conditions can be made part of the permit and the driller must conduct the drilling program in compliance with the specified conditions.

1. In preparation of the well site a pit or pits must be costructed in close proximity to the well to collect and confine drill cuttings and confine drilling muds or fluids.

2. Dikes may be constructed to prevent the escape of fluids from th well site.

3. Steel tanks, cribs or other approved containers may be required in an area where pits are not feasible or if the cuttings and fluids are to be removed from the well site.

4. Drilling shall not commence until the driller has complied with the specified conditions to prevent pollution.

5. Fencing, gates, warning signs may be required to protect life and property in a congested area.

6. The well site shall be maintained in an orderly manner and kept free and clear of debris and unnecessary or abandoned equipment.

7. In the drilling of th well the driller may be required to case and seal the well to provide protection to th ground and surface waters and to prevent migration of fluids between layers of earth material.

8. The removal of casing from a well upon completion of drilling and proposed abandonment can only be done with approval of the supervisor.

9. The operator, as a condition of the permit, shall keep and file a log of the drilling program with the supervisor. The log for a test well shall include the owner's name, permit number, site location, elevation, drilling contractor, drilling method, casing record, description and thickness of geologic materials penetrated, static water levels, flowing water zones, total depth, beginning and completion dates, occurrences of oil, gas or salt water and description of procedures and materials used in plugging.

10. A test well must be plugged promptly after abandonment or termination of the project in accordance to procedures specified by the supervisor in the drilling permit. The plugging may require the use of mud-laden fluid, cement, other suitable material or a combination of two or more of these items. Fluids and gases shall be sealed off and confined to the strata in which they occur. A suitable plug may be required at the surface.

11. The well site, upon abandonment, shall be cleaned up. All pits and excavations shall be filled, leveled off at the surface, debris removed and all conditions which may create a nuisance or fire or pollution hazard shall be eliminated. The surface of the abandoned well site shall be returned as nearly as possible to its original condition.

12. A report shall be filed with the supervisor after plugging of a test well within time specified by the supervisor in the permit.

The statute, then, provides a sufficient basis to regulate uranium exploration drilling. If individual permits are written to insure proper site preparation, mud and drilling pit construction, casing of the drill hole, cementing of the hole upon completion of data collection and sufficient soil coverage of mud pits and site restoration, the radiological and environmental impacts will not pose a health risk to the general public.

However, there is a provision in the statute which exempts a test well driller from the necessity of obtaining a permit prior to drilling test wells in areas with Precambrian rock directly underlying unconsolidated surface deposits. Since the areas of interest to uranium companies in the upper peninsula primarily include Precambrian rock with unconsolidated surface formations, a permit is not required.

This exemption should be reviewed in light of uranium exploration. It does not provide for the prior review of a specific drilling plan nor allow for the inclusion of specific safeguards in a permit. The driller is under no obligation to identify the proposed well location or disclose his drilling, cementing or abandonment procedures for up to two years after drilling the hole. Thus, it is difficult for the regulatory agency to know the location, inspect the well site and operations carried out to determine if they are sufficient to prevent surface or underground waste.

In light of the public concern over uranium exploration, it would be proper for the health and welfare of the general public to require submission of permit applications for uranium exploration in the Precambrian rocks. It would appear that the statute gives the supervisor the power to set aside the exemption through the execution of a special order to control pollution or eliminate a hazardous condition. It appears a public hearing before the supervisor and the mineral well advisory board is required to take evidence on the need for the exemption.

C. Federal Government

Exploration for uranium is regulated by federal agencies only when the exploration is done on federally owned land. The federal agency that has administrative control of the land and its use requires exploration permits.

D. Exploration Impact Conclusions

1. There are two types of environmental impacts associated with uranium exploration; (a) impacts due to the radioactivity of uranium and (b) other nonradioactive impacts including access roads, site preparation, noise and air emissions from mechanical equipment. The latter impacts are similar to those for other types of metallic mineral exploration and water well drilling. They are generally short term and can be minimized if site reclamation is carried out. For example, brush may be cut for laying survey lines for reconnaissance exploration or a road may have to be built to bring a rig into the site. Drilling can often be done during the winter when equipment can be moved on skids over the frozen ground, and road building is not necessary. Vegetation that is damaged can be replanted or allowed to revegetate naturally. Roads are either reclaimed to their original state or are left open at the discretion of the landowner.

2. The radiation associated with uranium exploration does not pose a health risk to general public. If proper drilling procedures are employed, the chance of groundwater contamination is very remote. The release of radon gas from the drill hole to the atmosphere does not pose a hazard to the general public. If drill holes are sealed properly, radon gas will not escape into the atmosphere upon the termination of testing. The radon gas release while the hole is open, based on the worst case analysis referred to previously, will be small and will be dispersed and diluted through atmospheric mixing as the gas moves away from the well site. Reclamation of the mud pits with the drill cuttings by covering with top soil will reduce and contain any radiological emissions within background levels.

3. Notwithstanding the conclusion that uranium exploration does not pose a significant health hazard to the general public, it is recognized that individual members of the public will remain unconvinced or skeptical. If uranium exploration is going to continue to be permitted and not prohibited by legislative action, it is recommended that the uranium mining companies improve their public relations with local government officials, landowners and general public.

   In Minnesota, Rocky Mountain Energy Company has developed a policy of inviting landowners and interested citizens to visit the sites and exploration surveys to observe and learn how data is collected. This company has developed a newsletter to describe its activities and has met with local units of government to describe its drilling program and safety procedures. Where applicable, it has worked with local county and township zoning boards to arrive at an exploration program consistent with zoning requirements. Further, it established a monitoring program to minimize drilling impacts and measure radiological exposure. It has also held an open house for citizens to visit its facilities.

   These types of activities do not insure general public acceptance, but it provides for an exchange of viewpoints and allows the public to learn more about uranium exploration from the people who do it. Similar programs by companies in Michigan would help in sharing information and help to answer the myraid of questions associated with uranium exploration. It is recognized this is a controversial issue. It is our opinion that attempts by companies to conduct these activities in a secretive manner will only contribute to the fear and suspicions of the public. An open and public exchange of questions and answers will aid in seeking a resolution.

V. ENVIRONMENTAL IMPACTS AND REGULATORY FRAMEWORK ASSOCIATED WITH URANIUM MINING AND MILLING

A. Land Use Impacts

Uranium mining and milling pose land use and land quality problems. Areas of land are taken away from their original use for extended periods of time. The amount of land required for a uranium mining and milling operation is dependent on the type of mining technique employed, the size, shape and depth of the ore body and the proximity of the mill to the mine. Open-pit mines impact more surface area than underground mines.

An open-pit uranium mine removing 500,000 tons of crude ore over a period of 20 years and consisting of one or more pits, ore, lean ore, waste rock

storage area, and associated buildings would occupy approximately 50 to 290 acres. The mill would require from 5 to 10 acres for facilities and from 20 to 80 acres for the tailings pond. These figures vary depending on the extent and depth of the ore, the location of the mill and the type of tailings pond construction

An underground uranium mine would disturb about one tenth of the surface area disturbed by an open-pit mine since overburden material is not removed and less land area is needed for waste storage. Surface area would be required for service buildings, a head frame and track-loading facility, a mine waste pile and a flow of water from underground sumps pumped to the surface for use in the mill and concentrator. The area occupied by the hoisting and loading facilities, shops, warehouse, changehouse and office may be only a few acres, but the reach of underground openings may be a mile or more. Most uranium ore deposits are long, but not thick and therefore require special adaptions of routine mining methods including highly mobile blasting and mining techniques to permit inexpensive and rapid digging (49).

The buffer zone of a one-half to one mile radius around uranium mining and milling facilities would be prudent to minimize the potential of radionuclides and other contaminants reaching the general public and to avoid obtrusive aesthetic impacts. With the inclusion of a buffer zone, the area required for an open-pit mine and mill during the operational phase would range from 1,300 to 3,300 acres or from two to five square miles.

Uranium mining usually restricts concurrent on-site land uses such as agriculture, although some land uses in the buffer area may be compatible with it. For example, timber production in the buffer region should be unaffected by mining. Some tree species are more susceptable to radiation than others. However, the expected radiation associated with a properly operated uranium mine mill is usually not at the level known to cause damage.

However, the effect of a properly operated mine on terresterial vegetation adjacent to the mine facilities would require monitoring of the plants and wildlife to assess the degree, if any, of bioaccumulation of radioactive molecules into the food chain.

In many cases mined areas can be reclaimed to their original use or to some other productive use at the cessation of mining. However, portions of a uranium mine and mill site may be permanently closed from future productive land use. Under current federal law the ownership of land used for uranium tailings disposal must be transferred to the federal or state government.

B. Milling And Tailings Impact

Mined uranium ore typically contains a few pounds of uranium oxide (U_3O_8) per ton of material. To extract the usable uranium oxide the ore must be milled in a process similar to concentrating processes used in other types of hard-rock milling. Because of economic factors, such as haulage costs, uranium mills are located near the sources of the ore.

A typical uranium processing mill is a complex of small buildings. They contain crushing machinery, receiving bins, screening operations, conveyors and a chemical-treatment facility. The uranium ore is crushed, ground and leached by chemicals to dissolve the uranium minerals from rock. The leached

uranium-bearing solution is separated from the undissolved material and uranium is recovered as a precipitated concentrate. This concentrate is roasted, pulverized, and drummed for shipment as a powdery material called "yellowcake". The wastes, known as mill tailings, are a slurry of finely ground solids in waste solutions. This slurry is transferred to a tailings pond.

The radioactive content of the tailings is about 85 percent of the radioactivity of the original uranium ore. A small percent of the uranium initially present in the ore remains in the tailings, as do most of the uranium decay products which were in the ore. Radium-226 is the most hazardous nuclide in the tailings. The quantity of radium and radon in the tailngs will diminish by only one-half in roughly 1,600 years.

Many studies have concluded that uranium mill tailings must be as carefully managed as the more highly radioactive wastes from other portions of the nuclear reactor fuel cycle. Congress has recognized that the past record of control at mill sites has been poor and that little attention has been given to the problem of proper disposal of tailings. In 1978 Congress passed an amendment to the Atomic Energy Act, the Uranium Mill Tailings Radiation Control Act. This act, and action by the Nuclear Regulatory Commission and the Environmental Protection Agency, are leading to a complete review and revision of the various steps involved in the management of tailings, which are now formally recognized as radioactive wastes. The ultimate objective is to dispose of the tailings in a manner that reduces emissions of radioactive materials, primarily radium and radon, to as low a level as can reasonably be achieved, to isolate the tailings and to eliminate the need for continuous maintenance.

The Nuclear Regulatory Commission completed in September of 1980 a Generic Environmental Impact Statement (GEIS) on uranium milling. Alternative methods for treating and disposing of mill tailings were evaluated. These include various degrees of treatment to remove the radium, thorium and uranium as well as ways to stabilize tailings piles and methods to place the tailings underground (49).

