URANIUM : a discussion guide

"White people came here a long time ago; took all the furs; trapped all the beaver out; and the otter and the mink, things like that; and they gathered all these things up. They went away and they left us with the bush and the rocks. It wasn't too much later they came back again. They call that logging. Cut down all the trees; white pine, red pine, cut it all down. And they left us on the bare rocks. Then they discovered uranium here. And the old man said, 'Now the sons-a-bitches are back for the rocks.' "

Gilbert Oskaboose, Serpent River Band.

"One of the central problems in the debate about the nuclear fuel cycle is ignorance. Scientists simply do not know what the effects of chronic exposure to low-level radiation are, either in people or in other biota. We can guess, based on extrapolations from victims of high-level radiation such as atomic bombs and nuclear reactor accidents like Chernobyl. We will only begin to know for sure after several more decades have passed and a large population of exposed people has been studied. In the meantime, we have to ask: 'Do we really want to live in this uncertainty? What risks are we willing to accept as a society?' "

Dr. Stella Swanson, research scientist.

National Film Board of Canada
Office national du film du Canada

Front cover photo: The Stanrock tailings wall near Elliot Lake, Ontario. This wall, over 10 metres high, is made of radioactive residues left over from an abandoned uranium milling operation.

Photo by **Robert Del Tredici**, from **At Work in the Fields of the Bomb** published by Douglas & McIntyre. Reproduced by permission.

PREFACE

This discussion guide has been prepared as a supplement to URANIUM, the National Film Board of Canada's documentary film on the consequences of uranium mining in Canada. The discussion guide attempts to address some of the questions raised by the film and focus public discussion in the context of a screening of the film.

The text was written by Dr. Gordon Edwards, with the exception of Chapter D8 which was written by Dr. Jim Harding and Chapter G8, which was written by Dr. Stella Swanson.

Dr. Robert Woollard, Dr. Rosalie Bertell, Dr. Harding and Dr. Swanson provided editorial consultation. The text was edited by Magnus Isacsson, Dale Phillips and Graydon McCrea who are, respectively, the researcher/director, producer and executive producer of the film.

All inset quotations are excerpted from the film.

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A. URANIUM AND RADIOACTIVITY

A.1. What is uranium?

Uranium is the heaviest metal that occurs in nature. It is an unstable material which gradually breaks apart or decays at the atomic level (as described in section A.2.). Any such material is said to be radioactive.

As uranium slowly decays, it gives off invisible bursts of penetrating energy called atomic radiation. It also produces more than a dozen other radioactive substances as by-products [see figure 1, p. 5].

These unstable by-products, having little or no commercial value, are called uranium decay products. One of them is a toxic radioactive gas called radon. The others are radioactive solids. They are discarded as waste when uranium is mined.

A.2. What is radioactivity?

Science teaches us that everything is made of tiny little particles called atoms. They are too small to be seen even under a powerful microscope. When a substance is radioactive, it means that its atoms are exploding (sub-microscopically) and throwing off pieces of themselves with great force. This process is called radioactive decay.

During radioactive decay, two types of tiny electrically charged particles are given off, travelling very fast. They are called alpha and beta particles.

Some radioactive materials are alpha emitters, and others are beta emitters. In addition, highly energetic rays called gamma rays are often emitted. Gamma rays are not material particles at all, but a form of pure energy very similar to x-rays, travelling at the speed of light.

A.3. Can atomic radiation penetrate living tissue?

Gamma rays penetrate through soft tissue just as light shines through a window. Beta particles have less penetrating power, travelling less than two centimeters in soft tissue. Alpha particles have the least penetrating power, travelling just a few micrometers in soft tissue, equivalent to a few cell diameters.

A.4. Is radioactivity dangerous?

Alpha particles, beta particles and gamma rays can do great harm to a living cell by breaking its chemical bonds at random and disrupting the cell's genetic instructions.

Massive exposure to atomic radiation can cause death within a few days or weeks. Smaller doses can cause burns, loss of hair, nausea, loss of fertility and pronounced changes in the blood. Still smaller doses, too small to cause any immediate visible damage, can result in cancer or leukemia in the person exposed, congenital abnormalities in his or her children (including physical deformities, diseases and mental retardation), and possible genetic defects in future generations.

Outside the body, because of their low penetrating power, alpha emitters are the least harmful while gamma emitters are more dangerous than beta emitters.

Inside the body, however, alpha emitters are the most dangerous. They are about 20 times more damaging than beta emitters or gamma emitters. Thus, although alpha radiation cannot penetrate through a sheet of paper or, in most cases, a dead layer of skin, alpha emitters are extremely hazardous when taken into the body by inhalation or ingestion or through a cut or open sore.

Uranium and most of its decay products are alpha emitters. As such, the uranium decay products are among the most toxic materials known to science.

A.5. How do radioactive elements produce other radioactive elements?

When atoms undergo radioactive decay, they change into new substances, because they have lost something of themselves. These by-products of radioactive decay are called decay products or progeny. In many cases, the decay products are also radioactive. If so, they too will disintegrate, producing further decay products and giving off even more atomic radiation.

The number which appears after the name of a substance [see figure 1, p. 5] helps to indicate its place in the list of decay products. When the numbers go down by four, an alpha particle has been emitted. When the numbers stay the same, a beta particle has been emitted. Most of the time, but not always, there is a gamma ray emitted to accompany the alpha or beta emission.

Thus uranium-238 changes into thorium-230 (in three stages), which then changes into radium-226, and thence into radon-222. The numbers keep getting smaller because the atoms are losing a part of themselves.

B. URANIUM AND ITS USES

B.1. Where is uranium found?

