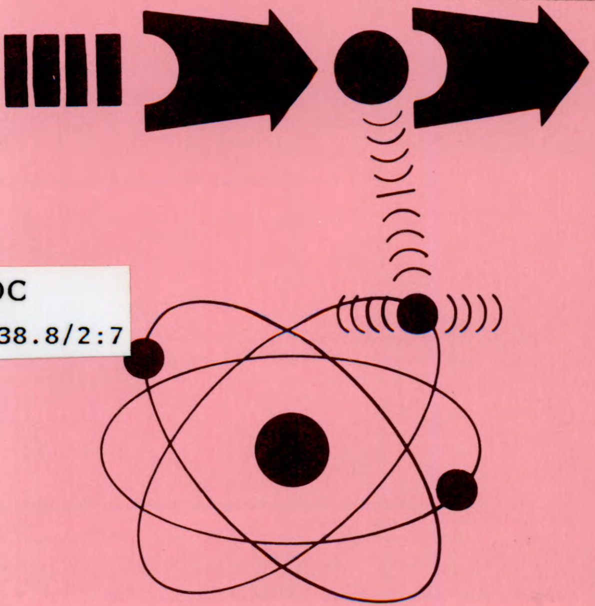
The Radiation Hazard in Mining

U.S. Department of Labor
Mine Safety and Health Administration
National Mine Health and Safety Academy

Safety Manual No. 7

Reprinted 1996



The cover of this publication has been modified to reflect MSHA as being an agency within the Department of Labor. The contents of the publication are identical to the safety manual of the same number previously published under MESA in the Department of the Interior.

The Radiation Hazard in Mining

U.S. Department of Labor
Robert B. Reich
Secretary

Mine Safety and Health Administration
J. Davitt McAteer
Assistant Secretary

Safety Manual No. 7

George Bauer, better known as Agricola, was the author of the book "De Re Metallica" published in 1556. Agricola stressed the need for adequate ventilation in mines.

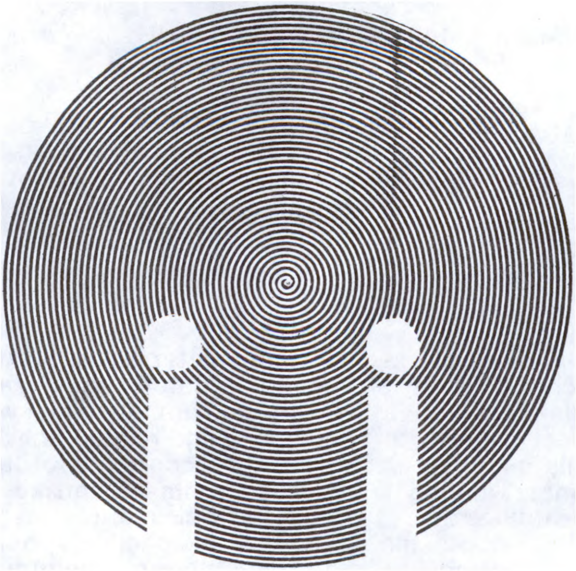
PREFACE

"It remains for me to speak of the ailments and accidents of miners and of the methods by which they can guard against these, for we should always devote more care to maintaining our health, that we may freely perform our bodily functions, than to making profits. Of the illnesses, some affect the joints, others attack the lungs, some the eyes, and finally some are fatal to men."

Agricola (1494-1555),
De Re Metallica, translated
by H. C. Hoover and L. H. Hoover,
The Mining Magazine, London
1912

This is one of a series of pamphlets prepared by the technical staff of the Mine Safety and Health Administration (MSHA) to acquaint the reader with specific areas of mining or mine-related activity. This pamphlet deals with the occurrence of lung cancer among underground miners caused by breathing radioactive dust particles. It informs the reader about the sources of radioactive airborne particles known as radon daughters in underground mines. The radiation control measures for underground workings and the medical surveillance for the mine personnel are noted.

A bibliography (a list of references) and a glossary of terms are included at the end of this manual. Individual copies of all of the safety manuals may be obtained from any MSHA District Office or from the National Mine Health and Safety Academy, Beckley, West Virginia.



