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TOXIC HAZARDS OF UNDERGROUND EXCAVATION

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By
R. Smith
V. Chitnis
M. Damasian
M. Lemm
N. Popplesdorf
T. Ryan
C. Saban

School of Public Health,
University of Michigan
Ann Arbor, MI

and

J. Cohen
C. Smith
F. Ciminesi

Science Applications, Inc.
Pleasanton, CA

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Ann Goulet
Kin Ho
Alan Hundley
Mark Levin
Bob McKinley

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ABSTRACT

Inadvertent intrusion into natural or man-made toxic or hazardous material deposits as a consequence of activities such as mining, excavation or tunnelling has resulted in numerous deaths and injuries in this country. This study is a preliminary investigation to identify and document instances of such fatal or injurious intrusion. An objective is to provide useful insights and information related to potential hazards due to future intrusion into underground radioactive-waste-disposal facilities. The methodology used in this study includes literature review and correspondence with appropriate government agencies and organizations. Key categories of intrusion hazards are asphyxiation, methane, hydrogen sulfide, silica and asbestos, naturally occurring radionuclides, and various mine or waste dump related hazards.

I. INTRODUCTION AND BACKGROUND

A frequently stated concern regarding the underground disposal of radioactive waste is that, at some future time, people may intrude into the disposal site and suffer the consequences of exposure to the radioactive materials. The sequence of events that may lead to drilling into or *exhumation of a nuclear waste repository* has been termed the "inadvertent intruder scenario". This scenario may occur as a result of man's future quest for minerals or energy resources, from activities such as excavation or from natural curiosity of what lies below the surface. The resultant exposure to the radioactive materials may cause injuries or fatalities over either a long or short term. However, the uncertainty associated with the intruder concept is large in that it is difficult to determine the probability of occurrence of such an event. The degree to which concern over intrusion is warranted can be evaluated by comparison to more common events. In order to place the intrusion problem into proper perspective, situations that are analogous to intrusion into a waste repository must be examined. *Underground hazards already exist and unlike the yet unbuilt repository, can be studied first hand to serve as a foundation for comparison to nuclear waste hazards.*

A preliminary investigation was initiated for this study to identify and document instances of injuries and fatalities resulting from such human activities as mining, excavation, or tunnelling. Knowledge of the number of

such injuries or fatalities can provide a means of comparison to the number of predicted injuries or fatalities from assessments of repository intrusion accidents.

Injuries and fatalities from the investigated mining or excavation activities can result either from mechanical processes (such as operational accidents or cave-ins) or from exposure to man-made or natural toxic materials. Examples of toxic materials that may be encountered during excavation include gases (H_2S , CO, CH_4), heavy metals (Hg, As), naturally radioactive materials (Ra, Rn) and toxic particulates (silica, asbestos). Asphyxiation as a result of lack of oxygen may be another hazard associated with these activities.

A probabilistic evaluation of the possible risks of such intrusion or excavation has not been attempted in this project. However, it is hoped that the data revealed by this investigation would be incorporated as consequence input into such an evaluation. A comparative analysis of excavation risks to those of possible intrusion into radioactive waste repositories can then be made.

This report presents our research methodology used in investigating occurrences of intrusion hazards, and then discusses background material and results (identification and documentation) for several major categories of hazards, including asphyxiation, methane, hydrogen sulfide, silica, asbestos, naturally occurring radionuclides, and various mine or waste dump related hazards. Appendices are included to provide additional background material concerning our research methodology, and data tables summarizing occupational illness/injury for Michigan in 1980.

II. RESEARCH METHODOLOGY

The methodology used to systematically obtain the data relevant to this study consists of a two-fold approach:

- (1) A literature review of published accounts of incidents involving exposure to toxic materials, relevant safety procedures, and chemical toxicity data.
- (2) Correspondence and personal interviews with appropriate state/federal agencies as well as other organizations involved in fields relevant to the subject of this study.

Two types of sources supplied the data for this study: (1) libraries and faculty members located at the University of Michigan, and (2) correspondence/interviews with non-university personnel.

Appendix A provides a detailed description of these data sources, including key libraries, computer search techniques, faculty members consulted, and a description of non-university resources and responses to our request for information.

The collected data presented in this report naturally does not contain all incidents of inadvertent exposure to randomly deposited underground toxic agents. Rather, the subject matter has been subdivided according to type of hazards most commonly found to produce injuries, illnesses or fatalities during excavation operations.

III. ASPHYXIATION

The introduction of new, mechanized equipment and modified techniques has provided increased rates of excavation with greater efficiency. While both of these improvements are welcome, they have produced an associated increase in undesirable by-products which include hazardous gases, subsequently producing an atmosphere with toxic gases or deficient in oxygen. In order to limit the adverse effects of such contaminants it is essential that industrial hygiene principles be applied to the work environment as a means of minimizing the potential for fatality by asphyxiation.

Hazards Within the Work Place

Sub-surface excavation fatalities occur for a variety of reasons as suggested below [1].

- Taking a risk without proper and adequate investigation of the work area.
- Failure to use methods and install safeguards indicated by an engineering analysis of the soil.
- Improper or improvised shoring along with its improper maintenance during operation.
- Inadequate support structures which are unable to compensate for excessive loads imposed on the surrounding terrain.
- Changing weather conditions and their effect of ground water and the soil.

The lack of consistent geological patterns across the United States makes it impossible to predetermine what undesirable contaminants will be encountered once digging is initiated. Therefore, proper excavating techniques should be selected on the basis of evaluating the following variables [2]:

- Type of soil and its structure in relation to ground water level and method of drainage.
- Underground utilities, sewers, tanks, and other sub-surface installations in and adjacent to the excavation area.
- Superimposed loads, fixed loads, transient loads by excavating equipment, handling and disposal of excavated materials, and subsequent construction necessities.
- Weather expectations and control of surface water.
- Length of time the excavation will be open.
- Local laws and regulations relative to blasting and public protection.
- Strength of material being trenched and its ability to withstand cave-ins.

During excavation operations and after the excavation is complete but continues to remain open, close control over the excavation proper and surrounding area should be maintained. Future inspections should be performed to look for evidence of impending problems which may subsequently occur after digging is complete.

Recommendations For Working In A Confined Space

A confined space refers to a space which by design has limited openings for entry and exit, unfavorable natural ventilation which could contain or produce dangerous air contaminants, and which is not intended for continuous employee occupancy. Confined spaces include but are not limited to storage tanks, compartments of ships, process vessels, pits, silos, vats, degreasers, reaction vessels, boilers, tunnels, underground utility vaults, and pipelines [3].

A potential hazards classification for entry into confined spaces based on the following characteristics: oxygen level, flammability, and toxicity, can be found in Table 1. This classification scheme is determined by selecting the most hazardous condition of entering, working in, and exiting a confined space which could exist during the work procedure. If any of the hazards present a situation which is immediately dangerous to life or health, the confined space is designated as Class A. A Class B confined space has the potential for causing injury and illness but is not immediately dangerous to life and health. Class C entry would be one in which the hazard potential would not necessitate any special modification of the work procedure. The Check List of Considerations in Table 2 delineates the minimum preparation required for each class of confined space entry. The Confined Space Classification Scheme and Check List are recommendations presented within the NIOSH criteria document for "Working in Confined Spaces." In addition to these recommendations, federal regulations which pertain to control of toxic, flammable, and oxygen deficient atmospheres in construction can be found in 29 CFR 1926 (refer to Table 3).

Recorded Fatalities Due To Asphyxiation

Conformance to safety regulations designed for excavation procedures should assist in reducing the number of serious fatalities arising from exposure to atmospheres which are life threatening. Unfortunately health hazards in the form of exposure to irritating dusts, toxic and flammable gases, as well as other harmful agents often are overlooked. Numerous cases are on record, many of them fatal, where workers will enter a confined space once excavation is complete, to encounter an atmosphere devoid of an adequate oxygen supply. While it is common knowledge that an oxygen

TABLE 1

CONFINED SPACE CLASSIFICATION TABLE

Parameters	Class A	Class B	Class C
Characteristics	immediately dangerous to life - rescue procedures require the entry of more than one individual fully equipped with life support equipment - maintenance of communication requires an additional standby person stationed within the confined space	dangerous, but not immediately life threatening - rescue procedures require the entry of no more than one individual fully equipped with life support equipment - indirect visual or auditory communication with workers	potential hazard - requires no modification of work procedures - standard rescue procedures - direct communication with workers, from outside the confined space
Oxygen	16% or less *(122 mm Hg) or greater than 25% *(190 mm Hg)	16.1% to 19.4% *(122 - 147 mm Hg) or 21.5% to 25% (163 - 190 mm Hg)	19.5% - 21.4% *(148 - 163 mm Hg)
Flammability Characteristics	20% or greater of LFL	10% - 19% LFL	10% LFL or less
Toxicity	**IDLH	greater than contamination level, referenced in 29 CFR Part 1910 Sub Part Z - less than **IDLH	less than contamination level referenced in 29 CFR Part 1910 Sub Part Z

*Based upon a total atmospheric pressure of 760 mm Hg (sea level)

**Immediately Dangerous to Life or Health - as referenced in NIOSH Registry of Toxic and Chemical Substances, Manufacturing Chemists data sheets, industrial hygiene guides or other recognized authorities.

Source: U.S. Dept. of Health, Education, and Welfare, NIOSH Criteria Document for a Recommended Standard - Working in Confined Spaces, December 1979.

TABLE 2

CHECK LIST OF CONSIDERATIONS FOR ENTRY,
WORKING IN AND EXITING CONFINED SPACES

ITEM	CLASS A	CLASS B	CLASS C
1. Permit	X	X	X
2. Atmospheric Testing	X	X	X
3. Monitoring	X	O	O
4. Medical Surveillance	X	X	O
5. Training of Personnel	X	X	X
6. Labeling and Posting	X	X	X
7. Preparation			
Isolate/lockout/tag	X	X	O
Purge and ventilate	X	X	O
Cleaning Processes	O	O	O
Requirements for special equipment/tools	X	X	O
8. Procedures			
Initial plan	X	X	X
Standby	X	X	O
Communications/observation	X	X	X
Rescue	X	X	X
Work	X	X	X
9. Safety Equipment and Clothing			
Head protection	O	O	O
Hearing protection	O	O	O
Hand protection	O	O	O
Foot protection	O	O	O
Body protection	O	O	O
Respiratory protection	O	O	
Safety belts	X	X	X
Life lines, harness	X	O	
10. Rescue Equipment	X	X	X
11. Recordkeeping/Exposure	X	X	
X - indicates requirement			
O - indicates determination by the qualified person			

Source: U.S. Dept. of Health, Education and Welfare. NIOSH Criteria Document
for a Recommended Standard - Working in Confined Spaces, December, 1979.

TABLE 3

**Regulations Found at 29CFR1926 That Pertain To Control
Of Toxic, Flammable, And Oxygen Deficient Atmospheres In Construction**

Regulation	Requirement
Subpart C—General Safety and Health Provisions Section 1926.21 (b) (5)	Specifies that training that must be given to an employee entering an area where toxic, flammable, or oxygen-deficient atmospheres may occur. Specifies that the employer must comply with any regulations specifically applicable.
Subpart D—Occupational Health and Environmental Controls Section 1926.28 (a) Section 1926.55 Section 1926.57	Appropriate personal protective equipment must be worn, as required Threshold Limit Values of Airborne Contaminants of the American Conference of Governmental Industrial Hygienists must not be exceeded. Specifies the installation and operation of ventilation systems used to control hazardous substances.
Subpart E—Personal Protective and Life Saving Equipment Section 1926.103	Specifies respiratory protection.
Subpart J—Welding and Cutting Section 1926.353 (b)	Specifies the ventilation and protection required when welding, cutting and heating is done in a confined space.
Subpart P—Excavations, Trenching and Shoring Section 1926.650 (g) Section 1926.651 (v)	Employees subject to hazardous or oxygen-deficient atmospheres must be protected with respiratory protection specified in Subpart D. Where air may be gaseous or deficient in oxygen, air must be tested. Ventilation must be provided, or sources of ignition eliminated. Provisions must be made for prompt rescue.
Subpart S—Tunnels and Shafts, Caissons, Cofferdams and Compressed Air Section 1926.800 (c) Section 1926.800 (e) (vii) Section 1926.803 (f) Section 1926.803 (1) (7)	Specifies the measures that must be taken to assure air quality and ventilation in tunnels and shafts "Air that has passed through underground oil or fuel-storage areas shall not be used to ventilate working areas". Ventilation and air quality in compressed air. Prohibits use of any fire extinguisher in the compressed air working chamber that contains any extinguishing agent that could be harmful to employees.
Subpart U—Blasting and the Use of Explosives Section 1926.910 (b) Section 1926.913 (f)	Requires that sufficient time elapse before returning to the blast area, in order that smoke and fumes can dissipate. This time must be at least 15 minutes in tunnels. Explosives used in compressed air work must be Fume Class 1.

Source: J.T. Patterson. "Hazardous Atmospheres in Underground Construction", Professional Safety, September, 1979.

deficient atmosphere represents a serious hazard, situations where this condition might arise are sometimes ignored. A select group of incidents involving individuals entering mines, sewers, and wells is summarized in Tables 4(A-E), acknowledging the types of problems and fatalities occurring upon entrance into a confined space which has not been adequately tested for atmospheric contaminants. In all cases there was no prior warning of imminent danger.

Entrance into an oxygen deficient atmosphere as exemplified in many of the mining fatalities can lead to unconsciousness within seconds. Physiological effects experienced by individuals are directly correlated with the atmospheric concentration of oxygen (refer to Table 5). At extremely low concentrations (less than 16%) it has been theorized that during an accident situation the worker often becomes acutely distressed and attempts to escape from the area without success. An olfactory response cannot be relied upon to alert the worker that he has entered an atmosphere deficient in oxygen. When such fatalities do occur the post mortem diagnosis is usually general anoxia or systematic poisoning [4].

There are a number of toxic gases which can produce symptoms of asphyxia. Common gaseous contaminants found in underground construction are described in Table 6 by: emitting source, Threshold Limit Value (TLV), health effects, flammability limits, and specific gravity. It is not unusual to encounter such products during tunnelling and deep excavations. Specific examples can be found in Reference 5.

An additional concern which one must acknowledge during excavation, particularly in urban areas, is the possibility of encountering petroleum products. The source of such products is normally a leaking underground storage tank or product line. Additional sources may include surface spills

TABLE 4-A
FATALITIES OF ASPHYXIATION RESULTING FROM OXYGEN DEFICIENCY WITHIN A CONFINED SPACE

Industry/Activity	Operation	Industrial Exposure	Effect
<u>PUBLIC WATER/WASTE SYSTEMS</u>			
Minnesota - 1950	Examination of a manhole	Oxygen deficient atmosphere. Cause: -inadequate ventilation.	2 deaths
Minnesota - 1952	Examination of watermain manhole.	Oxygen deficient atmosphere. Cause: -inadequate ventilation. -decline in barometric pressure. -organic material in surrounding subsoil. -influence of wind velocity and street traffic.	1 death
Ohio - 1953	Industrial discharge in the public sewage system.	Sewer Explosion. Cause: -unregulated discharge of flammable agents. -gasoline leakage from storage tanks. -inadequate manhole ventilation.	1 death 84 hospitalized
*Washington	Investigation of soil pipe drainage problem.	Oxygen deficient atmosphere (7-9%). Cause: -organic material in surrounding soil.	1 death
Washington	Examination of water system control valve.	Oxygen deficient atmosphere.	1 death
Washington	Examination of irrigation system control valve manhole.	Oxygen deficient atmosphere (12%). Cause: -manhole construction adjacent to garbage dump.	1 employee experienced: weakness dizziness
Michigan	Visual examination of a manhole prior to testing air quality.	Oxygen deficient atmosphere (11-16%). Cause: -blowage of sewer. -bacterial action of sludge. -manhole lacked adequate ventilation.	1 death 1 hospitalized
Michigan - 1976	Examination of underground water meters.	Oxygen deficient atmosphere. Cause: -water seepage into poorly ventilated area containing organic material.	2 deaths
Michigan - 1971	Examination of manhole.	Oxygen deficient atmosphere (7-12%). Cause: -air diffusion from manhole into adjacent soil. -inadequate ventilation. -change in barometric pressure. -organic decay.	1 death
<u>WELL INSTALLATION</u>			
*Iowa - 1980	Entrance into a newly dug well (depth 100 feet).	Oxygen deficient atmosphere. Cause: -interaction with an old mine shaft containing pockets of CO ₂ which became vented into the well.	2 deaths

(*) Excavation cited as the direct cause of death.

TABLE 4-B

FATALITIES OF ASPHYXIATION RESULTING FROM OXYGEN DEFICIENCY DURING MINING

Industry/Activity	Operation	Industrial Exposure	Effect
<u>MINING/TUNNELING</u>			
* Washington	Ventilation survey of ground gas theory within a tunnel.	Oxygen deficient atmosphere. Cause: - leakage of ground gas into tunnel. - organic decomposition. - increase in air pressure allowing seepage of gas from soil.	-----
** Interstate Mine Idaho - 1971	Transportation of ore into mine cars.	Oxygen deficient atmosphere. Cause: - unknown.	1 death **
** Black Hat Mine (Uranium) Utah - 1973	Examination of underground water pump at future drilling site.	Oxygen deficient atmosphere. Cause: - inadequate ventilation.	1 death **
** Anaconda Mine (Copper) Montana - 1975	Entrance into a restricted section of an underground shaft.	Oxygen deficient atmosphere. Cause: - inadequate ventilation.	1 death **
** Ajax Mine (Gold) Colorado - 1975	Performing shaft maintenance.	Oxygen deficient atmosphere. Cause: - emanation of rock strata gases from drill hole. - inadequate ventilation.	2 deaths **
** Bull Dog Mine (Silver/Lead) Colorado - 1978	Observing sand fill as co-worker pumps material from one site to another.	Oxygen deficient atmosphere. Cause: - inadequate ventilation.	1 death *
** Nash Draw Mine (Potash) New Mexico - 1976	Examination of groundfall which had covered undercutting machine.	Oxygen deficient atmosphere. Cause: - groundfall creating a void liberating unknown gases.	1 death **

(*) Excavation cited as direct cause of death.

(**) Excavation could have been a contributing factor in the causation of this fatality

Sources: * Univ. of Washington, Dept. of Preventive Medicine, Occupational Health Newsletter, Vol. 11, No. 10, Oct. 1962, Seattle, WA.

** U.S. Dept. of Interior, Bureau of Mines, Mining Enforcement and Safety Administration, Health and Safety Reports.

TABLE 4-C

SUFFOCATION, DROWNING, AND ASPHYXIA FATALITIES
IN COAL AND METAL/NONMETAL MINING, 1974-1978

During the period from 1974-1978, 160 fatalities occurred in coal and metal/nonmetal mining due to suffocation, drowning, or asphyxia. Separation of these fatalities is inadequate to identify whether or not excavation was a contributory cause. Examination of this data does provide information about the methodology by which MIOSHA performs its statistical analyses of industrial fatalities.

<u>Category</u>	<u>Coal</u>					<u>Total</u>	<u>Percent</u>
	<u>1974</u>	<u>1975</u>	<u>1976</u>	<u>1977</u>	<u>1978</u>		
Suffocation	2	5	1	5	2	15	42.9
Drowning	1	1	1	10 ^{1/}	2	15	42.9
Asphyxia	0	1	0	0	4	5	14.2
TOTALS	3	7	2	15	8	35	100.0

^{1/} includes nine fatalities in single accident

<u>Category</u>	<u>Metal/Nonmetal</u>					<u>Total</u>	<u>Percent</u>
	<u>1974</u>	<u>1975</u>	<u>1976</u>	<u>1977</u>	<u>1978</u>		
Suffocation	15	7	12	19	16	70	56.0
Drowning	13	6	8	9	3	39	31.2
Asphyxia	0	10	3	1	3	16	12.8
TOTALS	28	23	33	29	22	125	100.0

TABLE 4-D

Breakdown of causation of injuries in coal mining for each category.

Suffocation, drowning, and asphyxiation fatalities
in coal mining, 1974-1978--by cause of injury

<u>Suffocation</u>	
<u>Cause</u>	<u>Number</u>
Covered by material from roof fall, pressure bursts	5
Collapse of stockpile, or material in bin	4
Crushed by falling/overturning equipment or machinery	3
Covered by material from highwall	2
Crushed between machinery and object	<u>1</u>
Subtotal	15
 <u>Drowning</u>	
Inrush of water	9
Vehicle veered into water	5
Thrown from vehicle into water	<u>1</u>
Subtotal	15
 <u>Asphyxia</u>	
Entered unventilated area	<u>5</u>
Subtotal	5
TOTAL	35

TABLE 4-E

A breakdown of fatalities by cause of injury in metal/nonmetal mining.

Suffocation, drowning, and asphyxia in metal/nonmetal mining
1974-1978--by cause of injury

<u>Cause</u>	<u>Suffocation</u>	<u>Number</u>
Covered with material while working in bins, hoppers, R.R. cars		24
Covered with material while working on and around stockpiles		15
Fell into hoppers, covered with material		10
Covered with material from collapsing walls, roofs		9
Caught in rotating rollers, sprockets, shafts		6
Crushed between machinery and object		5
Pinned by prybar while freeing material in chute		<u>1</u>
	Subtotal	70
	<u>Drowning</u>	
Fell into water from boat, barge, dredge		15
Truck, front-end loader veered or slid into water		8
Fell into water from edge of pond, lake (occurred in normal working area)		3
Fell into water from edge of pond, lake (victim not in normal working area)		3
Walking on pipeline, fell into water		3
Thrown from machinery into water		3
Bank collapsed, dragline fell into water		2
Mancage lowered into water		1
Inundation of mine		<u>1</u>
	Subtotal	39
	<u>Asphyxia</u>	
Entered unventilated area		7
Working in or near toxic or suffocative gases		6
Fire or operating internal combustion engine in unventilated area		<u>3</u>
	Subtotal	16
	TOTAL	125

TABLE 5

PHYSIOLOGICAL RESPONSE TO AN OXYGEN DEFICIENT ATMOSPHERE

Oxygen Concentration (%)	Physiological Response
19.5 - 25	- Adequate levels at which no respiratory equipment need be used to function normally. Dependent on human variability.
16 - 19	- Minimum concentration to support life(16%). - Deterioration of night vision.
14 - 16	- Rapid fatigue. - Intermittent respiration. - Poor muscular coordination. - Accelerated heartbeat. - Increased breathing volume.
6 - 10	- Nausea. - Inability to perform. - Unconsciousness.
less than 6	- Spasmodic breathing. - Convulsive movements. - Death within minutes.

* Normal air at sea level contains approximately 21% oxygen, 79% nitrogen and other inert gases.