Tiny amounts of uranium are found almost everywhere. However, concentrated deposits of uranium (called ores) are found in just a few places, usually in hard rock or sandstone. These deposits are normally covered over with earth and vegetation.

In Canada [see figure II, p. 6], uranium mining has taken place in the Northwest Territories (Port Radium and Rayrock), in northern Saskatchewan (Cluff Lake, Key Lake, Rabbit Lake/Wollaston Lake and Uranium City), in Ontario (Elliot Lake and Bancroft), and in a few other places.

Uranium has also been mined in the southwest United States, Australia, parts of Europe, the Soviet Union, Namibia, South Africa, Niger and elsewhere.

In the 1970s, uranium deposits were discovered in British Columbia, Nova Scotia, and Labrador, but due to citizen opposition, the uranium mining companies have not been allowed to mine the ores in these areas. In the past fifteen years, Saskatchewan has become the uranium capital of the world. The richest uranium ores ever discovered are found in Saskatchewn.

FIGURE I: URANIUM DECAY PRODUCTS

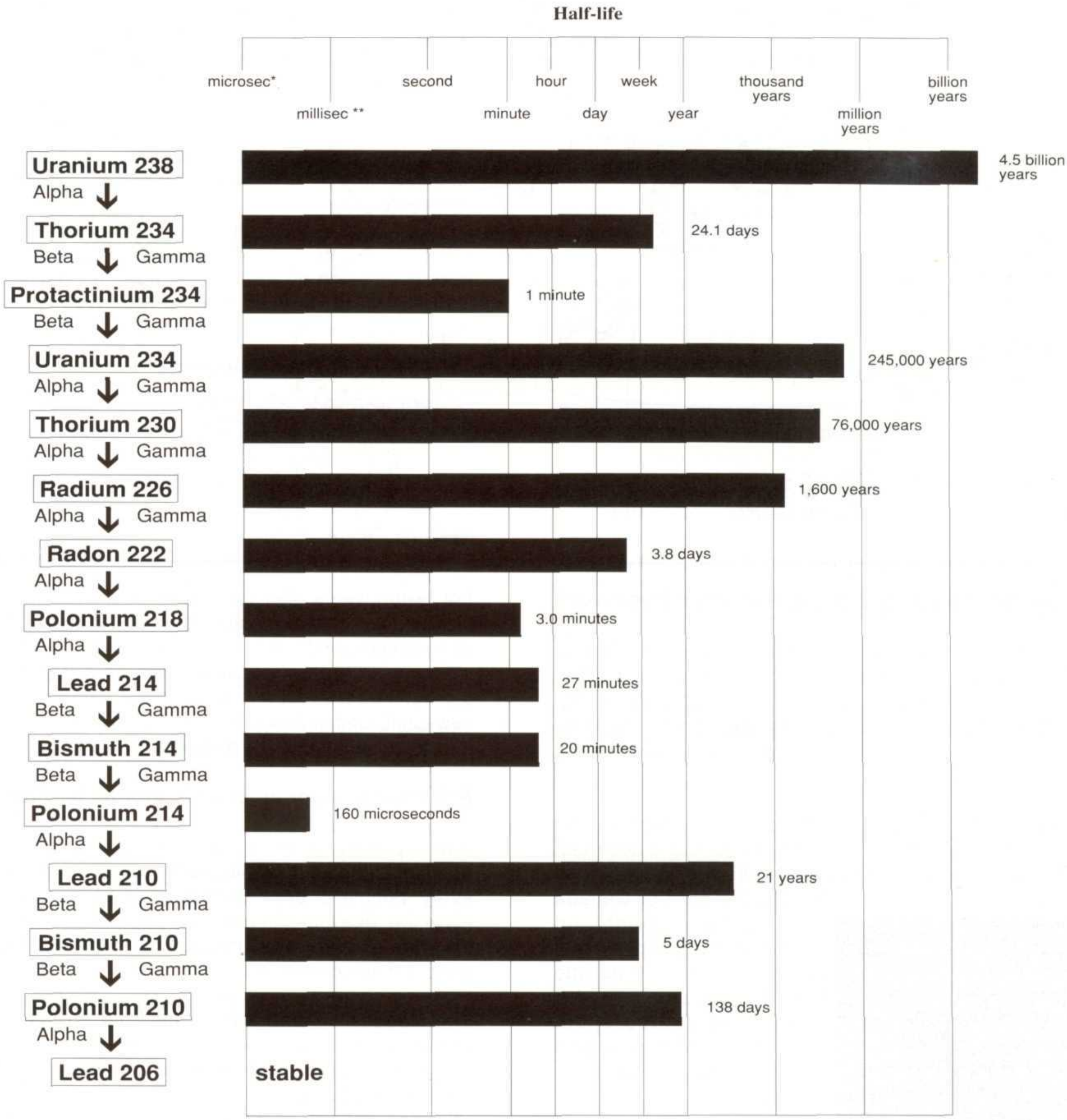
This graph lists all the decay products of uranium-238 in their order of appearance.

Each radioactive element on the list gives off alpha radiation or beta radiation -- and sometimes gamma radiation too -- thereby changing into the next element on the list.

During uranium milling, most of the uranium is removed from the crushed rock , but the decay products are left in the tailings.

The horizontal bar beside the name of each decay product indicates the "half-life" of that particular substance.

Lead-206, the last element on the list, is not radioactive. It does not decay, and therefore has no half-life.