The radium and radon problems of uranium mill tailings illustrate the underlying difficulties of managing radioactive wastes. The hazard is a long-term one and extends over thousands of years. Exposure to radiation is known to cause cancer and genetic damage. The impact per human generation may be relatively small, but the potential cumulative impact is large. Expenditures to manage the tailings (for example, chemical treatment to remove the radium, thorium, and residual uranium, developing methods to dispose of those elements safely, and placing tailings underground in a way that ensures they do not contaminate the circulating ground water) must be incurred at the time of milling, while the benefits of fewer cancers or genetic mutations would not be realized for a long time. These "value judgment" decisions emphasized by the NRC must be made prior to mining and milling.

Present NRC regulations require tailings to be disposed of in a natural basin sealed with an inactive clay or bentonite seal. These basins must be located and sited to avoid flooding from a 100-year flood cycle. The adequacy of these current regulations is now being examined.

Present measures are regarded as being adequate for the short term, but because the hazards persist for up to thousands of years, accepting these measures only postpones implementation of long-term safe management. Pending completion of the current NRC reevaluation, the requirements for new mines and mills cannot be stated (50).

C. Air Quality Impact

Uranium mining and milling may also diminish air quality both on and away from the mine site due to emissions of particulates and gases.

1. Mining operations

Radon gas has been the cause of a number of lung cancer deaths among uranium miners. To reduce radon exposure the mines must be well ventilated. Fresh air is usually directed downward through the production shaft, ducted to mining face, and returned through ore haulage ways where it is discharged through vent holes or shafts. The discharged mine air may contain significant quantities of rock dust and radioactive gases. Radon gas from mine shafts may infiltrate any accessible aquifers or contaminate the surface environment as it is released.

2. Fugitive dust

Particulate matter includes dust from tailings ponds (if less than 4% moisture content), mines, ore hauling, road construction, and piles of overburden and/or rock material. This dust would have a composition similar to that produced by mining or farming with one important difference; the presence of toxic ore particles that may be contained in the ore. These particles may include both radioactive and nonradioactive minerals.

The release of dust containing toxic ore particles can cause adverse health effects if ingested or inhaled. Large quantities of dust may reduce the photosynthetic activity of plants that become coated and may also have a negative aesthetic impact around the site. Fugitive dust may also contaminate nearby surface waters.

Most of the problems associated with fugitive dust can be mitigated by applying dust control measures. Tailings should be kept wet and stockpiles of waste and ore should be stabilized with vegetation or kept moist with water or chemical sprays. If these measures are not followed dust may be carried off-site and be deposited on the surrounding area. Transport of crude or crushed ore between the mine and the mill may also cause air pollution off-site if th ore is not covered and if unpaved transport roads are not sprayed regularly.

3. Gaseous emissions

Another potential impact to air quality is the release of gases including radioactive radon gas, gases from process chemicals, and hydrocarbon gases from mining and milling equipment that burn fossil fuels.

Radon gas can emanate from the walls of open-pit mines and from uranium mill tailings. Lesser amounts of radon may escape from the exhaust vents of underground mines, from ore storage piles and from mine waters that contain radium or radon.

The vent shafts, which flush the mine air for the miners, can pose a problem for nearby residents. Estimates of the magnitude of critical radon emission from the vented air vary greatly. Earlier studies, noting the remote location of most uranium mines, generally concluded that population exposures were negligible. Recent studies conclude differently. Radon gas decomposes rapidly but several of the resulting radioactive daughter isotopes appear to enter the food chain. The problem is critical where nearby homes are occupied by workers who are exposed to the same radon byproducts during working hours.

Impacts on air quality can also result if process chemicals escape from mills or other extraction facilities. Chemicals used in large amounts and having a high degree of volatility include sulfuric acid, anhydrous ammonia and organic solvents. Primary release of these substances would be from spills or evaporation from treatment ponds.

Combustion gases are produced by mining equipment, ore trucks and power generators that burn fossil fuel. These sources may not significantly degrade the air quality at the site but will incrementally add air pollutants such as oxides of carbon and nitrogen and particulates to the atmosphere.

D. Water Quality Impacts

1. Mining operations

A significant environmental impact associated with uranium mining results from the dewatering of underground or open-pit mines. Mining significantly modifies the normal ground water flow cycle below the water table. Dewatering is accomplished either by a ring of dewatering wells, the use of sumps within the mine or a combination of those two methods. The lower water table can result in exposing mineralized rocks to a new environment which can affect the geochemical structure of those rocks and lead to increased oxidation and the dissolving of radiochemical and toxic materials. Radium-226 with other minerals and decay particles is leached from the mine water as it flows through the mine to the sumps. Ammonia is also present in the mine water due to the use of ammonia blasting agents. In open-pit mines, precipitation falling on the exposed ore and waste rock can leach radiochemical and toxic pollutants.

Ground water that enters underground uranium mines contains a variety of dissolved materials including radium, radon and uranium. It is important to establish the level of natural contamination prior to the commencement of mining. AS the water travels through the mine to the collecting sumps it is likely to release radon gas into the mine atmosphere and the water may also become contaminated with uranium. This effluent can contain radioactive elements such as uranium and radium and concentrations of potentially toxic organic compounds such as amines, nitrated, and kerosene as well. The concentrations are dependent on the mining technique and the mineralogy of the deposit. In some operations it is economically feasible to recover uranium from this waste water. Effluent treatment is necessary prior to disposal.

2. Tailings ponds operations

Fluids containing toxic heavy metals may seep from tailings ponds and other ponds used for water treatment. The seepage from a tailings pond can contain a variety of radioactive and nonradioactive toxic heavy metals such as uranium, thorium, radium, selenium, molybdenum, arsenic, vanadium and others.

The ponds are usually constructed so that the soil which underlies the pond can trap dissolved ions and prevent their movement. It has been observed that some ions can still migrate from the pond through groundwater movement. Selenium migrated one half mile during a thirty year period from an unlined tailings pond in Canon City, Colorado and is now polluting wells in the area.

Seepage from unlined tailings or water treatment ponds may reach streams or lakes directly. Under arid conditions, evaporation of contaminated ground water may result in the deposition of salts at the surface where they are transported by runoff. The seepage is usually diluted during these processes, but the concentration of the contaminants can be increased by natural mechanisms. The trapping of radionuclides and heavy metals has been observed in soils and stream sediments. Sediments that contain radionuclides can be transported downstream causing a concentration of radioactive material to move to other areas, such as lake sediments.

3. Waste rock storage areas

Piles of waste rock and overburden dumps can also be sources of contaminated seepage. Water from rain and snowfall can dissolve and transport minerals such as copper, nickel, mercury and zinc. The composition of seepage will depend on the mineralogy of the ore and other factors including the pH of the precipitation.

The prevention of seepage may not be difficult. Lining mill and mine water treatment ponds with impermeable clay or synthetic materials reduces seepage significantly. The use of impervious ponds and covers for piles will help control both seepage and the removal of particles by wind action.

Waste rock containing uranium minerals of low grade ore can also present a potential for long-term radon emissions and dissolved toxics in surface runoff. Control practices range from no cover or stabilization to covering the waste with a gravel, clay or synthetic pad, and using a water treatment system for runoff from the pile. This problem, like that of management of the uranium tailings, is not yet resolved. Because of the long life of the radioactive materials the hazards persist for thousands of years. The long term effectiveness of radon emission control for various cover materials (or combinations of cover materials) is difficult to estimate due to variability of atmospheric influences, mechanicals stresses, and dislocations.

E. Postoperational Impacts

Postoperational impacts from a mining and milling operation will depend on the siting of the facilities and the type of reclamation procedures that are followed. There are essentially three parts of the mining and milling operation that need to be reclaimed: the mine site, the mill site and the tailings pond.

1. Underground mines

Reclamation of an underground uranium mine usually includes removal of all above ground equipment, decontamination of the soil, sealing of all mine openings, grading and reseeding of the site. Roads that were constructed may or may not be removed. In some cases structures may also be left on the site after being decontaminated.

Problems may develop in the future if subsidence takes place after the mine is closed. Subsidence could adversely affect land use, water quality and air quality. Backfilling of underground mines should help prevent this problem. In many cases, an underground mine site can be restored to its orginial use after reclamation.

2. Open-pit mines

In the case of open-pit uranium mines reclamation is usually not complete. In the past most open-pits were not reclaimed. This practice severely limits subsequent land use and may necessitate the permanent closing of the area from public use. Current reclamation practices involve backfilling the pit with waste rock and overburden, and then grading and reseeding the site. Open-pit uranium mines reclaimed in this manner may be suitable for some future uses such as timber production. Agricultural uses may be discouraged because of the possible bioaccumulation of residual metals.

Both open-pit or underground uranium mines can seriously affect the long-term water quality of a region if uranium mines are unreclaimed or reclaimed in such a way that waters from separate aquifers intermingle. Surface waters may also be contaminated from windblown dust or runoff from improperly reclaimed mining sites.

Further, the air quality of the surrounding area can be impacted by fugitive dust and radon gas releases from lean ore in the walls of unreclaimed open pit mines and waste rock stockpiles.

3. Mill site

The uranium mill site would be subject to reclamation. Structures and soil would be decontaminated or demolished, and the mill site could probably be restored to its preoperational settings.

4. Tailings basin

Since over 85 percent of the radioactive materials in the crude ore are retained in the tailings, special consideration must be given to the design, construction and reclamation of uranium tailings basins. Past mining practices have led to environmentally unsound disposal methods, including dumping tailings directly into streams and siting tailings basins near populated areas or within the floodplain of a river.

Since tailings will remain radioactive for hundreds of thousands of years the disposal system will need to isolate the tailings for an extrodinary period of time. Basic precautions would include siting the tailings pond away from populated areas and in a topographic area that is geologically stable and not subject to severe erosion.

The basin should be lined with clay. At the completion of the project, the pond should be covered with several feet of overburden and soil to reduce radiation and radon emanations. Long-term maintenance and monitoring of inactive tailings would be necessary to insure that the tailings are not removed or eroded. Since the effectiveness of tailings disposal methods is uncertain, future land uses of the tailings site are limited. The title to the land should carry a restriction noting the presence of tailings basin. Ownership and future uses should be limited by legal constraints to avoid undue future environmental and public exposure as well as future costs.

F. HEALTH IMPACTS

1. Radioactivity

Radioactivity is the property of atoms with unstable nuclear configurations (radionuclides) to spontaneously transform. Such transformations are accompanied by the emission of particles and/or electromagnetic energy. These transformations will continue until a stable configuration is reached. For example, uranium-238 undergoes a specific decay path from radioactive, unstable uranium-238 to stable, non-radioactive lead-206. It involves 14 separate intermediate decay steps with the release of energy (radiation) through alpha and beta emissions (particulate) and gamma emissions (electomagnetic). Each of these 14 elements is termed a daughter in the uranium-238 decay series (Figure 10). Similar decay schemes exist for other naturally occurring radionuclides, such as thorium-232 and uranium-235.