TABLE 6
COMMON GASEOUS CONTAMINANTS IN UNDERGROUND CONSTRUCTION

	Possible Sources	Threshold Limit Value	Effect Upon Body	Flammable Limits in Air % by volume		Specific Gravity (Air = 1)
				Lower	Upper	
Carbon Dioxide	Product of combustion, oxidation, and respiration. May be found in the vicinity of landfills, sewage lines, and sewage treatment plants	Simple Asphyxiant	Nontoxic. May displace oxygen. Concentrations of more than 5% may cause headaches, dizziness, nausea, vomiting, or suffocation.	Non-combustible		1.53
Carbon Monoxide	Product of combustion. May be found in the vicinity of internal combustion engines, blasting or fires.	50 PPM	Causes throbbing headaches, confusion, skin redness, blurred vision, or unconsciousness which can lead to death. Combines with hemoglobin in the blood and prevents blood from carrying oxygen to tissue.	12.5	74.0	0.96
Hydrogen Sulfide	Product of decomposition or organic sulfur-bearing material. May be found in the vicinity of swampy areas, landfills, sewage treatment plants, refineries and petroleum product lines.	10 PPM	Causes eye irritation/tearing, cough, dizziness, stomach irritation, muscle paralysis of the respiratory system, and unconsciousness which can lead to death.	4.0	44.0	1.189
Methane	Occurs in natural gas and as a result of decaying organic material. May be found in the vicinity of swampy areas, landfills, sewage treatment plants.	Simple Asphyxiant	Nontoxic. May displace oxygen.	5.0	15.0	0.415
Nitrogen Dioxide	Product of diesel engines, blasting, and high temperature welding.	5 PPM (ceiling value)	Dissolves moisture in lungs, forming nitrous and nitric acids. Only slightly irritating to upper respiratory system. Dangerous concentrations may be encountered without discomfort. Irritation may disappear upon reaching fresh air, but 6-24 hours later throat, bronchi and lungs suffer congestion and edema.	Non-combustible		1.491

Source: J.T. Patterson, "Hazardous Atmospheres in Underground Construction", Professional Safety, Sept., 1979.

permeating the soil to the water table or deliberate dumping of industrial waste into sewers or storm drainage systems. These products are capable of migrating 300 feet within an interval of three weeks. Since most petroleum liquids are lighter than water and produce vapors heavier than air, dangerous accumulations of liquid and vapors may occur in the invert of the excavation. Workers testing for the presence of contaminants may not detect these heavy vapors unless the detection device is held within three inches of the invert or sides of the confined space [5].

Detection And Control Of Asphyxiating Gases

Avoidance of asphyxiation from oxygen deficiency or toxic gases is dependent on the speed at which the exposed person can escape the contaminated area. Being in a confined space with a limited means of egress is a fatal handicap. The additional demands of speed and physical coordination are negated by panic, confusion, and the onset of unconsciousness [4]. The problem may escalate should rescuers entering a lethal atmosphere be unaware of the hazard present, and consequently, be inadequately protected. The importance of having adequate knowledge and instrumentation during the initial evaluation of the confined area and in the case of an emergency situation, cannot be overstated. There are a wide variety of instruments available for determining the presence of dangerous gases or the absence of oxygen. The instruments most commonly used are as follows: combustible gas indicators, oxygen deficiency indicators (direct or indirect reading), carbon dioxide detectors, and hydrogen sulfide detectors. For a more detailed description of such monitors and current manufacturers of these instruments, it is suggested that one refer to publications by the American Conference of Government Industrial Hygienists (A.C.G.I.H.).

The entry strategy employed before and during entrance into a confined or enclosed space should comply with specific state Department of Labor Construction Safety and General Industry Safety regulations. Proper and suggested safety procedures are summarized below [6]:

- Prior to employee entry, tests of the atmosphere should be made to evaluate if air contaminant levels exceed recommended limits. In spaces where the worker cannot breathe outside air, tests at different levels in addition to probe tests of corners should be performed. In the case of manholes containing vents, the first test should be made when the cover is in place (refer to Figure 1).
- If tests indicate the atmosphere is unsafe, proper ventilation should be employed prior to entrance.
- Frequent monitoring and continued ventilation should be maintained throughout the excavation. Refer to the A.C.G.I.H. Manual of Industrial Ventilation for appropriate methods of ventilation (refer to Figure 2).
- Caution should be exercised to prevent recirculation of exhaust or contaminated air.
- Entry permits to the confined area will allow prompt determination of individuals within the space in case of an emergency situation.
- If there is a possibility of encountering an oxygen deficient atmosphere, a self contained breathing apparatus or hose mask with blower should be used.
- An attendant with a preplanned rescue procedure should be stationed outside the work area to observe employee behavior at all times.

This guide is intended to acknowledge a select group of safety procedures which should be exercised during excavation proceedings. This by no means contains all information pertinent to hazard identification or control of personal exposure [6].

Fig. 1. Probing confined areas for contaminants.

Sources: "Preventing Confined Space Accidents", Michigan Occupational Health, Vol. 22 (2), Lansing, Michigan, August 1977.

"Atmosphere in Sub-Surface Structures and Sewers", National Safety Council Data Sheet, Chicago, Illinois, (1-550-79), 1979.

Fig. 2. Ventilation for a confined area.

Source: "Preventing Confined Space Accidents", Michigan Occupational Health, Vol. 22 (2), Lansing, Michigan, August 1977.

Advance knowledge, planning and preparation are important safety concepts to avoid potentially fatal situations. In all examples presented, there was no warning of the danger to be encountered. However, had early recognition of the hazards occurred, a provision for suitable ventilation or related safety devices could have been effectively utilized to prevent the fatality. Safety programs for protection against physical injury and death can be enhanced by incorporating the task of hazard recognition.

IV. METHANE

Methane is a non-toxic but very explosive gas often encountered during excavation. Emission of this gas is commonly seen in coal mining or when boring through rock containing carbonaceous material. In addition to its explosive property methane can also act as an asphyxiant when found within a poorly ventilated area.

Properties

At room temperature methane or "marsh gas" has no characteristic color or odor by which it can be identified. It is lighter than air (Air = 1.0, Methane = .544), thus it tends to rise, and is found in greatest concentration near the ceiling of an enclosed space. Its renowned explosive capabilities are characterized by a lower and upper explosion limit of 5.0% and 15.0% respectively. Thus, the methane concentration must be at least 5.0% and not greater than 15.0% in order for an explosion to occur [7,8]. Following are physical properties which should be considered when evaluating enclosed spaces in which methane could exist:

Ignition Temperature	- 705°C
Melting Point	- 180°C
Boiling Point	- 164°C
Solubility	- Alcohols, ethers, benzene, and slightly soluble in water.

Distribution

Methane is located throughout the United States. Large pockets of natural gas composed primarily of methane, are tapped and used as fuel. Smaller pockets can be found in rock strata which are often encountered during mining and tunnelling, thus representing a major potential hazard for inadvertent intrusion (refer to Table 7).

TABLE 7

HAZARD POTENTIAL FOR METHANE

<u>Activity/Location</u>	<u>Method of Gas Emission</u>	<u>Potential Hazard</u>
Coal Mining	Underground mining..	Explosion.
Non-coal Mining Tunnelling	Rock strata composed of carbonaceous material.	Explosion.
Drilling	Geological conditions promote association with water.	Explosion and fire.
Landfills	Organic decomposition of refuse, producing carbon monoxide, methane, and carbon dioxide.	Oxygen deficient at- mosphere in nearby subsurface dwellings or crawl spaces.
Sewers Holding Tanks Abandoned Mines	Methane buildup from lack of adequate ventilation.	Asphyxiation and explosion.

Coal mining predominates as the type of mining from which methane is most likely to be encountered. Methane tends to combine with coal dust and form a potentially explosive atmosphere even though the concentration of gas is well below the lower explosive limit [9].

The igniting force needed to achieve detonation is either frictional or non-frictional. Frictional ignition refers to the heat source produced from the resistance to motion of two moving objects or surfaces that touch. An example of this type of ignition source is any type of machine tool, colliding or striking rocks, and roof falls. Non-frictional ignition involves the production of a flame or heat not by friction, but rather by activities such as welding, electrical arcs, or explosives [9]. As shown in Table 8, frictional ignitions predominate, yet the number of injuries and fatalities associated with them is fewer. With the introduction of modern heavy mining equipment (particularly continuous mining) and the mining of gaseous coal seams, the probability of frictional ignitions may be increased [10].

Research under way to attempt to find methods of controlling both types of ignitions has introduced a number of promising control measures. One such measure being that of mounting water sprayers on mining machines. This not only appears to cut down the number of frictional ignitions but also lowers the amount of dust generated [10].

The atmosphere within the mine prior to an explosion poses no distress on the human respiratory system, yet once the explosion has occurred the quality of air is inferior. The oxygen content is generally well below safe levels because of the release of products of combustion: carbon monoxide and carbon dioxide. Entrance restrictions should be imposed within the area unless special breathing equipment is available and used properly. The danger or subsequent explosions can exist should the concentration of hydrocarbons continue to be excessive (refer to Table 9).

TABLE 8

CAUSES OF METHANE IGNITIONS IN UNDERGROUND COAL MINES, (1971-1976)

<u>Type of Ignition</u>	<u>(#) of Ignitions</u>	<u>Injuries</u>	<u>Fatalities</u>
Frictional	247	34	11
Non-frictional	51	38	23
<hr/>			
Total	298	72	34
<hr/>			

Source: Mine Safety and Health Administration. Frictional Ignition of Methane by Continuous Mining Machines in Underground Coal Mines.
U. S. Dept. of Labor. IR1110, 1979.

TABLE 9

GAS ANALYSES FOR TWO MINE FIRES

Gas	% by Volume		Threshold Limit Value*		Lower Explosive Limit
	Fire I	Fire II	PPM	% by Volume	
Carbon Monoxide	2.90	0.30	50	0.005	12.5%
Hydrogen	3.10	0.10	---	-----	4.0%
Ethane	0.18	0.009	---	-----	3.0%
Ethylene	0.01	0.001	---	-----	2.7%
Propane	0.03	0.005	---	-----	2.1%
n-Butane	0.01	0.002	800	0.08	1.8%
Methane	1.10	1.25	---	-----	5.0%
Carbon Dioxide	10.90	2.50	5000	0.5	----
Oxygen	7.30	16.25	---	-----	----

*Source: Mine Safety and Health Administration. Frictional Ignition of Methane by Continuous Mining Machines in Underground Coal Mines. IR1110, U.S. Dept. of Labor, 1979.

The ability to predict the occurrence of methane emission in non-coal mining operations is difficult. However, if surrounding rock strata have a significant amount of carbonaceous material, a methane hazard should be anticipated. This concept can also be applied to tunnelling operations [11]. Under proper geological conditions methane can be present at drilling sites, landfills, sewers, holding tanks, and abandoned mines, all of which are often inadequately evaluated prior to entrance [12].

Recorded Injuries/Fatalities Due To Methane Exposure

In decades past, methane explosions and fires were relatively commonplace in mines. Today, however, the frequency of large scale explosions is decreasing due to safer work practices. Unfortunately some accidents still occur as exemplified by the following incidents where methane was cited as a leading factor in the cause of injury or death.

In December, 1963, an explosion in a coal mine at Helper, Utah, killed 9 workers. The cause was believed to be frictional ignition of methane and coal dust [10]. In March, 1976, two explosions occurred by an electrical arc subsequently killing 15 miners. The first explosion to occur at the Scotia Mine was the one which resulted in 15 fatalities, even though a second explosion occurred two days later in the same area. The cause of these two explosions was theorized to be frictional ignition resulting from a roof fall [9].

In April, 1975, a gas explosion in an abandoned mine shaft, the Sterling "B", killed three and presumably a fourth (missing) employee of the Retsof Mine (International Salt Company, Retsof, New York); four other persons were injured. The involved workers were attempting to seal the bottom of an unlined shaft to prevent seepage of water from the rock strata

to salt beds 1,110 feet below the surface. This water, turning saline, constituted a pollution source when it was pumped to the surface. During the process of forming an impervious plug, material dumped from the surface (a large boulder), became lodged in the upper segments of the shaft, and efforts to dislodge the material resulted in the ignition of flammable gases. These gases has been identified as coming from gas-bearing rock strata in the shaft column. When the explosion occurred, the victims were peering down the shaft at the uppermost blockage 382 feet below, or were in the immediate vicinity of the shaft collar [13].

This accident was caused by a concentration of flammable hydrocarbon gases in an unventilated mine shaft, with subsequent detonation by an ignition source. The inexperience and/or disregard of employees with flammable mixtures was a causative factor in this fatal accident.

Louisiana was the site of another fatal accident which could have been prevented if proper safety procedures were considered prior to initiating industrial mine operations. The accident occurred in June, 1979, beginning about 10 minutes after an explosive charge was detonated, subsequently causing a methane explosion which killed 5 people. It is theorized that the detonation opened up a pocket of methane, releasing a high concentration of the gas, possibly above that for the upper explosive limit. In 10 minutes the gas became diluted below the upper explosive limit and came in contact with a spark which eventually caused the explosion. It is interesting to note that the mine was classified as "non-gassy", that is, the flammable gas concentration was considered to be too low to constitute an explosion hazard.

A highly publicized explosion occurring at Port Huron, Michigan in December, 1971, killed 21 persons and injured 8 others. A water intake tunnel was being bored under Lake Huron through Antrim shale, a rock

formation known to contain significant amounts of methane. Ventilation was carefully designed, and methane monitors, set to go off at 10% of the lower explosive limit, were strategically located in the work area. Despite these precautions, an explosion occurred in an unoccupied section of the tunnel when a drill, which had been used to bore ventilation holes within the tunnel, was being removed from the bore hole [11].

This section was an attempt to summarize and exemplify the methane hazards associated with excavation, i.e., explosions and asphyxiation. If a regular safety evaluation of the work area is performed, in addition to air monitoring in poorly ventilated confined spaces, the probability of the occurrence of accidents caused by methane emission shall be diminished.

V. HYDROGEN SULFIDE

The purpose of this section is to present the distribution, toxicity, and incidences related to hydrogen sulfide exposure. Presently, the National Institute of Occupational Safety and Health estimates approximately 125,000 employees are potentially exposed to hydrogen sulfide in the United States [14]. The processes involved may include mining, drilling, excavation, or other disturbances of the earth's crust.

Properties

Hydrogen sulfide, also known as sulfuretted hydrogen, hydrosulfuric acid, and stink damp, is a gas at normal temperature [15]. The gas has an ignition temperature of 260°C . Mixtures of air between 4.3% and 46% by volume are explosive. Its melting point is -85.4°C and it has a boiling point of -60.3°C [16].

Hydrogen sulfide is soluble in water at 290 volumes to 100 volumes of water at 20°C . It is also soluble in amine solutions, in alkali carbonates, bicarbonates, hydrosulfides, and several other hydrocarbon solvents [16]. Its specific gravity is 1.19 (Air = 1.00), so it will tend to settle in low areas such as sewers, cavities, and cellars [17].

Distribution

Hydrogen sulfide occurs naturally wherever deposits of fossil fuels are located. Volcanic gases and sulfur springs are also natural sources of hydrogen sulfide. Marshes and swamps, which are rich in organic matter, produce large quantities of hydrogen sulfide [16].

Natural gas deposits are one of the largest sources of hydrogen sulfide. Large deposits are located in parts of Wyoming, Texas, New Mexico, and Arkansas. In Wyoming, the concentration of hydrogen sulfide may be as

high as 42%. The sulfur content of petroleum and coal also is known to produce large quantities of hydrogen sulfide. The amount of gas produced depends on the percent and form of sulfur [16].

Steam from volcanoes and geothermal wells have sufficiently high temperatures to form hydrogen sulfide from inorganic sulfides. In many locations, lakes and swamps will tend to be the sources of this gas. It is produced by both chemical reactions and bacterial decomposition of protein and organic matter [16].

The industrial source of hydrogen sulfide is in the form of a waste by-product. Whenever sulfur compounds come in contact with organic material at high temperatures, hydrogen sulfide could be formed. Industrial processes such as the formation of carbon disulfide, thiophene, and rayon by the viscose method, produce varying quantities of hydrogen sulfide as waste. For example, 6 to 9 kilograms of hydrogen sulfide are produced for every 100 kilograms of rayon. Recovery of waste hydrogen sulfide from these processes can be converted to high quality sulfur to be sold on the market [16].

Biological Effects

Exposure to most stresses can be classified according to duration and dose. The classifications used to describe hydrogen sulfide exposure are also related to dose and duration. The exposure classifications are defined as follows [16]:

- Acute: exposure referring to a single massive dose of 700 parts per million or greater. At these concentrations hydrogen sulfide will rapidly produce respiratory distress.

- Subacute: exposure to continuous mid-level concentrations ranging from 100 to 700 parts per million. At these concentrations lung irritation occurs in addition to eye discomfort.
- Chronic: exposure to continuous low levels that produce lingering but not clearly defined symptoms.

A summary of effects from hydrogen sulfide at various concentration is presented in Table 10 [16].

The result of acute exposure is systemic poisoning caused by the gas's action on the nervous system. The toxic action of hydrogen sulfide is thought to be due to inhibition of cytochrome oxidase by binding the blood's iron component which is essential for cellular respiration [14]. This can only be accomplished by the free, unoxidized form of the gas.

Several organisms respond to this inhibition of cytochrome oxidase. Significant problems may develop because of the effects on the chemoreceptors of the carotid. The stimulation of these chemoreceptors results in very rapid breathing and depletion of carbon dioxide. This in turn, gives way to a period of respiratory inactivity [16]. If spontaneous recovery does not occur, death from asphyxia is inevitable. At concentrations greater than 2000 part per million, breathing becomes paralyzed after a breath or two. This respiratory failure is not related to the carbon dioxide concentration, but the paralyzing effect of the gas on the respiratory center [16]. Death from asphyxia can be prevented since the heart will continue to beat following the collapse. If artificial respiration is started quickly, the hydrogen sulfide concentration of the blood can be decreased and respiration will resume. Depending on the exposure there may or may not be continuing side effects.

TABLE 10
EFFECTS FROM HYDROGEN SULFIDE EXPOSURE

<u>Biological Effect</u>	<u>Concentration</u>	
	<u>g/liter</u>	<u>ppm</u>
Approximate odor threshold	0.14-0.28	0.1-0.2
Offensive odor	4.2-7.0	3-5
Threshold Limit Value (TLV)	14	10
Threshold-serious eye injury	70-140	50-100
Olfactory paralysis	210-350	150-250
Pulmonary edema, Imminent threat to life	420-700	300-500
Nervous system stimulation, Apnea	700-1400	500-1000
Respiratory collapse and paralysis	1400-2800	1000-2000

Source: Hydrogen Sulfide, National Research Council Subcommittee on Hydrogen Sulfide, Committee on Medical and Biological Effects of Environmental Pollutants, 1979.

Subacute damage is due to the irritating effects of hydrogen sulfide on the moist tissues of the body, particularly the eye and lungs. Hydrogen sulfide's irritative effects are due to the formation of alkali sulfide when the gas comes in contact with the moist tissues [15].

The most common subacute damage of hydrogen sulfide is on the eye tissue. Concentrations as low as 50 parts per million will produce inflammation of the conjunctival and corneal tissue. Victims may not be aware of this effect because of the anesthetic action on the nerves of the eye. Continued or increased exposure produces acute conjunctivitis with pain, lacrimation, blurred vision, and photophobia. Often the subject will report seeing colored rainbows around lights. More severe exposure may produce acute keraconjunctivitis with possible scar formation. It is possible, however, that the increased rubbing of the eye causes the keraconjunctivitis and not the gas [16].

Not as common but just as important, is the irritation of the lungs. Manifestations of the upper airways, such as pharyngitis, do occur but are not the serious problem. Manifestations of the lower airways are much more dangerous. Severe hemorrhagic pulmonary edema is often associated with high subacute exposure. This condition is often severe enough to be fatal [15].

Long term exposure to low level amounts of hydrogen sulfide produce no clear manifestations. Most continuing effects are of postacute or subacute exposures [16].

One of hydrogen sulfide's most interesting and dangerous properties is its effect on the olfactory system. Threshold for olfactory perception of hydrogen sulfide is both a dose-response and a duration-response. The lower detection threshold is .002 to .003 parts per million. From the threshold to 30 parts per million, the odor will be described as that of rotten eggs.

At 30 parts per million the odor will begin to change to that of a sickly sweet smell. Above 100 parts per million the sense of smell is quickly abolished. Extremely high concentrations may never be detected at all. Also, prolonged exposure may produce olfactory fatigue at concentrations below 100 parts per million. As a result, the sense of smell can not be relied upon to detect the presence of the gas [16].

Recorded Injuries/Fatalities Due To Hydrogen Sulfide Exposure

Numerous cases of hydrogen sulfide exposure have been documented. Exposures have occurred in a wide range of occupations from manufacturing to agriculture. For instance, the release of hazardous quantities of gas have occurred in sewers, cess pools, and manure piles. There are numerous reports in early France of accidental death caused by the release of gas from sewers. The first case of a hydrogen sulfide poisoning reported in the United States was caused by gas liberated from an outhouse [14]. However, the emphasis of this study is hazards from excavations in the earth; therefore the incidents summarized in Table 11 are confined to those shown to be directly related to mining, drilling, or tunnelling.

A particular incident of over exposure to hydrogen sulfide involved four men in the process of constructing a road used to service a phthalic anhydride plant. The road was being built on a filled-in marsh. While digging an anchorage pit for a water tower, the men were overcome. Rescuers administered oxygen and the men were transported to a nearby hospital for emergency care. By the next day all men had regained consciousness without any type of permanent disability from the exposure to hydrogen sulfide [18].

In another incident, a fatality occurred as a result of descending into a shaft that was being prepared for a raw water intake project. The victim descended the shaft to disconnect an electric water pump so that metal

TABLE 11

INJURIES AND FATALITIES DUE TO EXPOSURE TO HYDROGEN SULFIDE

<u>Location</u>	<u>Industry/Activity</u>	<u>Gas Concentration</u>	<u>Casualties</u>
Massachusetts	Construction-digging an anchorage pit.	294 - 540 ppm	4 men injured
Michigan	Mining-descending a mine shaft.	Unknown	1 death 3 injured
Illinois	Non-metal mining- entrance into gas containing area.	600 ppm	
Wyoming W. Texas	Oil exploration- drilling process.	Unknown	26 deaths

shielding could be lowered into the shaft. The previous afternoon the ventilation duct was removed for the same reason. As the victim got near the bottom of the shaft, he collapsed from the hydrogen sulfide seeping out of the 5 feet of water at the bottom of the shaft. Two workers attempted to rescue and were overcome. At this point air compressors were brought in to provide ventilation. A rescue team was eventually able to bring the men out. Unfortunately, the first victim entering the shaft was dead. With some forethought prior to entering this confined area, this accident most likely could have been prevented by utilizing safety equipment located at the worksite.

A tragic example of a fatal exposure to hydrogen sulfide in the mining industry occurred April 12, 1971. The incident was at a mine located in Pope County, Illinois. Ore production averaged approximately 250 tons a day. Principal products were fluorite, galena, and sphalerite.

During normal drilling operations, the miners struck water, forcing an interruption of work operations until the water had drained. The following day a couple of miners went to the site of the water inflow and reported that they had a "tightness" in their chest and that the gas had irritated their eyes. Several other miners went to the site returning with the same symptoms. The next day a miner went near the water inflow to pick up some equipment and never returned. When the foreman realized the employee was missing, he entered the area to search for him. An additional two men joined the search but were unable to make a rescue because of the effects of the gas. An alert was sent out to all miners to stay clear of the area. Not heeding the warnings of their co-workers, successive attempts to rescue the two men were made by fellow employees. All subsequently suffered the effects of the gas to some degree, with five additional men overcome by the

irritant. Rescue teams of the Illinois Department of Mines and Minerals arrived several hours later and removed the men. Four of the several men were still alive when brought to the surface, but all died shortly after [19].