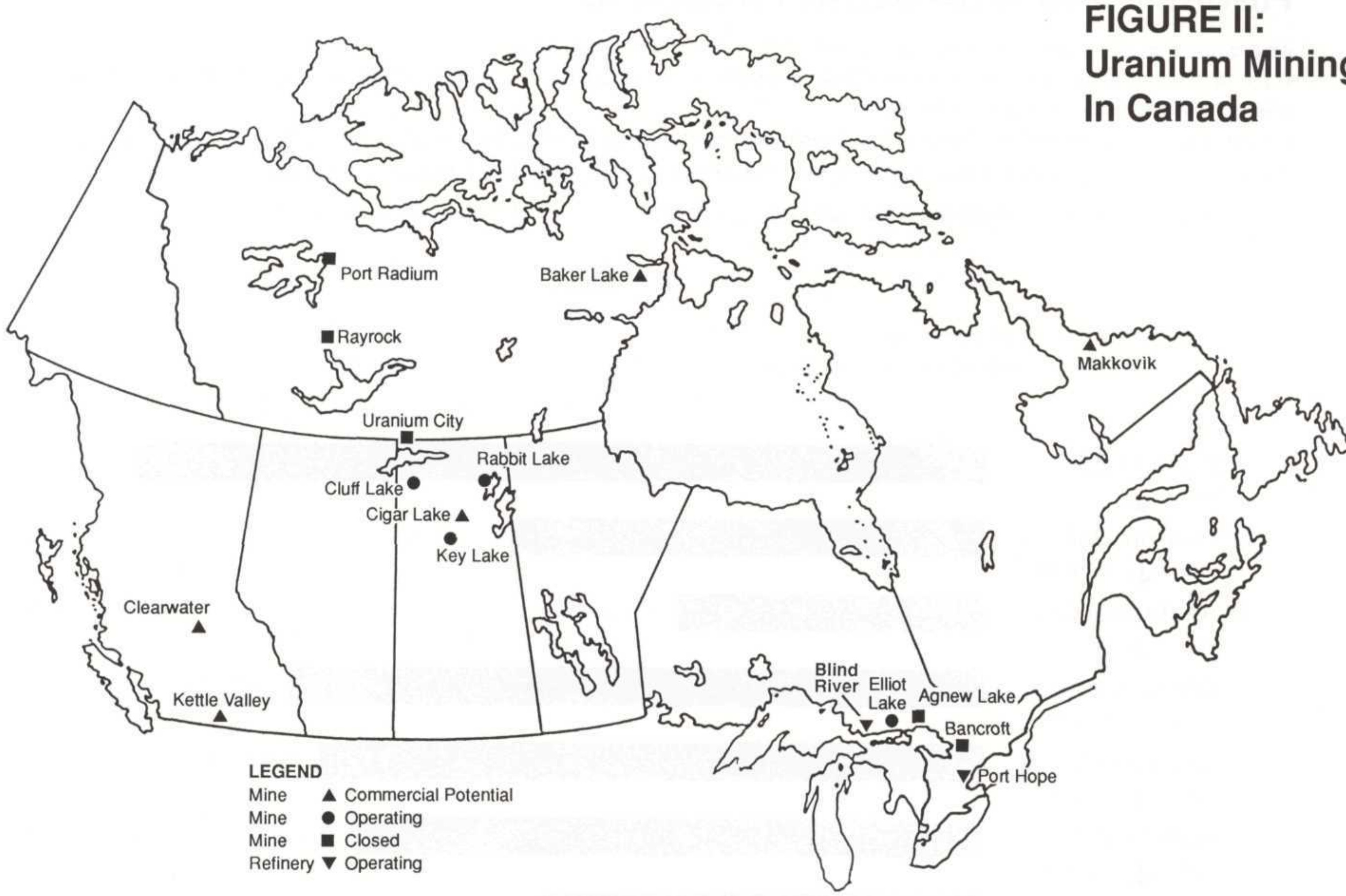
*Microsec; 1/1,000,000 of a second **Millisec; 1/1,000 of a second

What is the "half-life"?

The half-life of a radioactive element is the time it takes for half of its atoms to decay into something else. For example, the half-life of radium-226 is 1600 years. Therefore, in 1600 years, one gram of radium-226 will turn into half a gram of radium-226 and half a gram of something else (its radioactive decay products). After another 1600 years have elapsed, only a quarter of a gram of radium-226 will remain.

The quantity of any radioactive element will diminish by a factor of 1000 in ten half-lives. Thus, in 16,000 years, one gram of radium-226 will decay into a milligram of radium-226 and 999 milligrams of other decay products. Similarly, in 760,000 years, one gram of thorium-230 will be reduced to a milligram (because of the 76,000-year half-life of thorium-230).

FIGURE II: Uranium Mining In Canada



B.2. How did Canada get into the uranium business?

Before 1939, there was no significant use for uranium. German potters used it to make a reddish glaze and it was studied by scientists for its radioactive properties. Then, during World War II, scientists realized that extremely powerful bombs could be made by splitting uranium atoms using nuclear fission (which is described in section C).

When the U.S.A. needed uranium to build the world's first atomic bombs, the Government of Canada had a deserted, privately-owned radium mine in the Northwest Territories re-opened as a uranium mine. The Government of Canada also secretly bought up shares in the company that owned the mine, Eldorado Gold Mines, and turned it into a crown corporation, Eldorado Mining and Refining (later Eldorado Nuclear Ltd.).

> *"We didn't know anything about the rock they were taking out of the ground or what it was for. But, now that we found out, we really don't like it. All work should be to make things better for people. If it's for war, that isn't the case. It's not right for us to work on something (when) we don't know what it is."*
>
> **Jimmy Lacorde, former N.W.T. mineworker.**

At the Eldorado refinery in Port Hope, Ontario, uranium from the NWT and the Congo was processed for the U.S. army who used it to produce the world's first atomic bombs. These bombs completely destroyed two Japanese cities at the end of the war in 1945.