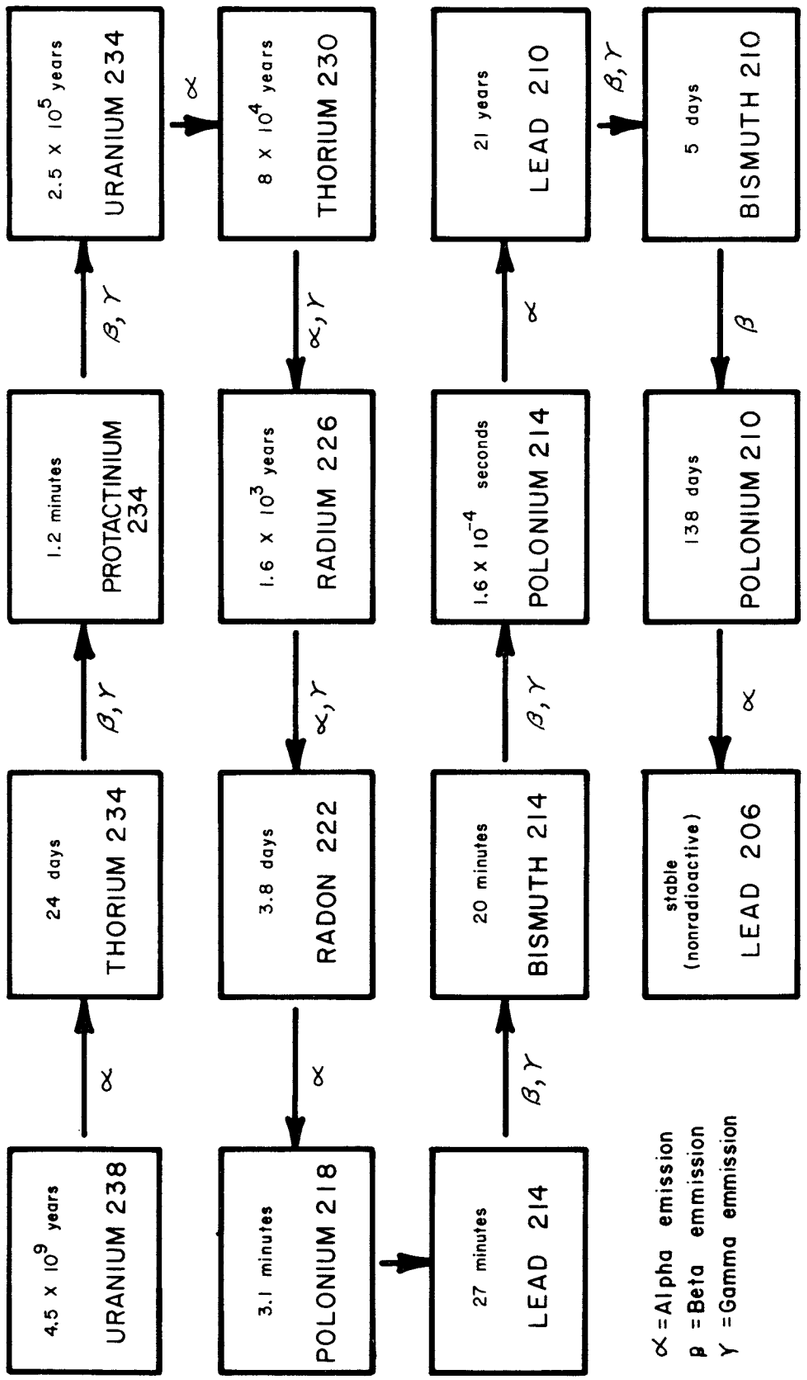
All unstable nuclides undergo radioactive decay at characteristic rates. The time required for half of the atoms of a given radionuclide to decay is called the radioactive half-life. Measured half-lifes range from less than a second to billions of years. For example, the half-life of polonium-214, is 0.00016 seconds and the half-life of uranium-238 is 4.47 billion years (55).

There are many naturally occurring radioactive elements in the earth's crust. Among these are uranium-238, thorium-232, and unanium-235 and their daughters. These radionuclides are continually undergoing decay to stable, non-radioactive elements. However, based on the known half-lives, the time involved is measured in billions of years. It will take 4.5 billion years for 1/2 of the uranium-238 now present in the earth's crust to decay to thorium-234. It will take another 4.5 billion years for 1/2 of the remaining uranium-238 to decay. So, in terms of human existence on earth, uranium-238, thorium-232, and uranium-235 have always been, and will continue to be, present in the earth's crust.

2. Sources of Radioactivity

All living organisms are constantly exposed to radiation from radioactive elements in the earth's crust and from extra-terrestrial or cosmic radiation from the sun. Life on earth has evolved amid the constant exposure to these sources. These types of sources are referred to as natural or background sources. In the last 100 years, exposure to radioactivity has occurred with the use of radioactive material by man. Often naturally occurring radioactive elements are mined and concentrated for medical or research purposes. Also, radioactivity is induced by high-energy particle bombardment in particle accelerators and by neutron activation in nuclear reactors. The testing of nuclear weapons has also contributed. These sources of radioactivity are often termed manmade or technology-enhanced.

Humans receive radiation doses from these natural and manmade sources by external exposure and through internal exposure by inhalation or ingestion of radioactive material. Each individual normally carries within his body small amounts of radioactive material derived from food, water or air. Some tissues and organs serve as depositories for certain radioactive materials. For example, radioactive iodine-131 tends to accumulate in the thyroid gland and radioactive radium-226 tends to accumulate in the bones. So, even in the absence of manmade sources of radiation, humans normally contain small amounts of radioactive material.



note: only primary branches are shown

FIGURE 10: URANIUM 238 DECAY CHAIN

The radiation levels measured from the earth's crust vary throughout the world. This is due primarily to the nonuniform distribution of radioactive elements in the earth's crust. Radioactive ore bodies are concentrated in relatively few locations and vary in percent of radioactive elements present. Also, an ore body can be near the surface or as much as several hundred feet below the land surface. These factors account for the fluctuations in radiation measurements at ground level

In addition to variations in radiation levels from the earth, there are variations in the levels of cosmic radiation. These variations are primarily related to altitude, with increasing levels associated with an increase in elevation. For example, Aiken, South Carolina and Dallas, Texas have cosmic radiation levels of 3.7 and 3.6 uR/hr, respectively. This is about 60 % of those recorded for Fort Collins, Colorado and Elko, Nevada (5.8 uR/hr). South Carolina and Texas have mean elevations of 350 and 1,700 feet, while Colorado and Nevada have mean elevations of 6,800 and 5,500 feet. (Table 6) (51).

A comparison of terrestrial radiation levels for these cities also shows a marked difference. The two western cities have measured levels in the 8.3-9.2 uR/hr. range while Dallas, Texas and Aiken, South Carolina record 2.9 and 2.7 uR/hr (Table 6). A review of this table further illustrates geographic differences in gamma radiation levels measured in 22 U.S. cities in 1965.

In comparing the exposure of humans from different sources of radiation, including natural background, the International Atomic Energy Agency in Vienna, Austria, used the pie chart reproduced in Figure 11. This figure was constructed for the United Kingdom, but it is generally applicable to other developed countries. It shows that industrial and commercial sources contribute 0.6% of the total radiation exposure to human populations while natural background and medical sources account for 98.3%. Uranium exploration and mining are included in the 0.45% occupational exposure contribution.

Individuals living in different parts of the United States are exposed to different levels of natural radioactivity. Radiation doses to humans are expressed in rems (roentgen equivalent man). The rem is used to account for the fact that some types of radiation cause more biological damage than others. The following table illustrates different radiation does units (Table 7). In Table 8, we see that the average annual external gamma whole body dose from terrestrial radioactivity is about 60 mrem/person (52). Measurements were made in 36 states and territories of the United States. Measurements of Michigan levels were not made but were assumed to be equal to the U.S. average.

The total annual dose rate to the average U.S. citizen from radioactive material in the earth and from cosmic radiation is about 100 mrem per year (51). In Table 9, which is taken from the publication Radiation in Medicine and Industry-Nuclear Radiation Facts and Figures (53), the average radiation dose in Michigan due to natural background is given as 80 mrem/person/year.

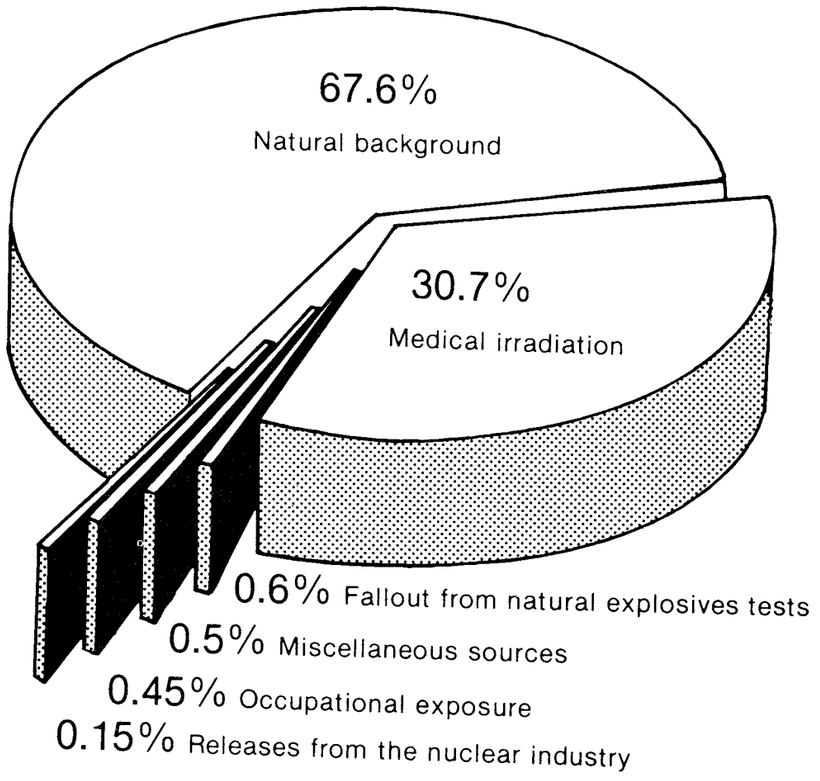
Table 6 Terrestrial and Cosmic Gamma Radiation Levels Measured in the United States, 1965 (uR/hr)[1] (51).