Monitoring the area for hydrogen sulfide provided readings in excess of 600 parts per million. Rescue teams were sent underground to repair and start the fan as well as to initiate water drainage. The mine was allowed to air out 8 days in order to bring the hydrogen sulfide to a safe level [19].

If there had been rescue breathing apparatus at the mine site, some of the men might still be alive. Prior to this accident the last hydrogen sulfide fatality in non-metal mining was in 1925 [19].

The drilling of fossil fuels has also produced incidents of acute hydrogen sulfide exposure. The drilling of high-sulfur oil in the United States resulted in an increase of occupational exposure. Men have been found dead on derrick floors, apparently overwhelmed by the rush of gas when they first drilled into the oil pockets [20]. In the high-sulfur fields of Wyoming and western Texas, 26 persons died from the gas at unspecified concentrations between October 1, 1971 and April 25, 1976 [21].

Detection And Control

As mentioned in prior sections of this report, hydrogen sulfide is a very toxic gas having a high potential of exposure to individuals. For this major reason several work practices must be established.

Although it has not been emphasized in other parts of this report, hydrogen sulfide has been classified in the highest flammability category by the National Fire Protection Association. Ten percent of the lower

explosive limit allows what is considered an acceptable margin of safety. Precautions must be taken to insure that airborne concentrations do not accumulate past 4.3% [22]. Because of the low ignition temperature (260°C) all potential sources of ignition must be kept away.

Since hydrogen sulfide may be produced from organic material, it is important that bacterial decomposition be controlled. This can be accomplished by adequate flow rates in sewers and preventing accumulation of organic material. A possible problem may arise from future excavations at the sites of old land fills.

If it is determined that hydrogen sulfide exposure may occur, proper monitoring methods must be used. Also workers must be advised on the hazards of exposure to the gas and trained in the use of respiratory protection. Hazardous areas must be posted and controlled. Portable or fixed detectors should be used in all areas where there is a possibility that gas concentration fluctuations may result in high exposures. The monitors should have a two stage alarm. The lower alarm should be set no higher than 10 parts per million to warn workers that hydrogen sulfide is present, and the higher trigger should be set no higher than 50 parts per million to warn workers to evacuate. Continuous monitoring is particularly important when operations involve mining and drilling. However, continuous monitoring can protect only when it is combined with an alerting system, adequate ventilation, respiratory protection, and other safety measures.

One of the best ways to protect workers from the sudden release of gas is to train all employees in the use of respiratory protection. Workers trained with self-contained breathing apparatus should be familiar with proper methods of operations and alarm systems indicating low air. Although good ventilation should keep levels of hydrogen sulfide safe, respirators must be kept near to prevent serious accidents.

Before anyone is allowed to enter confined spaces, tests should be conducted for levels of hydrogen sulfide, combustible gas, and low oxygen concentrations. Entering any confined space with improper atmospheric concentrations should only be done with self-contained respiratory protection. Also, an observer must be posted outside to monitor activities of the workers. The observer must be able to make rescues without help from the men performing work within the space.

The seriousness of exposures to relatively low concentrations of hydrogen sulfide requires that caution must be taken when excavations are conducted. Its infamous characteristic of olfactory paralysis makes it particularly difficult to work with since a person may not be able to smell its presence. Numerous cases of exposure and fatality have been documented, thus showing a definite possibility of encountering the gas while conducting excavations. However, by understanding the characteristics of the gas it is possible to use the necessary precautions to avoid injury.

VI. SILICA AND ASBESTOS

This section discusses the properties and distribution of silica and asbestos, two well-documented hazardous materials associated with excavation. Recorded injuries/fatalities due to exposure to these materials are presented as well as measures for their detection and control.

Properties

Free silica in airborne dust exists in two forms: crystalline and non-crystalline silica. Of these two forms, only crystalline silica has been recognized as a cause of silicosis, a respiratory disease [23]. Crystalline silica may be released from any mineral or rock with a sufficient silicon content, such as quartz or sandstone. Two additional forms of crystalline silica are cristobalite and tridymite, which may also be present in hard rock mines.

Asbestos minerals contain magnesium oxide and silica in large amounts, and traces of iron, chromium, cadmium and zinc. Varietal forms of asbestos include chrysotile, amosite, crocidolite, anthophyllite, actinolite and tremolite. Asbestos is a generic term for a variety of hydrated silicates having the common property of the ability to break into soft, elongated fibers.

Distribution

Silica may be present, as mentioned above, in hard rock mines with a sufficient quantity of quartz. Coal mines also may produce enough silica dust, along with graphite dust to pose a potential threat of anthrasilicosis [58].

Some occurrences of asbestos in mines, mills and quarries are presented in Table 12 [56]. Note that asbestos may be present in mines where the principal commodity may be an ore other than asbestos.

Recorded Injuries/Fatalities Due To Silica/Asbestos Exposure

Due to safer work practices, the prevalence of silicosis in hard rock miners has declined. A study conducted in 1913-1915 revealed 60.4% of the miners examined had lung disease caused by "rock dust". In 1958-1961, a different study showed the prevalence of silicosis to be 3.4%. Dust samples taken in each study likewise indicated a dramatic decrease in work area dust levels [24].

A second study (1958) provided evidence that the duration of exposure was an important variable to be considered for determining the history of the disease. Of those with less than 5 years exposure no cases of silicosis were found. The incidences rose rapidly as the duration of exposure increased, up to 16.6% for those with exposures of 30 years or more [24].

One of the most famous cases of silica exposure occurred in the 1930's at Gauley Mountain. A water tunnel was being drilled through a mountain containing high quantities of silica. Few safe work practices were implemented. In a matter of months, workers began contracting respiratory problems. A total of 475 men died during construction of the tunnel, and many hundreds died later as the result of silicosis. The company was supposedly aware of the problem prior to the initial construction yet did nothing to protect the workers [25].

Asbestos is a known human carcinogen, and is toxic when inhaled. No animal studies have demonstrated an effect due to ingestion. The physiological effects due to asbestos depend on: type of fiber, physical structure of the fiber, and minor chemical components [58].

TABLE 12

MINING OPERATIONS AND/OR LOCALITIES, BY COMMODITIES,
WHERE "FIBROUS" MINERALS MAY POSSIBLY BE FOUND

Unless otherwise specified, the pages listed refer to one or more of the following: Chrysotile, amosite, crocidolite, anthophyllite, tremolite, and actinolite.

<u>Iron</u>			
1. Cornwall Mine, PA, pp. 81-83	Refers also to zeolites, serpentine, and byssolite.		
2. Grace Mine, PA, pp. 110, 117-118	Refers also to serpentine and talc.		
3. Mesabi Iron Range, MI, pp. 325 and 328	Refers also to stilpnomelane, minnesotaite, cummingtonite, and amphiboles.		
4. Iron Mountain, MO, p. 299	Refers also to amphiboles.		
5. Eagle Mountain Sup'v'it, CA, pp. 1604-1605	Refers also to serpentines.		
<u>Copper</u>			
6. Ducktown District, TN, pp. 162-163, 222	Refers also to amphiboles, talc, and asbestos.		
7. Copper King Mine, CO, p. 374	Refers also to cummingtonite.		
8. Christmas Mine, Banner District, AZ, p. 1204	Refers also to serpentine.		
9. Mountain City Copper Mine, NV, p. 1080	Refers also to unaltered gabbro.		
<u>Lead-Zinc</u>			
10. Balmat-Edwards District, NY, pp. 13, 39, 41	Refers also to talc and serpentine.		
11. Van Stene Area, Stevens Co., WA, pp. 1313-1317	Refers also to brucitic fiber, palygorskite, and talc.		
12. Cover-d'Alene District, ID, p. 1429	Refers to grunerite needles.		
13. New Idria Group, CA, pp. 1628-1630, 1646-1647	Refers also to serpentine and asbestos.		
14. New Almaden Mine, Santa Clara County, CA	Refers to serpentine.		
<u>Chrysotile</u>			
15. Mistake Mine, CA, pp. 1648-1649	Refers also to asbestos and serpentine.		
16. Low's Pic (State Line Pits), PA	Refers to williamsite.		
17. Woods Chroma Mine Lancaster County, PA	Refers to clino-chrysotile, and deweyite (stevensite).		
<u>Gold</u>			
18. Homestake Mine, SD, p. 1437	See also Denver Technical Support Center memo dated 12/4/72. Refers to cummingtonite schist.		
<u>Tungsten</u>			
19. Bishop Tungsten District CA, p. 1549	Refers also to talc, wollastonite and pectolite.		
<u>Rare Earths</u>			
20. Mountain Pass, CA, p. 1528			
<u>Asbestos</u>			
21. Clear Creek (New Idria) CA, pp. 1628-1630, 1647- 1648	Refers also to serpentine and asbestos.		
22. Franklin-Somerset Area, MA, p. 137	Refers also to serpentine and asbestos.		
23. Webster and Spruce Pine, NC, (vicinity)			
24. Arizona, near Globe	Refers to serpentine.		
25. Bare Hills Area, MD			
26. Staten Island, NY	Refers to serpentine.		

TABLE 12 - CONTINUED

Magnetite

27. Magnetite-brucite deposit
Cobbs, NV, pp. 1617-1618.	Refers also to talc, brucite and
serpentine.
28. Gouverneur, NY vicinity	Refers also to talc and serpentine.
29. Saratow, CA vicinity	Refers also to talc and steatite.

Vermiculite

30. Libby MT vicinity	
31. North & South Carolina
deposits.	
32. Green Springs, Charlottes-
ville, VA, deposit	Refers also to amphibolites.

Crushed Stone

33. Rockville Quarry,
Rockville, MD | Refers also to serpentine, talc,
and doveylite. |
|--|--|

Additional locations where asbestos mineral fibers have been
confirmed to exist --

- (1) The Eastern Mesabi Iron Range country (The Reserve Mining
Company tailings disposal problem)
- (2) The Homestake Mine where a health hazard exists
- (3) The Mountain Pass, rare earth deposit
- (4) The wollastonite deposits of New York
- (5) The attapulgite deposits of Georgia
- (6) The Rockville Quarry (serpentine) near Washington, D. C.
- (7) Green Springs vermiculite deposits, VA.

TABLE 12 - CONTINUED

<u>Listing Number</u>	<u>Reference</u>
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14	Pennington, J.W. <u>Mercury- A Material Survey.</u> Bureau of Mines, IC 7941, 1959.
15	Op. Cit., Ridge.
16 - 17	Faust, G.T., and J.J. Fahey. <u>The Serpentine-Group Minerals.</u> USGS, Professional Paper 384-A, 1962.
18 - 22	Op. Cit., Ridge.
23	Chidester, A.H. and A.F. Shride, <u>Asbestos in the United States.</u> USGS, Mineral Investigations Resources Map MR-17, 1962.
24	Op. Cit., Pennington. Stewart, L.A. <u>Chrysotile-Asbestos Deposits of Arizona.</u> Bureau of Mines IC 7706, January 1955.
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26	Op. Cit., Faust and Fahey.
27	Op. Cit., Ridge.
28 - 29	Weiss, D. and E.A. Boettner. <u>Commercial Talc and Talcosis.</u> Archives Environmental Health. (14) 1950: 122-128.
29	Wright, L.A. <u>California Talcs.</u> <u>Mining Engineering.</u> (187) 1950: 122-128.
30 - 31	No Reference.
32	Rohl, A.N. and A.M. Langer. Internal Memorandum to Dr. I.J. Selikoff, Mount Sinai School of Medicine, New York. <u>Mineral Analysis of Core Samples from the Green Springs Area-Virginia Vermiculite Deposit.</u> July 1, 1977.
33	Rohl, A.N., A.M. Langer, and I.J. Selikoff. <u>Environmental Asbestos Pollution Related to Use of Quarried Serpentine Rock.</u> <u>SCIENCE.</u> (196) 1977: 1319-1322.

The biological pathways followed by asbestos to produce a toxic reaction within the body are not completely known. Asbestos alone, in the pleural cavity in animal models and in man leads to mesothelioma of the pleura which has a characteristically long latent period. Asbestos dust in combination with cigarette smoking can contribute synergistically to the development of lung cancer in humans [58]. A high incidence of cancer among asbestos miners and men working with insulation material has been implicated by epidemiologic evidence [82]. An excess of lung cancers exist among Finnish miners who were exposed to anthophyllite [56]. At a meeting of the Society for Occupational and Environmental Health (Dec. 4-7, 1977, Wash., D.C.) investigators believed that fibrous zeolite caused an epidemic of mesothelioma in Kariana, Turkey.

The first demonstration of asbestos exposure, of a magnitude known to be pathogenic, resulting from natural deposits not associated with mining, milling or industry, was from dustfall in a recreation area in San Benito County, California. Natural dust contained 90 percent or more chrysotile asbestos [83].

Detection and Control

The American Conference of Governmental Industrial Hygienists (ACGIH) have set the Threshold Limit Value for quartz dust at $10/(\% \text{ respirable dust} + 2) \text{ mg/m}^3$. However, for cristobalite and tridymite, two other forms of crystalline silica, the number obtained by this formula must be divided by two. A method to determine free silica in airborne dust collected on membrane filters uses x-ray diffraction [84]. This provides an accurate and rapid analysis of respirable dust, with a lower detection limit of 11 μg for quartz.

OSHA's standard for asbestos is 2 fibers/cc having a length of 5 micrometers [57]. X-ray diffraction techniques coupled with electronmicroscopy reveal the amounts of asbestos and the morphological characteristics of fibrous dust samples [83].

Fortunately, cases of gross negligence, like silica exposure at Gauley Mountain, do not exist today. Safe work procedures are followed such as:

- Adequate ventilation to remove dust in the atmosphere.
- Wet drilling to reduce the amount of dust in the air.
- Frequent surveillance of respirable dust in the air.
- Protective respiratory devices for dust producing operations such as blasting.

VII. RADIATION HAZARDS IN UNDERGROUND EXCAVATION

The rising importance of nuclear energy has been paralleled by an increase in interest concerning the potential hazards associated with radiation exposure of all types. This section attempts to provide some insight concerning the potential radiation hazards associated with underground excavation. The topics addressed will include hazards, pathways of human exposure, potential health effects, and control measures. The primary pathways of exposure from underground excavation consist of mining and inadvertent human intrusion.

Hazards

In general, concern about radiological hazards centers on the potential for exposure of an individual to a source of radiation. The degree of hazard (and health effect) depends on the level and duration of exposure [26]. Thus, the radiological properties of the materials present during any underground excavation will have a direct role in their potential for harm.

The two radioactive elements found in greatest abundance within the earth's crust, distributed in rocks, soils, and their constituent minerals, are thorium and uranium. Therefore the probability of encountering these two elements over other possible radioactive sources is great. Thorium is more abundant on earth, but uranium-238, by virtue of its very radiotoxic descendant radium-226, is probably more important. The behavior of radium-226 and the succeeding daughter elements (products resulting from the natural decay of a parent element such as radium-226) formed are illustrated in Table 13. A decay scheme for uranium-238 is included as Figure 3.

TABLE 13

Common name	Scientific name	Half life	Particle	Energy
Radium	Radium-226	1260 year	alpha	-----
Radon	Radon-222	3.82 day	alpha	5.49 Mev.
Radium A	Polonium-218	3.05 min	alpha	6.00 "
Radium B	Lead-214	26.8 min	beta,gamma	-----
Radium C	Bismuth-214	19.7 min	beta,gamma	-----
Radium C'	Polonium-214	10 ⁻⁶ min	alpha	7.68 Mev.
Radium D	Lead-210	22 year	beta	

Partial Decay Scheme of Radium-226 Chain

Source: U.S. EPA Preliminary Findings in Radon Daughter Levels in Structures Constructed On Reclaimed Florida Phosphate Land. Technical Note, ORP/CSD-75-4, September, 1975.

FIGURE 3

URANIUM - 238 DECAY SERIES

Source: May, Harold. *Ionizing Radiation Levels in Energy Conserving Structures*, Argonne National Laboratory, Argonne, Illinois, 1980.

When uranium and its daughter elements are confined, as for example within an impermeable rock, the local concentration of activity or decay rate of each member of the family is equal and constant with time, being determined solely by the 4.5 billion year half-life of U-238. The decay products are then said to be in equilibrium with the parent. In the much more common situation in which the gaseous decay daughter radon can escape, its half-life of 3.82 days is sufficient to permit transport over appreciable distances, and results in the consequent dispersion of the decay products. The activity concentrations of the family are then different, and normally vary with time [27].

The most significant radioactivity in rock is caused by the following three major natural decay series:

- 1) uranium-238 15 radioisotopes,
- 2) thorium-232 11 radioisotopes,
- 3) uranium-235 14 radioisotopes.

Except under extremely unusual conditions, external alpha and beta radiation levels are not sufficiently intense to present a measurable health hazard. The ore or rock itself is usually not of high enough radioactivity to cause acute exposure, although external exposure to these forms in a chronic pattern may be measurable under some conditions. Even when inhaled or ingested, radioactive mineral dusts are often too low in activity to present a radiation hazard. Radon daughters, however, can present an internal alpha radiation hazard to the lungs [29].

The fact that radon daughters occur in a wide variety of underground mines is not surprising because all that is required is the presence of normal amounts of uranium-238 or thorium-232 in the ore or in the surrounding host rock. These two elements are common constituents, in trace

amounts, within the earth's crust. Ground water can carry dissolved radon gas into otherwise non-radioactive environments; therefore, under unusual circumstances, neither the immediate host rock nor the ore need be radioactive for radon gas buildup to occur. Radon, being a noble gas, does not combine chemically with other available elements, but it may escape by diffusion from the mineral or rock where it originates. From a few to twenty percent is released, depending on the type of mineral, its past geological history, and physical condition [27]. When radon is inhaled, it diffuses throughout the body and gives what is essentially whole body radiation. Its retention, however, is limited, since most inhaled radon is also exhaled within its half-life of 3.8 days. For the immediate daughters of radon, however, the story is different. These radionuclides (Po-218, Bi-214, Pb-214, and Po-214) collectively have an average half-life of about 30 minutes. When formed in the air of a mine they quickly become attached to solid surfaces, most notably dust particles. When these dust particles with attached radionuclides are inhaled, the radiation from them (largely alpha particles) is deposited within the nose, pharynx, and tracheo bronchial tree. The radiation dose delivered to the lungs of uranium miners by these elements is about 20 times greater than that from inhaled radon [31]. Figures 4 and 5 provide decay schemes for radon-222 and radon-220 (thoron) [30]. Regarding radon-222, the short-lived daughters may attach to dust of respirable size. In addition, that portion of the inhaled radon gas decaying to RaA (Po-218) before the gas is exhaled may be retained internally. The short-lived, respirable, radon daughter particulates collect in the pulmonary tract where they are capable of delivering considerable alpha energy directly to the epithelial lining of the lungs in a short period of time. Radon-220, commonly called thoron, is the gaseous phase of the thorium-232 series. All thoron daughter members have

FIGURE 4

Source: Rock, R. L. et al., Evaluation of Radioactive Aerosols in U.S. Underground Coal Mines. U.S. Dept. Interior. Mining Enforcement and Safety Administration IR1025. 1975

FIGURE 5

Source: Rock, R. L. et al., Evaluation of Radioactive Aerosols in U.S. Underground Coal Mines. U.S. Dept. Interior. Mining Enforcement and Safety Administration IR1025. 1975

extremely short half-lives with the exception of Pb-212 (ThB) with a 10.6 hour half-life. This causes the concentration of Pb-212 (atoms per liter of air) to be the governing factor in the magnitude of the potential thoron daughter health hazard. Ventilation is therefore much more effective in controlling radon-222 daughters (because of the relatively long half-life) than it is in the control of thoron daughters, hence a hazard could only be present from thoron daughters where radon-220 daughters emanation rates are very high or ventilation rates are very low. As with radon-222 daughters, the hazard from radon-220 daughters is due to the alpha energy released in the bronchial tract by inhaled alpha-emitting particulates [30].

Types of Exposure

There are three possible routes of radiological exposure during underground excavation: mining of radioactive or non-radioactive material containing traces of radioactive parent nuclides, exposure to contaminated ground, air or mine water, and inadvertent human intrusion into an enclosed area of radioactive material (e.g., waste repository).

Mining of materials containing trace radioactive constituents has been previously described in relation to mode of exposure (specifically the inhalation of dust carrying radon daughter products). Within the confines of a mine, ground water percolating through rocks may dissolve radon gas and release it later when the concentration of radon in the environment is lower. As a rule, ground water contributes only an insignificant fraction to the total radon content of mine air. By contrast, the high radon content of some uranium mine sections, and underground workings of some non-uranium mines is essentially due to contributions from minerals relatively rich in radon-222 [34]. Release via man-made intrusions might be due to exploratory

drilling, archeological exploration, solution mining of salt or phosphates, or cavern construction for mining, storage of oil, industrial wastes, compressed air, etc. [44].

The hazards attending an intrusion into a radioactive waste repository according to the scenario are allegedly small [44]. Some radioactive material might be accidentally raised to the surface causing local contamination. Health effects would occur from direct penetrating radiation or inhalation of radon daughter products. More likely, the purpose of the site would be recognized, decontamination measures would be taken, and exploratory holes would be sealed. The area would then probably be placed under some form of administrative control [46].

Health Effects

The effects of radiation on human tissues include: ionization of atoms or molecules, formation of free radicals, and interaction with other components of live tissues by oxidation or reduction processes. These processes can lead to the disruption of vital systems in the body. The biological effects of radiation depend upon radiation dose, the type of radiation, the amount of energy absorbed by the body, the length of exposure time, the size of irradiated area, part of the body, and the sensitivity of the individual [35].

Internal and, to a lesser extent, external sources of ionizing radiation may cause adverse health effects to occupants in areas of high radium and radon concentrations. The dose due to external sources is primarily from radium daughter products that emit gamma rays capable of penetrating all tissues of the body.

Internal exposure will be due primarily to alpha particles from radon daughter decay products, the chain of radionuclides that follow radon-222 in the uranium-radium decay series. The radon daughters deposit in and irradiate parts of the lung, particularly the basement membranes of the bronchial airways. The expected response to this irradiation is an increase in lung cancer [34]. Penetrating radiation can cause somatic and genetic effects in humans. Somatic effects which might be expected include: leukemia, solid tumors, and cancer of the bone, breast, or lungs. Congenital defects might appear in the children of exposed parents.

The high rate of morbidity and mortality among miners unintentionally exposed to high levels of natural airborne radioactivity and among experimental animals that were intentionally exposed during clinical studies of radiotoxicity indicates the hazardous nature of radon daughters [36]. Breathing radon itself does not result in a significant health hazard. By far the most localized radiation exposure results from the inhalation of the attached fraction of daughter products. Up to 60% of the daughter ions borne by inhaled aerosols are retained on the bronchial epithelium or within the passages of the pulmonary system. The aerodynamic processes which determine quantitatively where this deposition takes place depends upon aerosol size distribution. Knowledge of these harmful effects are derived primarily from epidemiological studies of uranium miners [37].

Many factors are known to affect the severity of the radon daughter health hazard in underground excavation. An obvious factor is the radon emanation rate relative to air dilution and air exchange rates provided by ventilation. More subtle factors influencing the health hazard are related to the radon and daughter products which do not become attached to dust particles. Such free atoms tend to concentrate in the upper bronchial tree and give a higher relative alpha radiation dose to that area. Attached

daughters are more uniformly distributed throughout the bronchial system. Factors affecting percentages of free daughter atoms in underground air are condensation nuclei concentrations, age of the radon-air mixture, and diffusion characteristics. The latter can be a function of air turbulence and both kinetic and electrical interaction of radioactive and electrically charged particles in the air.