For twenty years after the first atomic explosions, Canada's uranium was sold to make many more atomic bombs, as well as hydrogen bombs which are even more powerful (but which still require uranium or plutonium as a trigger). In 1959, uranium was Canada's fourth most valuable export after newsprint, lumber and wheat. At that time, virtually all of it was sold for military explosive purposes.

B.3. How is uranium used in atomic bombs?

The explosive in the Hiroshima bomb was a rare kind of uranium (uranium-235), found in very low concentrations in every sample of ore. Before it can be used as a nuclear explosive, uranium-235 has to be painstakingly separated from the more abundant uranium-238 at a specialized factory called a uranium enrichment plant.

The Nagasaki bomb was made from a different nuclear explosive material called plutonium. Plutonium, the most commonly used nuclear explosive today, is a `man-made' element produced in nuclear reactors using uranium-238 (depleted uranium) as a raw material. Depleted uranium is also routinely used to manufacture metallic components for the hydrogen bomb, thereby doubling its explosive power.

In fact, without uranium, none of the world's current nuclear weapons could have been built.

B.4. How is uranium used to generate electricity?

In the 1960s, the nuclear fission process began to be used to produce electricity in special machines called nuclear reactors.

These machines use uranium as a kind of fuel to boil water. The steam that is produced spins a turbine to make electricity. There are now twenty nuclear power plants in Canada, and hundreds worldwide. Eighteen nuclear plants are operating in Ontario. There is also one in Quebec and another in New Brunswick.

Since the Three Mile Island accident in 1979, and especially since the Chernobyl accident in 1986, almost no new nuclear reactors have been sold. In 1990, Ontario Hydro announced that it wants to build about a dozen more.

B.5. Are there other uses for nuclear reactors?

Nuclear reactors fuelled with uranium can be used to produce artificial radioactive substances called radioisotopes for use in industry, scientific research and medicine. Alternatively, many of these radioisotopes can be produced in special machines called accelerators which do not require the use of uranium.

Nuclear reactors fuelled with uranium also serve as the propulsion units for nuclear submarines. In addition, special military reactors are used to produce most of the nuclear explosive materials (plutonium and tritium) used in nuclear weapons.

B.6. Are the peaceful and military uses of uranium incompatible?

Any nuclear reactor fuelled with uranium automatically produces plutonium as a byproduct. If that plutonium is chemically separated from the rest of the radioactive garbage in the spent reactor fuel, it can be used as a nuclear explosive. So, the spread of nuclear power around the world gives more and more countries the option of producing nuclear weapons at some future time.

In 1974, India exploded an atomic bomb. It was made from plutonium produced in a reactor given to the Indian government as a gift by the Canadian government. It was not an electricity-producing reactor, but a smaller machine called a research reactor.

Canada has also given or sold reactors to Taiwan, Pakistan, South Korea, Argentina and Romania. Some regimes in these client countries have displayed an interest in either developing nuclear weapons themselves, or in sharing their nuclear technology with other countries having such ambitions (e.g. Iraq and Libya).

B.7. Has Canada ever produced plutonium for use in bombs?

During World War II, European and Canadian scientists worked in a top-secret laboratory in Montreal, financed by Canada, to find the most efficient method of producing plutonium for atomic bombs. This involved the use of a special material called heavy water.

In 1944, a military decision was taken in Washington D.C. to build one or more heavy water reactors at Chalk River, Ontario, to test the Montreal laboratory's findings. When these Canadian reactors began operating after the war was over, they proved to be among the very best plutonium-producing reactors in the world. The reactor that was given to the Indian government was a copy of one of these.

To help defray the cost of its nuclear research program, the Canadian government sold plutonium produced in Chalk River reactors to the U.S. military for use in bombs for more than twenty years. Plutonium from Chalk River was also sent to the U.K. to assist the British in the development of their first atomic bombs. The British also learned how to separate plutonium for military use by building and operating a plutonium separation plant at Chalk River, in cooperation with Canadian scientists.

French scientists working at the Montreal laboratory likewise learned valuable lessons which assisted in the development of France's first nuclear weapons.

B.8. Does Canada currently sell uranium and plutonium for bombs?

Since 1965, Canada has had a policy of selling uranium for peaceful purposes only; that is, as fuel for nuclear reactors. Any country purchasing Canadian uranium or a Canadian nuclear reactor must promise not to use it or the byproduct plutonium for bombs. This policy is supplemented by an international nuclear Non-Proliferation Treaty.

However, as the Indian experience shows, this policy cannot be enforced. If a country chooses to make bombs, Canada cannot prevent it.

B.9. Does Canadian uranium currently find its way into nuclear bombs?

Over 85 percent of Canada's uranium is exported. In most cases, before being sent on to our foreign customers, it first goes to a uranium enrichment plant, usually in the U.S.A. or the U.S.S.R.

For every seven units of uranium that enters an enrichment plant, regardless of source, less than one unit ends up in the finished product: reactor fuel. The other six units, called depleted uranium, are discarded as waste. Depleted uranium has no significant civilian use.

Depleted uranium has been regularly used by the U.S. military in the manufacture of nuclear weapons. In fact, it is the raw material from which weapons-grade plutonium is created in special military reactors. Depleted uranium is also used in the manufacture of metal components for the bomb itself, thereby doubling the explosive power of each warhead.