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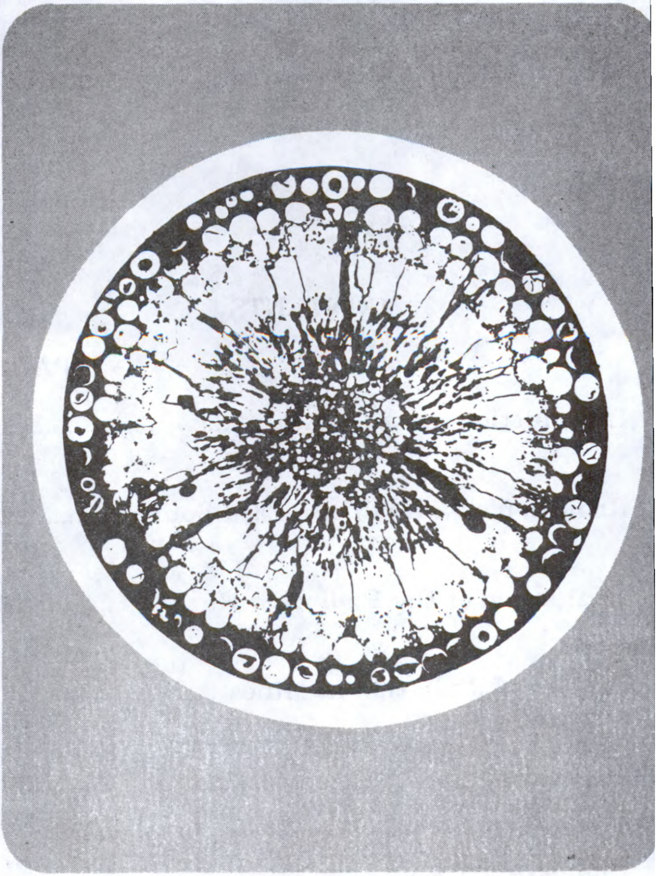


Uranium occurs in nature and is useful as a source of energy in explosive devices and in the generation of electric power.

INTRODUCTION

Many people know that mining is a hazardous job. Deaths caused by fatal accidents in mines make headlines in the newspapers. However, few people hear about the deaths from lung cancer among the miners affected by airborne radiation.

Between 1960 and 1975 when about 3,000 employees were working in underground uranium mines, the number of deaths caused by conventional safety-related accidents averaged about 5 per year. During the same period, about 30 miners are believed to have died every year from lung cancer as a result of their exposures to radiation since 1950. The demand for the development of nuclear energy calls for continued expansion of uranium mining.

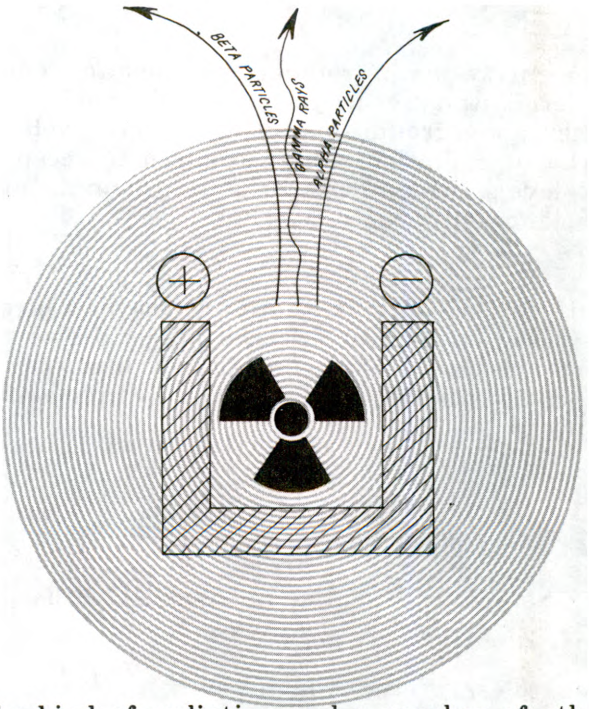
In the following pages, we will briefly discuss the need for recognition, evaluation, and control of the radiation hazard and we will mention the role of education, engineering, and enforcement in coping with this hazard.