Detection and Control

A standard method of sampling for radon daughters is the Kusnetz technique [32]. This method requires drawing an air sample through a suitable filter at a known rate of at least 2 liters per minute for 5 minutes. The radon daughter particulates collected on the filter are then counted in a calibrated alpha counter within a time interval of 40 to 90 minutes after the end of the sampling. The counts per minute obtained from this procedure are converted to disintegrations per minute (dpm) by utilizing an instrument calibration factor (detector efficiency). Subsequently, the resulting count rate is converted to dpm per liter of air by dividing by the total air sample volume. The dpm per liter value is converted to working levels (standard unit of measurement for radon daughter concentrations) by dividing the appropriate time factor from a radon daughter time factor curve [32].

Once the concentration of radon daughters is determined, as in the case for an underground mine, it is expressed in terms of a physical unit known as the working level (WL) [36]. The derivation of the WL is shown in Table 14. This term is defined as any combination of short-lived radon daughter products in 1 liter of air that will result in the ultimate emission of 1.3×10^{-5} MeV of potential alpha energy [38]. The numerical value of the WL

TABLE 14

DERIVATION OF THE WORKING LEVEL (WL)					
Nuclide	Alpha energy (Mev)	Half-period	Number of atoms per 100 pCi	Potential alpha energy per atom (Mev)	Total potential alpha energy (Mev/100 pCi)
Rn (Rn^{222})	5.49	3.825 days	1.77×10^8	*	none
RaA (Po^{218})	6.00	3.05 min	977	6.00 + 7.68	0.134×10^6
RaB (Pb^{214})	0	26.8 min.	8,580	7.68	0.659×10^6
RaC (Bi^{214})	0	19.7 min.	6,310	7.68	0.485×10^6
RaC (Po^{214})	7.68	10^{-6} min.	10^{-3}	7.68	0.000×10^6
Total					1.278×10^6
Corrected					1.3×10^6

* excluded

Source: Tompkins, P.L., "Radiation Protection and Uranium Mining",
J. Occup. Med., 10(12), December, 1968.

is derived from the alpha energy released by the total decay through RaC' of the short-lived radon daughter products, RaA, RaB, and RaC, at radioactive equilibrium with 100 pCi of ^{222}Rn per liter of air [39].

A Working Level Month (WLM) is the term used to express the occupational exposure incurred in one working month of 170 hours by a uranium miner laboring in an atmosphere containing radon daughter products; i.e., one working month in a mine atmosphere containing 1 WL of radon daughter products equals 1 WLM [37]. In 1972 the occupational exposure standard for radon daughters was placed at 4 WLM per year [40]. Several studies have concluded in part that a plausible hypothesis may be constructed implying that radon daughter exposure is causally related to an excess lung cancer risk in the 120-359 WLM category [35, 41, 42]. Figure 6 provides a graphic representation showing the relationship between observed and expected lung cancer mortality as a function of cumulative WLM.

The concern when implementing control measures is that of regulating radon and radon daughter levels and the prevention of inadvertent intrusion. Methods for controlling atmospheric concentrations of radon and radon daughters can be described under these general classifications:

- Removal of the contaminants from the working area (ventilation).
- Preventing the release of radon into working areas.
- Personal protective measures.

At least the first two procedures must be used to obtain effective control [47]. Prevention of inadvertent intrusion is a difficult problem to deal with, because any explanation of the situation uses probability, risk estimates, hypothetical models, and other methods of forecasting to discuss a rare event.

FIGURE 6

Observed and expected annual lung cancer mortality per 10,000 miners and 95% confidence limits in relation to exposure.

Source: Tompkins, P.L., "Radiation Protection and Uranium Mining", J. Occup. Med., 10(22), December, 1968.

Control of radon daughters in mines is sometimes considered to be basically a ventilation problem. However, the problem is of such a nature that control over the amount of contamination released into the mine environment and control over the manner in which that contamination is removed from the mine environment are major factors in determining the required level of ventilation [48]. The general principles involved have been pointed out by Harris and Bales [49] and by Kusnetz [50]. Examination of these theoretical considerations and experience show limitations in the effectiveness of general ventilation for reduction of atmospheric concentrations of radon daughters [51].

Despite genuine progress over the last three decades, many questions regarding control measures remain to be answered. These concern the variability of radiation levels, the adequacy of current exposure limits in protecting the health of mine workers, the relative effectiveness of different radiation exposure measurement instruments under varying conditions, medical screening procedures, and other subjects [40].

Summary

The primary pathways of exposure to radiation hazards in underground excavation are mining and inadvertent human intrusion. The significant potential health risk comes from exposure to radon and radon daughters. The hazard is due primarily to the alpha energy released in the bronchial tree by inhaled alpha emitting particles. The potential hazard of radioactive exposure during excavation depends on the radiological properties of the radioactive source. To be considered are the type of radiation emitted, the levels present, the duration of exposure, the activity of the source, and whether the exposure is external or internal. The information presented in

this section is intended to be used as a guide for the recognition and evaluation of potential radiation hazards in underground excavation. It should not be considered as a complete description of a complex topic. It also does not deal with the difficult problems of probability and risk of inadvertent intrusion.

VIII. OTHER HAZARDS OF UNDERGROUND EXCAVATION

Mining Incidents

It was difficult to obtain information on incidents of inadvertent exposures in mines, involving exposures other than those discussed previously. Data was obtained from the U.S. Department of Labor, Mine Safety and Health Administration (MSHA), on injuries experienced during underground Metallic Mineral Mining [52], Coal Mining [53], Non-metallic Mineral Mining [54], and Stone Mining [55] for 1979. The relevant data compiled by this agency in regard to underground mining is presented in Tables 15 A-E. Data used in compiling these reports was obtained from operators of the mines and preparation plants on a mandatory basis as required under the Federal Mine Safety and Health Act (MSHA) of 1977, PL 95-173 as amended by PL 95-164. Since January 1, 1978, operators of mines or preparation plants or both, which are subject to the Act, have been required under 30 CFR, Part 50, to submit reports of injuries, occupational illnesses, and related data [52].

Table 15 A, presents the number of injuries, incidence rates, and severity measures by degree for work location and nature of injury at these underground mining operations. Emphasis was placed on asphyxiation, systemic poisoning, and radiation. Asphyxiation and radiation incidents were most numerous in Bituminous Coal Mining operations. Few injuries were incurred due to radiation and systemic poisoning (unspecified origin) in all other mining operations.

Table 15 B, presents the number of injuries by accident classification and degree for work location and State of underground mining operations. The injuries involving ignition or explosion of a gas or dust, inundation, and others may be due to inadvertent excavation exposures. For comparison,

TABLE 15-A

NUMBER OF INJURIES, INCIDENCE RATES, AND SEVERITY MEASURES BY DEGREE FOR WORK LOCATION AND NATURE OF INJURY
AT METALLIC MINERAL OPERATIONS IN THE UNITED STATES, 1979

WORK LOCATION AND NATURE OF INJURY	NUMBER OF INJURIES							INCIDENCE RATES					SEVERITY MEASURES			
	FATAL	1 NFDL			TOTAL FATAL AND NFDL	2 NOL	TOTAL INJURIES	FATAL	NFDL	ALL FATAL AND NFDL	NOL	ALL INJURIES	FATAL	NFDL	ALL FATAL AND NFDL	
		PERMANENT		TEMPO- RARY												
		TOTAL	PARTIAL		TOTAL NFDL											
UNDERGROUND MINES:																
UNDERGROUND:																
AMPUTATION/ENUCLEATION	-	-	28	-	28	28	-	.14	.14	-	.14	-	-	114	114	
ASPHYXIATION/DROWNING	1	-	-	10	10	11	7	.01	.05	.06	.04	.09	.31	1	32	
BURN/SCALD (NOT CHEM.)	-	-	-	5	5	5	11	-	.03	.03	.06	.08	-	1	1	
CHEMICAL BURN	-	-	-	33	33	33	27	-	.17	.17	.14	.31	-	1	1	
CONCUSSION (CEREBRAL)	-	-	-	8	8	8	8	-	.04	.04	-	.04	-	5	5	
CONTUSION OR BRUISE	4	-	-	644	644	648	240	.02	3.32	3.34	1.24	4.57	124	31	155	
CUT OR PUNCTURE	-	-	1	417	418	418	766	1.184	2.15	2.15	3.95	6.10	-	27	27	
DERMATITIS	-	-	-	2	2	2	-	-	.01	.01	-	.01	-	(*)	(*)	
DISLOCATION	-	-	-	19	19	19	-	-	.10	.10	-	.10	-	4	4	
DUST IN EYE	-	-	-	69	69	69	77	-	.36	.36	.40	.75	-	2	2	
ELECTRIC SHOCK	1	-	-	7	7	8	4	.01	.04	.04	.02	.06	.31	(*)	31	
ELECT. BURN (CONTACT)	-	-	-	3	3	3	-	-	.02	.02	-	.02	-	(*)	(*)	
FRACTURE	4	-	2	396	398	402	125	.02	2.05	2.07	.64	2.71	124	28	251	
HEARING IMPAIRMENT	-	-	-	1	1	1	-	-	.01	.01	-	.01	-	(*)	(*)	
HEAT/SUNSTROKE	-	-	-	1	1	1	1	-	.01	.01	.01	.01	-	(*)	(*)	
HEMIA (NOT DISC)	-	-	12	7	19	19	-	-	.10	.10	-	.10	-	4	4	
POISONING (SYSTEMIC)	-	-	-	4	4	4	4	-	.02	.02	.02	.04	-	(*)	(*)	
RADIATION/ULTRA VIOLET	-	-	-	5	5	5	9	-	.03	.03	.02	.05	-	(*)	(*)	
SCRATCH/ABRASION	-	-	-	33	33	33	22	-	.17	.17	.11	.28	-	(*)	(*)	
STRAIN/SPRAIN	-	-	-	650	650	650	146	-	3.35	3.35	.75	4.10	-	48	49	
MULTIPLE INJURIES	-	1	1	212	214	214	331	-	1.10	1.10	.60	1.70	-	56	56	
OTHER INJURY, NEC	-	-	-	16	16	16	11	-	.08	.08	.06	.14	-	2	2	
UNCLASSIFIED (NO DATA)	3	-	-	86	86	89	40	.02	.44	.46	.21	.66	93	9	102	
TOTAL OR AVERAGE	13	1	44	2,628	2,673	2,686	1,602	4,288	.07	13.77	13.83	8.25	22.09	402	434	836

AT ALL COAL OPERATIONS IN THE UNITED STATES, 1979

UNDERGROUND MINES:																
UNDERGROUND:																
AMPUTATION/ENUCLEATION	-	1	113	-	114	114	-	114	-	.10	.10	-	.10	-	51	51
ASPHYXIATION/DROWNING	-	-	-	16	16	20	6	26	(*)	.01	.02	.01	.02	21	(*)	21
BURN/SCALD (NOT CHEM.)	-	-	-	75	75	75	16	91	-	.07	.07	.01	.08	-	(*)	(*)
CHEMICAL BURN	-	-	-	32	32	32	12	44	-	.03	.03	.01	.04	-	(*)	(*)
CONCUSSION (CEREBRAL)	1	-	-	52	52	53	1	54	(*)	.05	.05	(*)	.05	5	6	6
CONTUSION OR BRUISE	34	1	-	3,398	3,399	3,433	360	3,793	.03	2.95	2.98	.31	3.29	177	56	233
CUT OR PUNCTURE	1	-	1	1,109	1,110	1,111	1,029	2,340	(*)	1.14	1.14	.89	2.03	5	17	22
DERMATITIS	-	-	-	3	3	3	5	8	-	(*)	(*)	-	.01	-	(*)	(*)
DISLOCATION	-	-	-	90	90	90	12	102	-	.08	.08	.01	.09	-	3	3
DUST IN EYE	-	-	-	192	192	192	70	262	-	.17	.17	.06	.23	-	1	1
ELECTRIC SHOCK	8	-	-	42	42	50	7	57	.01	.04	.04	.01	.08	42	1	42
ELECT. BURN (CONTACT)	-	-	-	68	68	68	7	75	-	.06	.06	.01	.07	-	1	1
FRACTURE	3	6	4	1,841	1,851	1,854	302	2,156	(*)	1.61	1.61	.26	1.87	16	105	122
FREEZING/FROSTBITE	-	-	-	1	1	1	-	1	-	(*)	(*)	-	(*)	-	(*)	(*)
HEARING IMPAIRMENT	-	-	-	2	2	2	-	2	-	(*)	(*)	-	(*)	-	(*)	(*)
HEMIA (NOT DISC)	-	-	70	74	144	144	-	144	-	.13	.13	-	.13	-	6	6
POISONING (SYSTEMIC)	-	-	-	1	1	1	-	1	-	(*)	(*)	-	(*)	-	(*)	(*)
RADIATION/ULTRA VIOLET	-	-	-	158	158	158	34	192	-	.14	.14	.03	.17	-	1	1
SCRATCH/ABRASION	-	-	-	80	80	80	16	96	-	.07	.07	.01	.08	-	1	1
STRAIN/SPRAIN	-	1	-	4,984	4,985	4,985	228	5,213	-	4.33	4.33	.20	4.53	-	119	115
MULTIPLE INJURIES	11	2	1	803	806	817	111	928	.01	.70	.71	.10	.81	57	32	89
OTHER INJURY, NEC	3	-	-	89	89	92	12	104	(*)	.08	.08	.01	.09	16	2	18
UNCLASSIFIED (NO DATA)	41	-	1	673	674	715	88	803	.04	.59	.62	.08	.70	214	16	230
TOTAL OR AVERAGE	106	10	191	13,983	14,184	14,290	2,316	16,606	.09	12.32	12.41	2.01	14.42	552	415	968

AT ANTHRACITE COAL OPERATIONS IN THE UNITED STATES, 1979

UNDERGROUND MINES:																
UNDERGROUND:																
CONTUSION OR BRUISE	1	-	-	14	14	15	3	18	.38	5.31	5.69	1.14	6.82	2,274	51	2,326
CUT OR PUNCTURE	-	-	-	2	2	2	1	3	-	.76	.76	.38	1.14	-	3	3
DISLOCATION	-	-	-	2	2	2	-	2	-	.76	.76	-	.76	-	3	34
DUST IN EYE	-	-	-	2	2	2	-	2	-	.76	.76	-	.76	-	2	2
FRACTURE	-	-	-	10	10	10	-	10	-	3.79	3.79	-	3.79	-	242	242
HEMIA (NOT DISC)	-	-	-	1	1	1	-	1	-	.38	.38	-	.38	-	32	32
SCRATCH/ABRASION	-	-	-	12	12	12	-	12	-	4.55	4.55	-	4.55	-	103	103
STRAIN/SPRAIN	-	-	-	2	2	3	-	3	-	1.14	1.14	-	1.14	-	2,279	2,279
MULTIPLE INJURIES	-	1	-	2	2	2	-	2	-	.76	.76	-	.76	-	16	16
OTHER INJURY, NEC	-	-	-	4	4	4	-	4	-	1.52	1.52	-	1.52	-	17	17
UNCLASSIFIED (NO DATA)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TOTAL OR AVERAGE	1	1	-	52	53	54	4	58	.38	20.09	20.47	1.52	21.99	2,274	2,781	5,095

¹Non-Fatal with Days Lost

²No days Lost

TABLE 15-A - Continued

NUMBER OF INJURIES, INCIDENCE RATES, AND SEVERITY MEASURES BY DEGREE FOR WORK LOCATION AND NATURE OF INJURY
AT BITUMINOUS COAL OPERATIONS IN THE UNITED STATES, 1979

WORK LOCATION AND NATURE OF INJURY	NUMBER OF INJURIES							INCIDENCE RATES				SEVERITY MEASURES			
	FATAL	NFDL			TOTAL FATAL AND NFDL	NOL	TOTAL INJURIES	FATAL	NFDL	ALL FATAL AND NFDL	NOL	ALL INJURIES	FATAL	NFDL	ALL FATAL AND NFDL
		PERMANENT	TEMPO- RARY	TOTAL NFDL											
UNDERGROUND MINES:															
UNDERGROUND:															
AMPUTATION/ENUCLEATION--	-	1	113	-	114	114	-	-	.10	.10	-	.10	-	51	91
ASPHYXIATION/DROWNING--	4	-	-	16	16	20	-	(*)	.07	.02	.01	.02	21	(*)	21
BURN/SCALD (HOT CHEM)--	-	-	-	75	75	75	16	91	-	.07	.07	.01	.08	-	(*)
CHEMICAL BURN--	-	-	-	32	32	32	12	44	-	.03	.03	.01	.04	-	(*)
CONCUSSION (CEREBRAL)--	1	-	-	52	52	53	1	58	(*)	.05	.05	(*)	.05	5	6
CORTUSION OR BRUISE--	33	1	-	3,384	3,385	3,418	257	3,775	.03	2.99	2.98	.31	3.29	172	96
CUT OR PUNCTURE--	1	-	1	1,307	1,308	1,309	1,028	2,337	(*)	1.14	1.14	.89	2.03	5	17
DERMATITIS--	-	-	-	88	88	88	5	8	(*)	(*)	(*)	(*)	.01	-	3
DYSLOCATION--	-	-	-	12	12	100	12	100	-	.08	.08	.01	.09	-	(*)
DUST IN EYE--	-	-	-	190	190	190	70	260	-	.17	.17	.08	.23	-	1
ELECTRIC SHOCK--	8	-	-	42	42	50	7	57	.01	.04	.04	.01	.05	42	1
ELECT. BURN (CONTACT)--	-	-	-	68	68	68	7	75	-	.06	.06	.01	.07	-	1
FRACTURE--	3	6	4	1,831	1,841	1,844	302	2,146	(*)	1.60	1.61	.26	1.87	16	105
FREZING/FROSTBITE--	-	-	-	2	2	2	-	-	-	(*)	(*)	-	(*)	-	(*)
HEARING IMPAIRMENT--	-	-	-	2	2	2	-	-	-	(*)	(*)	-	(*)	-	(*)
HERNIA (NOT DISC)--	-	-	70	73	143	143	-	143	-	.12	.12	-	.12	-	6
POISONING (SYSTEMIC)--	-	-	-	1	1	1	-	1	-	(*)	(*)	-	(*)	-	(*)
RADIATION/ULTRA VIOLET--	-	-	-	158	158	158	34	192	-	.14	.14	.03	.17	-	1
SCRATCH/ABRASION--	-	-	-	79	79	79	16	95	-	.07	.07	.01	.08	-	1
STRAIN/SPRAIN--	-	-	1	4,972	4,973	4,973	228	5,201	-	4.33	4.33	.20	4.53	-	119
MULTIPLE INJURIES--	11	1	1	801	803	814	111	925	.01	.70	7.11	.10	.81	57	27
OTHER INJURY, NEC--	3	-	-	87	87	90	12	102	(*)	.08	.08	.01	.09	16	2
UNCLASSIFIED (NO DATA)--	41	-	1	669	670	711	88	799	.04	.58	.62	.08	.70	214	16
TOTAL OR AVERAGE--	105	9	191	13,331	14,131	14,236	2,312	16,548	.09	12.30	12.39	2.01	14.40	548	410

AT NONMETALLIC MINERAL OPERATIONS IN THE UNITED STATES, 1979

UNDERGROUND MINES:															
UNDERGROUND:															
AMPUTATION/ENUCLEATION--	-	-	4	-	4	4	-	-	.06	.06	-	.06	-	37	37
ASPHYXIATION/DROWNING--	-	-	-	-	-	-	1	-	-	-	.02	.02	-	-	1
BURN/SCALD (HOT CHEM)--	-	-	6	-	6	6	1	-	.10	.10	.05	.15	-	-	1
CHEMICAL BURN--	-	-	-	10	10	10	-	-	.16	.16	-	.16	-	2	2
CONCUSSION (CEREBRAL)--	-	-	2	2	2	2	-	-	.03	.03	-	.03	-	-	1
CORTUSION OR BRUISE--	1	-	-	109	109	110	25	.02	1.77	1.79	.41	2.19	98	21	119
CUT OR PUNCTURE--	-	-	2	2	2	2	96	-	.60	.60	1.56	2.16	-	7	7
DERMATITIS--	-	-	2	2	2	2	-	-	.03	.03	-	.03	-	(*)	(*)
DYSLOCATION--	-	-	2	2	2	2	-	-	.03	.03	-	.03	-	(*)	(*)
DUST IN EYE--	-	-	6	6	6	9	15	-	.10	.10	.15	.24	-	(*)	98
ELECTRIC SHOCK--	1	-	2	2	2	3	-	.02	.03	.05	-	.05	98	(*)	(*)
ELECT. BURN (CONTACT)--	-	-	1	1	1	1	-	-	.02	.02	-	.02	-	(*)	(*)
FRACTURE--	-	1	-	74	75	75	28	1.22	1.22	.46	1.67	-	145	145	145
HERNIA (NOT DISC)--	-	-	3	3	6	6	-	-	.10	.10	-	.10	-	5	5
RADIATION/ULTRA VIOLET--	-	-	1	1	1	1	-	-	.02	.02	-	.02	-	(*)	(*)
SCRATCH/ABRASION--	-	-	-	3	3	3	-	-	.05	.05	.02	.06	-	-	1
STRAIN/SPRAIN--	-	-	-	124	124	124	26	2.02	2.02	.42	2.44	-	40	40	40
MULTIPLE INJURIES--	4	-	-	45	45	48	18	.06	.73	8.00	.29	1.09	390	23	413
OTHER INJURY, NEC--	-	-	-	5	5	5	2	-	.08	.08	.03	.11	-	2	2
UNCLASSIFIED (NO DATA)--	6	-	-	19	19	25	11	.10	.31	.41	.18	.59	545	16	601
TOTAL OR AVERAGE--	12	1	7	451	459	471	220	.20	7.46	7.65	3.58	11.23	1,170	305	1,476

AT STONE OPERATIONS IN THE UNITED STATES, 1979

UNDERGROUND MINES:															
UNDERGROUND:															
AMPUTATION/ENUCLEATION--	-	-	3	-	3	3	-	-	.15	.15	-	.15	-	39	39
BURN/SCALD (HOT CHEM)--	-	-	3	3	3	3	-	-	.15	.15	-	.15	-	2	2
CHEMICAL BURN--	-	-	1	1	1	1	-	-	.05	.05	-	.05	-	(*)	(*)
CONCUSSION (CEREBRAL)--	1	-	-	27	27	28	9	.05	1.39	1.45	.15	1.60	310	64	374
CORTUSION OR BRUISE--	-	-	-	15	15	15	9	-	.77	.77	.46	1.24	-	10	10
CUT OR PUNCTURE--	-	-	-	5	5	5	2	-	.10	.10	-	.10	-	2	2
DYSLOCATION--	-	-	-	5	5	5	4	-	.10	.10	.21	.31	-	(*)	(*)
DUST IN EYE--	-	-	-	20	20	20	5	1.03	1.03	.26	1.29	-	57	57	57
ELECTRIC SHOCK--	-	-	-	1	1	1	-	-	.10	.10	-	.10	-	4	4
ELECT. BURN (CONTACT)--	-	-	-	4	4	4	-	-	.21	.21	-	.21	-	1	1
FRACTURE--	-	-	-	43	43	43	5	2.22	2.22	.26	2.48	-	32	32	32
HERNIA (NOT DISC)--	-	-	-	9	9	9	-	-	.46	.46	-	.46	-	12	12
RADIATION/ULTRA VIOLET--	-	-	-	2	2	2	1	-	.10	.10	.05	.15	-	1	1
SCRATCH/ABRASION--	-	-	-	13	13	13	6	.67	.67	.31	.98	-	25	25	25
STRAIN/SPRAIN--	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MULTIPLE INJURIES--	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
OTHER INJURY, NEC--	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
UNCLASSIFIED (NO DATA)--	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TOTAL OR AVERAGE--	1	-	4	146	150	151	33	.05	7.75	7.80	1.70	9.51	310	212	162