The U.S. military makes no distinction between depleted uranium of Canadian origin and depleted uranium of any other origin. When Canadian uranium is enriched in the Soviet Union, Canada does not allow the Soviets to keep the depleted uranium within its borders because of its military potential.

B.10. Are there any other uses for uranium?

There are other uses for uranium, but they are less important. Some bullets are coated with uranium so that they can pierce through heavy armour. Some tanks are reinforced with uranium to make them stronger. Uranium is used as a weight in some airplanes and in the Cruise missiles tested over the Canadian arctic.

C. URANIUM AND NUCLEAR FISSION

C.1. What is nuclear fission?

Nuclear fission was discovered by German scientists in 1939. They found that some uranium atoms will split (or fission) into two or three pieces, when bombarded by tiny projectiles called neutrons. When fission occurs, a great deal of energy is released, and more neutrons are thrown off with great force. These extra neutrons can cause additional uranium atoms to split, releasing even more energy and more neutrons. Thus one fission can cause many more by starting a chain reaction.

The fission process allows uranium to be used as an explosive in nuclear weapons or as fuel in a nuclear reactor. In an atomic bomb, fission takes place in an uncontrolled fashion, resulting in a gigantic explosion. In a nuclear power station, the fission process is very carefully controlled to produce a steady stream of heat for the production of electricity. Unlike the natural process of radioactive decay, the fission process can be started and stopped, speeded up and slowed down, by using special neutron-absorbing materials.

C.2. What are fission products?

All the broken pieces of uranium atoms left over from the fission process are atoms of new radioactive materials called fission products. These are not the decay products of uranium mentioned earlier; they are new radioactive materials not found in nature.

There are dozens of different fission products, including such substances as strontium-90, cesium-137 and iodine-131. They are all lighter than uranium, because their atoms are much smaller than uranium atoms. They give off beta radiation and gamma radiation, but not alpha radiation.

Fission products never occurred in human food, air or water before the first atomic bomb explosions. Now they are found all over the earth in small amounts. Each one behaves differently in the body. They are all dangerous.

Less than 4 percent of the fission products inside the Chernobyl reactor escaped, yet the consequences were felt worldwide. Four years after the accident, in 1990, reindeer in Scandinavia and sheep in Wales were still judged unfit for human consumption because of radioactive contamination by cesium-137 from Chernobyl.

If there are no accidents or leaks, the fission products will remain contained within the spent uranium fuel. Even so, the gamma radiation that they give off is so intense that a person would receive a fatal dose of radiation in less than a minute if he or she stood just a meter or so away from an unshielded spent fuel bundle fresh out of the reactor.

C.3. What is strontium-90; cesium-137?

Strontium-90 and cesium-137 are two of the most dangerous fission products created inside a reactor or released from a nuclear explosion.

When strontium-90 is ingested in food and drink, it is stored in bone, teeth and milk (like calcium). Atomic radiation from strontium-90 disturbs the bone marrow and the blood, leaving the individual more vulnerable to infectious diseases. It can also lead to serious blood and bone disorders, including cancers.

Cesium-137 is stored in the flesh of fish and animals. If it is stored at high enough levels, it makes the meat unfit for human consumption. Cesium-137 also adheres to the soil and to buildings. At high enough levels it can make contaminated areas of farmland unusable for growing crops, and in some cases it can make entire regions uninhabitable. That's why so many villages near Chernobyl had to be abandoned. That is also the reason Laplanders have been advised to refrain from eating reindeer meat.

Caribou in the Canadian arctic have more strontium-90 and cesium-137 in their bodies than other North American animals do, because they eat lichen which capture the radioactive materials right out of the air. Fish also concentrate cesium-137 in their fleshy parts. Being meat-eaters and fish-eaters, Canadian Inuit have higher levels of fallout radiation in their bodies than most other North American residents. These levels have been slowly decreasing since the 1960s, when governments stopped testing nuclear bombs in the atmosphere. The Chernobyl accident caused a slight increase. These levels are not so high as to cause Canadian authorities to ban the consumption of caribou or other animals.

Once distributed in the environment, strontium-90 and cesium-137 remain hazardous for many decades. One part in a thousand will still remain after 300 years.

C.4. What is nuclear weapons fallout?

When an atomic bomb explodes in the atmosphere, fission products are dispersed into the environment. They contaminate air, water and soil, as well as plants and animals. They attach themselves to dust particles and water droplets, and come down as rain or snow. Some are sent high up into the stratosphere; they descend very slowly for many years thereafter, all over the globe, as radioactive fallout.

If the bomb explodes at ground level, huge quantities of earth are scooped up into the fireball. Many of these materials, originally non-radioactive, become radioactive by absorbing stray neutrons from the fission process. These new radioactive substances, caused by neutron absorption, are not fission products; they are called activation products. They can contribute significantly to the fallout from an atomic explosion.

C.5. What is high-level radioactive waste?

Nuclear reactors produce large quantities of fission products (as discussed in section C.2.) which come out of the reactor in the form of spent fuel rods. These are not normally dispersed in the environment except in the case of an accident like the one at Three Mile Island in 1979 or the much more catastrophic accident at Chernobyl in 1986.

Spent nuclear fuel is too radioactive to be handled by human hands. It is moved only with robotic equipment. It is shipped in special flasks weighing over 50 tonnes, chained to flat-bed trucks or rail cars. This high level radioactive waste is unapproachable for centuries (due to the gamma radiation from fission products) and highly toxic for millenia (due to alpha radiation from plutonium and other transuranic elements as described in C6).

To dissolve to the maximum permissible levels of pollution all the spent nuclear fuel on hand by the year 2000 would require more than double the volume of water in all the lakes and rivers on the planet. Therefore, the material must be safely stored in a near-perfect containment system. But there is as yet no proven safe method for permanently disposing of high-level radioactive waste.