RADIATION AS A HEALTH HAZARD SOURCE

All substances, cells, and organs which make up the human body are made of atoms and molecules of various elements. **Ionizing radiation** is a form of energy that can change the structure of atoms, molecules, and cells, and change the life cycle of the organisms. The human body can compensate for some of the damage caused by radiation. This explains how our bodies have learned to adapt to natural radioactivity without showing adverse effects.

Radon and thoron daughters become attached to the airborne dust in the mine air and can be inhaled by those who work in the area. Dust levels can be reduced to acceptable levels through efficient ventilation.

In mining, the ionizing radiation occurs in many forms. Generally, it can be divided into two kinds, **particulate** and **electromagnetic radiation.** Alpha and beta particles are examples of particulate radiation, while gamma and X-rays represent electromagnetic radiation.



The kind of radiation and a number of other conditions determine the kind of injury a person can receive from radiation. Mine workers exposed to high levels of airborne radiation over a long period of time may become affected by a dreadful disease—lung cancer.

Extensive scientific and technical investigations and years of experience with the practical problems of radiation protection have shown that limited amounts of occupational exposure to radiation can be allowed. Such values were adopted by regulatory agencies as **maximum allowable doses.** These doses are believed to carry only a negligible risk of injury from radiation.

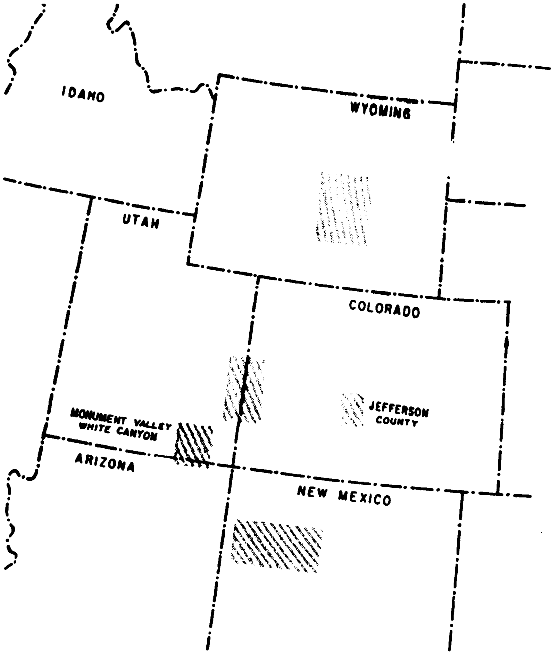
Concentrations of radioactive substances are generally higher in uranium mines than in other underground operations. High levels of airborne radiation can be reduced to acceptable levels through proper mine planning and efficient ventilation.

With few exceptions, there are **no** high levels of radiation in the U.S. coal mines. However, some mineral processing plants use special types of equipment which contain radioactive sources.

Sources of Radiation in Mines and Mills

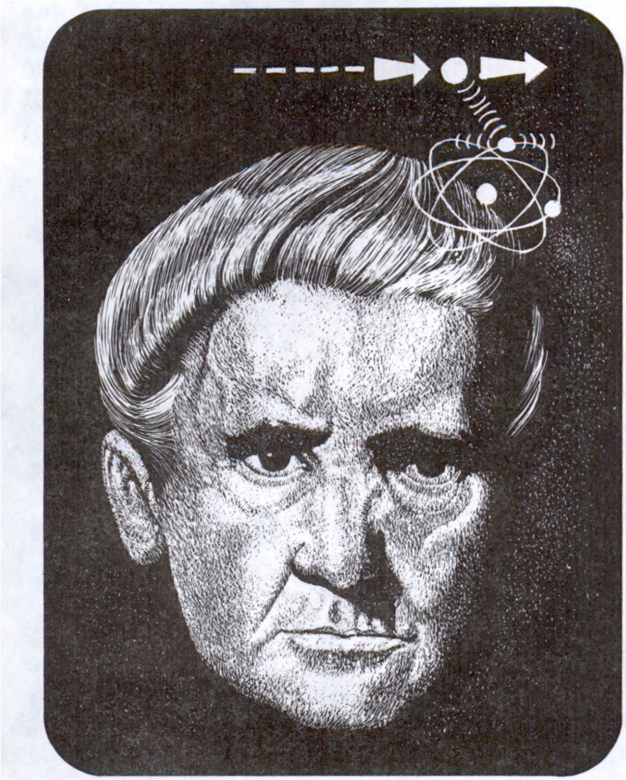
Regardless of the kind of mineral extracted from the earth's crust, the airborne radiation in underground mining can always be traced to the same source — uranium and thorium minerals. Traces of uranium and thorium minerals can be found in almost any kind of soil and rock.

