instructions shall be typed on a card and placed on the table in front of the two test jars (i.e. 1 and 2): "The purpose of this test is to determine if you can smell banana oil at a low concentration. The two bottles in front of you contain water. One of these bottles also contains a small amount of banana oil. Be sure the covers are on tight, then shake each bottle for two seconds. Unscrew the lid of each bottle, one at a time, and sniff at the mouth of the bottle. Indicate to the test conductor which bottle contains banana oil."

9. The mixtures used in the IAA odor detection test shall be prepared in an area separate from where the test is performed, in order to prevent olfactory fatigue in the subject.

10. If the test subject is unable to correctly identify the jar containing the odor test solution, the IAA qualitative fit test may not be used.

11. If the test subject correctly identifies the jar containing the odor test solution, the test subject may proceed to respirator selection and fit testing.

B. Respirator Selection

1. The test subject shall be allowed to pick the most comfortable respirator from a selection including respirators of various sizes from different manufacturers. The selection shall include at least five sizes of elastomeric half facepieces, from at least two manufacturers.

2. The selection process shall be conducted in a room separate from the fit-test chamber to prevent odor fatigue. Prior to the selection process, the test subject shall be shown how to put on a respirator, how it should be positioned on the face, how to set strap tension and how to determine a "comfortable" respirator. A mirror shall be available to assist the subject in evaluating the fit and positioning of the respirator. This instruction may not constitute the subject's formal training on respirator use, as it is only a review.

3. The test subject should understand that the employee is being asked to select the respirator which provides the most comfortable fit. Each respirator represents a different size and shape and, if fit properly and used properly will provide adequate protection.

4. The test subject holds each facepiece up to the face and eliminates those which obviously do not give a comfortable fit. Normally, selection will begin with a half-mask and if a good fit cannot be found, the subject will be asked to test the full facepiece respirators. (A small percentage of users will not be able to wear any half-mask.)

5. The more comfortable facepieces are noted; the most comfortable mask is donned and *worn at least five minutes* to assess comfort. All donning and adjustments of the facepiece shall be performed by the test subject without assistance from the test conductor or other person. Assistance in assessing comfort can be given by discussing the points in #6 below. If the test subject is not familiar with using a particular respirator, the test subject shall be directed to don the mask several times and to adjust the straps each time to become adept at setting proper tension on the straps.

6. Assessment of comfort shall include reviewing the following points with the test subject and allowing the test subject adequate time to determine the comfort of the respirator:

- Positioning of mask on nose.
- Room for eye protection.
- Room to talk.
- Positioning mask on face and cheeks.

7. The following criteria shall be used to help determine the adequacy of the respirator fit:

- Chin properly placed.
- Strap tension.
- Fit across nose bridge.
- Distance from nose to chin.
- Tendency to slip.
- Self-observation in mirror.

8. The test subject shall conduct the conventional negative and positive-pressure fit checks (e.g. see ANSI Z88.2-1980). Before conducting the negative- or positive-pressure test the subject shall be told to "seal" the mask by rapidly moving the head from side-to-side and up and down, while taking a few deep breaths.

9. The test subject is now ready for fit testing.

10. After passing the fit test, the test subject shall be questioned again regarding the comfort of the respirator. If it has become uncomfortable, another model of respirator shall be tried.

11. The employee shall be given the opportunity to select a different facepiece and be retested if the chosen facepiece becomes increasingly uncomfortable at any time.

C. Fit Test

1. The fit test chamber shall be similar to a clear 55 gal drum liner suspended inverted over a 2 foot diameter frame, so that the top of the chamber is about 6 inches above the test subject's head. The inside top center of the chamber shall have a small hook attached.

2. Each respirator used for the fitting and fit testing shall be equipped with organic vapor cartridges or offer protection against organic vapors. The cartridges or masks shall be changed at least weekly.

3. After selecting, donning, and properly adjusting a respirator, the test subject shall wear it to the fit testing room. This room shall be separate from the room used for odor threshold screening and respirator selection, and shall be well ventilated, as by an exhaust fan or lab hood, to prevent general room contamination.

4. A copy of the following test exercises and rainbow passage shall be taped to the inside of the test chamber.

Test Exercises

i. Breathe normally.

ii. Breathe deeply. Be certain breaths are *deep* and *regular*.

iii. Turn head all the way from one side to the other. Inhale on each side. Be certain movement is complete. Do not bump the respirator against the shoulders.

iv. Nod head up-and-down. Inhale when head is in the full up position (looking toward ceiling). Be certain motions are complete and made about every second. Do not bump the respirator on the chest.

v. Talking. Talk aloud and slowly for several minutes. The following paragraph is called the Rainbow Passage. Reading it will result in a wide range of facial movements, and thus be useful to satisfy this requirement. Alternative passages which serve the same purpose may also be used.

vi. Jogging in place.

vii. Breathe normally.

Rainbow Passage

When the sunlight strikes raindrops in the air, they act like a prism and form a rainbow. The rainbow is a division of white light into many beautiful colors. These take the shape of a long round arch, with its path high above, and its two ends apparently beyond the horizon. There is, according to legend, a boiling pot of gold at one end. People look but no one ever finds it. When a man looks for something beyond reach, his friends say he is looking for the pot of gold at the end of the rainbow.

5. Each test subject shall wear the respirator for at least 10 minutes before starting the fit test.

6. Upon entering the test chamber, the test subject shall be given a 6 inch by 5 inch piece of paper towel or other porous absorbent single ply material, folded in half and wetted with three-quarters of one cc of pure IAA. The test subject shall hang the wet towel on the hook at the top of the chamber.

7. Allow two minutes for the IAA test concentration to be reached before starting the fit-test exercises. This would be an appropriate time to talk with the test subject, to explain the fit test, the importance of cooperation, the purpose for the head exercises, or to demonstrate some of the exercises.

8. Each exercise described in #4 above shall be performed for at least one minute.

9. If at any time during the test, the subject detects the banana-like odor of IAA, the test has failed. The subject shall quickly exit from the test chamber and leave the test area to avoid olfactory fatigue.

10. If the test is failed, the subject shall return to the selection room and remove the respirator, repeat the odor sensitivity test, select and put on another respirator, return to the test chamber, and again begin the procedure described in the c(4) through c(8) above. The process continues until a respirator that fits well has been found. Should the odor sensitivity test be failed, the subject shall wait about 5 minutes before retesting. Odor sensitivity will usually have returned by this time.

11. If a person cannot pass the fit test described above wearing a half-mask respirator from the available selection, full facepiece models must be used.

12. When a respirator is found that passes the test, the subject breaks the faceseal and takes a breath before exiting the chamber. This is to assure that the reason the test subject is not smelling the IAA is the good fit of the respirator facepiece seal and not olfactory fatigue.

13. When the test subject leaves the chamber, the subject shall remove the saturated towel and return it to the person conducting the test. To keep the area from becoming contaminated, the used towels shall be kept in a self-sealing bag so there is no significant IAA concentration buildup in the test chamber during subsequent tests.

14. At least two facepieces shall be selected for the IAA test protocol. The test subject shall be given the opportunity to wear them for one week to choose the one which is more comfortable to wear.

15. Persons who have successfully passed this fit test with a half-mask respirator may be assigned the use of the test respirator in atmospheres with up to 10 times the PEL of airborne asbestos. In atmospheres greater than 10 times, and less than 100 times the PEL (up to 100 ppm), the subject must pass the IAA test using a full face negative pressure respirator. (The concentration of the IAA inside the test chamber must be increased by ten times for QLFT of the full facepiece.)

16. The test shall not be conducted if there is any hair growth between the skin the facepiece sealing surface.

17. If hair growth or apparel interfere with a satisfactory fit, then they shall be altered or removed so as to eliminate interference and allow a satisfactory fit. If a satisfactory fit is still not attained, the test subject must use a positive-pressure respirator such as powered air-purifying respirators, supplied air respirator, or self-contained breathing apparatus.

18. If a test subject exhibits difficulty in breathing during the tests, she or he shall be referred to a physician trained in respirator diseases or pulmonary medicine to determine whether the test subject can wear a respirator while performing her or his duties.

19. Qualitative fit testing shall be repeated at least every six months.

20. In addition, because the sealing of the respirator may be affected, qualitative fit testing shall be repeated immediately when the test subject has a:

(1) Weight change of 20 pounds or more,

(2) Significant facial scarring in the area of the facepiece seal,

(3) Significant dental changes; i.e., multiple extractions without prothesis, or acquiring dentures,

(4) Reconstructive or cosmetic surgery, or

(5) Any other condition that may interfere with facepiece sealing.

D. Recordkeeping

A summary of all test results shall be maintained in each office for 3 years. The summary shall include:

(1) Name of test subject,

(2) Date of testing,

(3) Name of the test conductor,

(4) Respirators selected (indicate manufacturer, model, size and approval number),

(5) Testing agent.

II. Saccharin Solution Aerosol Protocol

A. Respirator Selection

Respirators shall be selected as described in section IB (respirator selection) above, except that each respirator shall be equipped with a particulate filter.

B. Taste Threshold Screening

1. An enclosure about head and shoulders shall be used for threshold screening (to determine if the individual can taste saccharin) and for fit testing. The enclosure shall be approximately 12 inches in diameter by 14 inches tall with at least the front clear to allow free movement of the head when a respirator is worn.

2. The test enclosure shall have a three-quarter inch hole in front of the test subject's nose and mouth area to accommodate the nebulizer nozzle.

3. The entire screening and testing procedure shall be explained to the test subject prior to conducting the screening test.

4. During the threshold screening test, the test subject shall don the test enclosure and breathe with open mouth with tongue extended.

5. Using a DeVilbiss Model 40 Inhalation Medication Nebulizer or equivalent, the test conductor shall spray the threshold check solution into the enclosure. This nebulizer shall be clearly marked to distinguish it from the fit test solution nebulizer.

6. The threshold check solution consists of 0.83 grams of sodium saccharin, USP in water. It can be prepared by putting 1 cc of the test solution (see C 7 below) in 100 cc of water.

7. To produce the aerosol, the nebulizer bulb is firmly squeezed so that it collapses completely, then is released and allowed to fully expand.

8. Ten squeezes of the nebulizer bulb are repeated rapidly and then the test subject is asked whether the saccharin can be tasted.

9. If the first response is negative, ten more squeezes of the nebulizer bulb are repeated rapidly and the test subject is again asked whether the saccharin can be tasted.

10. If the second response is negative ten more squeezes are repeated rapidly and the test subject is again asked whether the saccharin can be tasted.

11. The test conductor will take note of the number of squeezes required to elicit a taste response.

12. If the saccharin is not tasted after 30 squeezes (Step 10), the saccharin fit test cannot be performed on the test subject.