Location	^{40}K	^{238}U + Dtrs[2]	^{232}Th + Dtrs[2]	Total Terres-trail	Cosmic	Total
Aiken, S.C.	0.1	1.2	1.4	2.7	3.7	6.4
Dallas, Tex.	0.6	0.9	1.4	2.9	3.6	6.5
Reno, Nev.	1.3	1.0	1.8	4.1	5.5	9.6
Rapid City, S.D.	1.1	1.5	1.7	4.3	4.7	9.0
Spring Valley, Minn.						
Salt Lake City, Utah	1.8	1.1	2.1	5.0	5.7	10.7
New Orleans, La.	1.9	1.2	2.6	5.7	3.5	9.2
Goleta Beach, Calif.	2.6	1.5	1.7	5.8	3.6	9.4
Largo, Md.	1.8	1.5	2.9	6.2	3.6	9.8
Pelham, N.Y.	2.2	1.3	3.0	6.5	3.6	10.1
Sundance, Wyo.	2.2	1.9	2.4	6.5	5.6	12.1
Argonne, Ill.	2.0	2.2	2.4	6.6	3.8	10.4
Sioux Falls, S.D.	2.1	1.8	3.0	6.9	4.1	11.0
Carlisle, Pa.	2.4	1.5	3.0	6.9	3.	10.6
Chadron, Neb.	2.3	1.7	3.3	7.3	4.8	12.1
New York, N.Y.	2.2	1.4	4.2	7.8	3.6	11.4
Alamagordo, N.M.	2.8	2.1	3.3	8.2	5.0	13.2
Fort Collins, Colo.	2.5	1.8	4.0	8.3	5.8	14.1
Elko, Nev.	2.7	3.0	3.5	9.2	5.8	15.0
Bonny Doon, Calif.	7.8	1.4	1.8	11.0	4.1	15.1
Denver, Colo. (various locations)	(2.3-3.9)	(1.3-2.4)	(3.4-7.4)	(7.1-13.2)	(5.9-6.0)	(13.0-19.2)
Rolesville, N.C.	5.2	2.3	10.2	17.7	3.7	21.4

1 uR/hr = 8.8 mR/year.
2 Dtrs. = Daughters.

Figure 11.

RADIATION EXPOSURE FROM DIFFERENT SOURCES



Adapted from National Radiological Protection Board publication NRPB-R77.

Table 7. Radiation Dose Units

Unit	Abbrevation	Definition	Comment
roentgen milliroentgen* microroentgen*	R (mR) (uR)	represents the absorption of energy in air	for X-rays and gamma rays only
radiation absorbed dose, or millirad	rad (mrad)	represents the absorption of 100 ergs of energy per gram of material	important unit because it represents how much energy is absorbed in the material of concern
roentgen equivalent man (or dose equivalent), or millirem	rem (mrem)	this unit is the product of the amount of energy absorbed (rad) times the efficiency of radiation in producing damage (QF)** rem = rad x QF	this unit accounts for the different degrees of damage produced by equal doses of different radiations, for example: X-rays, gamma rays, and beta particles.....QF=1 neutrons.....QF=2 to 10 alpha particles.QF=10 to 20

* A milliroentgen is one thousandth of a roentgen
A microroentgen is one millionth of a roentgen

** QF = Quality Factor. Since the QF for beta, gamma and X-radiation is 1, the rem and the rad are equivalent in this instance and are frequently used interchangeably.

Table 8. Estimated Annual External Gamma Whole-body Doses from Natural Terrestrial Radioactivity in Millirems Per Person (52, 53).

Political Unit	Average Annual Doses	Political Unit	Average Annual Doses
Alabama	70	New Jersey	60
Alaska	60*	New Mexico	70
Arizona	60*	New York	65
Arkansas	75	North Carolina	75
California	50	North Dakota	60*
Colorado	105	Ohio	65
Connecticut	60	Oklahoma	60
Delaware	60*	Oregon	60*
Florida	60*	Pennsylvania	55
Georgia	60*	Rhode Island	65
Hawaii	60*	South Carolina	70
Idaho	60*	South Dakota	115
Illinois	65	Tennessee	70
Indiana	55	Texas	30
Iowa	60	Utah	40
Kansas	60*	Vermont	45
Kentucky	60*	Virginia	55
Louisiana	40	Washington	60*
Maine	75	West Virginia	60*
Maryland	55	Wisconsin	55
Massachusetts	75	Wyoming	90
Michigan	60*	Canal Zone	60*
Minnesota	70	Guam	60*
Mississippi	65	Puerto Rico	60*
Missouri	60*	Samoa	60
Montana	60*	Virgin Islands	60*
Nebraska	55	District of Columbia	55
Nevada	40	Others	60*
New Hampshire	65	Total United States	60

* Assumed to be equal to the United States average

Table 9. Average Doses and Dose Rates
From Various Radiation Sources (52)

Source	*Amount of Radiation
Natural Background	
Florida	60 mrem/yr
Michigan	80 mrem/yr
Colorado	145 mrem/yr
U.S. average	100 mrem/yr
Medical Diagnosis	
Average (US)	75 mrem/yr
Chest film	10 mrem/film
Dental X-ray	300 mrem/film
Nuclear Power	
Maximum dose to a member of the public who remains continuously for one year at the site boundary of a typical 1,000 megawatt, electric boiling water reactor (Ref.2)	4.6 mrem/yr
Maximum dose to a member of the public who remains continuously for one year at the site boundary of a typical 1,000 megawatt, electric pressurized water reactor (Ref.2)	1.8 mrem/yr
Code of Federal regulations, Title 10, Part 50, Appendix 1 specifies the upper limit allowable dose to a member of the public remaining continuously for one year at the site boundary of a typical 1,000 megawatt, electric boiling water reactor or pressurized water reactor	5.0 mrem/yr
Three Mile Island accident (50-mile radius, average total dose per person)	1.4 mrem
Consumer Products	
High voltage color television sets (dependent on age and type of set, distance of viewer, etc.); wrist watches; smoke detectors	0.03 mrem/yr
Air Flight	
Los Angeles - London, round trip	4 mrem/trip
Global Fallout	4 mrem/yr

*These numbers will vary slightly in different publications.

3. Biological Effects of Radiation

Absorption of physical energy from ionizing radiation can damage or kill a cell. The absorbed energy causes ionization or excitation of molecules within the cell. For example, the excitation of water will produce extremely reactive free radicals (electrically neutral molecules containing an unpaired electron) which may then interact with biologically important macromolecules such as proteins and nucleic acids. These indirect reactions or the direct irradiation of these biologically important molecules may cause a variety of cellular and biochemical effects. The result is either cell death which, depending on the extent, could lead to malfunctioning or death of an organ, or a nonlethal change that may be expressed after a period of time, such as mutagenesis and carcinogenesis.

Cells vary in their sensitivity to radiation. The cells most sensitive to ionizing radiation are generally those that divide rapidly, while slowly dividing cells, completely differentiated cells, and other cells no longer undergoing mitosis are the most radioresistant. This principle was first recognized in 1906 by Bergonie and Tribondeau who stated that, "the radiosensitivity of cells is related directly to their reproductive capacity and indirectly to their degree of differentiation".

Based on this observation, five classes of radiosensitivity were developed. Cells having the highest sensitivity to radiation constitute the first class and include rapidly dividing types such as hematopoietic stem cells, cells of the intestinal lining, type A spermatogonia, germinal cells of the skin and granulosa cells of ovarian follicles. The second class contains cell types that are less sensitive to radiation. These include cells of the hematopoietic system, spermatogonia and oocytes that are undergoing some degree of differentiation. The third class contains cells that divide irregularly and are therefore intermediate in radiosensitivity. Included in this class are endothelial cells and fibroblasts. The fourth and fifth classes consist, respectively, of cells that only slowly divide or cells that have completely lost the ability to divide and are well differentiated. The fourth class are relatively radioresistant cells which include: ephithilial cells; duct cells of the salivary glands, liver, kidney, and pancreas; and cells of the adrenal, thyroid, parathyroid, and pituitary glands. Fifth class cells that are the most radioresistant are neurons, some muscle cells, erythrocytes, spermatozoa, and epithelial cells of the sebaceous glands.

There are several repair mechanisms available to the cell and organ that can offset some or all of the damage inflicted by radiation. However, the success of such repair is dependent on the extent of damage and the type of cell composing the tissue. For example, tissues containing rapidly dividing cells such as bone marrow, intestinal lining, and the developing embryo may undergo cell division before the repair process has time to correct the damage.

4. Health Consequences of Radiation Exposure

a. Dose relationship

The adverse health effects associated with high doses of ionizing radiation have been elicited from studies of laboratory animals and epidemiological studies of exposed humans. Studies have been conducted on the survivors of the nuclear explosion in Japan, Japanese fishermen, Marshall

Island residents exposed to nuclear weapon test fallout, and persons treated with radiation in medical therapy (52).

Based on these studies, it is known that deposition of sufficient energy in a particular organ will cause cell death, which, if sufficiently extensive, will lead to a malfunctioning of the organ or eventually its death. Symptoms associated with acute radiation damage include nausea, vomiting, diarrhea, skin lesions and cataracts. Death from high levels of exposure may be due to destruction of the gastrointestinal tract (gastroenteric syndrome), cardiovascular degeneration or damage to bone marrow cells. The onset of these effects is rapid and their severity and incidence are dose-dependent. Adverse health effects of this nature are generally referred to as acute radiation damage and can occur following a whole-body exposure of 50 rem and greater (Table 10). However, exposure levels of this magnitude are only likely to occur under extreme situations such as nuclear accidents or nuclear warfare.

Generally, the higher the dose, the more drastic are the effects and the sooner they appear. A thousand rem of acute whole-body exposure will kill any human within one or two weeks from blistering of the lining of the small intestine. If a number of humans are exposed to 350 rem (350,000 millirem) of acute, whole-body X-rays, approximately one-half the number will die of blood and bone marrow damage within the first 60 days.

Very large doses of radiation exposure also seem to accelerate the normal aging process. That is, persons exposed to very large doses of radiation may age more rapidly than those who are unexposed. Doses of between 50 rem (50,000 millirem) to 350 rem (350,000 millirem) and upward can produce a variety of subtle effects, including various degrees of nausea, vomiting, diarrhea, reddening of skin, loss of hair, blisters, a depression of the number of blood and bone-marrow cells and a decreased efficiency of immune response to infections.

Doses of between 25 and 50 rem (25,000 and 50,000 millirem) can produce measurable clinical (disease-related) effects in adult humans. In the human fetus, especially in the first trimester, injuries can be sustained from doses of from 1 to 10 rem (1,000 to 10,000 millirem). At later growth stages, the fetus is not as radiosensitive, but is still quite vulnerable.

At 4,000 to 12,000 mrem, following cardiac catheterization procedures, an increase in chromosome aberrations sometimes is observed wthin 30 minutes after human exposure. At 2,000 to 5,000 mrem, a reduction of as much as 35 percent in lymphocyte count can be observed in humans. At 1,000 to 3,000 mrem, the sensation of light can be produced in human subjects and is probably an effect on peripheral rod cells of the eye.

In addition to acute damage from radiation exposure there is also strong evidence that the induction of delayed somatic effects may occur. Animal studies and epidemiological studies of humans have clearly shown that ionizing radiation is leukemogenic, carcinogenic and mutagenic at high dosages. For example, laboratory animals exposed to sublethal doses of radiation have significantly shortened life spans due to death from cancer than the control animals. These studies have also demonstrated a dose-dependent leukemogenic effect for ionizing radiation.