Radon and thoron are **radioactive gases** released by minerals of uranium and thorium. Shortly after their release into the mine air, radon and thoron gases disintegrate. As a result of disintegration, new elements are formed. These newly born particles of atomic size are known as **radon and thoron daughters.** A few seconds after formation, they become attached to the airborne dust in the mine air and can be inhaled by those who work in the area. Thus, **airborne radiation** is a mixture of radon and/or thoron gas and their daughters.



Wyoming, New Mexico, Utah, and Colorado are the major producers of uranium ore in the United States.

Nuclear gauges are used in mines and mineral processing plants and mills. These gauges are designed to generate electromagnetic radiation (rays) that are used in monitoring industrial processes.



Marja Sklodowska was the Polish-born French chemist better known as Marie Curie (1867-1934). Along with her husband Pierre Curie (1859-1906) she separated and identified a number of radioactive elements for the first time.

Past Experience with Radiation in Mining

Ionizing radiation was discovered at the turn of this century. However, a high rate of deaths from lung cancer is known to have occurred among the hard rock miners of central Europe in the middle of the sixteenth century as a result of exposure to radiation.

In the 1940s, about 50 percent of deaths among fluorspar miners in Newfoundland was caused by lung cancer. Radiation in these mines is released by groundwater.

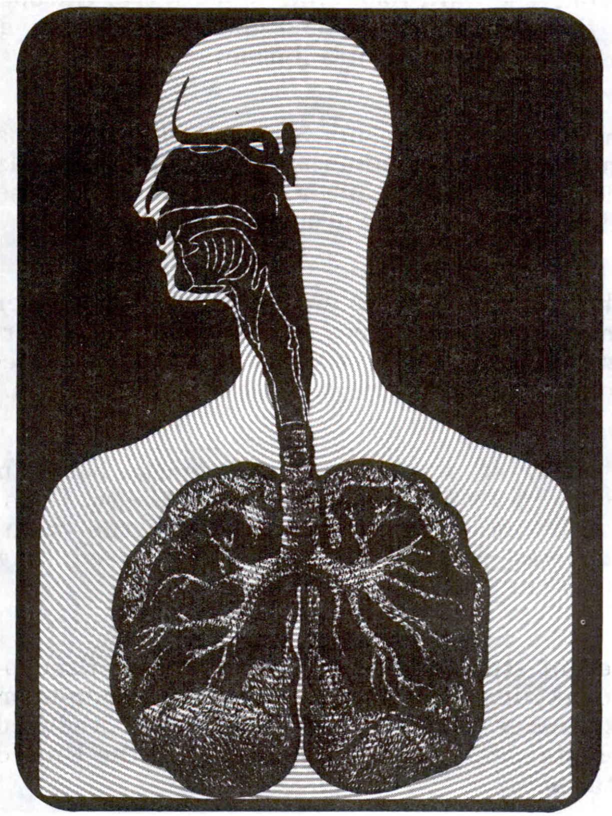
The unusually high incidence of lung cancer among the employees of nonuranium underground mines of Sweden in the 1960s was related to the airborne radiation in those mines.