13. If a taste response is elicited, the test subject shall be asked to take note of the taste for reference in the fit test.

14. Correct use of the nebulizer means that approximately 1 cc of liquid is used at a time in the nebulizer body.

15. The nebulizer shall be thoroughly rinsed in water, shaken dry, and refilled at least every four hours.

C. Fit Test

1. The test subject shall don and adjust the respirator without the assistance from any person.

2. The fit test uses the same enclosure described in IIB above.

3. Each test subject shall wear the respirator for at least 10 minutes before starting the fit test.

4. The test subject shall don the enclosure while wearing the respirator selected in secuon 1B above. This respirator shall be properly adjusted and equipped with a particulate filter.

5. The test subject may not eat, drink (except plain water), or chew gum for 15 minutes before the test.

6. A second DeVilbiss Model 40 Inhalation Medication Nebulizer is used to spray the fit test solution into the enclosure. This nebulizer shall be clearly marked to distinguish it from the screening test solution nebulizer.

7. The fit test solution is prepared by adding 83 grams of sodium saccharin to 100 cc of warm water.

8. As before, the test subject shall breathe with mouth open and tongue extended.

9. The nebulizer is inserted into the hole in the front of the enclosure and the fit test solution is sprayed into the enclosure using the same technique as for the taste threshold screening and the same number of squeezes required to elicit a taste response in the screening. (See B8 through B10 above).

10. After generation of the aerosol read the following instructions to the test subject. The test subject shall perform the exercises for one minute each.

i. Breathe normally.

ii. Breathe deeply. Be certain breaths are *deep* and *regular*.

iii. Turn head all the way from one side to the other. Be certain movement is complete. Inhale on each side. Do not bump the respirator against the shoulders.

iv. Nod head up-and-down. Be certain motions are complete. Inhale when head is in the full up position (when looking toward the ceiling). Do not bump the respirator on the chest.

v. Talking. Talk loudly and slowly for several minutes. The following paragraph is called the Rainbow Passage. Reading it will result in a wide range of facial movements, and thus be useful to satisfy this requirement. Alternative passages which serve the same purpose may also be used.

vi. Jogging in place.

vii. Breathe normally.

Rainbow Passage

When the sunlight strikes raindrops in the air, they act like a prism and form a rainbow. The rainbow is a division of white light into many beautiful colors. These take the shape of a long round arch, with its path high above, and its two ends apparently beyond the horizon. There is, according to legend, a boiling pot of gold at one end. People look, but no one ever finds it. When a man looks for something beyond his reach, his friends say he is looking for the pot of gold at the end of the rainbow.

11. At the beginning of each exercise, the aerosol concentration shall be replenished using one-half the number of squeezes as initially described in C9.

12. The test subject shall indicate to the test conductor if at any time during the fit test the taste of saccharin is detected.

13. If the saccharin is detected the fit is deemed unsatisfactory and a different respirator shall be tried.

14. At least two facepieces shall be selected by the IAA test protocol. The test subject shall be given the opportunity to wear them for one week to choose the one which is more comfortable to wear.

15. Successful completion of the test protocol shall allow the use of the half mask tested respirator in contaminated atmospheres up to 10 times the PEL of asbestos. In other words this protocol may be used to assign protection factors no higher than ten.

16. The test shall not be conducted if there is any hair growth between the skin and the facepiece sealing surface.

17. If hair growth or apparel interfere with a satisfactory fit, then they shall be altered or removed so as to eliminate interference and allow a satisfactory fit. If a satisfactory fit is still not attained, the test subject must use a positive-pressure respirator such as powered air-purifying respirators, supplied air respirator, or self-contained breathing apparatus.

18. If a test subject exhibits difficulty in breathing during the tests, she or he shall be referred to a physician trained in respirator diseases or pulmonary medicine to determine whether the test subject can wear a respirator while performing her or his duties.

19. Qualitative fit testing shall be repeated at least every six months.

20. In addition, because the sealing of the respirator may be affected, qualitative fit testing shall be repeated immediately when the test subject has a:

(1) Weight change of 20 pounds or more.

(2) Significant facial scarring in the area of the facepiece seal.

(3) Significant dental changes; i.e.: multiple extractions without prothesis, or acquiring dentures.

(4) Reconstructive or cosmetic surgery, or

(5) Any other condition that may interfere with facepiece sealing.

D. Recordkeeping

A summary of all test results shall be maintained in each office for 3 years. The summary shall include:

(1) Name of test subject.

(2) Date of testing.

(3) Name of test conductor.

(4) Respirators selected (indicate manufacturer, model, size and approval number).

(5) Testing agent.

III. Irritant Fume Protocol

A. Respirator selection

Respirators shall be selected as described in section IB above, except that each respirator shall be equipped with a combination of high-efficiency and acid-gas cartridges.

B. Fit test

1. The test subject shall be allowed to smell a weak concentration of the irritant smoke to familiarize the subject with the characteristic odor.

2. The test subject shall properly don the respirator selected as above, and wear it for at least 10 minutes before starting the fit test.

3. The test conductor shall review this protocol with the test subject before testing.

4. The test subject shall perform the conventional positive pressure and negative pressure fit checks (see ANSI Z88.2 1980). Failure of either check shall be cause to select an alternate respirator.

5. Break both ends of a ventilation smoke tube containing stannic oxychloride, such as the MSA part # 5645, or equivalent. Attach a short length of tubing to one end of the smoke tube. Attach the other end of the smoke tube to a low pressure air pump set to deliver 200 milliliters per minute.

6. Advise the test subject that the smoke can be irritating to the eyes and instruct the subject to keep the eyes closed while the test is performed.

7. The test conductor shall direct the stream of irritant smoke from the tube towards the faceseal area of the test subject. The person conducting the test shall begin with the tube at least 12 inches from the facepiece and gradually move to within one inch, moving around the whole perimeter of the mask.

8. The test subject shall be instructed to do the following exercises while the respirator is being challenged by the smoke. Each exercise shall be performed for one minute.

i. Breathe normally.

ii. Breathe deeply. Be certain breaths are *deep* and *regular*.

iii. Turn head all the way from one side to the other. Be certain movement is complete. Inhale on each side. Do not bump the respirator against the shoulders.

iv. Nod head up-and-down. Be certain motions are complete and made every second. Inhale when head is in the full up position (looking toward ceiling). Do not bump the respirator against the chest.

v. Talking. Talk aloud and slowly for several minutes. The following paragraph is called the Rainbow Passage. Reading it will result in a wide range of facial movements, and thus be useful to satisfy this requirement. Alternative passages which serve the same purpose may also be used.

Rainbow Passage

When the sunlight strikes raindrops in the air, they act like a prism and form a rainbow. The rainbow is a division of white light into many beautiful colors. These take the shape of a long round arch, with its path high above, and its two ends apparently beyond the horizon. There is, according to legend, a boiling pot of gold at one end. People look, but no one ever finds it. When a man looks for something beyond his reach, his friends say he is looking for the pot of gold at the end of the rainbow.

vi. Jogging in Place.

vii. Breathe normally.

9. The test subject shall indicate to the test conductor if the irritant smoke is detected. If smoke is detected, the test conductor shall stop the test. In this case, the tested respirator is rejected and another respirator shall be selected.

10. Each test subject passing the smoke test (i.e. without detecting the smoke) shall be given a sensitivity check of smoke from the same tube to determine if the test subject reacts to the smoke. Failure to evoke a response shall void the fit test.

11. Steps B4, B9, B10 of this fit test protocol shall be performed in a location with exhaust ventilation sufficient to prevent general contamination of the testing area by the test agents.

12. At least two facepieces shall be selected by the IAA test protocol. The test subject shall be given the opportunity to wear them for one week to choose the one which is more comfortable to wear.

13. Respirators successfully tested by the protocol may be used in contaminated atmospheres up to ten times the PEL of asbestos.

14. The test shall not be conducted if there is any hair growth between the skin and the facepiece sealing surface.

15. If hair growth or apparel interfere with a satisfactory fit, then they shall be altered or removed so as to eliminate interference and allow a satisfactory fit. If a satisfactory fit is still not attained, the test subject must use a positive-pressure respirator such as powered air-purifying respirators, supplied air respirator, or self-contained breathing apparatus.

16. If a test subject exhibits difficulty in breathing during the tests, she or he shall be referred to a physician trained in respirator diseases or pulmonary medicine to determine whether the test subject can wear a respirator while performing her or his duties.

17. Qualitative fit testing shall be repeated at least every six months.

18. In addition, because the sealing of the respirator may be affected, qualitative fit testing shall be repeated immediately when the test subject has a:

(1) Weight change of 20 pounds or more.

(2) Significant facial scarring in the area of the facepiece seal.

(3) Significant dental changes: i.e.: multiple extractions without prothesis, or acquiring dentures.

(4) Reconstructive or cosmestic surgery, or

(5) Any other condition that may interfere with facepiece sealing.

C. Recordkeeping

A summary of all test results shall be maintained in each office for 3 years. The summary shall include:

(1) Name of test subject.

(2) Date of testing.

(3) Name of test conductor.

(4) Respirators selected (indicate manufacturer, model, size and approval number).

(5) Testing agent

Quantitative Fit Test Procedures

1. General.

a. The method applies to the negative-pressure nonpowered air-purifying respirators only.

b. The employer shall assign one individual who shall assume the full responsibility for implementing the respirator quantitative fit test program.

2. *Definition.*

a. "Quantitative Fit Test" means the measurement of the effectiveness of a respirator seal in excluding the ambient atmosphere. The test is performed by dividing the measured concentration of challenge agent in a test chamber by the measured concentration of the challenge agent inside the respirator facepiece when the normal air purifying element has been replaced by an essentially perfect purifying element.

b. "Challenge Agent" means the air contaminant introduced into a test chamber so that its concentration inside and outside the respirator may be compared.

c. "Test Subject" means the person wearing the respirator for quantitative fit testing.

d. "Normal Standing Position" means standing erect and straight with arms down along the sides and looking straight ahead.

e. "Fit Factor" means the ratio of challenge agent concentration outside with respect to the inside of a respirator inlet covering (facepiece or enclosure).