TABLE 15-B

NUMBER OF INJURIES BY ACCIDENT CLASSIFICATION AND DEGREE FOR WORK LOCATION AND STATE AT METALLIC MINERAL OPERATIONS IN THE UNITED STATES, 1979

WORK LOCATION AND STATE	POWERED HAULAGE			HOISTING			IGNITION OR EXPLOSION OF GAS OR DUST			IMPRISONMENT			INUNDATION			MACHINERY			SLIPS OR FALLS OF PERSONS			OTHER			TOTAL		
	FTL	NFDL	NOL	FTL	NFDL	NOL	FTL	NFDL	NOL	FTL	NFDL	NOL	FTL	NFDL	NOL	FTL	NFDL	NOL	FTL	NFDL	NOL	FTL	NFDL	NOL	FTL	NFDL	NOL
UNDERGROUND MINES:																											
ALASKA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
ARIZONA	-	19	24	-	-	-	-	-	-	-	-	-	-	-	-	40	41	-	54	51	-	-	-	-	-	2	492
CALIFORNIA	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	448
COLORADO	-	6	10	-	-	-	-	-	-	-	-	-	-	-	-	139	37	1	98	17	-	15	23	1	673	197	13
IDAHO	-	24	34	1	-	-	-	-	-	-	-	-	-	-	-	48	22	-	34	11	-	6	1	1	267	116	1
KENTUCKY	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	22	10	-	8	11	-	3	4	-	5	23	2
MISSISSIPPI	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	2	-	2	2	-	-	-	-	-	-	44
MISSOURI	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5	5	-	2	2	-	-	-	-	-	-	27
MONTANA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	7	7	-	11	11	-	-	-	-	-	-	18
NEVADA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	2	-	10	10	-	-	-	-	-	-	19
NEW JERSEY	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4
NEW MEXICO	1	6	17	-	-	-	-	-	-	-	-	-	-	-	-	100	68	-	103	38	-	9	5	571	358	16	11
NEW YORK	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	-	-	-	-	-	-	-	-	-	2
OREGON	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	13
PENNSYLVANIA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	30	32	-	20	21	-	2	-	-	-	-	129
SOUTH CAROLINA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	11	6	-	15	28	-	-	-	-	-	-	64
TENNESSEE	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	11	6	-	15	28	-	-	-	-	-	-	64
TEXAS	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	31	20	-	37	6	-	2	1	1	178	64	1
UTAH	-	17	16	-	-	-	-	-	-	-	-	-	-	-	-	7	7	-	4	4	-	-	-	-	-	-	33
VIRGINIA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	7	7	-	4	4	-	-	-	-	-	-	32
WASHINGTON	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	12
WEST VIRGINIA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	13	3	-	9	4	-	-	-	-	-	-	79
WYOMING	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	27
TOTAL	2	228	82	3	23	12	-	-	-	-	-	-	9	2	-	450	258	1	615	166	-	64	24	13	2,613	1,602	1

NUMBER OF INJURIES BY ACCIDENT CLASSIFICATION AND DEGREE FOR WORK LOCATION AND STATE AT ALL COAL OPERATIONS IN THE UNITED STATES, 1979

WORK LOCATION AND STATE	POWERED HAULAGE			HOISTING			IGNITION OR EXPLOSION OF GAS OR DUST			IMPRISONMENT			INUNDATION			MACHINERY			SLIPS OR FALLS OF PERSONS			OTHER			TOTAL		
	FTL	NFDL	NOL	FTL	NFDL	NOL	FTL	NFDL	NOL	FTL	NFDL	NOL	FTL	NFDL	NOL	FTL	NFDL	NOL	FTL	NFDL	NOL	FTL	NFDL	NOL	FTL	NFDL	NOL
UNDERGROUND MINES:																											
UNDERGROUND:																											
ALABAMA	2	100	7	1	4	1	-	-	-	1	-	-	-	-	-	82	22	-	64	7	-	31	9	9	568	136	
COLORADO	-	34	12	-	-	-	-	-	-	-	-	-	-	-	-	29	12	-	43	3	-	-	1	1	258	48	
ILLINOIS	-	164	10	1	-	-	-	-	-	-	-	-	-	-	-	203	13	-	172	7	-	14	1	5	1,315	119	
INDIANA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5	5	-	-	-	-	-	-	-	-	-	12
KENTUCKY	3	244	38	-	-	-	-	-	-	-	-	-	-	1	-	5	268	54	-	112	7	17	-	23	1,436	319	
MARYLAND	-	3	2	-	-	-	-	-	-	-	-	-	-	-	-	5	5	-	-	-	-	-	-	-	-	-	18
MONTANA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
NEW MEXICO	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
OHIO	3	141	17	-	-	-	-	-	-	-	-	-	-	-	-	1	126	13	-	167	6	-	14	1	2	1,171	172
OKLAHOMA	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	-	-	-	-	-	-	-	-	-	5
PENNSYLVANIA																											
ALL COAL	3	342	41	1	-	-	-	-	-	2	1	-	-	-	-	2	350	66	-	419	35	-	47	5	12	2,991	534
ANTHRACITE	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	53
BITUMINOUS	3	342	41	1	-	-	-	-	-	2	1	-	-	-	-	2	349	65	-	417	35	-	44	5	11	2,938	530
TENNESSEE	1	19	2	-	-	-	-	-	-	-	-	-	-	-	-	24	8	-	6	2	3	-	-	5	114	15	
UTAH	2	50	4	-	-	-	-	-	-	-	-	-	-	-	-	41	10	-	52	4	-	6	6	344	57	-	1
VIRGINIA	4	204	23	-	-	-	-	-	-	-	-	-	-	-	-	213	32	-	38	8	-	29	4	14	1,259	155	
WEST VIRGINIA	3	609	77	-	-	-	-	-	-	-	-	-	-	-	-	632	118	-	504	47	-	58	8	22	4,643	741	
WYOMING	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	-	3	1	-	-	-	-	-	-	12
TOTAL																											
ALL COAL	19	1,919	225	3	15	2	-	-	-	5	2	-	1	-	1	8	1,986	345	-	1,615	126	-	220	28	106	4,164	2,316
ANTHRACITE	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4
BITUMINOUS	19	1,919	225	3	15	2	-	-	-	5	2	-	1	-	1	8	1,986	344	-	1,615	127	-	217	28	105	4,131	2,312

NUMBER OF INJURIES BY ACCIDENT CLASSIFICATION AND DEGREE FOR WORK LOCATION AND STATE AT NONMETALLIC MINERAL OPERATIONS IN THE UNITED STATES, 1979

WORK LOCATION AND STATE	POWERED HAULAGE			HOISTING			IGNITION OR EXPLOSION OF GAS OR DUST			IMPRISONMENT			INUNDATION			MACHINERY			SLIPS OR FALLS OF PERSONS			OTHER			TOTAL		
	FTL	NFDL	NOL	FTL	NFDL	NOL	FTL	NFDL	NOL	FTL	NFDL	NOL	FTL	NFDL	NOL	FTL	NFDL	NOL	FTL	NFDL	NOL	FTL	NFDL	NOL	FTL	NFDL	NOL
UNDERGROUND MINES																											
UNDERGROUND																											
CALIFORNIA	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
COLORADO	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
ILLINOIS	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
KANSAS	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
KENTUCKY	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
LOUISIANA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
MISSISSIPPI	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
MISSOURI	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
MONTANA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
NEVADA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
NEW JERSEY	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
NEW YORK	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
NORTH CAROLINA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
OHIO	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
PENNSYLVANIA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
TENNESSEE	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
TEXAS	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
UTAH	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
VERMONT	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
WEST VIRGINIA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
WORKING	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
TOTAL	-	67	-	22	-	2	8	-	24	-	5	-	6	-	-	-	-	-	-	-	-	-	-	-	-	-	95

TABLE 15-B - Continued

NUMBER OF INJURIES BY ACCIDENT CLASSIFICATION AND DEGREE FOR WORK LOCATION AND STATE AT STONE OPERATIONS IN THE UNITED STATES, 1979

WORK LOCATION AND STATE	POWERED HAULAGE			HOISTING			IGNITION OR EXPLOSION OF GAS OR DUST			IMPOUNDMENT			INUNDATION			MACHINERY			SLIPS OR FALLS OF PERSONS			OTHER			TOTAL		
	FTL	NFDL	NOL	FTL	NFDL	NOL	FTL	NFDL	NOL	FTL	NFDL	NOL	FTL	NFDL	NOL	FTL	NFDL	NOL	FTL	NFDL	NOL	FTL	NFDL	NOL	FTL	NFDL	NOL
UNDERGROUND MINES:																											
ALABAMA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	1	1	1
ARKANSAS	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CALIFORNIA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
GEORGIA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
ILLINOIS	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-
INDIANA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
IOWA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
KANSAS	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
KENTUCKY	-	-	6	2	-	1	-	-	-	-	-	-	-	-	-	-	-	5	1	-	3	-	-	-	-	3	1
MAINE	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MARYLAND	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MISSOURI	-	-	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-
NEBRASKA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
OHIO	-	-	8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
OKLAHOMA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
PENNSYLVANIA	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5	-	-	6	-	-	-	-	30	4
TENNESSEE	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
VERMONT	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
VIRGINIA	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	-	3	-	-	-	-	15	4
WEST VIRGINIA	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TOTAL	-	-	20	3	-	2	-	-	-	-	-	-	-	-	-	-	19	3	-	17	1	-	-	3	1	150	13

TABLE 15-C

NUMBER OF INJURIES BY ACCIDENT CLASSIFICATION AND DEGREE FOR WORK LOCATION AND KIND OF MINERAL AT METALLIC MINERAL OPERATIONS IN THE UNITED STATES, 1979

WORK LOCATION AND KIND OF MINERAL	POWERED HAULAGE			HOISTING			IGNITION OR EXPLOSION OF GAS OR DUST			IMPOUNDMENT			INUNDATION			MACHINERY			SLIPS OR FALLS OF PERSONS			OTHER			TOTAL			
	FTL	MFEL	NOL	FTL	MFEL	NOL	FTL	MFEL	NOL	FTL	MFEL	NOL	FTL	MFEL	NOL	FTL	MFEL	NOL	FTL	MFEL	NOL	FTL	MFEL	NOL				
UNDERGROUND MINES:																												
UNDERGROUND:																												
ANTHROHITE			11																									
COAL			9																									
COPPER			211		27																							
GOLD					5																							
IRON					3																							
LEAD-ZINC			35		117																							
NICKEL			38																									
PLATINUM																												
SILVER			263		28																							
TUNGSTEN			1																									
URANIUM			8		26																							
TOTAL	2	225	82	2	27	12		3							9	2		490	238	1	415	164		44	24	13	2,473	1,607

NUMBER OF INJURIES BY ACCIDENT CLASSIFICATION AND DEGREE FOR WORK LOCATION AND KIND OF MINERAL AT NONMETALLIC MINERAL OPERATIONS IN THE UNITED STATES, 1979

WORK LOCATION AND KIND OF MINERAL	POWERED HAULAGE			HOISTING			IGNITION OR EXPLOSION OF GAS OR DUST			IMPROVEMENT			IRRIGATION			MACHINERY			SLIPS OR FALLS OF PERSONS			OTHER			TOTAL		
	FTL	AFGL	NOL	FTL	NGL	NOL	FTL	NGL	NOL	FTL	NGL	NOL	FTL	NGL	NOL	FTL	NGL	NOL	FTL	NGL	NOL	FTL	NGL	NOL	FTL	NGL	NOL
UNDERGROUND MINES:																											
UNDERGROUND:																											
BORON	-	3	-	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	13	-	-
CLAY	-	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	7	1	-
FLUORSPAR	-	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	24	1	-
GILSONITE	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6	1	-
GYPSUM	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	12	1	-
OIL SHALE	-	1	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	34	-	-
PHOSPHATE	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	26	-	-
PIGMENT	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	13	1	-
POTASH	-	18	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	1	3	30	-
PYRITE	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6	21	-
SALT	-	16	-	-	-	-	5	5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	7	99	13	-
SODIUM COMPOUNDS	-	18	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	18	85	-
TALC-SOAPSTONE	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	34	-	-
WOLASTONITE-STALMIT	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-
TOTAL	-	67	22	2	8	2	5	6	-	-	-	-	-	-	-	61	37	-	70	14	-	5	-	12	459	220	-

NUMBER OF INJURIES BY ACCIDENT CLASSIFICATION AND DEGREE FOR WORK LOCATION AND KIND OF MINERAL AT STONE OPERATIONS IN THE UNITED STATES, 1979

[illegible]

TABLE 15-D

NUMBER OF INJURIES, LOST WORKDAYS, AND AVERAGE SEVERITY BY DEGREE FOR ACCIDENT CLASSIFICATION AND NATURE OF INJURY
AT METALLIC MINERAL OPERATIONS IN THE UNITED STATES, 1979

ACCIDENT CLASSIFICATION AND NATURE OF INJURY	NUMBER OF INJURIES								LOST WORKDAYS						AVERAGE SEVERITY		
	FATAL	NFDL			TOTAL FATAL AND NFDL	MDL	TOTAL INJURIES	FATAL	NFDL			TOTAL FATAL AND NFDL	PERMA- NENT PARTIAL	TEMPO- RARY	TOTAL FATAL AND NFDL		
		PERMANENT		TEMPO- RARY					PERMANENT		TEMPO- RARY					TOTAL NFDL	
		TOTAL	PARTIAL						TOTAL	PARTIAL							
IGNITION OR EXPLOSION OF GAS OR DUST: BURN/SCALD (NOT CHEM.)	-	-	-	8	4	8	1	9	-	-	-	379	379	379	-	47	47
TOTAL OR AVERAGE	-	-	-	8	8	8	1	9	-	-	-	379	379	379	-	47	47
INUNDATION:	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
ASPHYXIATION/DROWNING	-	-	-	4	4	4	2	6	-	-	-	5	5	5	-	1	1
CHEMICAL BURN	-	-	-	1	1	1	1	2	-	-	-	1	1	1	-	1	1
HEAT/SUNSTROKE	-	-	-	1	1	1	-	1	-	-	-	3	3	3	-	3	3
POISONING (SYSTEMIC)	-	-	-	1	1	1	-	1	-	-	-	8	8	8	-	8	8
STRAIN/SPRAIN	-	-	-	1	1	1	-	1	-	-	-	7	7	7	-	7	7
UNCLASSIFIED (NO DATA)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TOTAL OR AVERAGE	-	-	-	10	10	10	4	14	-	-	-	24	24	24	-	2	2

NUMBER OF INJURIES, LOST WORKDAYS, AND AVERAGE SEVERITY BY DEGREE FOR ACCIDENT CLASSIFICATION AND NATURE OF INJURY
AT ALL COAL OPERATIONS IN THE UNITED STATES, 1979

IGNITION OR EXPLOSION OF GAS OR DUST: ASPHYXIATION/DROWNING	-	-	-	-	-	-	1	1	-	-	-	-	-	-	-	-	-
BURN/SCALD (NOT CHEM.)	-	-	-	24	24	24	11	35	-	-	-	487	487	487	-	20	20
CORTUSION OF LIMBS	-	-	-	1	1	1	1	2	-	-	-	18	18	18	-	18	18
CUT OR PUNCTURE	-	-	-	1	1	1	1	1	-	-	-	6	6	6	-	6	6
MULTIPLE INJURIES	-	-	-	1	1	1	1	1	-	-	-	7	7	7	-	7	7
OTHER INJURY, NEC	-	-	-	1	1	1	-	1	-	-	-	4	4	4	-	4	4
UNCLASSIFIED (NO DATA)	-	-	-	1	1	1	-	1	-	-	-	4	4	4	-	4	4
TOTAL OR AVERAGE	-	-	-	28	28	28	14	42	-	-	-	522	522	522	-	19	19
INUNDATION: ASPHYXIATION/DROWNING	1	-	-	1	1	1	-	1	5,000	-	-	24	24	6,000	-	24	6,000
UNCLASSIFIED (NO DATA)	-	-	-	1	1	1	-	1	-	-	-	24	24	24	-	24	24
TOTAL OR AVERAGE	1	-	-	1	1	2	-	2	5,000	-	-	24	24	6,024	-	24	6,024

NUMBER OF INJURIES, LOST WORKDAYS, AND AVERAGE SEVERITY BY DEGREE FOR ACCIDENT CLASSIFICATION AND NATURE OF INJURY
AT NONMETALLIC MINERAL OPERATIONS IN THE UNITED STATES, 1979

IGNITION OR EXPLOSION OF GAS OR DUST: ASPHYXIATION/DROWNING	-	-	-	1	1	1	-	1	-	-	-	16	16	16	-	16	16
BURN/SCALD (NOT CHEM.)	-	-	-	10	10	10	-	10	-	-	-	127	127	127	-	13	13
CUT OR PUNCTURE	-	-	-	2	2	2	-	2	-	-	-	15	15	15	-	8	8
DUST IN EYE	-	-	-	1	1	1	-	1	-	-	-	4	4	4	-	4	4
FRACTURE	-	-	-	2	2	2	-	2	-	-	-	174	174	174	-	47	47
MULTIPLE INJURIES	1	-	-	1	1	1	-	1	6,000	-	-	1	1	6,000	-	1	6,000
OTHER INJURY, NEC	1	-	-	1	1	1	-	1	-	-	-	85	85	85	-	85	85
UNCLASSIFIED (NO DATA)	5	-	-	1	1	6	-	6	30,000	-	-	1	1	30,085	-	1	30,085
TOTAL OR AVERAGE	6	-	-	18	18	24	-	24	36,000	-	-	422	422	36,422	-	29	36,422

TABLE 15-D - Continued

NUMBER OF INJURIES, LOST WORKDAYS, AND AVERAGE SEVERITY BY DEGREE FOR ACCIDENT CLASSIFICATION AND NATURE OF INJURY
AT STONE OPERATIONS IN THE UNITED STATES, 1979 (CONTINUED)

ACCIDENT CLASSIFICATION AND NATURE OF INJURY	NUMBER OF INJURIES								LOST WORKDAYS						AVERAGE SEVERITY		
	FATAL	NFDL				TOTAL FATAL AND NFDL	NOL	TOTAL INJURIES	FATAL	NFDL				TOTAL FATAL AND NFDL	PERMA- NENT PARTIAL	TEMPO- RARY	TOTAL FATAL AND NFDL
		PERMANENT		TEMPO- RARY	TOTAL NFDL					PERMANENT		TEMPO- RARY	TOTAL NFDL				
		TOTAL	PARTIAL							TOTAL	PARTIAL						
IGNITION OR EXPLOSION OF GAS OR DUST:-----	-	-	-	17	17	17	3	20	-	-	-	870	870	870	-	51	51
BURN/SCALD (NOT CHEM.)-----	-	-	-	1	1	1	1	2	-	-	-	62	62	62	-	62	62
CHEMICAL BURN-----	-	-	-	1	1	1	-	1	-	-	-	11	11	11	-	11	11
CUT/ABRASION OR BRUISE-----	-	-	-	1	1	1	-	1	-	-	-	35	35	35	-	35	35
MULTIPLE INJURIES-----	-	-	-	1	1	1	-	1	-	-	-	24	24	24	-	24	24
OTHER INJURY, NEC-----	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TOTAL OR AVERAGE-----	-	-	-	21	21	21	4	25	-	-	-	1,002	1,002	1,002	-	48	48

TABLE 15-E

OCCURRENCES REPORTED TO MSHA AS OCCUPATIONAL ILLNESSES AT METALLIC MINERAL OPERATIONS IN THE UNITED STATES, 1979

WORK LOCATION, MINERAL (INDUSTRY AND STATE)	SKIN DISEASES OR DISORDERS	DUST DISEASES OF THE LUNGS	RESPIRATORY CONDITIONS DUE TO TOXIC AGENTS	POISONING-SYSTEMIC EFFECTS OF TOXIC MATERIALS	DISORDERS DUE TO PHYSICAL AGENTS (NONTOXIC)	DISORDERS ASSOCIATED WITH REPEATED TRAUMA	ALL OTHER OCCUPATIONAL ILLNESSES	TOTAL OCCUPATIONAL ILLNESSES
UNDERGROUND MINES:								
COPIROL:								
ARIZONA	5	-	-	-	8	-	-	13
TOTAL	5	-	-	-	8	-	-	13
GOLD:								
SOUTH DAKOTA	-	1	-	1	1	2	-	5
TOTAL	-	1	-	1	1	2	-	5
IRON:								
MICHIGAN	-	-	-	-	-	1	-	1
TOTAL	-	-	-	-	-	1	-	1
LEAD-ZINC:								
IDAHO	-	2	-	2	-	-	2	2
KENTUCKY	-	-	1	-	-	-	-	1
MISSOURI	-	-	-	-	-	-	-	-
NEW YORK	-	-	-	-	1	-	-	1
TENNESSEE	-	-	-	-	-	-	-	-
TOTAL	2	3	1	2	1	-	2	11
MOLYBDENUM:								
COLORADO	1	6	-	-	-	8	-	15
NEW MEXICO	1	-	-	-	-	-	-	1
TOTAL	2	6	-	-	-	8	-	16
SILVER:								
IDAHO	1	-	-	-	-	2	-	3
TOTAL	1	-	-	-	-	2	-	3
URANIUM:								
COLORADO	1	-	-	-	3	-	1	5
NEW MEXICO	1	-	-	-	-	1	-	2
TOTAL	2	-	-	-	3	1	2	8

OCCURRENCES REPORTED TO MSHA AS OCCUPATIONAL ILLNESSES AT NONMETALLIC MINERAL OPERATIONS IN THE UNITED STATES, 1979

UNDERGROUND MINES:								
UNDERGROUND:								
SALT:								
LOUISIANA	-	-	-	-	-	1	-	1
MICHIGAN	-	-	-	-	-	-	-	-
NEW YORK	-	-	-	-	-	3	-	3
TOTAL	-	-	-	-	-	3	-	3
SODIUM COMPOUNDS:								
WYOMING	81	-	-	1	-	-	-	82
TOTAL	81	-	-	1	-	-	-	82
TALC-SOAPSTONE:								
GEORGIA	-	1	-	-	-	-	-	1
NEW YORK	-	1	-	-	-	-	-	2
TOTAL	-	2	-	-	-	-	-	2

TABLE 15-E - Continued

OCCURRENCES REPORTED TO MSHA AS OCCUPATIONAL ILLNESSES AT ALL COAL OPERATIONS IN THE UNITED STATES, 1979

WORK LOCATION, MINERAL INDUSTRY AND STATE	SKIN DISEASES OR DISORDERS	DUST DISEASES OF THE LUNGS	RESPIRATORY CONDITIONS DUE TO TOXIC AGENTS	POISONING-SYSTEMIC EFFECTS OF TOXIC MATERIALS	DISORDERS DUE TO PHYSICAL AGENTS (NONTOXIC)	DISORDERS ASSOCIATED WITH REPEATED TRAUMA	ALL OTHER OCCUPATIONAL ILLNESSES	TOTAL OCCUPATIONAL ILLNESSES
UNDERGROUND MINES:								
UNDERGROUND:								
ALL COAL:								
ALABAMA	2	1	-	-	1	1	-	3
ILLINOIS	-	1	-	-	-	1	-	2
KENTUCKY	1	13	-	-	-	1	-	15
OHIO	-	6	-	-	-	4	-	10
PENNSYLVANIA	1	-	1	-	-	-	-	2
VIRGINIA	-	5	-	-	-	1	1	7
WEST VIRGINIA	7	189	3	1	-	7	3	210
TOTAL	11	214	4	1	1	14	4	249

OCCURRENCES REPORTED TO MSHA AS OCCUPATIONAL ILLNESSES AT BITUMINOUS COAL OPERATIONS IN THE UNITED STATES, 1979

UNDERGROUND MINES:								
UNDERGROUND:								
BITUMINOUS:								
ALABAMA	2	-	-	-	-	1	-	3
ILLINOIS	-	1	-	-	1	-	-	2
KENTUCKY	1	13	-	-	-	1	-	15
OHIO	-	6	-	-	-	4	-	10
PENNSYLVANIA	1	-	1	-	-	-	-	2
VIRGINIA	-	5	-	-	-	1	1	7
WEST VIRGINIA	7	189	3	1	-	7	3	210
TOTAL	11	214	4	1	1	14	4	249

OCCURRENCES REPORTED TO MSHA AS OCCUPATIONAL ILLNESSES AT STONE OPERATIONS IN THE UNITED STATES, 1979

UNDERGROUND MINES:								
UNDERGROUND:								
LIMESTONE (ALL OPS):								
KENTUCKY	-	-	-	1	-	-	-	1
TOTAL	-	-	-	1	-	-	-	1
LIMESTONE (CRUSHED):								
KENTUCKY	-	-	-	1	-	-	-	1
TOTAL	-	-	-	1	-	-	-	1
SANDSTONE (ALL OPS):								
IOWA	-	3	-	-	-	-	-	3
TOTAL	-	3	-	-	-	-	-	3
SANDSTONE (CRUSHED):								
IOWA	-	3	-	-	-	-	-	3
TOTAL	-	3	-	-	-	-	-	3

additional injury classifications are provided. Injuries resulting from inundation involve gases as well as liquids (semi-solids). Although few in number, the majority of inundations occurred in Metallic Mineral Mining (total 11 incidents). When compared to accidents involving machinery, powered haulage, and slips/falls of persons, inundation will have a much lower probability of occurrence. The prevalence of mine explosions, like inundation, is small in comparison to other types of accidents as exemplified by only 11 cases for 1979 within the Non-metallic Mineral operations.