A study of uranium miners' deaths between 1950 and 1968 in Colorado, New Mexico, Utah, and Wyoming has shown that airborne radiation was the major cause of increased lung cancer in that group.

Recent studies of lung cancer among Czechoslovak uranium miners show that long-term exposures to high radiation have produced results similar to those observed in the United States.

A recent report on health and safety of miners in Ontario, Canada, shows that lung cancer deaths among uranium miners were higher than that of the general population.

By contrast, the enforcement of control measures in French uranium mines over a period of many years has produced favorable results. Lung cancer among French uranium miners is reported no greater than that of the general population in France.



Human lungs exposed to high levels of airborne radiation over a long period of time may become affected by cancer. Lung cancer related to radiation in mining shows up six or seven years earlier among the cigarette smokers.

Causes of Lung Cancer

Not all causes of lung cancer are known. Here are some of the agents which may cause lung cancer:

- airborne ionizing radiation
- cigarette smoke
- asbestos fibers
- nickel and arsenic compounds

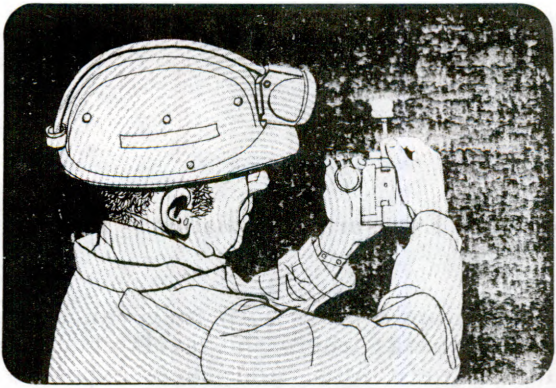
Two separate causes of lung cancer, such as cigarette smoking and radiation, when combined serve as a greater source of cancer. Thus, people who smoke cigarettes (on or off the job) and are exposed to hazardous levels of radiation are about 10 times more likely to get lung cancer. Moreover, lung cancer related to radiation in mining shows up six or seven years earlier among smokers.

EVALATION OF THE RADIATION HAZARD

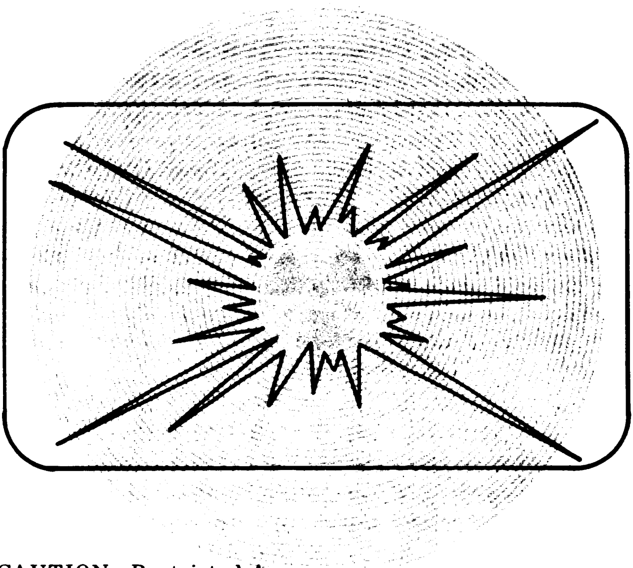
Human senses are **not** capable of detecting the presence of ionizing radiation — we **cannot** see, smell, hear, taste, or feel it. Special equipment and procedures are needed for this purpose.

Mine health and safety personnel and Federal and state mine inspectors are trained and equipped for detecting the presence of radiation and evaluating the hazard. In mines where radiation exists, the stagnant air contains the highest concentration of airborne radioactivity and offers the best opportunity for **detecting** the airborne radiation. The sampler's most important task is to determine the levels of radiation in work sites, lunchrooms and other places where people spend some time during their work.

Mine management concerned with the employee health and safety, posts warning signs in areas where high ionizing radiation is known to be present. Work areas are ventilated to keep the employee exposures well below the maximum allowable levels.



The presence of airborne radiation in mine workings is determined by mine safety personnel trained for evaluating this health hazard.