3. *Apparatus.*

a. *Instrumentation.* Corn oil, sodium chloride or other appropriate aerosol generation, dilution, and measurement systems shall be used for quantitative fit test.

b. *Test chamber.* The test chamber shall be large enough to permit all test subjects to freely perform all required exercises without distributing the challenge agent concentration or the measurement apparatus. The test chamber shall be equipped and constructed so that the challenge agent is effectively isolated from the ambient air yet uniform in concentration throughout the chamber.

c. When testing air-purifying respirators, the normal filter or cartridge element shall be replaced with a high-efficiency particular filter supplied by the same manufacturer.

d. The sampling instrument shall be selected so that a strip chart record may be made of the test showing the rise and fall of challenge agent concentration with each inspiration and expiration at fit factors of at least 2,000.

e. The combination of substitute air-purifying elements (if any), challenge agent, and challenge agent concentration in the test chamber shall be such that the test subject is not exposed in excess of PEL to the challenge agent at any time during the testing process.

f. The sampling port on the test specimen respirator shall be placed and constructed so that there is no detectable leak around the port, a free air flow, is allowed into the sampling line at all times and so there is no interference with the fit or performance of the respirator.

g. The test chamber and test set-up shall permit the person administering the test to observe one test subject inside the chamber during the test.

h. The equipment generating the challenge atmosphere shall maintain the concentration of challenge agent constant within a 10 percent variation for the duration of the test.

i. The time lag (interval between an event and its being recorded on the strip chart) of the instrumentation may not exceed 2 seconds.

j. The tubing for the test chamber atmosphere and for the respirator sampling port shall be the same diameter, length and material. It shall be kept as short as possible. The smallest diameter tubing recommended by the manufacturer shall be used.

k. The exhaust flow from the test chamber shall pass through a high-efficiency filter before release to the room.

l. When sodium chloride aerosol is used, the relative humidity inside the test chamber shall not exceed 50 percent.

4. *Procedural Requirements.*

a. The fitting of half-mask respirators should be started with those having multiple sizes and a variety of interchangeable cartridges and canisters such as the MSA Comfo II–M, Norton M, Survivair M, A-O M, or Scott-M. Use either of the tests outlined below to assure that the facepiece is properly adjusted.

(1) *Positive pressure test.* With the exhaust port(s) blocked, the negative pressure of slight inhalation should remain constant for several seconds.

(2) *Negative pressure test.* With the intake port(s) blocked, the negative pressure slight inhalation should remain constant for several seconds.

b. After a facepiece is adjusted, the test subject shall wear the facepiece for at least 5 minutes before conducting a qualitive test by using either of the methods described below and using the exercise regime described in 5.a., b., c., d., and e.

(1) *Isoamyl acetate test.* When using organic vapor cartridges, the test subject who can smell the odor should be unable to detect the odor of isoamyl acetate squirted into the air near the most vulnerable portions of the facepiece seal. In a location which is separated from the test area, the test subject shall be instructed to close her/his eyes during the test period. A combination cartridge or canister with organic vapor and high-efficiency filters shall be used when available for the particular mask being tested. The test subject shall be given an opportunity to smell the odor of isoamyl acetate before the test is conducted.

(2) *Irritant fume test.* When using high-efficiency filters, the test subject should be unable to detect the odor of irritant fume (stannic chloride or titanium tetrachloride ventilation smoke tubes) squirted into the air near the most vulnerable portions of the facepiece seal. The test subject shall be instructed to close her/his eyes during the test period.

c. The test subject may enter the quantitative testing chamber only if she or he has obtained a satisfactory fit as stated in 4.b. of this Appendix.

d. Before the subject enters the test chamber, a reasonably stable challenge agent concentration shall be measured in the test chamber.

e. Immediately after the subject enters the test chamber, the challenge agent concentration inside the respirator shall be measured to ensure that the peak penetration does not exceed 5 percent for a half-mask and 1 percent for a full facepiece.

f. A stable challenge agent concentration shall be obtained prior to the actual start of testing.

(1) Respirator restraining straps may not be overtightened for testing. The straps shall be adjusted by the wearer to give a reasonably comfortable fit typical of normal use.

5. *Exercise Regime.* Prior to entering the test chamber, the test subject shall be given complete instructions as to her/his part in the test procedures. The test subject shall perform the following exercises, in the order given, for each independent test.

a. *Normal Breathing (NB).* In the normal standing position, without talking, the subject shall breathe normally for at least one minute.

b. *Deep Breathing (DB).* In the normal standing position the subject shall do deep breathing for at least one minute pausing so as not to hyperventilate.

c. *Turning head side to side (SS).* Standing in place the subject shall slowly turn his/her head from side between the extreme positions to each side. The head shall be held at each extreme position for at least 5 seconds. Perform for at least three complete cycles.

d. *Moving head up and down (UD).* Standing in place, the subject shall slowly move his/her head up and down between the extreme position straight up and the extreme position straight down. The head shall be held at each extreme position for at least 5 seconds. Perform for at least three complete cycles.

e. *Reading (R).* The subject shall read out slowly and loud so as to be heard clearly by the test conductor or monitor. The test subject shall read the "rainbow passage" at the end of this section.

f. *Grimace (G).* The test subject shall grimace, smile, frown, and generally contort the face using the facial muscles. Continue for at least 15 seconds.

18. In addition, because the sealing of the respirator may be affected, qualitative fit testing shall be repeated immediately when the test subject has a:

(1) Weight change of 20 pounds or more.

(2) Significant facial scarring in the area of the facepiece seal.

(3) Significant dental changes; i.e., multiple extractions without prothesis, or acquiring dentures.

(4) Reconstructive or cosmestic surgery, or

(5) Any other condition that may interfere with facepiece sealing.

C. Recordkeeping

A summary of all test results shall be maintained in each office for 3 years. The summary shall include:

(1) Name of test subject.

(2) Date of testing.

(3) Name of test conductor.

(4) Respirators selected (indicate manufacturer, model, size and approval number).

(5) Testing agent

APPENDIX D

RESPIRATOR SELECTION DECISION LOGIC

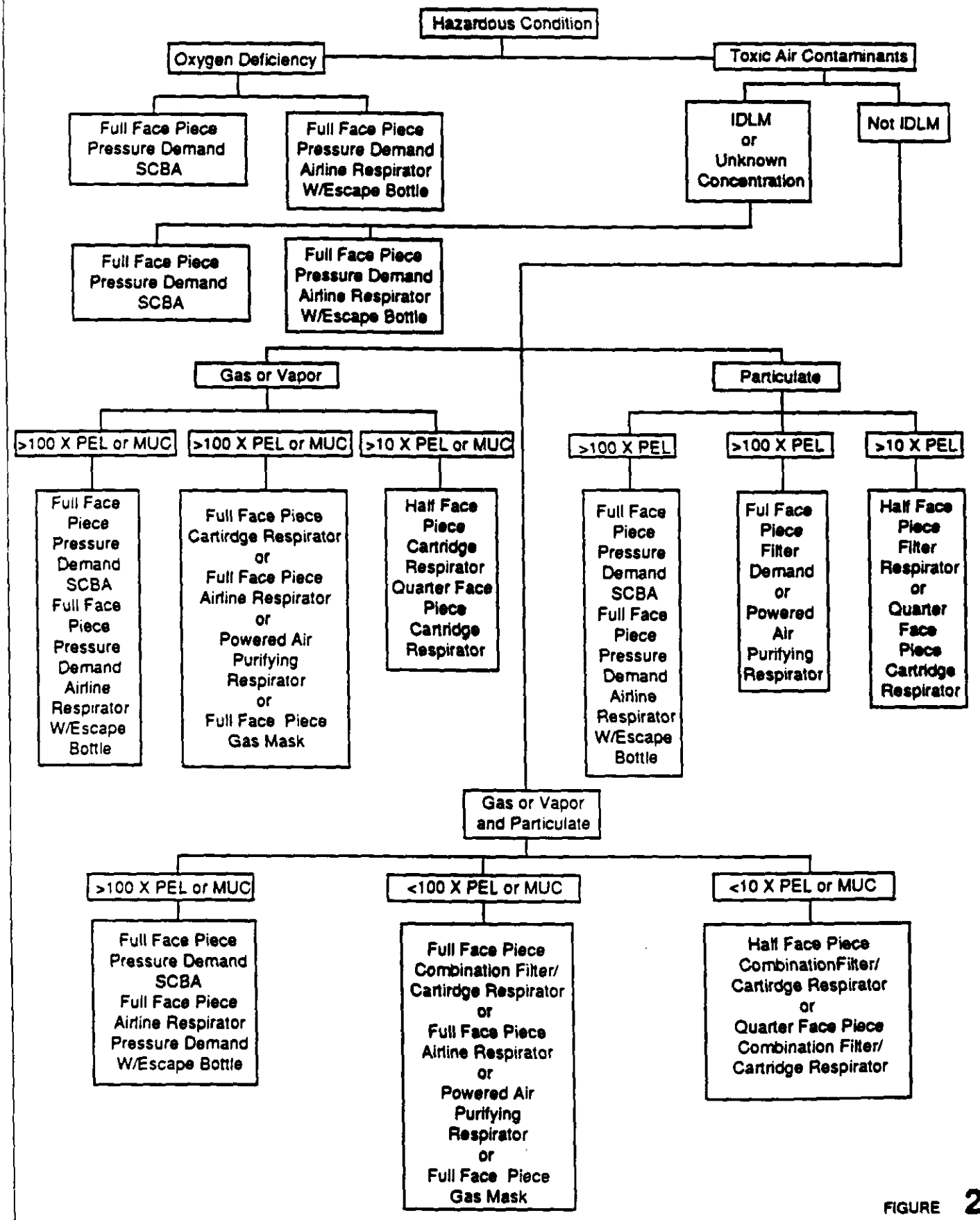


FIGURE **2**

RESPIRATORY SELECTION DECISION LOGIC

HEALTH AND SAFETY

PROJECT NO. 993-1014 DWG. NO. 22671 DATE 7/12/90 DRAWN DC

Golder Associates

APPENDIX E

ENDANGERMENT ASSESSMENT PLAN

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APPENDIX E

1.0 ENDANGERMENT ASSESSMENT

The baseline risk assessment will be conducted during the RI portion of the investigation to determine whether the Site poses an imminent and/or substantial endangerment to public health and the surrounding environment. The baseline risk assessment will provide an evaluation of the potential threat to human health and the environment in the absence of any remedial action at the Site and provide the basis for determining whether or not remedial action is necessary and the justification for performing remedial actions. The baseline risk assessment will be developed in accordance with the Risk Assessment Guidance for Superfund Volume I and Volume II (December, 1989).

The risk assessment will be divided into four activities:

- selection of contaminants for risk assessment,
- exposure assessment,
- toxicity assessment, and
- risk characterization.

2.0 CONTAMINANT IDENTIFICATION

The objective of the contaminant identification is to identify the hazardous substances present in the environmental media at the Site and to identify parameters of interest for which subsequent efforts in the risk assessment process will be focused. Parameters of interest for the risk assessment will be selected for each environmental media based on their presence at the Site, detected concentrations, toxicity, mobility, persistence, and propensity for bioaccumulation.

In addition, it may be necessary to select "indicator chemicals" as part of this process. Indicator chemicals for each class of chemicals present in environmental media at the Site would be selected to represent the most toxic and/or mobile substances among those identified and for which the best toxicity and environmental data are available.