Table 15 C, presents the number of injuries by accident classification and degree for work location and kind of mineral mined at underground mining operations. This table indicates that salt mines had the greatest number of explosions in 1979 (10 incidents) and platinum mines had the greatest number of inundations (6 incidents) in 1979.

Table 15 D, presents a more comprehensive classification of explosion and inundation incidents by giving the part of the body exposed in these accidents for each underground mining operation. Accidents due to asphyxiation and systemic poisoning are narrowed down further.

Table 15 E, presents occurrences reported to MSHA as occupational illnesses at underground mining operations by State and nature of the mine. Illnesses found within these industries are as follows: skin diseases (8 incidents) - salt mines of Wyoming; dust diseases of the lungs and respiratory conditions due to toxic agents (189 and 3 incidents respectively) - Bituminous Coal operations in West virginia; systemic poisoning (2 incidents) - lead/zinc mines of Kentucky; repetitive trauma disorders (8 incidents) - molybdenum mines of Colorado.

Mercury

Mercury is cited as an occupational hazard in cinnabar (HgS) ore mining. A California study on mercury poisoning among workers in California's mercury mills and mines [59], reported that exposure to mercury vapor (Hg^0) in mining operations is negligible under normal conditions. The study stated that no miners had mercury poisoning, although some had fairly high levels of mercury in their urine. In one mine, a fire probably caused some mercury exposure not otherwise present, since cinnabar ore requires considerable temperature to produce mercury vapor [59]. Mercury poisoning in mines occurs principally due to inhalation of elemental mercury (Hg^0) [59]. Eighty percent of inhaled Hg^0 is deposited and retained by man. Less than 0.01% is absorbed from the gastrointestinal tract [58].

Inhalation of Hg^0 results in poisoning of the central nervous system. Transfer of the lipid soluble Hg^0 from the blood to the brain is sufficiently rapid to result in a toxicologically significant differential distribution to that organ. The subsequent oxidation of Hg^0 in the brain serves to trap it there [58].

The effects of Hg^0 exposure on man are tremors, which progress in severity with duration of exposure. Initially it involves only the hands but later may spread to other parts of the body. Tremors are triggered by voluntary use of affected muscles. Neuropsychiatric signs also occur at relatively low levels of exposure, notably excessive shyness, insomnia, and emotional instability with depressive moods, and irritability most frequently reported. This neuropsychiatric complex is known as "erethism" [58].

Another area of concern in underground mining is abandoned mines. The following incident exemplifies the hazards present within these unattended areas:

Four teenagers died in December, 1980, from exposure to toxic gas when they were spelunking in the abandoned Nortonville, California coal mines. A metal roadblock was the only obstacle preventing access to the mines. The youths, apparently hiking within the vicinity, gained entrance into the mine and were overcome by toxic gases. In October, 1981, two more teenagers, friends of the youths who had died earlier, went back to the same mine for further exploration (the mine was still accessible), narrowly escaping death following a cave-in. Officials believe the structural decay of the 120 year old Nortonville mine has hastened, causing more cave-ins and the release of poisonous gases [60].

These underground abandoned mines present a significant hazard to adjacent communities and should be barricaded to minimize the possibility of individuals entering the area.

Man Made Hazards - Waste Dumps

Vast quantities of hazardous waste have been produced in the U.S. in the past four decades [61]. Hazardous waste is defined as any discarded chemical or radioactive material that, when improperly handled, may pose a substantial threat or potential hazard to human health or the environment. This waste may be in the form of solids, liquids, contaminated gases or sludges. Table 16 presents a list of possible chemical wastes which may be present at dump sites, and their associated health effects from acute and chronic exposures. Hazardous wastes have been dispersed throughout the

TABLE 16

HEALTH EFFECTS FROM EXPOSURE TO INDUSTRIAL CHEMICALS

Chemical	Route of Exposure	Acute Exposure Effects	Chronic Exposure Effects
C-56	Skin absorption and injection.	Hyperexcitability, incoordinated movements, ataxia, prostration, and death.	Bioaccumulation in fatty tissue with unknown effects.
TCE	Inhalation and skin absorption.	CNS depressant and a skin irritant.	Neurological changes and ventricular fibrillation.
Benzidene	Inhalation, injection, and skin absorption.	Skin irritation.	Bladder cancer.
Curene #42	Skin absorption and injection.	Dermatitis.	Unknown effects in humans but is an animal carcinogen.
PCBs	Skin absorption and injection.	Eye and skin irritant, will also produce liver damage.	Bioaccumulation in fatty tissue.
Benzene	Inhalation and skin absorption.	Marcosis and skin irritation.	Leukemia and other blood disorders.
Tris	Skin absorption.	Skin burns.	Unknown effects in humans but is an animal carcinogen.
DDT	Inhalation and skin absorption.	Hyperexcitability, ataxia, incoordinated movements, prostration, and death.	Bioaccumulation in fatty tissue.
Vinyl Chloride	Inhalation.	Narcotic effect.	Hepatic damage, angiosarcoma, acro-osteolysis, and Raynaud's Syndrome.
Mercury	Inhalation and ingestion.	Skin irritation, tremors, and metal fume fever.	Mercurialism, personality changes, ataxia, and fine motor control disturbance.
Lead	Inhalation and ingestion.	Gastrointestinal disturbance.	Lead colic, anemia, and renal dysfunction.
CCl ₄	Inhalation.	Unconsciousness, ventricular fibrillation, and renal damage.	Cirrhosis of the liver, Gastrointestinal disturbance.
PPBs	Inhalation and injection.	Unknown acute effects	Bioaccumulation in fatty tissue.

environment and have been allowed to accumulate in an estimated 30,000 to 50,000 disposal sites across the nation of which 1,200 to 2,000 may present potentially significant problems [62]. Figure 7 illustrates the national distribution of toxic waste dumps and their relative severity statewide [63]. The extent of this problem can be identified by examining one of the toxic waste danger zones classified as "alarming". One such zone is located in the state of Michigan. A Department of Natural Resources (DNR) study [64] compiled data which provides insight into the potential problems which exist due to dump sites within Michigan (refer to Table 17). Sixty-three of the "worst sites" were given top priority for cleanup. Table 18 summarizes the hazardous wastes most often encountered within Michigan's dump sites, their use in industry, and the hazard they present when humans are exposed to them [65].

Other states have done similar surveys of hazardous waste sites. In New York, a 1980 list pointed to 680 suspected abandoned hazardous waste sites containing 852 separate disposal areas [66]. An Illinois EPA study [67] has identified 28 potentially hazardous waste dumps in Illinois. This compilation contains data on active and inactive waste sites.

Problems have resulted from legal and illegal dumping. Approximately half of the problem is due to illicit dumping, improper storage or other haphazard land disposal. Practices such as dumping of residuals on land, unregulated dumping of drummed or liquid wastes, and dumping into sewer systems or along roadsides unfortunately have increased in number. A common practice among waste disposal operators is to accumulate wastes in drums or bulk tankage and then to abandon the disposal site they initially were responsible for. After a period of time the barrels and tanks begin to leak, allowing contamination of surface and ground waters and frequently producing a severe fire or explosion potential [68].

FIGURE 7

Radiation waste storage sites

Source: Brown, M. "The Poisoning of America," Family Weekly,
January 11, 1981

TABLE 17

EVALUATION OF MICHIGAN HAZARDOUS WASTE DUMP SITES

<u>(#) of Sites</u>	<u>Contaminated Source</u>	<u>Cause of Contamination</u>
268	Ground Water	49% Hazardous Waste 34% Oil/Gas Pollutant 17% Salt/Sanitary Waste
381	Ground Water (suspected)	72% Hazardous Waste 26% Salt/Sanitary Waste 2% Oil/Gas Pollutant
50,000	Ground Water (potential)	-----

Source: Assessment of Groundwater Contamination in Michigan, (Part 1 and 2) Dept. of Natural Resources, Lansing, Mich., December, 1979.

TABLE 18
COMMON HAZARDOUS WASTES
(MICHIGAN)

Chemical	Use	Hazard
C-56	Bug and insect killer.	Acutely toxic, suspected carcinogen.
TCE	Degreaser	Suspected carcinogen.
Benzidene	Dye industry.	Known human carcinogen.
Curene 442	Plastics industry.	Suspected carcinogen.
PCBs	Insulators, paints, and electrical circuitry.	Acutely toxic, suspected carcinogen.
Benzene	Solvent.	Suspected carcinogen.
Tris	Fire retardant	Suspected carcinogen.
DDT	Bug and insect killer.	Acutely toxic.
Vinyl Chloride	Plastic industry.	Known human carcinogen.
Mercury	Multiple purposes.	Acutely toxic
Lead	Multiple purposed.	Acutely toxic, suspected carcinogen.
CCl ₄	Solvent.	Acutely toxic, suspected carcinogen.
PPBs	Fire retardant	Effects unknown.

Source: Hall, D. and E. Sharp "Haulers Fouling State with Deadly Chemicals", Detroit Free Press, Dec. 12, 1979, p.19A.

The risks are magnified for workers who must investigate, or participate in emergency clean-up operations of dump sites [69]. During this type of excavation workers may be exposed to toxic agents by inhalation, topical contact, or inadvertent ingestion. Such contaminants which could be encountered are: volatile organic chemicals, pesticide fumes, toxic dusts, acids, and sludges. Occasionally explosions occur when these old dump sites are disturbed because mixtures of wastes are often placed in dumps without regard to possible chemical reactions; the effects of heat and sunlight may cause chemical activation; and chemical deterioration may occur with age producing new unstable by-products [69].

It was difficult to find documented cases of injuries, illnesses or fatalities resulting from excavating wastes unless the effects were immediate such as in explosions. It must be remembered, however, that most cases of toxic exposure to hazardous pollutants manifest themselves in insidious chronic effects that are almost impossible to trace to causative agents. Only in rare cases of chronic poisoning is a positive correlation between cause and effect possible [70].

A first step in the reduction of occupational hazards to workers involved in waste dump operations is the identification of the toxic materials to which workers are exposed and a determination of their toxicity [69]. However, it is often difficult to determine the extent of contamination around an old, unmarked site. As a result, there can be a significant risk of exposure to cleanup workers. Excavation of contaminated soil or old wastes from past disposal sites is justified only when public health considerations demand removal of an imminent hazard [66].

If the hazards at the dump can be determined, worker protection can be designed around a program of appropriately engineered safeguards such as remote-control handling devices, reinforced bulldozers with sealed cabs, and properly designed landfills. In emergency clean-ups, or when it is not possible to identify the wastes to which workers are exposed, respirators, gas masks, and impervious protective clothing should be utilized. Such equipment is, however, always a poor substitute for engineered safeguards. Respirators may malfunction and suits may be dissolved by corrosive chemicals. Workers who must wear impervious suits are at a heightened risk of heat exhaustion [73]. The size of the work force engaged in the cleanup of hazardous wastes will increase greatly in the next decade. Research is needed to develop better engineering controls and personal gear for protection of the health and safety of this expanded group of workers [69].

These problems, and the high cost associated with excavation and removal of old wastes, makes containment of wastes the preferred method for controlling dump sites [66]. Confining a toxic contaminant may be as simple and inexpensive as covering the site to stop volatilization and direct contact, or as complicated and expensive as installing full-scale systems to divert, remove, or treat contaminated underground water [66].

Contamination of water by waste buried underground can be prevented by engineered systems involving surface water diversion, underground curtain walls, draw-down wells, and leachate collection and treatment for any water that might escape from a site. To reduce rainwater infiltration, a site is usually lined and covered with an appropriate material, such as low-permeability clay; the cover serves to control volatilization and to prevent contact with the wastes [66].

The general public may also be exposed to toxic chemical wastes as exemplified at Love Canal in New York State. Love Canal, with its large amount of highly toxic substances found near a residential neighborhood, appears to be unique among New York's old dump sites. Investigation of industrial waste sites have revealed no location comparable to Love Canal in the extent of the seriousness of its public health impact [66].

When the cap on the chemical waste storage sites at Love Canal was disrupted by construction activities, toxic chemicals leaked to the surface of the soil and into basements of nearby homes [74]. The results of air samples taken in basements in the Love Canal area are given in Table 19 [75]. Table 20 gives a list of some of the more important chemicals identified at the Love Canal site and the human biological hazards associated with them [75]. It was a relatively easy matter to identify the major chemicals present and to measure their concentrations. It was far more difficult to determine which residents of the area, if any, had been exposed to the chemicals and, if so, to which ones, and for how long. Even today, that determination has still not been made to anyone's satisfaction [74].

According to Renata Kimbrough of Center for Disease Control (CDC), "The real problem is that we don't yet have the scientific tools to answer the broad questions that are being asked of us in situations involving dump sites and other environmental problems" [76]. The scientific tools referred to by Kimbrough were ways to assess chromosomal aberrations, sister chromatid exchanges, sperm studies, spontaneous abortions, birth weight, and neurotoxic examinations [72]. All methods are in the development stage and give results which are difficult to interpret and are usually suspect for one reason or other.

TABLE 19

CHEMICAL ANALYSES OF AIR SAMPLES FROM LOVE CANAL, NEW YORK

Chemical	Frequency of Occurrence	% of Total Homes Sampled	Highest Concentration	Hazard
Chloroform	23	26	24 $\mu\text{g}/\text{m}^3$	Animal Carcinogen
Benzene	20	23	270 $\mu\text{g}/\text{m}^3$	Suspected human carcinogen.
1,1,1-Trichloroethane	74	84	73 $\mu\text{g}/\text{m}^3$	Eye irritant, and dermatitis.
Toluene	54	61	570 $\mu\text{g}/\text{m}^3$	Dermatitis, narcosis.
Tetrachlorethene	82	93	1140 $\mu\text{g}/\text{m}^3$	Animal carcinogen
Chlorobenzene	6	7	240 $\mu\text{g}/\text{m}^3$	Animal carcinogen
Chlortoluene	32	36	6700 $\mu\text{g}/\text{m}^3$	Animal carcinogen
(M & P) Xylene	35	40	140 $\mu\text{g}/\text{m}^3$	Skin irritant.
O-Xylene	17	19	73 $\mu\text{g}/\text{m}^3$	Skin irritant.
Trichlorobenzene	11	13	74 $\mu\text{g}/\text{m}^3$	Irritant.

Source: Whalen, R.P., Material submitted to Governor Hugh L. Carey and Members of the New York State Legislature, "Special Report on the Love Canal Crisis." Sept. 1978.

TABLE 20

CHEMICALS IDENTIFIED AT LOVE CANAL, NEW YORK
Reference 75

<u>Chemical</u>	<u>Acute Effect</u>	<u>Chronic Effect</u>
Benzene	Narcosis and skin irritation.	Acute leukemia, aplastic anemia, pancytopenia, chronic lymphatic leukemia, and probable lymphomas.
Toulene	Narcosis (more powerful than Benzene).	Anemia and leukopenia possible.
Benzoic Acid	Skin irritation.	
Lindane	Convulsions and elevated white blood cell count.	
Trichloroethylene	Central nervous system depressant, skin irritant, and liver damage.	Finger paralysis, respiratory and cardiac arrest, visual defects, and deafness.
Dibromoethane	Skin irritant	
Benzaldehydes	Allergen	
Methylene Chloride	Anesthesia (increased carboxy-hemoglobin).	Respiratory distress and death.
Carbon Tetrachloride	Narcosis, hepatitis, and renal damage.	Liver tumors possible
Chloroform	CNS narcosis, skin irritant, respiratory irritation, and GI discomfort.	

Apart from certain neurotoxic effects and obvious cases of outright poisoning, any health effects that result from hazardous waste storage or disposal sites will most likely be subtle and hard to detect. They will tend to be long-term and may remain asymptomatic and subclinical, possibly through long latent periods. Illnesses that do arise from chemical exposures can be expected to resemble or be identical to the conventional community health problems such as cancer, miscarriages, and nerve damage [72].

One study has been completed on cancer incidence in the Love Canal area using controls [77]. It has been attacked by critics for using inappropriate control data, collected 10 years previously from a different population [72]. However, it does conclude that data from the New York Cancer Registry shows no evidence for higher cancer rates associated with residence near the Love Canal toxic waste burial site in comparison with the entire state outside of New York City. Rates of liver cancer, lymphoma, and leukemia, which were selected for special attention, were not consistently elevated (refer to Table 21). Among the other cancers studied, a higher rate was noted only for respiratory cancer, but it was not consistent across age groups and appeared to be related to a higher rate for the entire city of Niagara Falls (refer to Table 22). In addition, no evidence seems to exist which links an elevated lung cancer rate with the toxic wastes buried at the dump site (refer to Table 23) [77].

Policy Toward Hazardous Wastes

To combat the hazardous waste dilemma the Federal government has recently passed PL 96-510, the Comprehensive Environmental Response, Compensation, and Liability Act, also known as "Superfund". This has a

TABLE 21

Comparison of observed and expected numbers of cases of liver cancer, lymphoma, and leukemia in the Love Canal census tract between 1955 and 1977.

Cancer	Male cases				Female cases			
	Observed	Expected	5 percent confidence limits*	SIR†	Observed	Expected	5 percent confidence limits*	SIR‡
<i>1955 to 1965</i>								
Liver (155)‡	0	0.4	0 to 2	0.0	2	0.3	0 to 1	6.7
Lymphomas (200 to 202)	3	2.5	0 to 5	1.2	2	1.8	0 to 4	1.1
Leukemias (204 to 208)	2	2.3	0 to 5	0.9	3	1.7	0 to 4	1.8
<i>1966 to 1977</i>								
Liver (155)	2	0.6	0 to 2	3.3	0	0.4	0 to 2	0.0
Lymphomas (200 to 202)	0	3.2	0 to 6	0.0	4	2.5	0 to 5	1.6
Leukemias (204 to 208)	1	2.5	0 to 5	0.4	2	1.8	0 to 4	1.1
<i>1955 to 1977</i>								
Liver (155)	2	1.0	0 to 3	2.0	2	0.7	0 to 2	2.9
Lymphomas (200 to 202)	3	5.6	2 to 11	0.5	6	4.3	1 to 8	1.4
Leukemias (204 to 208)	3	4.8	1 to 9	0.6	5	3.5	0 to 7	1.4

*Approximately 5 percent of the sample values fall outside these limits in a Poisson distribution with a mean equal to the stated expected value. For example, for females in the 1955 to 1965 period, the two cases of liver cancer are outside of the limits 0 to 1 and are statistically significant at the 5 percent level. This 5 percent is entirely in the upper tail when the expected value is 3.6 or less. †Ratio of observed to expected number (age standardized). ‡Numbers in parentheses are designations from the International Classification of Diseases (9th edition).

Source: Janerich, D.T. et al., "Cancer Incidence in the Love Canal Area", SCIENCE (212), 1981.

TABLE 22

Comparison of observed and expected numbers of cases of selected cancers in the Love Canal census tract between 1966 and 1977.

Cancer site	Male cases				Female cases			
	Observed	Expected	5 per-cent confidence limits*	SIR†	Observed	Expected	5 per-cent confidence limits*	SIR†
Buccal cavity and pharynx (140 to 149)‡	2	2.7	0 to 6	0.7	1	1.1	0 to 3	0.9
Digestive organs (150 to 154, 156 to 159)	13	15.7	8 to 24	0.8	15	13.8	7 to 22	1.1
Respiratory system (160 to 165)	25	15.0	8 to 23	1.7	9	4.6	1 to 8	2.0
Connective tissue, bone, skin, and breast (170 to 172, 174 to 175)	2	2.1	0 to 5	1.0	27	21.2	13 to 31	1.3
Genital organs (179 to 187)	13	7.9	3 to 14	1.6	8	12.5	6 to 20	0.6
Bladder, kidney, and ureter (188 to 189)	7	6.0	2 to 11	1.2	1	2.4	0 to 5	0.4
Liver, lymphoma, and leukemia (155, 200 to 202, 204 to 208)	3	6.3	2 to 12	0.5	6	4.7	1 to 9	1.3
Others (190 to 199, 203)	6	5.1	1 to 10	1.2	4	5.1	1 to 10	0.8
All sites (140 to 172, 174 to 208)	71	60.8	46 to 77	1.2	71	65.4	50 to 82	1.1

*Approximately 5 percent of the sample values fall outside these limits in a Poisson distribution with a mean equal to the stated expected value. The 5 percent is entirely in the upper tail when the expected value is 3.6 or less. †Ratio of observed to expected number (age standardized). ‡Numbers in parentheses are designations from the International Classification of Diseases (9th edition).