TABLE 10. A Summary of Acute Dose-Response Effects in Humans

Dose (rem)	Dose (mrem)	Effect
10,000	10,000,000	Immediate prostration, comma, followed by death within 1 or 2 days from severe central nervous system damage.
1,000	1,000,000	Immediate nausea, vomiting, diarrhea. Death within 1 or 2 weeks from blistering of small intestine. Complications from depressed bone marrow activity.
100	100,000	No overt effects. Some depression of white cell count. Statistical increase in probability of radiogenic leukemia and life shortening (1 to 5 days/rem).
10	10,000	Effects are difficult to measure. In early embryo, developmental defects are possible. Subtle abnormalities of brain structure and perhaps also function may occur above 10 rem.
1	1,000	No measurable effects except a statistical increase of tumor incidence before age of 10 in infants exposed in utero.
		Subacute - clinical effects are unmeasurable with current technology

b. Carcinogenic and mutagenic effects

Although the toxic effects of high doses of radiation are well understood (Table 10), the health effects associated with low level exposure (less than 1,000 mrems) to radiation are questionable. This is due to the uncertainties associated with dose-response projections in the low dose range and specifically, whether the dose-response relationship is linear or nonlinear and whether there is a no-effect threshold.

Low level exposure to radiation has been associated with various somatic effects such as leukemia, cancer and shortened lifespan in addition to genetic mutations. Unlike the cell damage and death associated with acute radiation, low level radiation is less likely to kill or damage cells, thus allowing the body's repair processes to correct the damage. However, if cell division occurs before the damage is corrected, serious genetic flaws may be incorporated into future generations of cells which may later manifest themselves as malignacies or genetic changes. Since the appearance of these effects may be delayed for years, they present a serious concern in dealing with low level exposure.

Several mechanisms have been postulated that could explain radiation-induced carcinogenesis. One of the most popular theories proposes the production of breaks or mutations in the DNA molecule from either a direct hit of radiation energy or from the production of reactive radicals such as those generated by irradiation of water in the cell. Another theory suggests that rather than direct damage to the genetic material, irradiation may damage various mechanisms that regulate the expression of the genetic material. For example, information regulating cell growth may be repressed. Other investigators have proposed mechanisms that involve the activation of an inert virus resulting in destructive infection and changes in the antigens of the cell membrance which could disrupt the control of cell growth by contact inhibition.

The genetic effects from low level exposure to ionizing radiation can occur because of the high radiosensitivity of spermatogonia and oocytes in the early states of differentiation. Irradiation of these cells may result in an alteration or breakage of their DNA. If this is sufficiently extensive, the genes responsible for carrying the genetic information necessary to govern cellular functions and the nature of future offspring may be changed.

Alteration of a single gene can result in several types of mutations. Dominant mutations show up quickly in successive generations of cells and include such anomalies as neurofibromatosis and achrondoplasia. Recessive mutations are usually delayed in their expression resulting in diseases such as cystic fibrosis and Tay-Sachs. In addition to dominant and recessive mutations, there are sex-linked mutations such as color blindness in males. Multifunctional-type mutations are another type which include complex disorders involving the interaction of an altered genome and environmental factors. Birth defects and diseases developing later in life such as heart disorders, asthma, diabetes and hypertension are included in this group.

Besides the induction of mutations in the DNA strand, chromosomal breaks may also occur following exposure to radiation. Although the majority of these defects are spontaneously aborted, several are expressed, the most common being Downs Syndrome.

Genetic effects from radiation can range from trivial to lethal. However, as stated earlier, the incidence and severity of these effects is generally dose-dependent. Though genetic effects are well documented in laboratory animals exposed to high levels of ionizing radiation, the frequency and nature of genetic effects in humans exposed to low level radiation is unclear. For example, long term studies of bomb survivors at Hiroshima have as yet been unable to detect an increased incidence of genetic effects in offspring of this group.

c. Specific effects associated with uranium mining

Radon and its daughter products have been studied in relation to uranium mining and are known to cause serious health effects if inhaled over long periods of time. Radon daughters attach themselves to larger dust particles and water droplets and can be inhaled. Once in the lungs, they become lodged in close contact with tissue. Radon daughters emit radiation, which can cause the cellular changes that induce cancer.

Epidemiological studies of uranium miners in Colorado and Ontario indicate a higher incidence of lung cancer than expected. The investigators suggest that the higher incidence of cancer was related to radon gas which emanates into the mines and whose radioactive daughters then become attached to dust particles. Inhalation of this dust by the workers resulted in alpha irradiation of the lung. This lung cancer is believed to be the result of high level exposure which occurred before control measures were enforced in uranium mines.

d. Risk assessment of low dose of radiation

The health effects associated with low-level radiation, as produced by uranium ore, is a controversial issue. While there are many uncertainties associated with health effects of low-level radiation, there appears to be general agreement that no specific level of radiation, including background levels, can be characterized as safe or risk free. In other words, there is no definitive radiation level above which exposures are generally agreed to be "unsafe" and below which exposures are generally thought to be "safe" (56).

Risk assessment is an analytical process to estimate the probability of occurrence of an adverse health effect in humans from work or recreational activities or following exposure to a specific toxic agent. This process involves an assessment of the toxicological properties of the agent in addition to its exposure potential for a given situation. It is not limited only to radiation hazards.

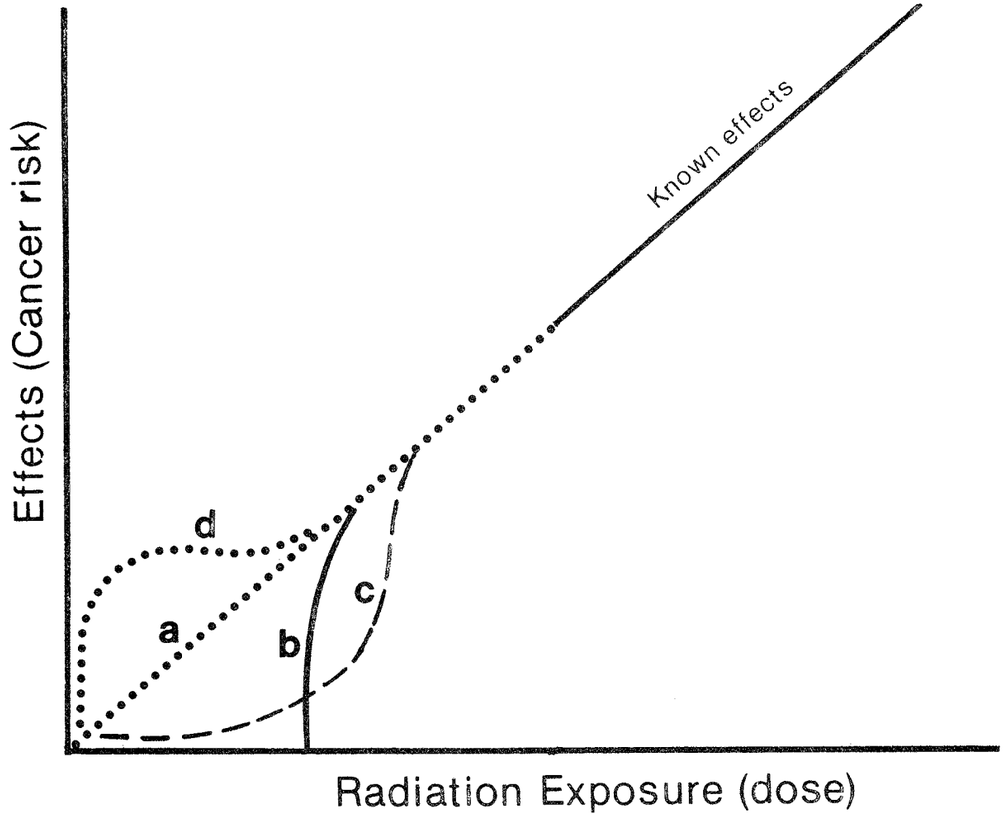
Before a calculation of risk to human health from exposure to radioactive material can be performed, several decisions must be made regarding which harmful effect of radiation best serves as an index of risk and which mathematical extrapolation model will provide an accurate calculation of risk. Most studies of radiation exposure select carcinogenicity or mutagenicity (birth defects, specifically) as suitable endpoints for determining risk. Their selection is based on the assumption that these adverse effects lack a dose-response threshold and therefore, will occur in the exposed population at some frequency down to zero dose.

The absence of a threshold for carcinogenicity and mutagenicity is difficult to prove as only a small proportion of exposed individuals will demonstrate any effects at low levels of exposure. This is complicated further by the delayed time for expression of these effects. For example, various types of cancer may not show up in the exposed population until 5 to 40 years after the initial exposure.

Therefore, because it's not possible to prove conclusively that a threshold exists below which no effects would occur, it is assumed for purposes of risk assessment that there is no threshold limit and the fraction of individuals affected would be proportional to the dose down to zero.

The choice of an accurate extrapolation model is complicated by the same factors that do not allow demostration of the absence or presence of a threshold. Given that a threshold does not exist for these effects, there are still a number of paths the dose-response curve can follow as it approaches zero. (Figure 12). Since none of the hypotheses that generate these various curves can be clinically proven, the dose-response curve is assumed to be linear (Figure 12, curve a) and therefore may be used in an estimation of risk.

Figure 12.
Some proposed models of how the effects of radiation vary with doses at low levels.



At present, the assessment of the risk from low levels of radiation exposure is estimated by extrapolation of the results obtained from populations exposed to high doses of radiation (e.g., atomic bomb survivors, individuals treated with x-rays, laboratory animals exposed to high doses, and uranium miners exposed to radon gas) by application of the linear model. The Biologic Effects of Ionizing Radiation (BEIR) Report (57) assumes the validity of the linear extrapolation model for risk assessment and has used it to estimate the excess number of cancer deaths per year in the United States population following exposure to 100 mrem per year.

The calculations indicate that this level of exposure would cause between 1,700 to 9,000 cancer deaths per year. There are approximtaly 311,000 naturally occurring cancer deaths per year. Since naturally occurring background radiation is approximately 100 mrem per year, about 0.6 percent to 2.9 percent of the naturally occurring cancer deaths are the result of exposure to this background radiation. Using these figures the lifetime risk of cancer death for a population exposed to 100 mrem of radiation per year is between 9.0 to 46.0 deaths per one million individuals. Therefore, an individual receiving a dose of 100 mrem per year would have a probability of death from cancer of 0.9 to 4.6 in 100,000.

In the occupational setting, where there is a 5 rem per year maximum permissible level for workers, a risk of 4.5 to 24.0 in 10,000 is calculated. Approximately one-fifth of these deaths would be from leukemia.