As discussed in Section 3.0 of the RI/FS Work Plan, previous investigations indicate that in general, PCBs, PAHs, and metals are the classes of compounds of concern at the Site.

3.0 EXPOSURE ASSESSMENT

The objective of the exposure assessment is to determine the type and magnitude of potential contaminant exposures to human and environmental receptor populations. The exposure assessment will be performed in accordance with the Risk Assessment Guidance for Superfund Volumes I and II and the Superfund Exposure Assessment Manual.

Section 3.0 of the RI/FS Work Plan, Volume I, summarizes the results of previous environmental monitoring at the Site. An initial evaluation of the pathways of concern at the Site and the potential impacts to human and environmental populations from exposures to contaminants within these pathways is also included. The following table summarizes the anticipated pathways/media of concern at the Site, the anticipated exposure routes, and the anticipated human and environmental receptor populations to be evaluated in the endangerment assessment. The environmental sampling and monitoring to be performed during the RI to characterize the concentration and distribution of contaminants in the media/pathways of concern for the PHE are also included in the table.

Media/Pathway of Concern	Anticipated Potential Receptor Population	Exposure Route	Environmental Monitoring and Sampling Planned to Characterize the Pathway
Groundwater	Downgradient residents who obtain groundwater from the sand and gravel outwash unit	Ingestion Inhalation Dermal contact	Groundwater sampling at perimeter and downgradient of the Site

Media/Pathway of Concern	Anticipated Potential Receptor Population	Exposure Route	Environmental Monitoring and Sampling Planned to Characterize the Pathway
	Aquatic life in surface water bodies (e.g., ponded water bodies, Yeoman Creek, and the wetlands) which receive groundwater discharge	Ingestion Dermal contact Absorption	
Surface Water/ Sediment	People in contact with water/sediment in Yeoman Creek and nearby surface water bodies	Inhalation Dermal contact Incidental ingestion	Surface water and sediment sampling in Yeoman Creek and nearby surface water bodies
	Aquatic life in Yeoman Creek, nearby ponded water bodies, and the wetlands		
Surface Soil/ Seeps/Seep Sediment	People, animals, and plants in contact with contaminated surface sediments at the Site	Inhalation Ingestion Dermal contact	Surface soil, seeps, and seep sediment sampling
Air	People, flora and fauna near the Site	Inhalation	Ambient air survey on and around the Site Landfill gas investigation (subsurface probes around the perimeter of the Site)

Media/Pathway of Concern	Anticipated Potential Receptor Population	Exposure Route	Environmental Monitoring and Sampling Planned to Characterize the Pathway
			Possibly monitoring air in nearby basements

Potential future land uses that may be evaluated during the exposure assessment include development of the Site as a park or golf course. Future use of the Site as a residential, commercial, or industrial area will be evaluated as part of the no action scenario during the exposure assessment even though these uses are not considered likely as the Site is currently publicly owned and institutional controls will probably be implemented at the Site following the RI/FS. The residential development scenario will include ingestion of groundwater/leachate, exposure to landfill gases and exposure to soils, including those at seeps, as a result of residential activities.

The first step of the exposure assessment process is contaminant release analysis. Significant release points will be identified for each parameter of interest and indicator compound, and the release point concentration will be determined or estimated. The Field Sampling Plan, Appendix B, Volume II, provides details on the source characterization and constituent characterization of pathways investigations that will provide the necessary data for this step of the exposure assessment.

The second step is the analysis of contaminant transport and fate, a description of the extent and magnitude of environmental contamination, including an estimation of future

conditions. A variety of computer models may be used in conducting this phase of the exposure assessment.

Step three is an exposed population analysis. Human and environmental receptor populations with the potential to be exposed to contaminants from the Site are evaluated through identification, enumeration, and characterization. In addition to delineating which populations could come in contact with contaminants from the Site, this analysis estimates how and with what frequency and durations such contacts occur.

The fourth step is an integrated exposure analysis. In this step, the individual contaminant specific exposure estimates are developed. All exposure to each of the target or indicator contaminants are identified for each human and environmental receptor population. This analysis will also evaluate exposure rates and contaminant intakes for a reasonable maximum exposed individual as recommended in the Risk Assessment Guidance for Superfund. It is anticipated that long term chronic exposures will be the concern at the Site.

The fifth and final exposure assessment step is an uncertainty analysis. The exposure assessment process involves several necessary estimates. These estimates are reviewed to identify uncertainties and to evaluate their separate and cumulative impacts on the results of the assessment.

Solicitor A5320

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION V

IN THE MATTER OF: YEOMAN CREEK LANDFILL FACILITY LAKE COUNTY WAUKEGAN, ILLINOIS Respondents, Proceeding under Section 122(a) and (d)(3) of the Comprehensive Environmental Response, Compensation, and Liability Act of 1980, as amended.	ADMINISTRATIVE ORDER BY CONSENT RE: REMEDIAL INVESTIGATION AND FEASIBILITY STUDY U.S. EPA Docket No.

The United States Environmental Protection Agency ("U.S. EPA"), Illinois Environmental Protection Agency ("IEPA") jointly referred to herein as the "Agencies") and the Respondents have each agreed to the making and entry of this Administrative Order by Consent ("Consent Order").

I. JURISDICTION

A. This Consent Order is issued pursuant to the authority vested in the President of the United States by Section 122(a) and (d)(3) of the Comprehensive Environmental Response, Compensation, and Liability Act of 1980, 42 U.S.C. Section 9601 et seq., as amended by the Superfund Amendments and Reauthorization Act of 1986, Pub. L. 99-499 ("CERCLA"), and delegated to the Administrator of the U.S. EPA on January 29, 1987, by Executive Order 12580, 52 Federal Register 2923, and further delegated to the

Assistant Administrator for Solid Waste and Emergency Response and the Regional Administrators by U.S. EPA Delegation No. 14-14-C on February 26, 1987 and to the Waste Management Division Director by U.S. EPA, Region V, Delegation No. 14-14-C on September 14, 1987. This Consent Order is also issued pursuant to the authority vested in the IEPA by the Illinois Environmental Protection Act, Ill. Rev. Stat. Ch. 111 1/2, para. 1001 et seq.

B. The Respondents to this Consent Order agree to undertake all actions required by the terms and conditions hereunder, and consent to and will not contest or legally challenge the issuance of this Consent Order or the U.S. EPA's or IEPA's jurisdiction regarding this Consent Order.

II. NOTICE OF ACTION

A. U.S. EPA has notified all potentially responsible parties that it has identified as of the date of entry of this Consent Order of this action to the extent such notification is required, pursuant to Section 122(e) of CERCLA.

B. U.S. EPA has notified the Federal Natural Resource trustee of this action pursuant to the requirements of Section 122(j) of CERCLA. The IEPA has notified, pursuant to Section 104(b)(2) of CERCLA, the State Natural Resource Trustees, who are the Director of the Department of Energy and Natural Resources, the Director of the Department of Conservation, the Director of the Division of Water Resources of the Illinois Department of Transportation, and the Director of the IEPA.

III. PARTIES BOUND

A. This Consent Order applies to and binds the following persons as defined in Section 101(21) of CERCLA:

(1) U.S. EPA, through the Waste Management Division Director, Region V;

(2) IEPA, through the Director;

(3) the individuals and corporations, their respective successors and assignees, (referred to collectively as "Respondents") identified in Attachment A of this Consent Order.

B. Each of the undersigned representatives of the U.S. EPA, IEPA and the Respondents certifies that he or she is fully authorized to enter into the terms and conditions of this Consent Order and to execute and legally bind such party to this document.

C. No change in ownership, corporate, or partnership status shall in any way alter the status or responsibility of the Respondents under this Consent Order. The Respondents shall be jointly and severally responsible for carrying out all actions required of the Respondents by the terms and conditions of this Consent Order. Respondents shall be responsible for ensuring that all contractors, consultants, firms and other persons or entities acting under or for it with respect to matters included herein comply with the terms of this Consent Order. Respondents shall not raise as a defense to enforcement of this Order that its officers, directors, principals, employees, agents, servants, contractors, subcontractors, firms and/or other persons or entities acting under or for them violated this Consent Order.

IV. STATEMENT OF PURPOSE

A. In entering into this Consent Order, the mutual objectives of the U.S.EPA, IEPA and the Respondents are for the Respondents: (1) to conduct a remedial investigation (RI) to determine fully the nature and extent of the release or threatened release of hazardous substances, pollutants or contaminants from the Yeoman Creek Landfill Facility, (2) to perform a feasibility study (FS) to identify and evaluate alternatives for the appropriate extent of remedial action to prevent or mitigate the migration or the release or threatened release of hazardous substances, pollutants, or contaminants from the Yeoman Creek Landfill Facility, and (3) to implement certain measures consisting of restricting site access, and eliminating presently existing erosion gullies, which shall be incorporated in the work to be performed during the RI.

B. The activities conducted pursuant to this Consent Order are subject to approval by the U.S. EPA and IEPA as provided herein, shall employ sound scientific, engineering and construction practices and shall be consistent with the National Contingency Plan, 40 CFR Section 300.68(a) through (j) as amended, CERCLA, and applicable State laws.

V. FINDINGS OF FACT

Based upon information available on the effective date of this Consent Order, and without admission of any fact, conclusions of law or liability by the Respondents, the Waste Management Division

Director of the U.S. EPA, Region V, and the Director of the IEPA make the following findings:

A. The Yeoman Creek Landfill (Facility) is located in the City of Waukegan, Lake County, Illinois. The Facility was operated as a sanitary landfill for the City of Waukegan and is presently a closed and covered landfill owned and maintained by the Waukegan Unit School District #60.

B. The Facility is approximately 40-50 acres in area and is located south of Sunset Avenue, west of Butrick Drive and east of Elmwood and Lorraine Avenues in Waukegan, Illinois. The site is not fenced and has unrestricted access. Some erosion is occurring at two gullies on the western edge of the facility. The south boundary is a peat bog that continues to Edwards Field. Apartments, homes and businesses directly border the Facility on the east, west and north.

C. By contract with the City of Waukegan, National Disposal Service of Illinois, Inc. operated the Facility from 1959 to February 1969. The city then awarded the contract to T-K City Disposal, Inc. who operated the Facility until September 1969. Under the contract, each of these contractors was to collect and dispose of all residential garbage within the City of Waukegan. These contractors were also permitted to accept waste materials from private disposal companies. Since Yeoman Creek Landfill was the only authorized municipal landfill in Waukegan for the period in which it was in operation, some industrial wastes were sent for disposal at the Facility through private disposal companies.

D. Leachate seepage from the Facility is known to enter Yeoman Creek which is a tributary of the Waukegan River emptying into Lake Michigan less than one mile from the Waukegan drinking water aqueduct intake. Tests conducted by U.S. EPA in 1985 indicated the presence of PCBs and other organic chemicals in the sediments of Yeoman Creek at the Facility and further downstream at Yeoman Park.