In Canada, the Federal Environmental Assessment Review Office started, in 1990, to review a concept proposed by Atomic Energy of Canada Limited for the burial of high-level radioactive wastes deep in the rock of the Canadian shield. Similar concepts advanced in the U.S. have not been accepted to date.

C.6. How are plutonium and the other transuranic elements produced?

Although plutonium is an indirect byproduct of the fission process, it is not a fission product. Since it is heavier than uranium, this 'man-made' radioactive element is called a transuranic element. Inside a nuclear reactor, some of the uranium atoms in the fuel are gradually "cooked" into plutonium atoms when they absorb neutrons without splitting. Additional neutron captures yield other transuranic elements, such as neptunium, americium, curium and californium. Most of them, including plutonium, will continue to give off alpha radiation for centuries or even millenia.

Plutonium is one of the most toxic man-made substances in existence. A few milligrams of plutonium dust inhaled into the lungs, though invisible to the naked eye, will cause death in a short time due to massive fibrosis of the lungs. A few micrograms (a microgram is one thousand times less than a milligram) can cause a fatal lung cancer ten or twenty years later. Although relatively few cells are affected (refer to back cover photo), these are the cells that could become cancerous in later years .

C.7. What is plutonium used for?

Plutonium, like uranium, can undergo nuclear fission. This substance can therefore be used as a nuclear explosive or as fuel for a nuclear reactor.

As noted earlier, the Nagasaki bomb utilized plutonium. For technical reasons, it is easier to use plutonium instead of uranium as a nuclear explosive. In fact, most of the warheads in the world's nuclear arsenals use plutonium as the primary explosive.

Plutonium can also be used to fuel a nuclear reactor. Some of the electrical energy produced in any nuclear reactor comes from the splitting of plutonium atoms, but there is a considerable amount of unused plutonium left over in the spent nuclear fuel. If nuclear power is to be a major energy source in the future, plutonium will almost certainly have to be used instead of uranium as a nuclear fuel because of diminishing supplies of uranium. To extract plutonium, however, the spent fuel must first be dissolved in boiling nitric acid, releasing radioactive gases and vapours and creating millions of litres of high-level radioactive liquid waste.

Much has been written about the dangers of relying on plutonium as a fuel, partly because of its extraordinary toxicity, partly because of the inherently dangerous process of extracting it from spent fuel, and partly because of the threat of nuclear blackmail. Criminals, terrorists, or irresponsible political leaders could use the separated plutonium to make crude but powerful nuclear weapons with relatively little effort.

D. URANIUM AND PUBLIC POLICY

D.1. Is nuclear-generated electricity inevitable?

Nuclear proponents claim that the only substitutes for our rapidly diminishing oil supplies are coal and uranium. Since coal is such a dirty fuel, they say that nuclear power will be needed. But others disagree, maintaining that nuclear plants can't replace oil because they are too expensive and time consuming to build. Besides, nuclear power plants supply electricity; yet 85 percent of our current energy needs are non-electrical.

Numerous studies around the world -- such as **Energy Future**, the Harvard Business School Task Force Report on Energy and **2025: Soft Energy Futures for Canada** -- have argued that we can live quite affluently without requiring more nuclear, oil or coal generated electricity by investing in energy efficiency, energy conservation, and renewable forms of energy. According to these studies, our best hope for the future lies with technologies such as solar heating, biologically renewable fuels (methane or fuel alcohols), solar electricity, wind power, geothermal energy, ocean thermal energy, wave power, etc.

D.2. Are the alternatives to nuclear power feasible?

Through efficiency improvements alone, according to these alternative studies, we can free up more energy than is currently produced by nuclear plants. Moreover, such efficiency measures are less costly than nuclear power and create more jobs. They reduce emissions of acid gases and greenhouse gases faster than nuclear power can. They allow us to provide the same energy services (heat, light, transportation) while using far less energy to do so. The energy saved can then be used for other purposes if so desired.

According to these studies, once demand has been trimmed by efficiency (doing more with less) and conservation (eliminating wasteful uses), renewable energy sources can meet most if not all of our diminished energy needs. In general, these alternative supply technologies (solar heating, wave power, wind power, biologically renewable fuels, geothermal, etc.) are portrayed as no more expensive than nuclear power, yet they are faster, cleaner, more easily sustainable, and they create more jobs. There are also cleaner coal-burning technologies that can be used during the relatively short transition period to a sustainable society powered by renewable forms of energy.

D.3. Is uranium and nuclear power accepted in Canada and the rest of the world?

The population of Canada, indeed the world, is sharply divided on the merits of uranium and nuclear technology. Most Canadians and Americans oppose nuclear power because of the unsolved waste problems and the links to nuclear weapons.

Since the Three Mile Island accident in 1979, there hasn't been a single nuclear reactor sold in all of North America. Since the Chernobyl accident in 1986, millions of European and Soviet citizens have turned against nuclear power. Sweden, Austria, Italy, Switzerland and the Phillippines are some of the countries that have decided to phase out nuclear power, partly because the risks are so extreme.

The insurance underwriters of the world acknowledge that damages arising from a serious nuclear reactor accident could amount to over ten billion dollars. They are not prepared to accept that risk. Hence, the nuclear exclusion clause in standard homeowner insurance policies makes it clear that there is no coverage in the event of nuclear contamination.