Source: Janerich, D.T. et al., "Cancer Incidence in the Love Canal Area", SCIENCE (212), 1981.

TABLE 23

Comparison of observed and expected numbers of cases of cancer of the respiratory system (International Classification of Dept. of Health edition, numbers 160 to 165) by census tract, Niagara Falls, New York, from 1966 to 1977.

Census tract	Male cases				Female cases			
	Observed	Expected	5 per-cent confidence limits*	SIR†	Observed	Expected	5 per-cent confidence limits*	SIR†
Love Canal	25	15.0	8 to 23	1.7	9	4.6	1 to 8	2.0
A	24	29.5	19 to 41	0.8	16	8.2	3 to 14	2.0
B	13	10.5	5 to 17	1.2	2	3.0	0 to 6	0.7
C	13	9.7	4 to 16	1.3	0	2.6	0 to 5	0.0
D	14	14.6	8 to 23	1.0	5	4.4	1 to 9	1.1
E	28	22.7	14 to 32	1.2	10	7.8	3 to 14	1.3
F	18	16.5	9 to 25	1.1	10	5.0	1 to 10	2.0
G	26	22.4	14 to 32	1.2	5	6.3	2 to 12	0.8
H	8	7.8	3 to 14	1.0	3	2.1	0 to 5	1.4
I	32	20.1	12 to 29	1.6	7	5.7	2 to 11	1.2
J	28	26.5	17 to 37	1.1	5	7.0	2 to 13	0.7
K	23	20.3	12 to 30	1.1	8	6.6	2 to 12	1.2
L	18	21.6	13 to 31	0.8	3	6.7	2 to 12	0.4
M	18	20.7	12 to 30	0.9	10	5.8	2 to 11	1.7
N	34	17.6	10 to 26	1.9	3	4.9	1 to 10	0.6
O	34	19.9	12 to 29	1.7	4	5.2	1 to 10	0.8
P	26	13.7	7 to 21	1.9	2	3.4	0 to 7	0.6
Q	28	18.5	11 to 27	1.5	5	5.3	1 to 10	0.9
R	19	14.0	7 to 22	1.4	8	3.7	1 to 8	2.2
S	15	6.2	2 to 12	2.4	2	1.6	0 to 4	1.3
T	27	16.5	9 to 25	1.6	6	4.5	1 to 9	1.3
U	19	13.7	7 to 21	1.4	1	3.4	0 to 7	0.3
V	27	25.6	16 to 36	1.1	7	7.1	2 to 13	1.0
W	17	18.2	10 to 27	0.9	9	5.4	1 to 10	1.7
X	13	10.5	5 to 17	1.2	1	2.7	0 to 6	0.4
Niagara Falls (city)	547	432.1	391 to 473	1.3	141	123.2	102 to 145	1.1

*Approximately 5 percent of the sample values fall outside these limits in a Poisson distribution with a mean equal to the stated expected value. The 5 percent is entirely in the upper tail when the expected value is 3.6 or less. †Ratio of observed to expected number (age standardized).

Source: Janerich, D.T. et al., "Cancer Incidence in the Love Canal Area", SCIENCE (212), 1981.

\$1.6 billion kitty accumulated from taxes on industrial chemicals [69]. EPA published a list of 115 hazardous waste sites in October, 1981, which will be the priority sites for the Superfund allocation. There is however, controversy surrounding EPA's listing, with critics urging that EPA has used inappropriate criteria in preparing rankings. These conflicting opinions symbolize the most crucial problem confronting individuals and agencies that must deal with the hazardous waste problems. There is no firm consensus about how to determine a potential hazard of chemicals at a dump site, the risk of exposure, and the potential health effects from such an exposure [78].

In addition, \$1.6 billion does not clean up many dumps and each state and/or agency is vying for funds. A 1979 survey by EPA of 100 waste disposal sites produced an average estimated cost for cleanup of more than \$8 million, with the cost at some sites running as high as \$25 million [78].

The Resource Conservation and Recovery Act (1976) (RCRA), PL 94-580, envisions a scheme of "cradle-to-grave" safeguarding of toxic chemicals. This act strictly regulates chemical dumping according to the toxicity, reactivity, flammability, and corrosiveness of each chemical discarded [69]. It should upgrade existing and future disposal sites, and discourage "midnight dumpers" and others who dump waste illegally. Violators may be fined up to \$25,000 per day [72]. These regulations issued in late 1980 have been stayed pending appeal.

RCRA, however, is not well suited to remedying the effects of unsound past disposal practices [68]. RCRA does provide authority to deal with imminent hazards under Section 7003. Section 7003 authorizes EPA to bring suit in district courts to enjoin an owner or other responsible party of an active or inactive site to take remedial action to prevent or abate an

imminent and substantial danger to human health or the environment.

Therefore, EPA can only exercise this authority effectively when the owner or responsible party is identifiable and financially or otherwise able to remedy it [68].

States may gain authority to regulate waste. If they do not, EPA must administer the program. Today, Michigan [79], New York [80], and New Jersey [81], have comprehensive state plans for hazardous waste management.

IX. SUMMARY AND CONCLUSIONS

This report has identified and documented a variety of information sources relevant to the question of the toxic hazards of underground excavation. The survey represented by this study has verified that incidents resulting in injury or death from intrusion into man-made or natural deposits are not uncommon. Hazards due to excavation or intrusion include asphyxiation and exposure to toxic substances such as methane, hydrogen sulfide and asbestos. While mine safety and other procedures can reduce the hazards associated with excavation, there can be no guarantee that these hazards can be completely eliminated.

The implications of the existence of inadvertent intrusion incidents to the problem of radioactive or toxic waste disposal are interesting to consider. In the area of radioactive waste disposal, for example, policies and designs are frequently driven by the idea that any inadvertent (or intentional) intruder must be protected at virtually any cost. The information in this study documents in a preliminary way the fact and extent of intrusion incidents involving both natural and man-made toxic deposits. This information can be useful in placing greater perspective on the overall question of protecting inadvertent intruders from unreasonable or unusual risks from excavation. The incidents examined in this survey and the number of injuries and deaths as a result of these incidents could be considered as

data on the consequences of possible intrusion given that intrusion has occurred. It is hoped that this data will be useful for a more detailed probabilistic evaluation of the risks involved with intrusion or excavation. A comparison of intrusion risks predicted from analysis of radioactive repositories to the risks determined or implied from intrusion in the absence of repositories, would be useful in lending perspective to the problem or as an aid to decision-making for repository siting or licensing.

Prudent public health practice calls for the allocation of the limited resources available for health protection to areas where change can be most beneficially applied. To a large extent, this goal requires a degree of consistency in controlling various hazards. In light of the broad spectrum of potential hazards due to underground excavation, there may be an inordinate degree of concern devoted to protecting against those hazards which could result from inadvertent intrusion into underground radioactive waste repositories at some time in the distant future. Whether or not this is the case is a question which should be seriously considered in policy formulation.

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APPENDICES

APPENDIX A: DETAILS OF RESEARCH METHODOLOGY

This appendix provides a detailed description of the study data sources, including key libraries, computer search techniques, faculty members consulted, and a description of non-University resources and responses to our request for information.

University of Michigan-Ann Arbor

Libraries:

The key libraries at the University of Michigan which were visited are:

- Harlan Hatcher Graduate Library
- School of Public Health Library
- Taubman Medical Library
- Natural Science Library
- Engineering Library

Appropriate materials were collected and bibliographies within these references were screened for further leads.

A manual search and a computer search were conducted using a number of different indices. The Readers Guide, Index Medicus, and The New York Times Index were chosen for manual searching. The computer data systems chosen were: MEDLINE (a data base providing references to the biomedical literature from 1966 to the present), TOXLINE (a data base containing references to the literature of human and animal toxicity studies, health effects of environmental pollutants, pesticides, and adverse drug reactions), and the NEWSPAPER INDEX (a data base covering the N.Y. Times, Wall Street Journal, and The Christian Science Monitor). Key terms used for these searches are listed in Table A-1. The majority of articles obtained involved chronic rather than acute exposures to toxic materials.

TABLE A-1

KEY WORDS AND TERMS USED FOR THE COMPUTER DATA BASE SEARCHES

ACCIDENT	INTRUSION
ASPHYXIATION	METALS
CHEMICAL DUMPS	MINING
EXCAVATION	METHANE
EXCLUDE CAVE-IN	RADIO ISOTOPE
GEOCHEMISTRY	TOXIC
HYDROGEN SULPHIDE	TUNNELLING

University of Michigan Faculty:

A list of faculty members contacted at the University of Michigan-Ann Arbor is presented in Table A-2 by department of study area of expertise. The response from these individuals was enthusiastic with many suggestions offered for different agencies or interest groups to contact.

Resources Outside the University

Government agencies, unions, insurance companies, interest groups, and all U.S. Schools of Mines were contacted for assistance. The general form letter used for this correspondence can be found on page A-4. The response was encouraging in the sense that of those contacted only a small number did not respond. Located within Table A-3, by state, are the agencies contacted, their replies, and whether or not our request was forwarded to another organization. Information supplied by respondents to our request and used in the final report were primarily in the form of literature sources.

TABLE A-2

FACULTY OF THE UNIVERSITY OF MICHIGAN, ANN ARBOR

<u>Name</u>	<u>Department of Study</u>	<u>Area of Expertise</u>
Berstien, Isadore, Ph.D.	Environ. and Ind. Health	Toxicology
Boettner, Edward, M.S.	Environ. and Ind. Health	Environ. Chemistry
Brewster,	Geology	Environ. Geology
Burch, John, Ph.D.	Zoology and Biological Sciences	Ecology/Evolutionary Bio.
Deininger, Rolf, Ph.D.	Environ. and Ind. Health	Computer Sciences
Eschman, Donald, Ph.D.	Geol. and Mineralogy	Geology
Fine, Larry, M.D.	Environ. and Ind. Health	Occupational Medicine
Hartung, Rolf, Ph.D.	Environ. and Ind. Health	Environ. Toxicology
Hilbert, Morton, M.P.H.	Environ. and Ind. Health	Environ. Health
Jacobson, Arnold, Ph.D.	Environ. and Ind. Health	Radiation Biology
Kaplan, Stephen, Ph.D.	Environ. Studies	Environ. Sciences
Kikuchi, Chihiro, Ph.D.	Engineering	Nuclear Engineering
Mancy, Khalil, Ph.D.	Environ. and Ind. Health	Environ. Chemistry
Meier, Peter, Ph.D.	Environ. and Ind. Health	Industrial Health
Nystuen, John, Ph.D.	Geology	Geology
Overberger, Charles, Ph.D.	Chemistry	Macromolecular Chem.
Polakowski, Kenneth	Natural Resources	Land Arch./Natural Res.
Rehmus, Charles, Ph.D.	Political Sciences	Labor/Industrial Relations
Smith, Donald, B.S.	Industrial Development	Industrial Development
Smith, Ralph, Ph.D.	Environ. and Ind. Health	Industrial Hygiene
Stevens, Walter	Safety	Safety
Watson, A., Ph.D.	Atmospheric and Oceanic Sciences	Atmos. and Oceanic Sci.
Whipple, Hoyt, Ph.D.	Environ. and Ind. Health	Radiological Health

THE UNIVERSITY OF MICHIGAN

SCHOOL OF PUBLIC HEALTH

ANN ARBOR, MICHIGAN 48109

Department of Environmental
and Industrial Health

Dear

I am a graduate student at the University of Michigan School of Public Health. I am working on a research project involving toxic hazards of underground excavation. One of the areas I will be concerned with is obtaining information regarding deaths and illnesses directly attributable to activities such as mining, tunneling, excavation, etc. which disturb the earth's crust and result in the release of toxic substances.

If you are aware of any incidences of cases where people have been injured due to an acute exposure as a result of the release of toxic gases (H_2S , CO) minerals (Hg, Pb, asbestos, silver) or radioactive materials (Ra, Rd) I would appreciate having a copy of the report.

Any information you can give me will be greatly appreciated. If you know of other departments which would have this information please pass this request to the appropriate person. In return, I will send you the results of these findings if you are interested in obtaining them.

Yours sincerely,

Ann M. Goulet
Research Assistant

TABLE A-3

CORRESPONDENCE

Organization	State	Response		Letter Forwarded
		Positive	Negative	
Alaska Dept. of Labor P.O. Box 1149 Juneau, Alaska 99811	AK			
Raymond Jorgensen Industrial Hyg. State of Alaska Dept. of Labor Occup. Safety & Hlth. 3301 Eagle St. Suite 303 Pouch 7-022 Anchorage, Alaska 99510	AK		X	
Jerry C. Ray Commissioner of Labor State of Alabama Dept. of Labor Montgomery, Alabama 36104	AL		X	X
Fay Dobbins Dir. of Admin. Operations Bureau of Env. Hlth. Serv. Arkansas Dept. of Health 4815 W. Markham St. Little Rock, Arkansas 72201	AR		X	X
Louis A. Dooley Asst. Director Env. Health System County of Fresno Dept. of Health P.O. Box 11867 Fresno, California 93775	CA		X	
State of California Dept. of Ind. Relations Division of Labor Stat. Res. P.O. Box 603 San Francisco, California 94101	CA			
U.S. Dept. of Labor-BLS Mr. Bruce Hanchett Rm. 10456 450 Golden Gate Ave. Box 36017 San Francisco, California 94102	CA			X

Organization	State	Response		Letter Forwarded
		Positive	Negative	
Harold R. Smith Area Director U.S. Dept. of Labor OSHA - 2nd Floor 555 Main St. Hartford, Connecticut 06103	CT		X	
Leo F. Alix Director State of Connecticut Labor Dept. 200 Folly Brook Blvd. Wethersfield, Connecticut 06109	CT		X	X
U.S. Dept. of Agriculture Economics and Stat. Serv. Washington, D.C. 20250	D.C.			X
John F. Jackson Gov't of D.C. Dept. of Labor Office of Labor Standards Occup. Safety & Hlth. Div. 2900 Newton St., N.E. Washington, D.C. 20018	D.C.			X
Bruce Hillenbrand U.S. Dept. of Labor OSHA Washington, D.C. 20210	D.C.			X
John P. DeLeonardis Dept. of Transportation U.S. Coast Guard-G-MV1-2/24 Washington, D.C. 20593	D.C.		X	
U.S. Department of Labor ESA/OWCP/DCMMC 200 Constitution Ave. N.W. Washington, D.C. 20210 (Branch of Operational Policies, Regulations, & Procedural Staff)	D.C.		X	
United Mine Workers of America Health & Retirement 2021 K Street N.W. Washington, D.C. 20006	D.C.	X		

TABLE A-3 - CONTINUED

Organization	State	Response		Letter Forwarded
		Positive	Negative	
R.L. Hebblethwaite Occupational Hlth. Prog. State of Florida Dept. of Hlth. and Rehab. P.O. Box 230 Jacksonville, Florida 32231	FL		X	X
Lavine Skipper Coordinator Research & Ping. State of Florida Dept. of Labor and Employment Security Div. of Workers' Comp. 1321 Executive Center Dr. E. Tallahassee, Florida 32301	FL		X	
M.A. Mock, Jr. Pollution Control & Occupational Hlth. Eng. Fulton County Health Dept. 99 Butler St. S.E. Atlanta, Georgia 30303	GA		X	
U.S. Dept. of Labor-BLS 1371 Peachtree St. N.E. Rm. 504 Atlanta, Georgia 30367	GA	X		
Juan I. Limtiaco Administrator Guam Occup. Safety & Hlth. Div. Dept. of Labor Gov't of Guam Agana, Guam 96910	GU		X	
H.W. Mount Administrator Div. of Occup. Safety & Hlth. Div. State of Hawaii Dept. of Labor & Industrial Relations 766 Ala Moana Suite 910 Honolulu, Hawaii 96813	HI		X	

Organization	State	Response		Letter Forwarded
		Positive	Negative	
George Smedly Industrial Commission Dept. of Labor 317 Main St. Room 400 Boise, Idaho 83720	ID		X	
U.S. Dept. of Labor 230 S. Dearborn 32nd Floor OSHA Chicago, Illinois 60604	IL			X
Virgil Konopinski Div. Of Ind. Hyg. & Rad. Hlth. State of Indiana State Board of Hlth 1330 W. Michigan St. P.O. Box 1964 Indianapolis, Indiana 46206	IN		X	
Howard Williams Commissioner of Labor State of Labor 1013 State Office Bldg. Indianapolis, Indiana 46204	IN		X	
David Trott Ind. Hyg. State of Iowa Bureau of Labor 307 E. Seventh Des Moines, Iowa 50319	IA		X	
Victoria C. Moullie OSHA Project Coordinator Louisiana Dept. of Labor Div. of Res. & Stat. P.O. Box 44094 Baton Rouge, Louisiana 70804	LA			X

TABLE A-3 - CONTINUED

Organization	State	Response		Letter forwarded
		Positive	Negative	
William A. Peabody Director Res. & Stat. Div. State of Maine Dept. of Manpower Affairs Bureau of Labor State House Station 45 Augusta, Maine 04333	ME		X	
Katherine Farrell, M.D. Div. of Env. Disease Cont. Office of Env. Programs Dept. of Hlth & Mental Hyg. 201 W. Preston St. Baltimore, Maryland 21201	MD	X		
M.J. Rupp, Jr. Ind. Hyg. State of Maryland Dept. of Licensing & Regulation Div. of Labor & Industry Occup. Safety & Hlth. 203 E. Baltimore St. Baltimore, Maryland 21202	MD		X	
William Savage, Jr. The Commonwealth of Mass. Executive Office of Man- power Affairs Dept. of Labor & Ind. 283 Main St. Worcester, Massachusetts 01608	MA			X
Gerald M. Du Wors Asst. Reg. Admin. for Technical Support U.S. Dept. of Labor OSHA 16-18 N. St. 1 Dock Square, 4th Floor Boston, Massachusetts 02109	MA	X		
James O. Butt Div. Of Occup. Hlth. Dept. of Public Hlth. 3500 N. Logan P.O. Box 30035 Lansing, Michigan 48909	MI	X		

Organization	State	Response		Letter forwarded
		Positive	Negative	
Rudolf Greuer Dept. of Mining Eng. College of Eng. Michigan Technological Univ. Houghton, Michigan 49931	MI	X		
Michael A. Beebe Statistical Technician Vital Stat. Unit Dept. of Public Hlth. 3500 N. Logan P.O. Box 30035 Lansing, Michigan 48909	MI	X		
Mary Fulmer U.S. Dept. of Labor OSHA Detroit Area Office Region V 231 W. Lafayette-Ave. 52B Detroit, Michigan 48226	MI			X
Arthur G. Gatsche Research & Stat. State of Minnesota Dept. of Labor & Ind. St. Paul, Minnesota 55101	MN	X		
William Carlson U.S. Dept. of Labor-MSHA 228 Federal Building Duluth, Minnesota 55802	MN			X
Darrel E. Anderson Occup. Hlth. Minnesota Dept. of Hlth. 717 S. E. Delaware St. Minneapolis, Minnesota 55440	MN			X
Henry L. Laird Occup. Hlth. & Safety State Board of Hlth. 2423 W. State St. P.O. Box 1700 Jackson, Mississippi 39205	MS	X		

TABLE A-3 - CONTINUED

Organization	State	Response		
		Positive	Negative	Letter Forwarded
Mary Murphy Ind. Hyg. Office of Technical Support U.S. Dept. of Labor OSHA 911 Walnut St. Kansas City, Missouri 64106	MO			X
Thomas Rehlander Associated General Contractors of St. Louis 2301 Hampton Ave. St. Louis, Missouri 63139	MO	X		
Henry G. McClernan Econ. Geologist Montana Bureau of Mines & Geology Montana College of Mineral Science & Technology Butte, Montana 59701	MT			X
Man Salazar Div. of Workers' Comp. State of Montana 815 Front St. Helena, Montana 59601	MT	X		
William A. Hooper Dept. of Hlth. & Env. Sciences State of Montana Occup. Hlth. Bureau Cogswell Building Helena, Montana 59601	MT			X
Janet Vallery Div. of Safety Dept. of Labor State of Nebraska Box 95024 State Capitol Lincoln, Nebraska 68509	NE		X	
Bette Hinrichs Nebraska Workmen's Comp. Court Capitol Building Lincoln, Nebraska 68509	NE	X		

Organization	State	Response		
		Positive	Negative	Letter Forwarded
Paul C. Lincoln Ind. Hlth. Program State of New Hampshire Dept. of Hlth. & Welfare Div. of Public Hlth. Serv. Hlth. & Welfare Building Hazen Dr. Concord, New Hampshire 03301	NH		X	
Jere B. Millard State of New Mexico Env. Improvement Div. P.O. Box 968 Santa Fe, New Mexico 87503	NM			X
Marion Morgan Uranium Epid. Study Cancer Research & Treatment Ctr. The University of N.M. 900 Camino De Salud, NE Albuquerque, New Mexico 87131	NM			
Sam Rogers State of New Mexico Env. Improvement Div. P.O. Box 968 Santa Fe, New Mexico 87503	NM		X	
C. Saucom Occup. Hlth. Branch State of North Carolina Dept. of Human Resources Div. of Hlth. Serv. P.O. Box 2091 Raleigh, North Carolina 27602	NC		X	
James Brandon Mine & Quarry Div. State of North Carolina Dept. of Labor 4 West Edenton St. Raleigh, North Carolina 27601	NC		X	

TABLE A-3 - CONTINUED

Organization	State	Response		Letter Forwarded
		Positive	Negative	
Adeline Alexander Div. of Occup. Hlth. State of Ohio Dept. of Hlth. 246 W. High St. P.O. Box 118 Columbus, Ohio 43216	OH		X	
Blaney Qualls State of Oklahoma Dept. of Mines Suite 107 4040 W. Lincoln Oklahoma City, Oklahoma 73105	OK		X	
Dale McHard Occup. & Radiological Hlth. Services Oklahoma State Dept. of Hlth. 1000 NE 10th St. P.O. Box 53551 Oklahoma City, Oklahoma 73152	OK			X
Kenneth Keith Oklahoma City City Hlth. Dept. 921 NE 23rd St. Oklahoma City, Oklahoma 73105	OK			X
Darrel Douglas Worker's Comp. Dept. Accident Prevention Div. Labor & Ind. Building Salem, Oregon 97310	OR	X		
David Rhone U.S. Dept. of Labor Occup. Safety & Hlth. 3535 Market St. Philadelphia, Pennsylvania 19104	PA	X		
John W. Knauber Commonwealth of PA Dept. of Env. Resources P.O. Box 2063 Harrisburg, Pennsylvania 17120	PA	X		

Organization	State	Response		Letter Forwarded
		Positive	Negative	
John Daly, Jr. Commonwealth of PA Dept. of Env. Resources 1475 New Hope St. Norristown, Pennsylvania 19401	PA		X	
Richard H. Zinn Commonwealth of PA Dept. of Env. Resources 1012 Water St. Meadville, Pennsylvania 16335	PA		X	
Mark A. Roller Commonwealth of PA Dept. of Env. Resources 736 W. Fourth St. Williamsport, Pennsylvania 17701	PA		X	
Dept. of Labor & Human Resources Commonwealth of Puerto Rico 505 Munoz Rivera Ave. Hato Rey, Puerto Rico 00917	PR			
Patrick Walker State of South Carolina Land Resources Conservation 2221 Devine St. Suite 222 Columbia, South Carolina 29205	SC			X
Becky Marr State of South Carolina Dept. of Labor P.O. Box 11179 Columbia, South Carolina 29211	SC			X
Steve M. Stampfli South Dakota Dept. of Agriculture Div. of Conservation Anderson Building Rm 324 Pierre, South Dakota 57501	SD			X