E. The Facility is included in the National Priorities List (NPL) of hazardous waste sites with a Hazardous Ranking Score of 33.23.

VI. CONCLUSIONS OF LAW

Based upon information available on the effective date of this Consent Order, and without admission of any fact, conclusions of law or liability by the Respondents, the Waste Management Division Director of the U.S. EPA, Region V, and the Director of IEPA make the following conclusions of law:

A. The Yeoman Creek Landfill, as defined in Section V., is a "Facility" as defined in Section 101(9) of CERCLA.

B. "Hazardous substances" as defined in Section 101(14) of CERCLA have been deposited, stored, disposed of, placed, or otherwise come to be located at the Facility.

C. The spilling, leaking, leaching, dumping, or disposing of hazardous substances into the soils and groundwater at the Facility, and the past, present, and potential migration of hazardous substances from the Facility constitutes an actual and/or

threatened "release" of hazardous substances into the environment as defined in Section 101(22) of CERCLA.

D. The Respondents are "persons" as defined in Section 101(21) of CERCLA.

E. The Respondents are liable persons pursuant to Section 107 of CERCLA and are potentially responsible parties for the purposes of Section 122 of CERCLA.

VII. DETERMINATIONS

Based on the foregoing Findings of Fact and Conclusions of Law, the Waste Management Division Director of U.S. EPA, Region V, and the Director of the IEPA have determined that:

A. Respondents shall promptly and properly take appropriate response action at the Facility by conducting a Remedial Investigation and Feasibility Study ("RI/FS"), and are qualified to perform the RI/FS; and

B. In order to ensure orderly conduct of the RI/FS, it is necessary to implement access restrictions (i.e., a fence) and erosion control measures.

C. The actions outlined in this Consent Order are necessary to ensure the protection of public health, welfare and the environment.

D. The actions required by this Consent Order are in the public interest and are consistent with the National Contingency Plan, 40 CFR Part 300, as amended, (hereinafter "NCP") and with CERCLA.

VIII. WORK TO BE PERFORMED

A. All work to be performed by the Respondents pursuant to this Consent Order shall be under the direction and supervision of a qualified professional engineer or certified geologist. Prior to the initiation of work at the Facility, the Respondents shall notify the U.S. EPA and IEPA, in writing, of the name, title, and qualifications of the proposed engineer or geologist, and of the names of principal contractors and/or subcontractors proposed to be used in carrying out the work to be performed pursuant to this Consent Order. Selection of any such engineer or geologist or contractor and/or subcontractor shall be subject to approval by the U.S. EPA in consultation with the IEPA. If the U.S. EPA disapproves of the Respondent's proposed engineer or geologist or contractor or subcontractor, the U.S. EPA shall specify, in writing, the bases for such disapproval.

B. Attachment I to this Consent Order provides a Statement of Work ("SOW") for the completion of the RI/FS, including access and erosion control measures. The SOW is incorporated into and made a part of this Consent Order.

C. The following work shall be performed:

1. Within sixty (60) calendar days of the effective date of this Consent Order, the Respondents shall submit a work plan to the U.S. EPA and IEPA for a complete Remedial Investigation and Feasibility Study (hereinafter RI/FS Work Plan). The RI/FS Work Plan shall be developed in conformance with the SOW, the standards

set forth in CERCLA, including Section 121 of CERCLA, the NCP, U.S. EPA guidance on remedial investigations and feasibility studies, as amended, "the Superfund Remedial Design and Remedial Action Guidance," (February 1985), as amended, and any additional guidance documents provided by U.S. EPA. In the event that any such additional guidance document is provided to the Respondents by the Agencies after the effective date of this Consent Order, the Respondents shall have fifteen (15) calendar days to revise the Work Plan as necessary, and any time limits provided in this Consent Order shall be extended as necessary to accommodate said fifteen (15) day period.

2. The RI/FS Work Plan submittal shall include, but not be limited to, the following project plans: (1) an access restriction and erosion control measures plan; (2) a field sampling plan; (3) a health and safety plan; (4) a quality assurance project plan ("QAPP"); (5) provisions for the preparation of an endangerment assessment plan; (6) a data management plan, and; (7) a schedule, including specific dates for implementation of RI/FS tasks and deliverables such as technical memoranda, preliminary and final Remedial Investigation reports, preliminary and final endangerment assessments, and preliminary and final Feasibility Study reports.... The preliminary and final Remedial Investigation reports and the preliminary and final Feasibility Study reports shall be prepared in accordance with the applicable U.S. EPA guidance.

3. The RI/FS Work Plan shall be subject to review,

modification, and approval by the U.S. EPA in consultation with the IEPA.

4. Within forty five (45) calendar days of receipt of the RI/FS Work Plan, the U.S. EPA Project Coordinator shall notify the Respondents, in writing, of approval or disapproval of the RI/FS Work Plan, or any part thereof. In the event that a longer review period is required, the U.S. EPA Project Coordinator shall notify the Respondents of that fact within thirty (30) calendar days of receipt of the Work Plan. In the event of any disapproval, the U.S. EPA shall specify, in writing, any deficiencies and required modifications to the RI/FS Work Plan.

5. Within fifteen (15) calendar days of receipt of any U.S. EPA RI/FS Work Plan disapproval, the Respondents shall submit a revised RI/FS Work Plan to the U.S. EPA and the IEPA which incorporates the U.S. EPA modifications.

6. In the event of subsequent U.S. EPA disapproval of the RI/FS Work Plan, the U.S. EPA retains the right to conduct a complete or partial RI/FS and/or to enforce the terms of this Consent Order.

7. The Respondents shall commence implementation of the work detailed in the RI/FS Work Plan within fifteen (15) calendar days after the RI/FS Work Plan is fully approved by the U.S. EPA. The fully approved RI/FS Work Plan shall be deemed incorporated into and made an enforceable part of this Consent Order. All work shall be conducted in accordance with the National Contingency Plan, the RI/FS Guidance and the guidance

specified in paragraph C.1., above, and the requirements of this Consent Order, including the standards, specifications and schedule contained in the RI/FS Work Plan.

IX. PLANS AND REPORTS

A. The Respondents shall provide a preliminary and final Remedial Investigation Report and Feasibility Study Report and any other plans or reports required by the RI/FS Work Plan to the U.S. EPA and the IEPA according to the schedule contained in the RI/FS Work Plan.

B. The U.S. EPA shall approve, in consultation with the IEPA, the preliminary and final Remedial Investigation Report, the preliminary and final Feasibility Study Report, and any other preliminary or final plans or reports specified in the RI/FS Work Plan as requiring U.S. EPA approval.

C. If the U.S. EPA, in consultation with the IEPA, disapproves any preliminary or final plan or report, the U.S. EPA shall specify, in writing, any deficiencies and required modifications and the Respondents shall submit a revised plan or report to the U.S. EPA and IEPA within forty five (45) calendar days or such longer period as the U.S. EPA Project Coordinator may establish, which plan or report shall incorporate any U.S. EPA modifications or additions.

D. In the event of subsequent disapproval of any revised plan or report, the U.S. EPA, and the IEPA under State authority, retain the right to perform additional studies, to conduct a

complete or partial RI/FS, and/or to enforce the terms of this Consent Order.

E. The Respondents shall provide monthly written progress reports to the U.S. EPA and the IEPA. The past reportable month refers to the month immediately preceding the report submittal date, and the next reportable month refers to the month following the report submittal date (e.g., for a report due February 20, the past reportable month is January, and the next reportable month is March). At a minimum, these monthly written progress reports shall include the following:

1. A description of the action during the past reportable month which has been taken toward achieving compliance with this Consent Order, including all plans and procedures completed, and changes in key personnel;
2. A description of difficulties encountered during the past reportable month, and all actions taken to rectify the difficulties;
3. All results of sampling and tests produced during the past reportable month, relating to the Facility, and subjected to the QA/QC program;
4. Results or a description of sampling and tests produced during the past reportable month, relating to the Facility, but not subjected to the QA/QC program. Results of all such sampl-

ing and tests, whether subjected to the QA/QC program or not, shall be submitted by the next monthly written progress report;

5. All plans, procedures, actions, and data which are scheduled for the next reportable month;

6. Target and actual completion dates for each element of activity, including the project completion, and an explanation of any deviation from the schedules in the RI/FS Work Plan schedule; and

7. A description of any observed change in the cap and site security during the past reportable month, including but not limited to, erosion and leachate.

F. The monthly written progress reports shall be submitted to the U.S. EPA and the IEPA by the twentieth (20) business day of each month following the date of commencement of the work detailed in the RI/FS Work Plan.

X. ADDRESS FOR ALL CORRESPONDENCE

Documents, including reports, approvals, disapprovals and other correspondences to be sent by certified mail or any other form of mail delivery which records the date of receipt to the following addresses, or to such other addresses as the Respondent, the IEPA or the U.S. EPA may hereafter designate for themselves in writing:

A. Documents to be submitted to the U.S. EPA should be sent to:

Richard Boice
Remedial Project Manager
Remedial and Enforcement Response Branch (5HS-11)
U.S. Environmental Protection Agency
Region V
230 S. Dearborn Street
Chicago, Illinois 60604

B. Documents to be submitted to the IEPA should be sent to:

Scott Moyer
Project Manager
Division of Land Pollution Control
Illinois Environmental Protection Agency
2200 Churchill Road
Springfield, Illinois 62706

C. Documents to be submitted to the Respondents should be sent to a name and address to be designated by the Respondents within ten (10) calendar days of the effective date of this Consent Order.

XI. ADDITIONAL WORK

A. In the event that the U.S. EPA, the IEPA or the Respondents determines that additional work, including remedial investigatory work and/or engineering evaluation, is necessary to accomplish the objectives of the RI/FS, written notification of such additional work shall be provided to each of the other parties.

B. Any additional work determined to be necessary by the Respondents shall be subject to approval by the U.S. EPA, in consultation with the IEPA.

C. Any additional work determined to be necessary by the Respondents or the IEPA and approved by the U.S. EPA, or determined to be necessary by the U.S. EPA in consultation with the IEPA, shall be completed by the Respondents in accordance with the standards, specifications, and schedule determined or approved by the U.S. EPA in consultation with the IEPA and shall be incorporated into this Consent Order and made an enforceable part thereof.

XII. COMPLIANCE WITH APPLICABLE LAWS

All work undertaken by the Respondents pursuant to this Consent Order shall be performed in compliance with all applicable Federal and State laws and regulations, including all Occupational Health and Safety Administration and Department of Transportation regulations. The Respondents shall be responsible for obtaining all State or local permits which are necessary for the performance of any work hereunder.