CAUTION - Restricted Area
CAUTION - Radiation Area
CAUTION - High Radiation Area

Warnings such as these and signs with radiation symbol in form of a three-bladed design in magenta or purple color on a yellow background should be observed by all employees.

How Much Exposure to Radiation is Hazardous

Most uranium miners with lung cancer have worked in areas where the levels of airborne radiation were high, and their exposure to high radiation levels continued for many years. Most lung cancer deaths among miners have occurred 10 years or more after they started working in uranium mines.

A special unit, called **working level month** (WLM), is used to measure workers' **exposure** to airborne radiation. Exposure to radiation involves two measurements, the **level** of radiation and the length of exposure in terms of **time:**
(radiation level) × (time) = exposure

The unit used for measuring the levels of airborne radiation is known as **working level** (WL). Now, using the above formula we can show the exposure in proper units:

(Working Level) × (Months) = Working Level Months

WL × M = WLM

This indicates that a person should **not** spend too much time in areas where high levels of radiation are known to exist. By the same token, if the levels of radiation are low, a person may be able to work safely without worrying about the time.

The U.S. and Czechoslovak studies of uranium miners have shown that when the total exposure of a person exceeds 120 working level months the person is more likely to get lung cancer. Assuming that individuals work 30 years, the maximum dose can be calculated:

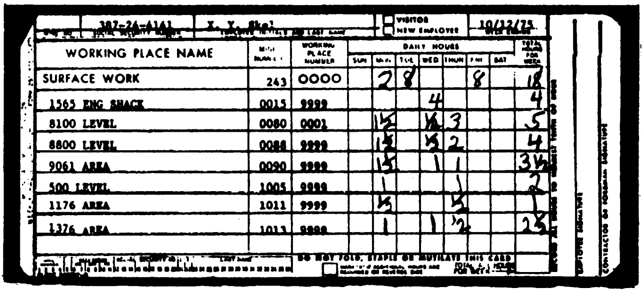
(120 WLM)÷(30 years) = 4 WLM per year

The present health standards state that individual exposures should be kept below the maximum allowable dose — that is below 4 WLM in any calendar year.

Who Keeps Track of the Exposures to Radiation

Some state regulations require that uranium mine operators report employees' exposure to radiation when such doses are in excess of maximum doses specified by Federal or state regulations. To comply with such a requirement, the mine operators must monitor radiation levels in underground uranium workings and keep track of the time each employee spends in these workings. If the levels of radiation in a mine area are high enough to require record-keeping, an additional health standard — prohibition of smoking in that area — becomes mandatory.

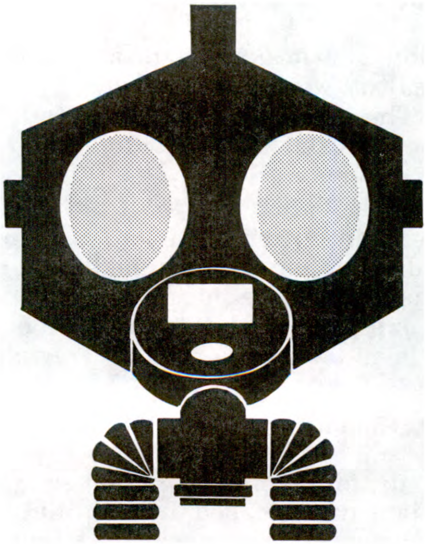
The Federal or state mine inspectors perform spot-check sampling to make sure that mandatory standards on radiation are observed in mining operations. Mine operators who encounter special problems in controlling the airborne radiation can take advantage of the technical support available to them through the Mining Enforcement and Safety Administration (MESA).



WORKING PLACE NAME	MINE NUMBER	WORKING PLACE NUMBER
SURFACE WORK	243	0000
1565 ENG SHACK	0015	9999
8100 LEVEL	0080	0001
8800 LEVEL	0088	9999
9061 AREA	0090	9999
500 LEVEL	1005	9999
1176 AREA	1011	9999
1376 AREA	1013	9999

CONTROL OF RADIATION IN MINES

Uranium mines, and other mines where high levels of radiation are expected to be a problem, should be developed in a special way to reduce the employee exposure to radiation. These mines should have a ventilation system capable of delivering uncontaminated air to the work areas.