The International Commission on Radiological Protection is currently considering an acceptable level of annual mortality due to radiation exposure of 1 in 10,000. This would be 4.5 to 24.0 times lower than the risk calculated above for the worker's exposure to 5 rem per year. However, it should also be pointed out that studies by the International Commission on Radiological Protection have shown that the average radiation worker is exposed to only 0.5 rem per year and that very few workers receive a dose approaching the 5 rem per year maximum level. In view of this finding, the Commission has agreed to use the 0.5 rem level as the average dose received by radiation workers. This level of exposure would result in a risk of 0.45 to 2.4 in 10,000 which now brackets the 10^{-4} (1 in 10,000)proposed acceptable risk.

As a means of comparison, Table 11 lists the risks of death per 10,000 individuals per year for various occupations and recreational activities.

Besides the induction of cancer, radiation may also cause genetic effects as the result of damage to the DNA of sperm and ova. Estimates of the frequency of all genetic effects are based primarily on animal experiments. Epidemiological studies of humans exposed to radiation, specifically atomic bomb survivors, have not as yet shown any genetic effects. Therefore, the animals studies may provide an upper limit for the risk of genetic effects due to radiation exposure.

Table 11. Risks of Death per 10,000 per Year

Recreational Actitivies	
Football	0.4
Skiing	0.3
Canoeing	4.0
Motorcycle racing	180.0
Occupations	
Coal Mining, black lung disease	1000
Firefighters	100
Steel workers	6
Railroad workers	40

Reference: Chemical and Engineering News, January 30, p.35 (1978)

To minimize the genetic effects the International Commission of Radiological Protection has recommended a 5 rem maximum exposure level over a reproductive lifetime of 30 years for the general public. This corresponds to approximately 170 mrem per year which is slightly higher than the 100 mrem background value.

The BEIR Report has estimated the number of genetic effects produced by a radiation exposure of 170 mrem per year and they are expressed as the number of first generation genetic effects per one million live births. These estimates range from 120 to 1080 in one million or in other words, given an annual total of 3 million live births in the United States, from 0.012 to 0.11 percent of live births would be affected. Although many of these genetic effects will have a minimal impact on the individuals health, 10 to 20 percent may result in early death.

Assuming a worst case situation of a worker exposed to the maximum permissible level of 5 rem per year using the above figures, the incidence of genetic effects would range from 3,500 to 32,000 per one million live births (0.4 to 3.2%). A 0.5 rem average level of exposure to the radiation worker results in a risk of 350 to 3200 in one million (0.04 to 0.32%).

Given a normal incidence of 180,000 to 300,000 genetic effects per 3 million live births, the 170 mrem per year exposure to the general population would correspond to an increase in those born with genetic effects of 0.0012 to 0.018 percent. For workers exposed to doses of 0.5 rem per year and 0.5 rem per year this would result in ranges of 0.0035 to 0.05 percent and 0.035 to 0.5 percent, respectively.

Epidemiological studies of uranium miners in Colorado and Ontario strongly indicate a relationship between high exposure to radon gas and increased incidence of lung cancer. The risk of lung cancer from low level exposure was

determined in the BEIR Report by applying the linear extrapolation model to data obtained from uranium mines in the United States over the period of 1951 to 1971. The report concluded that each Working Level Month (WLM) of exposure resulted in approximately 3.2 excess cases of lung cancer per one million workers per year. Given that the maximum permissible exposure to radon daughters is 4 WLM per year for uranium miners and 0.02 WL per year for the general public, estimation of the risk would be 13 and 0.064 excess cases of lung cancer per one million individuals, respectively.

Given the above calculations of risk to cancer or genetic anomalies from exposure to ionizing radiation it is important and appropriate to reexamine the numerical risk assessment process and underscore the assumptions necessary for its use. Given the absence of well defined epidemiological studies in terms of levels of exposure and corresponding response rates, the dose-response relationship of chronic health effects versus radiation dose are based on laboratory animal studies. Extrapolation from these studies to the human situation calls for the assumption that there are no basic metabolic or kinetic differences between laboratory animals and man. The use of mathematical models which serve as vehicles for this extrapolation also dictates the acceptance of various assumptions which further restrict the scientific basis of risk assessment such as: linear extrapolation outside the experimental data from one point on the dose-response curve and the absence of any repair mechanisms. All of these assumptions tend to influence conservatively the estimation of risk, however, from the standpoint of establishing guidelines which are designed to adequately protect human health, this approach to risk assessment is necessary especially when faced with the alternative "wait-and-see" approach.

Assuming the non-threshold nature of the risk assessment models means there will always be some risk associated with any level of radiation above zero. It now becomes a matter of defining a level of acceptable risk. Mantel and Bryan (54) define "virtual safety" as a risk less than or equal to 1 in 100 million for a lifetime. The FDA however, in 1977, considered a risk of 1 in 1 million for a lifetime to be acceptable in terms of impact on public health (55). C. L. Comar suggests several guidelines for dealing with risks (56):

1. eliminate all voluntary or involuntary risks that have no benefit and are avoided without great cost.

2. eliminate any large risk, 10^{-4} (1 in 10,000) or greater, having no overriding benefits.

3. ignore any small risk, 10^{-5} (1 in 100,000) or less, that is not covered in number 1 above and most importantly,

4. actively study risks falling between these limits and do not proceed with action until benefits and risks are evaluated carefully.

These are very general statements and are certainly open to subjective interpretation depending on the situation. However, they serve to emphasize a very important point concerning acceptable risk. The determination of acceptable risk is not a scientific decision but rather one which must be made by society and only after a clear understanding of the benefits and the risks.

5. Radiation Standards

Recognizing that natural and manmade sources of radiation have caused lethal and may cause sublethal impacts on humans, standards for protecting the general public and occupational workers from radiation hazards have been developed. The standards have been developed primarily by three organizatons; the International Commission on Radiological Protection, the National Council on Radiation Protection and Measurement and the American National Standards Institution (53).

Since World War II, several federal agencies in the United States have been responsible for the enforcement of radiation standards. The include:

Environmental Protection Agency (EPA), successor to Federal Radiation Council (FRC)

Nuclear Regulatory Commission (NRC), successor to Atomic Energy Commission (AEC)

Department of Health and Human Services (HHS)--Bureau of Radiological Health (BRH)

Interstate Commerce Commission (ICC)

Department of Defense (DOD)--military application only

Occupational Safety and Health Administration

Table 12 indicates the three major areas of federal regulation over radiation hazards: Standards for Protection Against Radiation (10 CFR 20), Environmental Radiation Protection Standards for Nuclear Power Operations (40 CFR 190) and Interim Primary Drinking Water Regulations-Radionuclides (40 CFR 141). Table 13 identifies the array of subjects included in the radiation standards or the advisory recommendations on development of federal radiation standard policy (61).

The Standards for Protection Against Radiation (10CFR20)generally cover two areas; exposure standards for occupational workers and exposure standards for the general public. There are five general occupational areas associated with radiation exposure:

1. Medical
2. Industrial
3. Research
4. Nuclear Power Plants
5. Military

In each category all workers exposed to ionizing radiation in the course of their normal duties are regulated. The standards address the maximum permissible dose and the long-term accumulated maximum permissible whole-body dose.

Table 12. United States Government and advisory organization's documents describing regulations and recommendations on radiation standards

Regulations	
10 CFR 20,	Standards for Protection Against Radiation
40 CFR 190,	Environmental Radiation Protection Standards for Nuclear Power Operations
40 CFR 141,	Interim Primary Drinking Water Regulations - Radionuclides
Recommendations	
NCRP Report 39,	Basic Radiation Protection Criteria
NCRP Report 42,	Radiological Factors Affecting Decision-Making in a Nuclear Attack
NCRP Report 43,	Review of the Current State of Radiation Protection Philosophy
NCRP Report 46,	Alpha-Emitting Particles in Lungs
NCRP Report 48,	Radiation Protection for Medical and Allied Health Personnel
NCRP Report 50,	Environmental Radiation Measurements
NCRP Report 52,	Cesium-137 from the Environment to Man: Metabolism and Dose
NCRP Report 53,	Review of NCRP Radiation Dose Limit for Embryo and Fetus in Occupationally-Exposed Women
NCRP Report 54,	Medical Radiation Exposure of Pregnant and Potentially Pregnant Women
NCRP Report 55,	Protection of the Thyroid Gland in the Event of Releases of Radio-iodine
NCRP Report 56,	Radiation Exposure from Consumer Products and Miscellaneous Sources
HEW/BRH,	Regulations, Standards, and Guides for Microwaves, Ultraviolet Radiation, and Radiation from Lasers and Television Receivers-An Annotated Bibliography
NBS Handbook 69,	Maximum Permissible Body Burdens and Maximum Permissible Concentrations of Radionuclides in Air and Water for Occupational Exposure
ICRP Publication 6	Recommendations of the International Commission on Radiological Protection
ICRP Publication 8	The Evaluation of Risks from Radiation
FRC Report 1,	Background Material for the Development of Radiation Protection Standards
Federal Register 9/26/81,	Federal Radiation Council: Radiation Protection Guidance for Federal Agencies
FRC Report 5,	Background Material for the Development of Radiation Protection Standards (Iodine-131)
FRC Report 8,	Guidance for the Control of Radiation Hazards in Uranium Mining
NAS Analytical Studies for US EPA, Vol. VI,	Implications of Environmental Regulations for Energy Production and Consumption

TABLE 13. ARRAY OF SUBJECT AREAS COVERED BY FEDERAL GOVERNMENT AND ADVISORY ORGANIZATIONS IN REGULATIONS AND RECOMMENDATIONS FOR RADIATION STANDARDS

	10 CFR 20	40 CFR 190	40 CFR 141	NCRP Report 39	NCRP Report 42	NCRP Report 43	NCRP Report 46	NCRP Report 48	NCRP Report 50	NCRP Report 52	NCRP Report 53	NCRP Report 54	NCRP Report 55	NCRP Report 56	NEW/DRH	NBS Handbook 69	ICRP Publication 6	ICRP Publication 8	FRC Report 1	Federal Register 9/26/61	FCR Report 5	FCR Report 8	NAS Analytical Studies for US EPA
Personal dosage limits	X	X	X	X		X		X		X	X			X	X	X	X			X	X	X	X
Minors	X			X		X				X													
Pregnant women and fetuses				X		X				X	X	X							X				
Medical and dental exposure	X			X				X				X		X									
Drinking water contamination			X																				
Environmental effects - radioecology		X	X	X					X											X	X		X
Biological effects - somatic and genetic				X		X	X	X		X			X	X	X	X	X		X	X	X	X	X
Manmade sources - consumer products								X						X	X								
TV sets														X	X								
Lasers															X								
Radionuclides (general)	X													X		X	X			X			
Tritium			X										X										
Iodine		X								X										X	X		
Cesium			X																				
Radium			X																	X		X	
Radon and daughters		X																					
Uranium		X																				X	
Plutonium and transuranics		X																				X	
Alpha emitters		X	X				X																
Beta and photon emitters			X																				
Strontium			X																				
X-rays						X		X						X	X					X			
Microwaves														X	X								
Ultraviolet radiation														X	X								
Nuclear power		X																					X
Uranium fuel cycle		X																					X
Uranium mining																							
Workroom standards	X	X																				X	X
Occupational exposure	X	X		X		X		X			X					X			X			X	X
Waste disposal	X																						X
Caution sign	X																						
Records and reports	X							X															
Loss and theft of radioactive material	X																						
Risks of radiation																		X				X	X
Radiation protection criteria				X															X				
Radiation protection costs																						X	X
Radiation protection philosophy						X																	X
Accidents, terrorism, or nuclear attack	X			X	X								X										X

The National Council on Radiation Protection and Measurements (NCRP) defines the maximum permissible dose as the highest dose of ionizing radiation (from external and internal sources) that is not expected to cause appreciable bodily injury to a person at any time during his or her lifetime. This standard is set in light of present knowledge and is subject to continual review by the NCRP. The standard varies for different parts of the body. For example, the maximum permissible occupational dose for whole-body (internal and external organs) exposure is not to normally exceed 1,250 mrem (1.25 rems) per quarter year. Occupational dose of the skin of the whole body is set at 7,500 mrems (7.5 rems) per quarter year. The dose to hands, forearms, feet and ankles is not to exceed 18,750 mrem (18.75 rems) per quarter year.