XIII. ACCESS

A. To the extent that the Facility or other areas, where work is to be performed hereunder, is presently owned by parties other than those bound by this Consent Order, the Respondents shall obtain, or shall use their best efforts to obtain, access agreements from the present owners within thirty (30) calendar days of approval of the RI/FS Work Plan. Such agreements shall provide access for the Respondents, the U.S. EPA, the IEPA and authorized representatives of the U.S. EPA and the IEPA, as specified below.

In the event that such access agreements are not obtained within the time referenced above, the Respondents shall so notify the U.S. EPA and the IEPA, in writing, and shall specify the efforts to obtain access, and the responses thereto. If, despite the Respondents' best efforts to obtain access under this provision, the Respondents are unable to obtain access necessary to carry out the terms of this Consent Order, the Director, Waste Management Division, U.S. EPA, Region V agrees to recommend that the U.S. EPA's authority under Section 104(e) of CERCLA be exercised to secure such access on behalf of the Respondents. This agreement shall be subject to the following: (1) The U.S. EPA's determination that Respondents have exercised best efforts to obtain access necessary to carry out the terms of this Consent Order; (2) U.S. EPA guidance, including, but not limited to guidance entitled "Entry and Continued Access Guidance Under CERCLA," dated June 5, 1987; (3) consultation with the U.S. EPA's Office of Regional Counsel, the U.S. EPA's Office of Enforcement and Compliance Monitoring and, to the extent necessary, concurrence by the Department of Justice; and (4) agreement by the Respondents to cooperate with U.S. EPA in the exercise of this authority. The Respondents are advised that the expenses incurred by the United States in gaining access are response costs for which the Respondents may be liable. The U.S. EPA reserves the right to terminate this Consent Order should the Respondents' inability to gain access to the Facility or other areas materially affect the Respondents' ability to perform the work required herein.

B. Authorized representatives of the U.S. EPA and the IEPA shall be allowed access to the Facility and other areas by the Respondents, and as part of any agreement obtained under paragraph A above, for purposes including, but not limited to: inspecting records, operating logs and contracts related to the Facility; reviewing the progress of the Respondents in carrying out the terms of this Consent Order; conducting such tests, inspections, and sampling as the U.S. EPA and the IEPA may deem necessary; using a camera, sound recording, or other documentary type equipment; and verifying the data submitted to the U.S. EPA and the IEPA by the Respondents hereunder. Subject to applicable attorney-client and work product privileges as defined in Section XXI.B., below, the Respondents shall permit such authorized representatives to inspect and copy all records, files, photographs, documents, and other writings, including all sampling and monitoring data, which pertains to this Consent Order. All persons with access to the Facility pursuant to the Consent Order shall comply with approved health and safety plans.

C. Nothing herein shall be construed as restricting the inspection or access authority of the U.S. EPA or the IEPA under any law or regulation.

XIV. PROJECT COORDINATORS

A. On or before the effective date of this Consent Order, the U.S. EPA, the IEPA and the Respondents shall each designate a Project Coordinator. Each Project Coordinator shall be responsible

for overseeing the implementation of this Consent Order. The U.S. EPA Project Coordinator will be the U.S. EPA designated representative at the Facility. The IEPA Project Coordinator will be the IEPA's designated representative at the Facility. To the maximum extent possible, communications between the Respondents, the IEPA and the U.S. EPA, and all documents, reports, approvals and other correspondences concerning the activities performed pursuant to the terms and conditions of this Consent Order, shall be directed through the Project Coordinators. During implementation of the RI/FS Work Plan, the Project Coordinators shall, whenever possible, operate by consensus and shall attempt in good faith to resolve disputes informally through discussion of the issues.

B. The U.S. EPA, the IEPA and the Respondents shall each have the right to change their respective Project Coordinators. Such a change shall be accomplished by notifying each of the other parties in writing at least ten (10) calendar days prior to the change.

C. The U.S. EPA Project Coordinator shall have the authority vested in an On-Scene Coordinator and a Remedial Project Manager (OSC, RPM) by the National Contingency Plan, 40 CFR Part 300, as amended, including the authority to halt, conduct, or direct any work required by this Consent Order, or to direct any response action undertaken by the U.S. EPA when conditions at the Facility may present an imminent and substantial endangerment to the public health or welfare or the environment. In the event that the U.S. EPA Project Coordinator halts or substantially modifies work

specifically required by the Work Plan pursuant to this paragraph, the Respondent may request a modification of the schedule or work described in the RI/FS Work Plan and this Consent Order.

D. The absence of the U.S. EPA or IEPA Project Coordinator from the Facility shall not be cause for stoppage of work.

E. The Project Coordinator for the Respondents or his designated representative shall be on-site during all hours of site work and shall be on call during the pendency of this Consent Order.

XV. SAMPLING AND DATA/DOCUMENT AVAILABILITY

A. The Respondents shall make the results, including raw data, of all sampling and/or tests or other data generated by the Respondents, or on behalf of the Respondents, pursuant to implementation of this Consent Order, available to the U.S. EPA and the IEPA, and shall submit these results in written monthly progress reports as required by Section IX of this Consent Order.

B. At the request of the U.S. EPA or the IEPA, the Respondents shall provide split or duplicate samples to the U.S. EPA or the IEPA of any samples collected by the Respondents pursuant to the implementation of this Consent Order. The Respondents shall notify the U.S. EPA and the IEPA at least ten (10) calendar days or such other time period as may be agreed upon by the project coordinators, in advance of any sample collection activity. If the Agencies take their own samples, they shall provide Respondents a reasonable opportunity to collect split or duplicate samples.

C. Pursuant to applicable Federal laws and regulations, (Section 104(e) of CERCLA and 40 CFR Part 2), the Respondents may assert a confidentiality claim with respect to any or all of the information requested or submitted pursuant to the terms of this Consent Order. Such an assertion must be adequately substantiated when the assertion is made. Analytical data and other information described in Section 104(e)(7)(F) of CERCLA shall not be claimed as confidential by the Respondents. Information determined to be confidential by the U.S. EPA in accordance with applicable Federal laws and regulations will be afforded the full protection provided by such laws and regulations. Information determined to be confidential by IEPA pursuant to applicable State laws and regulations will be afforded the full protection provided by such laws and regulations. If no confidentiality claim accompanies information when it is submitted to the U.S. EPA and the IEPA, or if information claimed as confidential is determined by the U.S. EPA or the IEPA not to be confidential, the information may be made available to the public by the U.S. EPA or the IEPA.

XVI. QUALITY ASSURANCE

A. The Respondents shall use quality assurance, quality control, and chain of custody procedures in accordance with U.S. EPA "Interim Guidelines and Specifications for Preparing Quality Assurance Project Plans" QAMS-005-80 (U.S. EPA, 1980c) throughout all data collection activities.

4.0 TOXICITY ASSESSMENT

To assess the risks associated with the release of contaminants, a comparison is performed between the acceptable levels of contamination and the actual levels identified in the exposure assessment. Contaminant-specific ARARs, when available, will be used to determine acceptable levels. When contaminant specific ARARs are not available, acceptable levels will be based on either regulatory advisories or guidance values (to-be-considered values) or on environmental concentrations that will yield exposures no greater than either of the following:

- The reference dose (RFD) for non-carcinogens, and
- The risk specific dose (RSD), in the range of 10^{-6} to 10^{-4} excess lifetime cancer risk, for carcinogens.

Toxicity information available through the Integrated Risk Information System (IRIS) and the Health Effects Assessment Summary Tables (HEAST) will be utilized to identify appropriate RFDs and carcinogenic slope factors necessary to determine acceptable environmental concentrations.

The acceptable environmental concentrations, as determined from the contaminant specific ARARs, the regulatory guidance, or the risk-based determinations, will be given priority in establishing contaminant specific cleanup goals for the final corrective measures.

5.0 RISK CHARACTERIZATION

The final subtask of the baseline assessment involves the characterization of risks whenever the potential for adverse human health or environmental impacts are predicted for a receptor population. A summary of the risks posed by the Site will be generated. Such factors as the weight of evidence associated with toxicity information, estimated uncertainties associated with the previous subtasks, and assumptions contained within the estimates used will be incorporated into the summary.

APPENDIX F

DATA MANAGEMENT PLAN

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APPENDIX F

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(Continued)

1.0 INTRODUCTION AND OBJECTIVES

This Data Management Plan presents a program for systematically managing information acquired during RI/FS activities to be conducted at the Site. This plan describes the procedures for tracking information, measurements and observations, as well as a system for uniformly recording project data. In addition, a summary of likely data presentation displays to be used for both raw data and final data that are generated as part of the RI/FS activities are discussed below.

The Data Management Plan has been designed to satisfy the following objectives:

- Identify and establish data documentation materials and procedures for the RI/FS activities;
- Develop and establish project file requirements to allow collection and tracking of project materials;
- Identify project related progress reporting procedures and documents to be used in this regard;
- Provide anticipated formats to be used to present raw data and conclusions of the RI/FS activities.

An extensive amount of site characterization data will be generated during the RI/FS activities at the Site. In addition, records, documents, correspondence, and other critical information will be generated. These validated data and other information will be used to evaluate the need for, and the selection of, remedial actions for the Site. The integrity of the data and information is critical to the quality of the final decision. Therefore, it is essential that the data and information be properly managed to provide for access by authorized persons and the adequate tracking of receipt, storage, and control both during and after the RI/FS process.

This Data Management Plan describes the types of data and information that are expected to be collected and the types of procedural controls that will be enacted to assure its integrity. The procedural controls comprise a Data Management System (DMS) that is also described within this plan.

2.0 TYPES OF DATA TO BE COLLECTED AND ANALYZED

The data and information collected during the RI/FS process have been divided into two categories; technical data and administrative data. These two types of data are discussed in greater detail below.

2.1 Technical Data

Examples of technical data and information that are generated through the RI/FS process and need to be included in the DMS are provided in Table F-1. The raw data represent the actual field and laboratory measurements or observations that will be made during the RI/FS process. The summary data represent the first-order analysis of raw data.

2.2 Administrative Data

Examples of administrative data and information that are generated through the RI/FS process and need to be included in the DMS are provided in Table F-2. Administrative data are data that are required for the performance of the project but cannot be considered field or laboratory data.

A library of applicable EPA guidance documents and other pertinent documents will be maintained.

3.0 DATA TRACKING

As indicated in Section 1.0, adequate tracking of the data types listed in section 2.0 must be provided. This section describes the data tracking system that will be employed during RI/FS activities at the Site including project data flow, project documentation materials, and project files.