Face masks and respirators should be required when working in unventilated areas such as abandoned workings, for a short period of time. However, ventilation of work areas is required to provide a healthy work environment.

Face masks and respirators offer a certain degree of personal protection against air contaminants in ordinary industrial settings. In mines, however, such personal protection devices are **not** used continuously. Even well-designed devices of this kind cause discomfort to the wearer and tend to restrict the person's ability to breathe easily, see, and communicate with fellow workers. Respirators designed to filter out the particulate radiation do not stop the radon gas from entering the lungs. Because of this, face masks and respirators should be required only when inspecting abandoned mine workings, or when working in unventilated areas for a short period of time.

Ventilation of work areas is required to provide a healthy work environment for mine employees. The efficiency of ventilation system should be checked by frequent sampling and analysis of mine air.

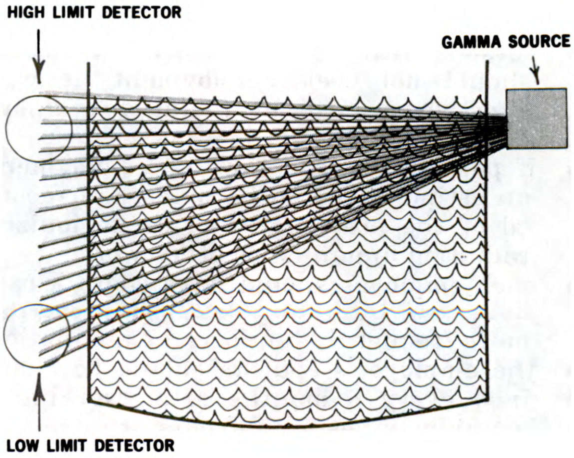
A person unintentionally exposed to high levels of radiation may be assigned to work areas where the levels of radiation are such that the average exposure of that person stays below 4 working level months per year.

Gamma and X-ray Exposures

In most uranium mines, employee exposures to gamma rays released by uranium ore are **not** excessive. Some mineral enrichment mills use nuclear gauges with properly enclosed and shielded X-ray or gamma sources. Such gauges are safe as long as they remain intact and are used and handled properly. By contrast, even short exposures to intense X-rays can cause skin burns.

In mines where high grade ores are handled, a radiation film badge worn during the shift is used to measure the worker's exposure to gamma radiation released by ore. Such exposure should be kept below 5 rems per year.

Women of childbearing capacity are subject to the same maximum dose; when a pregnancy has been diagnosed, the dose accumulated during the remaining period of the pregnancy should not exceed 0.5 rem.



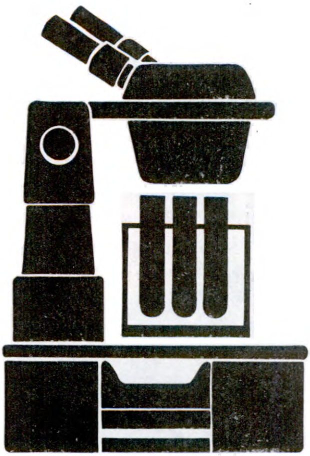
Nuclear gauges, mounted outside tanks, pipes, bins, hoppers or other types of vessels, use gamma rays to sense the level of liquids, slurries or solids. Gauge shutters must be closed and locked before any individual is allowed to enter such vessels.

Breathing a uranium dust concentration in excess of 0.2 milligrams per cubic meter in an 8-hour day may affect the kidneys. But, this is a toxic, and **not** a radiological hazard. The end product of uranium mills — the "yellowcake" — is only mildly radioactive. The weighing and packaging of the yellowcake into drums must be performed in enclosed areas with exhaust ventilation to protect the workers.