Since it is known that most tissue and organs are more sensitive to radiation in the early stages of fetal development, the most restrictive standards are directed at pregnant women. Women who are exposed to ionizing radiation in the course of their work are limited to a radiation dose no greater than 500 mrem (0.5 rem) for the entire period of gestation.

As noted earlier, occupational workers exposure is regulated not only for the maximum permissible dose, but also regulated for the long-term accumulated maximum whole-body dose. This latter standard recognizes the accumulated effect of continual exposure to ionizing radiation. The standard does not allow any person 18 years or younger to be occupationally exposed. To calculate a worker's long-term accumulated maximum permissible whole-body dose, the following formula is used which takes into account the person's age.

5000 (N-18) = maximum accumulated dose in mrem.
N is the age of each worker in years.

Thus, a 20-year old worker can receive only 10,000 mrem in accumulated dose while a 40 year old worker can receive up to 110,000 mrem, but neither can receive more than 3000 mrem/quarter year during one year.

For the general public the National Council on Radiation Protection recommends that exposure from all man-made radiation sources to a single maximally exposed individual should not exceed 500 mrems/year. However, to account for very young (under 18), very old and pregnant individuals, the recommended average annual dose rate is 170 mrem/year. Specific regulations limit the contribution to this total from the uranium fuel cycle. Members of the public are not to receive more than 25 mrems/year from the total nuclear fuel cycle (uranium mining, milling, fuel fabrication, power plant operation and waste disposal). Out of these five stages, a nuclear power plant is to be designed and operated to meet a dose limit of 5 mrems/year at the property boundary of the facility. This limit assumes conditions under which a member of the public would remain continuously at the property boundary for one year.

Sources controlled by the Nuclear Regulatory Commission include byproduct material, source material, and special nuclear material. By definition, source material means uranium or thorium, or any combination thereof, in any physical or chemical form or ores which contain by weight 1/20 of 1% (0.05%) or more of uranium, thorium, or any combination thereof. Source material does not include special nuclear material. Also, by definition, special nuclear material in quantities not sufficient to form a critical mass means uranium

enriched in the isotope U-235 in quantities not exceeding 350 grams of contained U-235; uranium-233 in quantities not exceeding 200 grams; plutonium in quantities not exceeding 200 grams; or any combination of them in accordance with the following formula: for each kind of special nuclear material, determine the ratio between the quantity of special nuclear material and the quantity specified above for the same kind of special nuclear material. The sum of the ratios for all kinds of special nuclear material in combination shall not exceed "1" (i.e., unity).

In Michigan, the promulgation and enforcement of ionizing radiation regulations is divided between the federal and state governments. As can be seen in Table 14, the Michigan Department of Public Health has adopted the standards recommended by the National Council on Radiation Protection (NCRP).

Taole 14. Maximum Permissible Dose Equivalent for Occupational Exposure, Non-Occupational Exposure and General Population Dose Limits.

Occupational Exposure	
Dose to the whole body	1.25 rem per quarter
Skin of whole body	7.5 rems per quarter
Hands	18.75 rems per quarter
Fertile women (with respect to fetus)	0.5 rem in gestation period
Non-Occupational Exposure	
Individual	0.5 rem in any one year
Population Exposure	
Genetic	0.17 rem average per year
Somatic	0.17 rem average per year

Radiation levels from external sources in unrestricted areas, concentrations in effluents to unrestricted areas, and disposal by release into sewerage systems are also addressed in Michigan and NRC standards. In addition to the exposure limits in Table 14, state standards require that unauthorized persons shall not receive, acquire, possess, use, or transfer sources of radiation in such a manner as to result in an individual in an unrestricted area receiving a dose in excess of: (a) 2 millirems in any 1 hour, (b) 100 millirems in any 7 consecutive days, and (c) 500 millirems in any 1 year.

A person may apply for proposed limits of radiation in unrestricted areas in excess of those specified above resulting from the applicant's possession or use of sources of radiation. The application shall include information as to anticipated average radiation levels and anticipated occupancy times for each unrestricted area involved. The Michigan Department of Public Health shall approve the proposed limits if the applicant demonstrates to the

satisfaction of the MDPH that the proposed limits are not likely to cause any individual to receive a dose to the whole body in any period of one calendar year in excess of 0.5 rem.

State controlled radiation sources include x-ray machines, particle accelerators, material rendered radioactive by bombardment in an accelerator, radium and other naturally-occurring radioactive material, except source material and special nuclear material in quantities not sufficient to form a critical mass.

VI. REGULATORY FRAMEWORK IN MICHIGAN FOR URANIUM MINING AND MILLING

Mining and milling are considered together because these operations are generally performed in close proximity to each other. It is often uneconomical to transport crude ores very far from the mine site. Mining refers to the process of removing crude metal ores from the ground either through underground or open pit mines while the milling process concentrates and refines the ore prior to marketing and shipping.

The ore is initally crushed into a fine powder. The powder is then mixed with a liquid acid solution which dissolves the uranium oxide. The liquid with the dissolved uranium is decanted off and ammonia is added to precipitate the uranium from solution. This precipitate is dried, pulverized and is shipped as powdery "yellowcake". The liquid solution is recycled for reuse.

The disposal of waste products which must be controlled include: (1) the mill tailings which are finely ground solids in a slurry and are deposited in a settling pond and (2) small amounts of spent acid solution not recycled for reuse. Although no information was found in the literature as to how spent solvents were typically disposed, it is assumed that they are disposed in the tailings ponds.

A. Local Government -- Local units of governments may impose restrictions upon mining through the promulgation of zoning ordinances as discussed previously in the Exploration Impact section (page 48). Although most counties in Michigan do not have zoning ordinances for metallic mineral mining, the public reaction to proposed uranium mining may cause such ordinances to be promulgated.

B. State Government -- The Federal Atomic Energy Act of 1954 established certain materials as "licensable materials" to be regulated by the Atomic Energy Commission (now the Nuclear Regulatory Commission - NRC). Uranium mill tailings (the byproduct of the milling process) and yellowcake produced by milling are to be licensed. However, uranium ores and mining wastes are not licensable and states retain control over the management of these materials. In addition, the Atomic Energy Act specifically notes that nothing in the act will affect the authority of states to regulate any aspect of mining or milling operations except for regulation of radiation hazards which is reserved to the U.S. government.

   The state of Michigan currently does not have promulgated regulations dealing specifically with the mining of uranium. However, Part 135 of the Public Health Code (Act 368, P.A. of 1978) does provide for control of certain radioactive materials by the Department of Public Health. Radioactive mine wastes are subject to state control while source material, byproduct material and special nuclear material are exempt.

The Department of Public Health also has the responsibility to monitor radioactive emissions from facilities which emit or could emit significant quantities of radioactive effluents in order to assess the effect on public health and safety. Thus, if uranium mining were to take place in Michigan, the Department of Public Health could exercise a certain degree of control over their activity under the auspices of this act.

1. Surface and Groundwater Discharge

All surface water and groundwater discharges from mining and ore milling facilities are subject to state regulation. Existing mining operations with surface water discharges must have a National Pollutant Discharge Elimination System (NPDES) permit issued by the Water Resources Commission under the authority of the Water Resources Commission Act (Act 245 P.A. of 1929, as amended) and the Federal Clean Water Act (P.L. 95-217). Surface water discharges are subject to maximum effluent limits for various pollutants as set forth in Part 4 of the General Rules of Act 245. Rule 58 states that the control and regulation of radioactive substances discharged to surface waters shall be subject to standards prescribed by the Nuclear Regulatory Commission in Title 10, Part 20 of the Federal Code of Regulations. The standards presented in 10 CFR 20 are the maximum effluent concentrations that could be discharged to waters in, or which flow into, unrestricted areas. The state, in its review of an NPDES permit application, could establish more stringent effluent limits if more stringent limits were shown to be necessary to protect public health and the environment. Such a permit application would be reviewed by Department of Natural Resources, Water Quality Division and by the Division of Radiological Health within the Department of Public Health.

The Water Resources Commission Act also provides for the nondegradation of the state's groundwaters. Because seepage into the ground is likely to occur from mill tailings basins, a groundwater discharge permit could be required under the newly promulgated groundwater rules (Part 22). A permit application requires a detailed study of site geology and hydrology to evaluate the feasibility of each site to insure that groundwater degradation will not occur if a discharge is permitted. Further, if it is likely that critical materials, such as heavy metals, would be associated with the uranium ore and be present in the mill tailings, Part 5 of the Water Resources Commission rules requires the development of a Pollution Incident Prevent Plan (PIPP) to develop a method to contain accidental spills from entering the surface or groundwater.

2. Air Protection

Radioactive air emissions are regulated by the Nuclear Regulatory Commission or by the state depending on the source of the contaminants. The NRC retains control over the emissions of radioactive air contaminants from licensed facilities (i.e., milling operations) in non-agreement states. The state is only delegated control over licensed facilities upon the development of a federal-state agreement. Presently, Michigan has not entered into an agreement and any uranium milling facilities constructed in Michigan

would be licensed and radioactive emissions regulated by the Nuclear Regulatory Commission. Air emissions associated with uranium mining and defined as nonlicensed are open to regulation by the state whether or not it is an agreement state.

In Michigan, regulatory control over radioactive air pollutants lies with the Department of Public Health under the Public Health Code. The administrative rules under the act establish maximum public exposure rates to radioactivity which are based upon, but not identical to the federal limits set in 10 CFR 20. Standards for radioactive isotope emissions from federally licensed facilities are presented by NRC in 10 CFR 20. State standards have been determined by the NRC to be adequate. This is a prerequisite to delegation of authority to the state by NRC.