3.1 Project Data Flow

A schematic representation of project data flow is included in Figure F-1. As indicated in this figure, all project information will reside in a central project data base and filing system which will be maintained at the Golder Associates' Chicago, Illinois office. Field information collected by Golder Associates' personnel and subcontractors will be recorded using the uniform field data collection sheets described in the RI/FS Work Plan, the Field Sampling Plan, the Quality Assurance Project Plan, and in the referenced attachments. These records will be stored in the project data files and pertinent information for use in data assessment will be entered into the project data base for later merging with laboratory results as appropriate. This project data base and filing system provides a means of tracking and assuring that all samples collected in the field can be accounted for through the laboratory and during subsequent stages of data analysis.

Laboratory analysis data, which will be generated by CompuChem Laboratories, Mid-Pacific Environmental Laboratory, and Warzyn Analytical Laboratories, will be tracked by Golder Associates' personnel through the evaluation of hard copy laboratory results. Upon transmittal from CompuChem Laboratories or others, laboratory results from a given sample or sample set will be merged with corresponding field records. These data, field observations and records, and laboratory measurements,

will be subjected to quality control review by the technical staff, and validated. This quality assured information will then form a final data set in the project data base and file system. Subsequent phases of the data flow chart, as indicated in Figure F-1, describe the preparation of preliminary data summary information, and the review and refinement of this information resulting in completion of the draft RI and FS reports.

3.2 Project Documentation Materials

Standardized project forms and formats have been developed for the collection of field data and observations, recording of laboratory information, and routine project communications. These forms and formats for data collection are discussed in the RI/FS Work Plan, the Field Sampling Plan, the Quality Assurance Project Plan, and in the attachments referenced in these sections. Routine project communications will be documented on standardized forms for telephone communications and project memoranda.

3.3 Project Files

To accommodate the diversity of information that will be accumulated during the RI/FS activities, a project filing system will be developed to integrate and track project data and historical information. The system will be structured to permit collection of files of one type to be collected together. The skeleton structure of the filing system is shown on Table F-3. All project records will be logged in and filed to allow for careful tracking of both internal and external communications.

The filing system is fundamental to the orderly referencing of correspondence, reports, calculations, and other information

relating to the project. The filing system will be carefully maintained so that information can be readily retrieved when required.

There are a number of basic procedures which must be followed to prevent a breakdown in the system.

- All incoming items must be logged in and stamped with a circulation stamp and given an index reference number and item number. The item is then circulated to the appropriate personnel, as directed by the Project Manager. After circulation, the item is returned to the project secretary and placed into the central file.
- All information must be returned to the files as soon as possible. Copies of items may be made to assist project team members maintaining current information, particularly in calculation files.
- When any file folder, report, drawing, or other data is removed from the file, a file record card will be completed and placed in the file where the folder was removed, until the information is returned.

4.0 DATA RECORDS

This section describes data record requirements and the project data base including the identification of existing Data Management Systems and data entry and review.

4.1 Data Record Requirements

A data record for information collected during RI/FS activities will be developed to provide all information needed to subsequently analyze and assess the results of the field and laboratory work. Data records require consistent labeling and recording of field observations to facilitate future data reduction and analysis, and to eliminate the need for speculation concerning the quality of observations or the influence of environmental factors on an ultimate result. The following requirements will be met by the data record:

- Unique sample or field measurement code;
- Sampling or field measurement location and sample type;
- Laboratory analysis measured;
- Property or component measured;
- Results of analysis (concentration);
- Detection limit; and
- Reporting units.

All data collected during the investigation will be accounted for and reported to the agency including suspected outliers or samples contaminated due to improper collection, preservation, or storage procedures. Data that are invalidated during the quality control assessment should be marked as such, and reference made to explanations relating to the reasons for data invalidation.

In addition to the above, certain field information must be recorded during sample collection to document procedures used and to indicate the prevailing conditions during the time of sampling. This information includes:

- Name and address of sampler;
- Purpose of sampling;
- Date and time of sampling;
- Sample type and suspected contaminants;
- Sampling location description;
- Sampling method, sample containers, and preservative used;
- Sample weight or volume;
- Number of samples taken;
- Sample identification numbers;
- Amount purged for ground water monitoring well sampling;
- Field observations (prevailing weather conditions and other relevant factors that might influence sample integrity);
- Field measurements conducted; and
- Name and signature of person responsible for observation.

In addition to the above information, unusual conditions encountered during sampling should be described to allow interpretation of erroneous data at a later date.

Each sample collected as part of this investigation will be assigned a unique sample number that will include some of the information outlined above. These sample identification numbers will be maintained in a project data base to allow tracking of sample status throughout the project.

4.2 Project Data Base

If, after evaluation, it is decided that an electronic data base system is required, information gathered during the RI/FS activities at the Site will be stored, tracked, and evaluated using a PC based data base system in the Golder Associates' Chicago office. If an electronic data base is not required, the filing system described above will be used as the data base. If an electronic data base is required, it will be developed using existing software and data handling systems to allow electronic manipulation of data at an early stage, and avoid errors associated with data transcription.

4.2.1 Identification of Existing Data Management Systems

Data management systems often are implemented electronically providing on-line access to data. Golder Associates will evaluate the need for this type of system. No electronic database system of site data currently exists. If it is determined that this type of system is required or will be cost effective, available commercial software packages will be evaluated. Several packages that have been successfully used in other RI/FS investigations include: RBASE, DBASE, FOXBASE, and ORACLE.

Regardless of the specific database system implemented, or which software package, if any, is used, extensive QA/QC will be used to ensure that the data are accurate and appropriate for inclusion in the evaluation of remedial alternatives.

4.2.2 Data Entry and Review

Data collected in the field will be entered into the data base and hard copy records kept in the project file using a project specific file system. Upon entry of the sample collection

data, tracking of these data elements will begin and continue through their life in the project. As laboratory data are merged with field records, new data files will be created that include the current status (validated, etc.) of the information. In addition, review of the data will necessitate the inclusion of comments and remarks (indicated by a data flag) to describe data that is qualified based on failure to meet criteria. These flags will be included in the data base so that final interpretation and assessment of project results will be based upon best available knowledge of the status of each measurement and observation made during the project. Figure F-1 describes the overall flow of project data and indicates the use of the project data base and files during various stages of data evaluation. To the extent possible, checking, evaluation, and assessment will be done electronically through the use of the Golder Associates' computer system to provide a cost effective and efficient means of tracking information, and to reduce transcription errors by eliminating the need for this procedure.

5.0 TECHNICAL DATA MANAGEMENT

The management of technical data including field data, subcontractor data, and calculation are described in this section.

5.1 Field Data

All field activities will be overseen by Golder Associates. The Golder Associates site representative will be responsible for entering all daily field activities, measurements and observations in a bound field log book. All data will be recorded legibly in the log book with each day's entries signed and dated. The field log book will be assigned an identification number and all pages will be numbered so that continuity of the log book can be checked. All entries will be made in ink. The personnel responsible for the changes will initial and date all modifications to the log. Upon completion of all field work, the field log book will be assigned a file number and placed in the project file.

In addition to the field log book, daily field report forms will be completed by the site representative. These forms may include, but may not be limited to, Daily Drilling Reports, Daily Field Reports, and Measurement of Groundwater forms. All forms will be signed, dated, issued a file number, and placed in the project file.

During sampling activities, chain-of-custody forms will be completed. These forms will accompany the samples to the analytical laboratory and will serve as a record of any transfer of possession of samples. Completed chain-of-custody forms will be included with the laboratory analytical results report.

5.2 Subcontractor Data

All subcontractors must comply with the requirements of the Quality Assurance Project Plan (QAPP). Subcontractors who have QA programs in place are required to submit the QA programs to the Golder Associates Project Manager prior to initiating any project related activities. Subcontractors are responsible for making any necessary revisions to the program to meet the general requirements of the Project QA Plan. If a subcontractor does not have a QA program or if such a program does not meet the requirements of the Project QA Plan, personnel and activities of the subcontractor will be controlled by the requirements of the Plan. In this regard, all data from subcontractors are reduced, validated and reported in accordance with the Project QA Plan.

Activities of subcontractors will be audited periodically by the Golder Associates QA Officer. This audit may be conducted through surveillance visits or through reports provided by individual subcontractors. All audit findings will be reported to the Project Manager and the audited subcontractor. Audit results will be included in the appropriate Quarterly Report or in technical memoranda. Also, a discussion of the validity of the data affected by the audit results will be incorporated into the appropriate report. All documents supporting major QA/QC actions resulting from audits or identified during the progress of the work, will be maintained in the project files and quality assurance files. Documents generated by the contract analytical laboratory, or other subcontractor, will be transferred to the project files upon completion of assigned project activities.

5.3 Calculations

The management of data used in, and generated by, technical calculation including the preparation of calculations and calculation files is discussed in this section.

5.3.1 General

Engineering calculations include design calculations, quantity estimates, cost estimates and any other material of a similar nature which has permanent value in relation to the project. The following instructions provide the basic procedures to be followed in the preparation of such calculations.

5.3.2 Preparation of Calculations

Calculations shall be legible, concise and prepared in a logical sequence, with the steps adequately described. The result must be understandable to another engineer who may not be familiar with the calculation.

All calculations shall be prepared under the direction of the Project Manager. All calculations must be checked. The checker must be of such competence that he could originate the calculations.

Calculations on a computer must be adequately documented. The documentation should be understandable to personnel unfamiliar with the computer program. Computer outputs must always be checked for errors in the program or the information input.

5.3.3 Calculation Sheets

Calculations shall be prepared on Golder Associates standard calculation sheets. All sheets shall be completed in the title section with:

- job number;
- file number;
- sheet number;
- an adequate description of the calculation;
- analysts' initials and date;
- checker's initials and date;
- reference to reports, papers, sketches, drawings and relative correspondence; and
- QA/QC requirements for the preparation of drawings and specifications.

5.3.4 Calculation Files

Calculation sheets shall be filed in standard folders and, where applicable, each folder shall contain at least the following information in the order shown;

- index;
- summary page(s) listing design objectives, conclusions and recommendations;
- design criteria;
- detailed calculations;
- QC/QA requirements for drawings and specifications; and
- appendix (reference material).

All calculation file folders will contain the appropriate file number for the project involved, as specified in the File Index.

The folder will be submitted to the Project Manager for approval, who will, if necessary, submit the calculations for the review by other individuals in the project or for peer review by others outside the project.

When the Project Manager has indicated final approval on the calculation file, the calculations will be inserted in the file folder. The file folder number and description will be entered in a calculation log book and the folder will be filed in the appropriate project file.

5.4 Document Control

A Document Approval List identifying personnel responsible for document review and approval will be compiled.

Reports (internal and external) for the project will be given appropriate project file numbers. Distribution of reports will be determined at the time of document preparation. All documents issued for final use on the project will have controlled distribution. Draft documents will not be controlled, but will be stamped DRAFT.

5.5 Drawings

No engineering design drawings are expected to be generated in conjunction with the RI/FS activities. If drawings are to be generated, this Data Management Plan will be amended to include the corporate drafting procedures.