By virtue of Canada's Nuclear Liability Act, the legal liability of operators of nuclear reactors is limited to a maximum of 75 million dollars per reactor accident for off-site damages. The act also protects manufacturers of nuclear reactor components from any liability due to failure of their manufactured products. Critics of the Nuclear Liability Act argue that it is an incentive to carelessness as well as being tantamount to an unfair subsidy of the nuclear industry.

When the government of Prime Minister Margaret Thatcher privatized the British electricity industry in 1989, no private investors could be found to buy the nuclear plants. Of major consideration was the tremendous expense associated with dismantling the radioactive structures at the end of their useful lifetimes, and the disposal of all the radioactive wastes.

Likewise, the governments of Canada and Saskatchewan are experiencing difficulty with privatization of the large jointly crown-owned uranium company, CAMECO (Canadian Mining and Energy Corporation), formed in 1988 by the merger of Eldorado Nuclear Limited (a federal crown corporation) and the Sakatchewan Mining Development Corporation (a provincial crown corporation). Because of an abundance of uranium on international markets, record low international prices and CAMECO's burdensome debt load, the company is not an attractive buy. The federal government incurred a major writedown in the value of its interest in CAMECO in 1990.

Of ongoing concern to the international community is the fact that France continues to expand its nuclear power industry while refusing to separate its civilian nuclear program from its nuclear weapons program. France has not signed the nuclear Non-Proliferation Treaty which would effectively open all its nuclear facilities to international inspection.

D.4. To what extent has Canada invested in uranium and nuclear power?

During World War II, Canada spent more on the nuclear weapons program than on all other scientific research and development activities. After the war, Ottawa decided to pursue the civilian possibilities of nuclear technology. According to a study prepared for the Economic Council of Canada, close to 19 billion tax dollars (in 1990 currency) have been spent since the early 1940s to develop the nuclear power option.

Federal subsidies continue unabated to the present day. Research funding has consistently been far greater for nuclear power than for all other energy options combined (oil, coal, gas, hydro, energy conservation, and renewable forms of energy), even though nuclear power contributes only 3.3 percent of Canada's delivered energy.

D.5. To what extent has Canada intervened in the uranium market?

The federal government monopolized uranium mining, milling and refining until the mid 1950s; then private enterprise was allowed to invest. In the 1960s, when no new military contracts were forthcoming, the government of Prime Minister Lester Pearson (Member of Parliament for Elliot Lake) began stockpiling uranium, at public expense, to keep two privately-owned Elliot Lake mines from going out of business. In 1965, Pearson promised in the House of Commons that, henceforth, Canadian uranium would be sold for peaceful purposes only.

In the early 1970s, the Trudeau cabinet was instrumental in establishing an international uranium price-fixing cartel in collaboration with South Africa, Australia, France and the British mining conglomerate Rio Tinto Zinc. The cartel used secret quotas and phony bidding to boost world prices in apparent violation of Canadian and international laws. When prices soared, Canada financed an ambitious uranium reconnaissance program to help mining companies locate and exploit economically recoverable reserves. Meanwhile, Ottawa continued to own and operate the largest uranium refinery in the world (at Port Hope, Ontario) through Eldorado Nuclear Limited. The price of uranium later collapsed in spite of the Canadian government's intervention.

Critics of the nuclear industry maintain that the Canadian public would have been better served if the tax money and political will that has been poured into uranium and nuclear power had been channelled into alternative energy technologies instead.

D.6. What is Canada's 1990 status in the international uranium market?

Canada is the most important uranium supplier in the world. The first country ever to mine and refine uranium on a large scale, Canada remains the undisputed world leader in uranium exports.

For about 25 years, beginning in the mid-1950s, the U.S. led the world in production while Canada led in exports. During the 1980s, however, Canada became the world's leading producer and exporter, largely because of the extraordinarily rich uranium deposits found in northern Saskatchewan. These deposits are much less costly to mine because they are close to the surface.

The price of uranium has been falling steadily since the dissolution of the uranium cartel, reaching an all-time low in 1990. Many uranium producers have been forced to shut down, because they are unable to compete with uranium from Saskatchewan. Massive layoffs have already occurred in Elliot Lake, Ontario. Uranium mines in Saskatchewan have also had to slow production in response to soft demand and low prices.

D.7. Why is uranium mining expanding in Canada?

It is unclear why Canada is expanding uranium mining activities when the price of uranium is so low and the market is glutted. The investors in Canada's uranium resources are mostly large foreign corporations who are interested in stockpiling Canadian uranium at bargain prices.

In the meantime, no money is being put aside to deal with potentially serious environmental damage from waste containment failures or to dispose of some 100 million tonnes of radioactive waste left behind at abandoned uranium mines and mills.

D.8. Does uranium mining in Canada have implications for aboriginal land title and rights?

Uranium mines in Canada are, for the most part, located in areas traditionally inhabited by aboriginal people, on land for which aboriginal Canadians continue to assert title. Even where treaties are in place (Ontario and Saskatchewan), aboriginal communities believe their full rights have not been extinguished, that they should have a say over whether or not mining proceeds and, at the very least, that they should receive compensation (such as revenue sharing) if mining proceeds. In Canada, there is no necessary legal provision for such compensation.

The Inuit of the Keewatin region in the eastern arctic (a non-treatied area) believe that uranium exploration on land where they have hunted caribou for several thousand years contravenes their aboriginal rights. Though a federal court ruling in 1979 upheld the legality of uranium exploration in the region, it rejected the federal government and corporate argument that the Inuit had no aboriginal rights in respect of the land. More recent judgements (notably, the 1990 Sparrow decision by the Supreme Court of Canada) have strengthened the acknowledgement of aboriginal rights of Canada's first people.