TABLE A-3 - CONTINUED

Organization	State	Response		
		Positive	Negative	Letter Forwarded
Lawrence Nanney State of Tennessee Dept. of Public Hlth. Cordell Hull Building Nashville, Tennessee 37219	TN		X	
Harry A. Pullum State of Tennessee Dept. of Labor Div. of Occup. Safety & Hlth. Suite 300 501 Union Building Nashville, Tennessee 37219	TN		X	
Dr. J. Michael Holland Biological Div. Oak Ridge Nat. Lab. Oak Ridge, Tennessee 37830	TN		X	
Gilbert Sautler U.S. Dept. of Labor OSHA 555 Griffin Square Building Dallas, Texas 75202	TX			X
Thomas Curry U.S. Dept. of Labor OSHA Riverview Professional Building 1325 S. 77 Sunshine Strip Suite 9 Harlingen, TX 78550	TX			X
Walter Martin Texas Dept. of Hlth. 1100 W. 49th St. Austin, Texas 78756	TX		X	
Ned Brookes Texas Dept. of Health Public Hlth. Region II 4709 66 Street Lubbock, Texas 79414	TX		X	
Samuel Cook Texas Dept. of Hlth Public Hlth. Region V 701 Directors Drive Arlington, Texas 76011	TX			X

Organization	State	Response		
		Positive	Negative	Letter Forwarded
E. Wentworth Texas Dept. of Health Public Hlth. Region VII P.O. Box 2501 1517 N. Front St. Tyler, Texas 75710	TX		X	
William Treacy Texas Industrial Accident Brd. 1st Floor 200 E. Riverside Dr. Austin, Texas 78704	TX		X	
Arthur Lange State of Vermont Agency of Human Services Dept. of Health Administration Building 10 Baldwin St. Montpelier, Vermont 05602	VT		X	
Alfred Meyer U.S. Dept. of Labor MSHA 12th Floor 4015 Wilson Blvd. Arlington, Virginia 22203	VA	X		
Wayne Rohde Geological Survey, Land Info. Earth Resources Observation Systems Program 1925 Newton Square E. Reston, Virginia 22090	VA			X
Dr. John Hicken Commonwealth of Virginia Dept. of Hlth. 109 Governor St. Richmond, Virginia 23219	VA			X
C.P. Deane Commonwealth of Virginia Dept. of Labor & Industry 205 N. Fourth St. P.O. Box 12064 Richmond, Virginia 23241	VA		X	
Richard Watkins U.S. Dept. of the Interior Geological Survey Reston, Virginia 22092	VA		X	

TABLE A-3 - CONTINUED

Organization	State	Response		Letter forwarded
		Positive	Negative	
James W. Lake U.S. Dept. of Labor OSHA 909 First Ave. Seattle, Washington 98174	WA	X		
Andrew A. Brown State of West Virginia Dept. of Labor Charleston, West Virginia 25305	WV			X
Appalachian Lab. for Occup. Safety & Hlth. Morgantown, West Virginia 26505	WV	X		
David Kessler State of West Virginia Dept. of Mines Charleston, West Virginia 25305	WV	X		
William Aaroe State of West Virginia Dept. of Hlth. Charleston, West Virginia 25305	WV		X	
Donald D. Owsley State of Wyoming Occup. Hlth. and Safety Cheyenne, Woming 82002	WY			X

A-17

TABLE A-3 - CONTINUED

SCHOOLS OF MINES

Dr. John Golden
Graduate School
Colorado School of Mines
Golden, Colorado
80401

Columbia University
Department of Geological Sciences
New York, New York
10027

McGill University
Department of Mining
Montreal Quebec
Canada, H3A 2T5

Michigan Technological University
Department of Mining
Houghton, Michigan
49931

Montana College of Mineral
Science & Technology
Butte, Montana
59701

Dr. Marvin Wilkening
Dean of Graduate Studies
New Mexico Inst. of Mining
& Technology
Socorro, New Mexico
87801

Queens University
Department of Mining
Charlotte, North Carolina
28774

Pennsylvania State University
University Park Campus
Department of Mining Engineering
Kern Grad. Building
University Park, Pennsylvania
16802

Dr. R. Norman Orava
Dean, Graduate Division
School of Mines & Technology
South Dakota School of Mines
& Technology
Rapid City, South Dakota
57701

Dr. Davis
Department of Mining Engineering
S. Illinois University-Carbondale
Carbondale, Illinois
62901

University of Alabama
Department of Mining
University Station
Birmingham, Alabama
35294

University of Alaska-Fairbanks
Department of Earth Sciences
Fairbanks, Alaska
99701

University of Alberta
Department of Mining
Edmonton, Alberta
Canada T6G 2M7

University of Arizona
Mining & Metallurgical Engineering
Tucson, Arizona
85721

University of British Columbia
Department of Mining
Vancouver, British Columbia
Canada V6T 1W5

University of California-Berkeley
Department of Mineral Engineering
Berkeley, California
94720

University of Idaho
Mines & Earth Resources
Moscow, Idaho
83843

University of Illinois-Urbana-Champaign
Department of Geology
Urbana, Illinois
61801

University of Minnesota
Department of Mining
Minneapolis, Minnesota
55455

TABLE A-3 - CONTINUED

Dr. N. Aughenbaugh
Department of Mining Engineering
University of Missouri-Rolla
Rolla, Missouri
65401

University of Nevada-Reno
Department of Geology
Reno, Nevada
89557

Dr. E. Lidiak
Department of Geology
University of Pittsburgh
Pittsburgh, Pennsylvania
15260

University of Wisconsin-Madison
Department of Geology
Madison, Wisconsin
53706

University of Wyoming
Department of Geology
Laramie, Wyoming
82071

Dr. J.R. Lucas
Department of Mining Engineering
Virginia Polytechnic Inst. &
State University
Blacksburg, Virginia
24061

West Virginia University
College of Mines
Morgantown, West Virginia
26506

Direct verbal communications with appropriate individuals were made by phone or personal interviews. The following offices were visited by research members, providing additional data to supplement this report.

- Michigan Department of Public Health, Lansing, Michigan.
- Michigan Occupational Safety and Health Administration, Lansing, Michigan.
- National Safety Council, Chicago, Illinois.
- Federal Department of Labor's Bureau of Labor Statistics, Chicago, Illinois.
- Mine Safety and Health Administration, Washington, D.C.
- Library of Congress, Washington, D.C.

APPENDIX B

OCCUPATIONAL ILLNESSES: NUMBER AND PERCENT DISTRIBUTION OF CASES, BY MAJOR INDUSTRY GROUP, ALL WORKERS.
REPORTED CASES WHICH OCCURRED DURING THE YEAR.

MICHIGAN, 1980.

SIC CODE 1/ INDUSTRY	TOTAL	OCCUPATIONAL ILLNESSES										ALL OTHER DISEAS- ES
		INFE- CTIVE OR PARA- SITIC DIS- EASES	DERMA- TITIS	EFFECTS OF ENVI- RON- MENTAL HEAT	INFLAM- MATION OF JOINTS, ETC.	POISON- ING, SYSTEM- IC	RADIA- TION EFFECTS	CONDI- TIONS OF THE CIRCULATORY SYSTEM, NEC	CONDI- TIONS OF THE NERVOUS SYSTEM	CONDI- TIONS OF THE RESPI- RATORY SYSTEM, PNEUMO- CONIO- SIS	HEART CONDI- TIONS	
TOTAL ALL INDUSTRIES- PUBLIC AND PRIVATE SECTORS.	4,333	87	473	9	2,332	236	23	93	9	83	427	561
PERCENT.....	100.0	2.0	10.9	.2	53.6	5.4	.5	2.1	.2	1.9	9.9	12.9
TOTAL PRIVATE SECTOR-ALL INDUSTRIES.	3,822	59	429	9	2,169	203	23	83	8	69	329	421
PERCENT.....	100.0	1.5	11.2	.2	57.3	5.3	.6	2.2	.2	1.8	8.6	11.0
AGRICULTURE, FORESTRY, AND FISHING.....	30	1	5	-	4	4	-	1	-	4	9	2
PERCENT.....	100.0	3.3	16.7	-	13.3	13.3	-	3.3	-	13.3	30.0	6.7
01 AGRICULTURAL PRODUCTION-CROPS..	17	-	3	-	3	4	-	-	-	3	3	1
PERCENT.....	100.0	-	17.6	-	17.6	23.5	-	-	-	17.6	17.6	5.9
02 AGRICULTURAL PRODUCTION- LIVESTOCK.....	1	-	1	-	-	-	-	-	-	-	-	-
PERCENT.....	100.0	-	100.0	-	-	-	-	-	-	-	-	-
07 AGRICULTURAL SERVICES.....	11	1	1	-	1	-	-	1	-	1	5	1
PERCENT.....	100.0	9.1	9.1	-	9.1	-	-	9.1	-	9.1	45.5	9.1
08 FORESTRY.....	1	-	-	-	-	-	-	-	-	-	1	-
PERCENT.....	100.0	-	-	-	-	-	-	-	-	-	100.0	-
MINING.....	14	-	1	-	4	1	-	-	-	1	6	1
PERCENT.....	100.0	-	7.1	-	28.6	7.1	-	-	-	7.1	42.9	7.1

¹SIC Code refers to the classification presented in the Standard Industrial Classification Manual, 1972, Bureau of Labor Statistics, Statistical Policy Division, Stock No. 4101-0066.

OCCUPATIONAL ILLNESSES: NUMBER AND PERCENT DISTRIBUTION OF CASES, BY MAJOR INDUSTRY GROUP, ALL WORKERS.

REPORTED CASES WHICH OCCURRED DURING THE YEAR.

-CONTINUED

MICHIGAN, 1980.

SIC CODE 1/	INDUSTRY	TOTAL	OCCUPATIONAL ILLNESSES										
			INFEC- TIVE OR PARA- SITIC DIS- EASES	DERMA- TITIS	EFFECTS OF ENVI- RON- MENTAL HEAT	INFLAM- MATION OF JOINTS, ETC.	POISON- ING, SYSTEM- IC	RADIA- TION EFFECTS	CONDI- TIONS OF THE CIRCULATORY SYSTEM, NEC	CONDI- TIONS OF THE NERVOUS SYSTEM	CONDI- TIONS OF THE RESPI- RATORY SYSTEM, PNEUMO- CONIO- SIS	HEART CONDI- TIONS	ALL OTHER DISEAS- ES
10	METAL MINING.....	4	-	1	-	3	-	-	-	-	-	-	-
PERCENT.....		100.0	-	25.0	-	75.0	-	-	-	-	-	-	-
13	OIL AND GAS EXTRACTION.....	5	-	-	-	1	1	-	-	-	-	2	1
PERCENT.....		100.0	-	-	-	20.0	20.0	-	-	-	-	40.0	20.0
14	NONMETALLIC MINERALS, EXCEPT FUELS.....	5	-	-	-	-	-	-	-	-	1	4	-
PERCENT.....		100.0	-	-	-	-	-	-	-	20.0	80.0	-	-
	CONSTRUCTION.....	185	3	7	1	73	12	4	11	2	5	56	13
PERCENT.....		100.0	1.6	3.8	.5	39.5	6.5	2.2	5.9	-	2.7	30.3	7.0
15	GENERAL BUILDING CONTRACTORS....	43	1	-	-	19	1	-	1	-	1	17	3
PERCENT.....		100.0	2.3	-	-	44.2	2.3	-	2.3	-	2.3	39.5	7.0
16	HEAVY CONSTRUCTION CONTRACTORS....	27	1	4	1	7	3	1	-	-	2	8	-
PERCENT.....		100.0	3.7	14.8	3.7	25.9	11.1	3.7	-	-	7.4	29.6	-
17	SPECIAL TRADE CONTRACTORS.....	115	1	3	-	47	6	3	10	-	2	31	10
PERCENT.....		100.0	.9	2.6	-	40.9	7.0	2.6	8.7	-	1.7	27.0	8.7
	MANUFACTURING.....	2,427	12	274	6	1,704	117	16	27	7	33	73	158
PERCENT.....		100.0	.5	11.3	.2	70.2	4.8	.7	1.1	.3	1.4	3.0	6.5
	MANUFACTURING DURABLE GOODS....	2,002	11	233	4	1,440	72	15	18	5	26	55	123
PERCENT.....		100.0	.5	11.6	.2	71.9	3.6	.7	.9	.2	1.3	2.7	6.1

NATURE OF INJURY OR ILLNESS: NUMBER AND PERCENT DISTRIBUTION OF CASES, BY INDUSTRY, WOMEN WORKERS.

REPORTED CASES WHICH OCCURRED DURING THE YEAR.
-CONTINUED

MICHIGAN, 1980.

SIC CODE 1/	INDUSTRY	TOTAL	NATURE OF INJURY OR ILLNESS										
			AMPUTA- TIONS	BURNS (HEAT)	BURNS (CHEMI- CAL)	CONTU- SIONS, BRUISES	CUTS, LACERA- TIONS	FRAC- TURES	SCRA- TCH- ES, ABRA- SIONS	SPRAINS STRAINS	ALL OCCU- PATIO- NAL DISEA- SES	ALL OTHER CLASSI- FIABLE	NON- CLASSI- FIABLE
08	FORESTRY.....	6	-	-	-	1	-	1	-	4	-	-	-
	PERCENT.....	100.0	-	-	-	16.7	-	16.7	-	66.7	-	-	-
081	TIMBER TRACTS.....	1	-	-	-	-	-	1	-	-	-	-	-
	PERCENT.....	100.0	-	-	-	-	-	100.0	-	-	-	-	-
082	FOREST NURSERIES AND SEED GATHERING.....	5	-	-	-	1	-	-	-	4	-	-	-
	PERCENT.....	100.0	-	-	-	20.0	-	-	-	80.0	-	-	-
	MINING.....	6	-	1	-	-	-	-	-	4	1	-	-
	PERCENT.....	100.0	-	16.7	-	-	-	-	-	66.7	16.7	-	-
10	METAL MINING.....	2	-	1	-	-	-	-	-	1	-	-	-
	PERCENT.....	100.0	-	50.0	-	-	-	-	-	50.0	-	-	-
101	IRON ORES.....	2	-	1	-	-	-	-	-	1	-	-	-
	PERCENT.....	100.0	-	50.0	-	-	-	-	-	50.0	-	-	-
13	OIL AND GAS EXTRACTION.....	3	-	-	-	-	-	-	-	3	-	-	-
	PERCENT.....	100.0	-	-	-	-	-	-	-	100.0	-	-	-
130	OIL AND GAS FIELD SERVICES.....	3	-	-	-	-	-	-	-	3	-	-	-
	PERCENT.....	100.0	-	-	-	-	-	-	-	100.0	-	-	-
1301	DRILLING OIL AND GAS WELLS.....	2	-	-	-	-	-	-	-	2	-	-	-
	PERCENT.....	100.0	-	-	-	-	-	-	-	100.0	-	-	-
1302	OIL AND GAS EXPLORATION SERVICES.....	1	-	-	-	-	-	-	-	1	-	-	-
	PERCENT.....	100.0	-	-	-	-	-	-	-	100.0	-	-	-

NATURE OF INJURY OR ILLNESS: NUMBER AND PERCENT DISTRIBUTION OF CASES, BY INDUSTRY, WOMEN WORKERS.

REPORTED CASES WHICH OCCURRED DURING THE YEAR.

-CONTINUED

MICHIGAN, 1980.

SIC CODE 1/	INDUSTRY	TOTAL	NATURE OF INJURY OR ILLNESS										
			AMPUTA- TIONS	BURNS (HEAT)	BURNS (CHEMI- CAL)	CONTU- SIONS, BRUISES	CUTS, LACERA- TIONS	FRAC- TURES	SCRA- TCH- ES, ABRA- SIONS	SPRAINS STRAINS	ALL OCCU- PATIO- NAL DISEA- SES	ALL OTHER CLASSI- FIABLE	NON- CLASSI- FIABLE
14	NONMETALLIC MINERALS, EXCEPT FUELS.....	1	-	-	-	-	-	-	-	-	1	-	-
PERCENT.....		100.0	-	-	-	-	-	-	-	-	100.0	-	-
144	SAND AND GRAVEL.....	1	-	-	-	-	-	-	-	-	1	-	-
PERCENT.....		100.0	-	-	-	-	-	-	-	-	100.0	-	-
1442	CONSTRUCTION SAND AND GRAVEL.....	1	-	-	-	-	-	-	-	-	1	-	-
PERCENT.....		100.0	-	-	-	-	-	-	-	-	100.0	-	-
	CONSTRUCTION.....	74	-	1	2	6	5	13	-	33	4	7	3
PERCENT.....		100.0	-	1.4	2.7	6.1	6.8	17.6	-	44.6	5.4	9.5	4.1
15	GENERAL BUILDING CONTRACTORS.....	16	-	-	-	1	2	3	-	7	2	1	-
PERCENT.....		100.0	-	-	-	6.3	12.5	18.8	-	43.8	12.5	6.3	-
152	RESIDENTIAL BUILDING CONSTRUCTION.....	10	-	-	-	1	1	2	-	4	2	-	-
PERCENT.....		100.0	-	-	-	10.0	10.0	20.0	-	40.0	20.0	-	-
1521	SINGLE-FAMILY HOUSING CONSTRUCTION.....	3	-	-	-	-	-	1	-	2	-	-	-
PERCENT.....		100.0	-	-	-	-	-	33.3	-	66.7	-	-	-
1522	RESIDENTIAL CONSTRUC- TION, NEC.....	2	-	-	-	-	-	1	-	-	1	-	-
PERCENT.....		100.0	-	-	-	-	-	50.0	-	-	50.0	-	-

NATURE OF INJURY OR ILLNESS: NUMBER AND PERCENT DISTRIBUTION OF CASES, BY INDUSTRY, WOMEN WORKERS.

REPORTED CASES WHICH OCCURRED DURING THE YEAR.

-CONTINUED

MICHIGAN, 1980.

SIC CODE 1/	INDUSTRY	TOTAL	NATURE OF INJURY OR ILLNESS										
			AMPUTA- TIONS	BURNS (HEAT)	BURNS (CHEMI- CAL)	CONTU- SIONS, BRUISES	CUTS, LACERA- TIONS	FRAC- TURES	SCRA- TCH- ES, ABRA- SIONS	SPRAINS STRAINS	ALL OCCU- PATIO- NAL (DISEA- SES	ALL OTHER CLASSI- FIABLE	NON- CLASSI- FIABLE
	RESIDENTIAL BUILDING CONSTRUCTION, UNS.....	5	-	-	-	1	1	-	-	2	1	-	-
PERCENT.....		100.0	-	-	-	20.0	20.0	-	-	40.0	20.0	-	-
154	NONRESIDENTIAL BUILDING CONSTRUCTION.....	6	-	-	-	-	1	1	-	3	-	1	-
PERCENT.....		100.0	-	-	-	-	16.7	16.7	-	50.0	-	16.7	-
1541	INDUSTRIAL BUILDINGS AND WAREHOUSES.....	4	-	-	-	-	1	1	-	1	-	1	-
PERCENT.....		100.0	-	-	-	-	25.0	25.0	-	25.0	-	25.0	-
	NONRESIDENTIAL BUILDING CONSTRUCTION, UNS.....	2	-	-	-	-	-	-	-	2	-	-	-
PERCENT.....		100.0	-	-	-	-	-	-	-	100.0	-	-	-
16	HEAVY CONSTRUCTION CONTRACTORS.....	9	-	-	1	1	-	1	-	3	-	2	1
PERCENT.....		100.0	-	-	11.1	11.1	-	11.1	-	33.3	-	22.2	11.1
161	HIGHWAY AND STREET CONSTRUCTION.....	6	-	-	1	-	-	1	-	2	-	1	1
PERCENT.....		100.0	-	-	16.7	-	-	16.7	-	33.3	-	16.7	16.7
162	HEAVY CONSTRUCTION, EXCEPT HIGHWAY.....	3	-	-	-	1	-	-	-	1	-	1	-
PERCENT.....		100.0	-	-	-	33.3	-	-	-	33.3	-	33.3	-
1622	BRIDGE, TUNNEL, & ELEVATED HIGHWAY.....	1	-	-	-	-	-	-	-	-	-	1	-
PERCENT.....		100.0	-	-	-	-	-	-	-	-	-	100.0	-

NATURE OF INJURY OR ILLNESS: NUMBER AND PERCENT DISTRIBUTION OF CASES, BY INDUSTRY, WOMEN WORKERS.

REPORTED CASES WHICH OCCURRED DURING THE YEAR.

-CONTINUED

MICHIGAN, 1980.

SIC CODE 1/	INDUSTRY	TOTAL	NATURE OF INJURY OR ILLNESS										
			AMPUTA- TIONS	BURNS (HEAT)	BURNS (CHEMI- CAL)	CONTU- SIONS, BRUISES	CUTS, LACERA- TIONS	FRAC- TURES	SCRA- TCH- ES, ABRA- SIONS	SPRAINS STRAINS	ALL OCCU- PATIO- NAL DISEA- SES	ALL OTHER CLASSI- FIABLE	NON- CLASSI- FIABLE
1629	HEAVY CONSTRUCTION, NEC	2	-	-	-	1	-	-	-	1	-	-	-
PERCENT.....		100.0	-	-	-	50.0	-	-	-	50.0	-	-	-
17	SPECIAL TRADE CONTRACTORS..	49	-	1	1	4	3	9	-	23	2	4	2
PERCENT.....		100.0	-	2.0	2.0	8.2	6.1	18.4	-	46.9	4.1	8.2	4.1
171	PLUMBING, HEATING, AIR CONDITIONING.....	6	-	-	-	-	-	1	-	4	-	1	-
PERCENT.....		100.0	-	-	-	-	-	16.7	-	66.7	-	16.7	-
172	PAINTING, PAPER HANGING, DECORATING.....	5	-	-	-	-	1	1	-	3	-	-	-
PERCENT.....		100.0	-	-	-	-	20.0	20.0	-	60.0	-	-	-
173	ELECTRICAL WORK.....	13	-	-	-	2	-	4	-	4	-	1	2
PERCENT.....		100.0	-	-	-	15.4	-	30.8	-	30.8	-	7.7	15.4
174	MASONRY, STONENWORK, AND PLASTERING.....	4	-	-	-	1	-	1	-	1	1	-	-
PERCENT.....		100.0	-	-	-	25.0	-	25.0	-	25.0	25.0	-	-
1741	MASONRY AND OTHER STONENWORK.....	2	-	-	-	-	-	-	-	1	1	-	-
PERCENT.....		100.0	-	-	-	-	-	-	-	50.0	50.0	-	-
1742	PLASTERING, DRYWALL AND INSULATION.....	2	-	-	-	1	-	1	-	-	-	-	-
PERCENT.....		100.0	-	-	-	50.0	-	50.0	-	-	-	-	-
175	CARPENTERING AND FLOORING	3	-	-	-	-	-	-	-	3	-	-	-
PERCENT.....		100.0	-	-	-	-	-	-	-	100.0	-	-	-
1751	CARPENTERING.....	1	-	-	-	-	-	-	-	1	-	-	-
PERCENT.....		100.0	-	-	-	-	-	-	-	100.0	-	-	-