6.0 DATA PRESENTATION

6.1 Data Presentation Objectives

RI/FS data will be arranged and presented to facilitate interpretation and understanding of this information as it pertains to the overall objectives of the investigation. Typical data displays include tabulation of measurements and observations and graphical displays to summarize information as it relates to conditions present at the Site. It is anticipated that raw data will be evaluated predominantly through use of the appropriate tables and screening procedures to evaluate outliers, produce summary statistics and information, and provide validated data sets. Final data will be assessed using a variety of summary procedures, including tabular and graphic forms.

6.2 Raw Data

Raw data will be evaluated in tabular form using Golder Associates project data base software, electronic spread sheets such as LOTUS 123 or EXCEL, or other software such as SURFER, GRAPHER, or Harvard Presentation Graphics. In addition, data will be sorted and evaluated by examination of its relationship to the Site to determine the presence of outliers or invalid data points. Once raw data have been screened and the data assessment has been completed, final tables and displays will be prepared.

6.3 Final Data

Final project data will be displayed using a variety of tabular and graphical displays to allow interpretation and development of a clear understanding of the nature of any potential contaminant releases from the facility. Graphical displays

that might be appropriate for use at the Site include the use of bar and line graphs, cross-sectional plots, work and plan maps to examine changes in concentration with time, depth and distance from a suspected source, and display sampling locations and areas.

Spatial distribution of contaminants found will be examined through displaying contaminant concentrations on site facility maps representing the various sampling points. Contaminant isopleth maps will also be prepared for groundwater to indicate groundwater flow and contaminant concentration patterns.

Subsurface information will be displayed using vertical profiles and cross-sections to allow an examination of the change in soil or groundwater contamination with depth. Hydrogeologic cross-sections will be used as appropriate to determine more fully the impact of potential releases from the Site on groundwater. It may also be necessary to prepare three dimensional plots and/or stratigraphy fence diagrams for adequate description of features present at the Site.

Final data reporting will include both graphical and tabular presentations, as well as a discussion of summary statistics and other mathematical simulations used in evaluating project data.

7.0 DATA MANAGEMENT PLAN SCOPE RELATIVE TO OTHER RI/FS WORK PLAN COMPONENTS

The DMS will provide for receipt and control of validated data obtained through implementation of the Work Plan, the Field Sampling Plan, and the Health and Safety Plan. The Quality Assurance Project Plan provides specific procedural direction and control for obtaining and analyzing samples in conformance with applicable requirements to assure quality data and results of analyses. The Field Sampling Plan provides the detailed logistical methods to be employed in selecting the location, depth, frequency of collection, etc., of media to be sampled and in methods to be employed to obtain samples of the selected media for cataloging, shipment, and analyses. The data that result from the analyses will be entered into the DMS for subsequent control and tracking. In a similar manner, data from field and bench tests of potential remedial techniques will be entered into the DMS. Procedural controls for such testing are specified in the Quality Assurance Project Plan.

Specific directions and logistical methods to be employed for field and bench testing will be provided prior to initiation of these activities. Site and personnel health data needed to assure worker safety will be specified in the Health and Safety Plan, which will also specify the manner in which these data are to be obtained. Personnel health records will be protected and secured in such a way that only authorized personnel will have access to these data.

TABLE F-1

TYPES OF RI/FS STUDY TECHNICAL
INFORMATION AND DATA TO BE INCLUDED
IN THE DATA MANAGEMENT SYSTEM

Raw data/sample analyses	- Groundwater samples - Sediment samples - Soil samples - Surface water samples - LNAPL samples - Air samples (from health and safety monitoring) - Landfill gas samples (from gas probes) - Personnel exposure monitoring records - Site descriptive information - Pilot/bench test data - Engineering design data
Summary data	- Analytical results of environmental media by time, location, depth, contaminant, etc. - Health risk assessment results - Engineering results
Sampling/analyses/ data handling	- Sampling schedule - Sample collection procedures - Field/laboratory notebooks - Analyses scheduling - Laboratory quality assurance/quality control - Calibration tracking - Instrument coordination - Data entry procedures - Data reduction, validation, storage, and transfer procedures

TABLE F-2

TYPES OF RI/FS STUDY ADMINISTRATIVE INFORMATION AND DATA TO BE INCLUDED IN THE DATA MANAGEMENT SYSTEM

Project management	- Project schedule and milestones - Project cost - Equipment, personnel, and supplies scheduling - Document tracking - Subcontractors - Project quality assurance/ quality control procedures
Personnel	- Personnel training and qualifications - Occupation exposure reports - Personnel health and safety records
Compliance/regulatory	- Applicable or relevant and appropriate requirements (ARARs) - Screening levels - Guidance document tracking - Compliance issues - Problem resolution

TABLE F-3

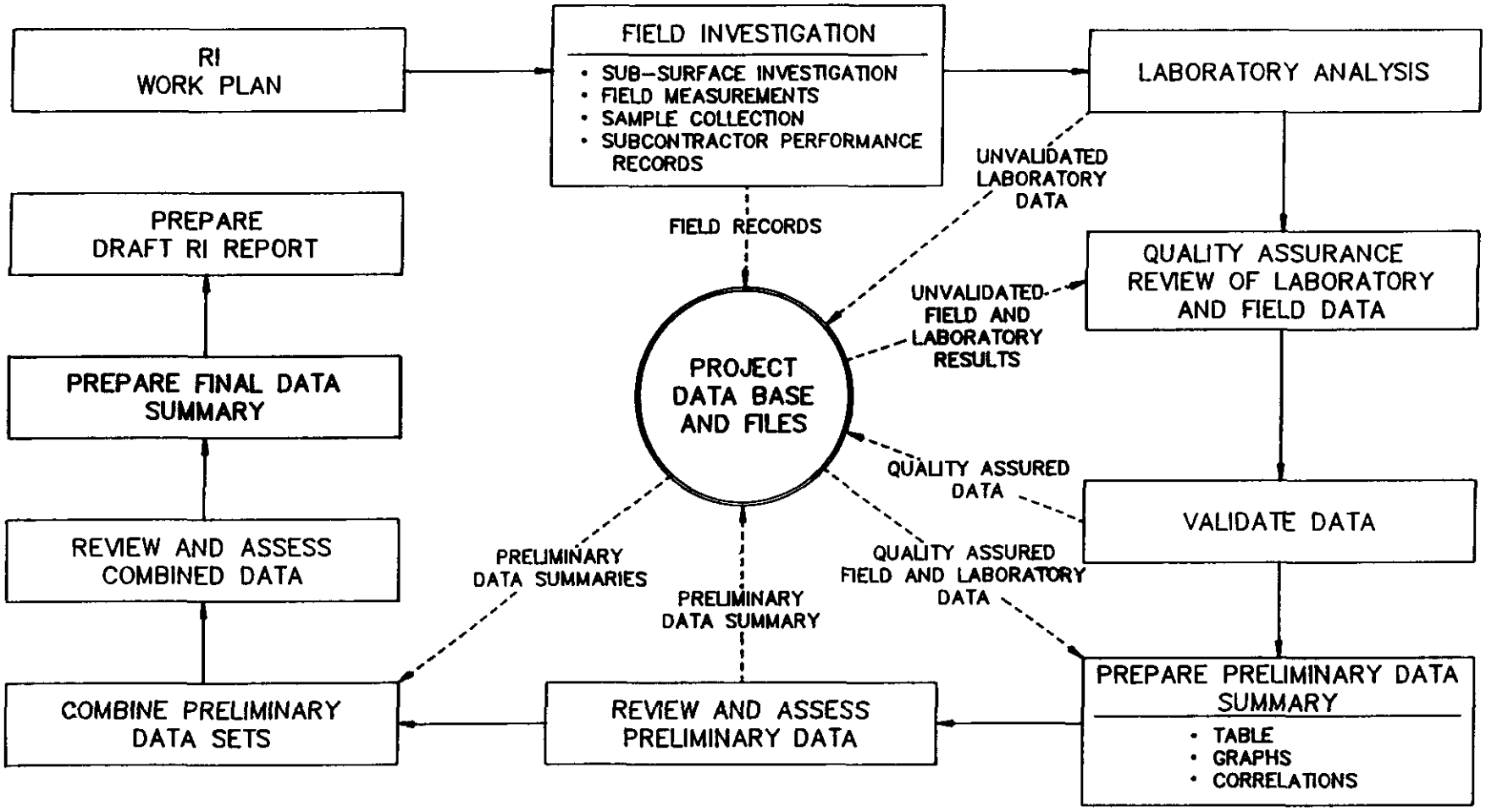
BASIC PROJECT FILING SYSTEM

FILE NUMBER	TITLE	ACTIVE	INACTIVE
000	FILE DIRECTORY		
010-019	PROPOSAL/CONTRACT		
020-029	BUDGETARY INFORMATION		
030-039	SUBCONTRACTS		
040-049	MANAGEMENT INFORMATION		
050-059	QUALITY ASSURANCE		
060-069	ADMIN. CORRESPONDENCE		
070-079	PROGRESS REPORTS		
100	CORRESPONDENCE LOG		
110-110	EXTERNAL CORRESPONDENCE		
120-129	INTERNAL MEMORANDA		
130-139	TELEPHONE MEMORANDA		
140-149	TELECOPY AND TELEX		
150-159	MEETING NOTES		
200	REPORT ORIGINALS		
201-250	DRAFTS		
251-299	FINALS		
1300	FIELD INFORMATION		
1301-1305	COPIES OF FIELD NOTEBOOKS		
1306-1310	HEALTH AND SAFETY PLANS		
1311-1315	BORING LOGS		
1316-1320	WELL INSTALLATION LOGS		
1321-1325	GROUNDWATER DATA		
1400	GOLDER LABORATORY INFORMATION		
1401	GOLDER LAB ASSIGNMENT SHEET		
1402-1430	GOLDER LAB TEST RESULTS		
1431-1450	CHEMISTRY DATA		
1500	REFERENCE INFORMATION		
1600	CALCULATIONS		
1700	DESIGN INFORMATION		

PROJECT NUMBER:_____ PROJECT TITLE:_____

PROJECT MANAGER:_____ TASK NUMBER:_____

DATE:_____ PROJECT ENGINEER:_____



CLIENT/PROJECT						TITLE			
PRP/YEOMAN/ILLINOIS			Golder Associates Chicago, Illinois			EXAMPLE RI DATA FLOW CHART			
DRAWN TPK	CHECKED JDM	REVIEWED	DATE 1-28-91	SCALE N.T.S.	JOB NO. 893-8026.01	FILE NO 893-8026.01	DWG. NO./REV. NO. 15	FIGURE F-1	

APPENDIX G

ATTACHMENTS