The Department of Public Health does maintain monitoring stations off-site of nuclear power plants to test for compliance with the state exposure limits. It could do so for uranium mining or milling operations in Michigan even if federal delegation was not received.

The Department of Natural Resources would regulate non-radioactive air pollutants from a mining or milling operation under Michigan's Air Pollution Act (Act 348 P.A. of 1965). Under this act, emission limits are placed on the criteria pollutants of carbon monoxide, sulfur dioxide, nitrogen oxides, hydrocarbons and total suspended particulates. The Air Quality Division within DNR would issue construction and operation permits on all large process machinery to control the level of emissions from this equipment. Airborne dust from the milling process can be a significant source of radioactivity if it is not controlled. For mines where fugitive dust might pose a problem, any air quality permit would also include an approvable fugitive dust control plan.

Michigan's Hazardous Waste Management Act (Act 64, P.A. of 1979), administered by the DNR, specifically excludes radioactive mill tailings from the list of substances controlled under this act. However, spent nonradioactive solvents from in-situ acid leaching processes and certain chemicals used in milling processes may fall under the purview of the act. Such wastes would have to be disposed at a licensed hazardous waste facility and would have to be manifested and transported by licensed hazardous waste haulers.

Michigan's Underground Injection Control (UIC) program administered by DNR Geological Survey Division under the Mineral Wells Act requires a permit for solution mining such as uranium acid-leach mining. Since no permit application has ever been made for a solution mining activity, specific permit application requirements are not developed. However, safeguards similar to those required for a disposal well permit would be required including initial and periodic testing fo the integrity of the well. Table 15 lists the divisions within the Department of Natural Resources which would be involved in the review of a proposed uranium mine and mill seeking permission through permits or licenses to carry out uranium mining or milling in Michigan. Table 16 lists the Michigan Department of Public Health divisions with regulatory control over uranium exploration, mining and milling.

Table 15. Department of Natural Resources programs involved in review of uranium mining and milling site specific applications.

Water Quality Division	
	Permits for wastewater or process water discharges to surface waters
	Permits for groundwater discharges
	Permits for construction and operation of a sanitary waste treatment system
Air Quality Division	
	Air quality permits (installation and operation permits) for point source discharges
	Permits for fugitive dust control
Geological Survey Division	
	Permits to drill test wells under Mineral Wells Act
	Administers mine reclamation statute
	Permits for in-situ mining under Mineral Wells Act
Land Resource Programs Division	
	Permits under Soil Erosion and Sedimentation Control Act (Act 347, P.A. of 1972)
	Permits under Inland Lakes and Streams Act (Act 346, P.A. of 1972)
Environmental Services Division	
	Administers Hazardous Waste Management Act (Act 64, P.A. of 1979)
	Permits for hazardous waste disposal sites
	Permits for waste manifest system
Resource Recovery Division	
	Permits for solid (non-hazardous) waste landfills

Table 16. Department of Public Health Regulatory programs involved in uranium exploration, mining and milling.

Radiological Health Division	
	Licenses for non-NRC licensed material contained in mine and/or mill tailings
	Environmental monitoring of exploration, mining and milling operations
	Coordination of radiological aspects of other State programs acting within their statutory authority
Water Supply Division	
	Radiological monitoring of community public water supplies for natural radionuclides

3. Michigan Environmental Review Board

In addition to specific environmental legislation administered by the Department of Natural Resources or the Department of Public Health, the Governor, through Executive Order 1974-4, established the Michigan Environmental Review Board (MERB) to review commercial, industrial, agricultural and natural resource projects with significant environmental or human health impact prior to the issuance of public health or environmental permits. This 17 member citizen and state agency board can request the preparation of an environmental impact statment by the state agency with major statutory responsibility for regulation of the project.

The approval of a uranium mining or milling permit or permits by the Department of Natural Resources and Public Health would undoubtedly be considered a major state action, especially in light of the public controversy that has been generated. Public involvement in the development of the environmental impact statement (EIS) and the use of public hearings is encouraged by the Executive Order.

4. Worker Protection

In 1967 the Michigan Mine Safety Act was passed. The Act provided for the health and safety of persons employed in and about mines; provided for the appointment, qualification, duties and compensation of mine inspectors; and created a mine safety board in the Department of Labor and prescribe its powers and duties; and to provide penalties for violations. However, this act was repealed (October 25, 1977) primarily because funding was not provided to the Department of Labor to carry out the provisions of the act. Presently, the Michigan Department of Public Health, through the occupational safety act

does not have responsibility for insuring the safety of workers in uramium mining and milling. The major source of regulation lies with the federal Mine Safety and Health Act of 1977.

C. Federal Government

Federal regulations address two environmental and health issues related to uranium mining and milling operations; the control of health conditions within uranium mines and control over materials "licensed" under the Atomic Energy Act.

1. Worker Protection

The Federal Mine Safety and Health Act of 1977, under the Department of Labor, sets guidelines in Title 30 of the Code of Federal Regulations to regulate the exposure of miners to airborne radioactive contaminants. Adequate ventilation of mine shafts is required to limit exposures to threshold limits on radon gas, radioactive dust and other radioactive isotopes produced by radon decay. The act requires that complete individual personnel exposure records be maintained. The Mine Safety and Health Act does not provide for the delegation of authority over these functions to the states. However, the states can enact more stringent health standards.

2. Environmental Protection

The Nuclear Regulatory Commission and the U.S. Environmental Protection Agency exercise regulatory control over mining and milling operations primarily through three federal laws; the Atomic Energy Act of 1954, the Resource Conservation and Recovery Act of 1976 and the Uranium Mill Tailings Radiation Control Act of 1978.

Under the Atomic Energy Act, the Nuclear Regulatory Commission has jurisdiction over licensed source materials (yellowcake) and mill byproduct materials (mill tailings). The Nuclear Regulatory Commission licenses milling operations only after the applicant has demonstrated the capability to comply with regulations contained in 10 CFR, Part 20 and Part 40. Part 20 in addition to setting exposure limits to radioactive iotopes requires the licensee to initiate and maintain both a preoperational and operational radiological monitoring program of air, water and soil samples. The Atomic Energy Act also permits the NRC to delegate to individual states some of its regulatory authority through a state-NRC agreement.

The Uranium Mill Tailings Radiation Control Act of 1978 (P.L. 95-604) was enacted to expand NRC jurisdiction over radioactive mill tailings and waste rock and to make more explicit the responsibilities of states under state-NRC agreements. The Act requires that prior to the construction of any milling operation an environmental impact statement be prepared. This EIS may be prepared under the auspices of the National Environmental Policy Act of 1970, or under an analogous state requirement. Title II of the Act established requirements for the decontamination, decommissioning, and reclamation of mill tailings at presently operating and future facilities. Although it is unclear to what extent states retain control over mill tailings prior to the full enactment of the Act in November 1981, this confusion has little significance in Michigan since no milling operation will exist before that time. The Federal Environmental Protection Agency is currently promulgating standards

applicable to the hazards associated with the processing, transfer and disposal of mill tailings.

Under the Federal Resource Conservation and Recovery Act of 1976, regulations have been proposed, but not yet adopted, which delineate two basic requirements for the ultimate disposal of radioactive waste rock from uranium mining operations. Wastes are prohibited for use as a building material (e.g., for use in cement) and the radioactive overburden must be buried under "clean" overburden.

3. State-Federal Cooperative Agreements

The Atomic Energy Act enables states to enter into a cooperative agreement with the Nuclear Regulatory Commission (62). Under such an agreement, a state can assume some of NRC's regulatory control over "licensable" materials, including uranium mill tailings and yellowcake. It also grants the state ability to license mill operations. A state-NRC agreement can also provide for joint inspections of facilities and permit the NRC to provide training and other assistance to the state.

The jurisdictional transfer is accomplished through an agreement between the Nuclear Regulatory Commission and the Governor of the state. The basic prerequisite for the development of a state-NRC agreement is that the state's regulatory program be substantially equivalent to the Federal program in respect to insuring the public health and wefare and that it be in accordance with section 274(o) of the Atomic Energy Act. The state must demonstrate that its rules and regulations are sufficient for the protection of the public and that there is an adequate administrative structure to enforce the regulations. Michigan is not currently an agreement state. Although the Governor is authorized to enter into such agreements by Part 135 of the Public Health Code (Act 368, P.A. 1978) and the NRC has found the Division of Radiological Health program to be adequate with regard to byproduct, source, and special nuclear material. Citing economic conditions, the decision to enter into an agreement with the NRC has been postponed by the Governor.

VII. Post Operational Regulatory Framework in Michigan for Uranium Mines

Postoperational treatment of a uranium mining and milling operation focuses primarily upon reclaiming the site to its natural condition and reducing the radioactive emissions from the site as close to background levels as possible. The most important single activity must be the isolation of radioactive mill tailings from the environment. Radium-226 remaining in the tailings can contain 70 to 80 percent of the ore's original radioactivity and can be a significant source of radon gas. A Presidentially-appointed interagency work group in 1979 has recommended that due to their very long half lives, these mill wastes should be as carefully managed as high level radioactive wastes.

A. Local government

Local regulatory controls will be limited to zoning ordinances and would focus on site reclamation. Typical mining zoning ordinances would require a site reclamation plan as part of any application for a mining permit. The reclamation plan would include such measures as erosion control, landscaping and revegetation, the removal of structures, roads, other facilities and the

final disposal or treatment of any harmful or toxic materials left on-site. However, a municipality cannot regulate radioactive emissions by way of setting standards nor may it require the registration of radioactive materials as such local control is prohibited in Part 135, Public Health Code.

B. State government

The administrative rules under the Mine Reclamation Act (Act 92, P.A. 1979) provide for the reclamation of mine sites. The Department of Natural Resources, Geological Survey Division administers this Act. The rules provide for the landscaping of the site, backfilling holes and open pits with overburden and stockpiles and for the use of vegetative plantings to stabilize areas where erosion is occuring or likely to occur. Tailings basins are to be drained and reclaimed within practical limitations.

However, the Department of Natural Resources has no permitting authority under the Act and regulatory control is not really sufficient to insure that reclamation efforts are thoroughly carried out. In addition, the rules do not address the special problems associated with radioactive waste rock and tailings. This is one area where state regulations could be strengthened.

C. Federal government

Title II of the Uranium Mill Tailing Radiation Control Act of 1978 requires that all mill tailing licensees make necessary financial agreements for whatever postoperational maintenance and monitoring will be necessary prior to license termination. The NRC and agreements states are given the authority to require a licensee to furnish bonding in some cases. These requirements are to induce licensees to adopt decommissioning schemes that will be reliable, permanent and that will minimize the need for active care of a disposal site.

The Act also requires that following decommissioning, the licensee will transfer ownership of the mill tailings without cost to either the state or Federal government. The option as to which government, state or federal, will acquire the mill tailing and disposal site is the state's. The state retains this option whether or not the state is an agreement state.

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