Medical Checkups

The Federal and state regulations do **not** require medical surveillance for mine and mill workers who handle radioactive ores. Individuals concerned with exposure to radiation may use the following guidelines:

- persons with chronic respiratory disease should **not** seek employment at work sites where airborne radiation is known to exist
- if possible, at the time of employment, an estimate should be made and recorded of the previous exposure to ionizing radiation in mining or other work
- each employee should have chest X-rays at 5-year intervals except if prescribed more frequently for special examinations
- the employee's sputum should be examined every 6 months after working in uranium mines for 10 years or more
- analysis for uranium in urine should be carried out for mill operators
- in view of the greater risk among heavy cigarette smokers, such individuals should **not** seek employment where airborne radiation is known to be present, unless the person intends to give up smoking



Periodical medical checkups will provide information on the general health of the worker and will detect changes which may be related to his occupational exposure.

SUMMARY

Cancer of the lungs may be caused by occupational exposure to airborne radiation in mines and mills. The risk of this fatal disease may be tenfold for those who smoke cigarettes. However, **not** all mines and mills have hazardous concentrations of airborne radiation. Effective ventilation can maintain the airborne radiation at the work site below the maximum allowable levels. In addition, education of employees on the hazards of ionizing radiation and cigarette smoking, coupled with medical checkups will reduce the incidence of lung cancer among uranium mine workers.

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GLOSSARY OF TERMS

Alpha particle — An energetic particle ejected by some radioactive material. Alpha particles are positively charged.

Beta particle — An electron ejected by some radioactive substances. In contrast to an alpha particle it has a smaller mass and carries a negative electrical charge.

Gamma rays — Electromagnetic waves forming a part of the radiation of radioactive substance. Gamma rays are similar to X-rays.

Ionizing radiation — Radiation capable of changing a neutral atom into an ion. An ion is an electrically charged atom or molecule.

Milligram — A metric unit of mass. A grain of salt weighs about 1 milligram.

Radioactivity — A natural property of some elements to emit particles or radiation from their atomic nuclei such as alpha particles, beta particles or gamma rays, as is the case with radium, uranium, thorium, etc.

Radon daughters — Radioactive elements produced in the disintegration of radon.

Radon — The radioactive gaseous element produced in the disintegration of radium.

Rem — A special unit of radiation dosage absorbed by man.

Thoron — A radioactive isotope of radon, produced in the disintegration of thorium.

X-rays — A form of electromagnetic radiation, similar to light but of a shorter wave length and capable of penetrating solids.

ABOUT THE AUTHOR

Leo Misagi

Dr. Misagi is currently Staff Assistant/Mining Engineer in the Office of the Superintendent, National Mine Health and Safety Academy, Mine Safety and Health Administration of the U.S. Department of Labor at Beckley, West Virginia. As a mining engineer he has worked in underground coal and non-coal mines in Iran, has taught at the New Mexico Institute of Mining and Technology, and has worked on various health-related research projects at the U.S. Bureau of Mines, Bruceton, Pennsylvania, and Denver, Colorado. Prior to his transfer to the Academy, Dr. Misagi was a staff engineer with MSHA's Metal and Non-Metal Mine Health and Safety's Health Division in Arlington, Virginia. He holds a BS degree from Tehran University, an MS degree from the University of Oklahoma, and a DS from the University of Mining and Metallurgy, Leoben, Austria.

Notes

Notes

SAFETY MANUALS

Accident Investigation
Accident Prevention
Back Injuries in the Mining Industry
Carpal Tunnel Syndrome
Coal Mine Maps
Coal Mine Roof and Rib Control
Coal Mining
Coping with Substance Abuse in Mining
Electrical Hazards
Fault Tree Analysis
Fire Safety
First Aid
Heat Stress in Mining
Industrial Hygiene for Healthier Miners
Job Safety Analysis
Laboratory Safety
Mine Escapeways
Mine Gases
Mine Ventilation
Permissibility - Electric Face Equipment
Personal Protective Equipment
The Radiation Hazard in Mining
Safety Tips for Underground Coal Mining
Stockpiling Safety
Surface Haulage Safety
System Safety Engineering
Winter Alert