Under various international conventions, collective aboriginal rights of ownership over lands occupied by aboriginal people are explicitly upheld. Foreign owned uranium mining companies operating in Canada under license from the Government of Canada frequently undercut these rights of ownership over treatied and non-treatied land, often with the approval of their home governments. The government of Germany, for example, has not ratified one such convention because there are no native peoples, as defined in the convention, living in the Federal Republic of Germany.

Consideration of the aboriginal rights of native people living in northern Saskatchewan (where the world's largest uranium mines are located) was ruled out by the public inquiries on uranium mining in the province in the l970s. Nevertheless, the Cluff Lake Board of Inquiry recommended that a northern development board be created to provide aboriginal people more control over uranium mining in northern Saskatchewan. The recommendation has not been implemented.

According to at least one legal expert (Bartlett), "The furtherance of uranium development represents an unjustifiable extinguishment of aboriginal title without compensation."

The terms of reference set for the FEARO (Federal Environmental Assessment Review Office) review of the proposed Kiggavik uranium mine near Baker Lake, NWT, also rule out consideration of aboriginal rights. The Kiggavik mine is being proposed by Urangesellschaft, a uranium mining corporation based in Germany.

E. THE HEALTH HAZARDS OF URANIUM MINING

E.1. What are the health hazards of uranium mining?

Uranium mining is hazardous. In addition to the usual risks of mining, uranium miners worldwide have experienced a much higher incidence of lung cancer and other lung diseases. Several studies have also indicated an increased incidence of skin cancer, stomach cancer and kidney disease among uranium miners.

E.2. How long have we known that lung cancer is caused by uranium mining?

For four centuries, beginning in 1546, it was reported that most underground miners in Schneeberg, Germany, died from mysterious lung ailments. In 1879, it was shown that up to three quarters of them were dying of lung cancer and other lung diseases.

By 1930, similar grim statistics were found among miners in Joachimsthal, Czechoslovakia, on the other side of the same mountain range. More than half of them were dying of lung cancer. Among the non-mining populations on both the German and Czech side of the mountains, lung cancer was all but unknown.

The ores in question were particularly rich in uranium. Men who mined other types of ores were not found to suffer the same epidemic of lung cancer and other fatal lung diseases.

E.3. How did we learn that radioactivity causes lung cancer?

In 1897 it was learned that uranium ores are radioactive. By 1900 it was found that severe skin damage can be caused by prolonged contact with some of the radioactive decay products of uranium. By 1920 it was well established that chronic exposure to atomic radiation, even without any visible damage to skin or other bodily tissues, can cause cancers and leukemias, years later, in both humans and animals.

By the 1930s, scientists were convinced that the centuries-old lung cancer epidemic among German and Czechoslovakian miners was caused by the men inhaling airborne radioactive materials in the underground mines.

Decades later, Japanese atomic bomb survivors were found to have an abnormally high rate of lung cancer.

E.4. Which radioactive materials cause lung cancer among miners?

Before World War II, it had been established that radon gas, rather than uranium ore dust, was the cause of lung cancer among underground miners. This conclusion was reached by comparing the miners with other workers who breathed radioactive dust but got almost no lung cancer. It was confirmed by experiments with animals.

Scientists were baffled as to why this alpha-emitting gas, radon, was such a powerful cancer-causing agent. It seemed much more damaging than other alpha emitters such as those found in the ore dust. The mystery went unexplained for more than a decade.

Then, in the l950s, it was pointed out that the radon gas, hovering in the stagnant air of the mine, produces radioactive decay products called radon progeny (formerly called radon daughters). These solid radioactive byproducts (see Figure III, p. 14), produced a single atom at a time, hang in the air along with radon gas. When radon gas is inhaled, the radon progeny are also inhaled, resulting in a much larger dose of alpha radiation to the lungs than would be delivered by the gas alone.

E.5. Have uranium miners in North America suffered from excess lung cancers?

When uranium mining began in earnest in the 1940s, first to supply uranium for bombs, and later for nuclear reactors, the warnings from Schneeberg and Joachimsthal were ignored.

In the four corners area (New Mexico, Arizona, Utah, and Colorado) of the U.S., Navajo Indians were sent into the uranium mines and exposed to levels of radon (the gas and its progeny) every bit as high as those recorded in the German and Czechoslovakian mines, with equally tragic results. At least 450 former uranium miners have already died of lung cancer. The U.S. House of Representatives passed the Radiation Exposure Compensation Act in 1990 after reviewing documented testimony that the Atomic Energy Commission and the Public Health Service failed to warn the miners of the hazards they were facing.

In Canada, excess lung cancer deaths occurred among the Newfoundland fluorspar miners, who began work in the 1930s, as well as among the uranium miners of the Northwest Territories, Saskatchewan and Ontario, who started mining in the 1940s and 1950s. Although radiation exposures in Canadian mines were less than those in American mines, significant increases in lung cancer deaths still occurred.

Uranium itself was not present in the Newfoundland fluorspar mines, but high levels of radon gas were dissolved in water seeping into those mines. When the gas was released into the mine atmosphere and inhaled by the miners, it killed many of them.

E.6. Are there high rates of lung cancer among uranium miners today?

In 1976, an Ontario Royal Commission (the Ham Commission) found that 81 Canadian uranium miners had died from lung cancer. That was twice as many as expected based on Ontario cancer statistics. By the end of 1977, the number had risen to 119; by the end of 1981, the toll was 174; and by the end of 1984, it was 274. A 1980 report from the British Columbia Medical Association (BCMA) said that we must anticipate "a gradually-flowering crop of (radiation-induced) cancers" among the uranium mining population.

> *"There is no other industry that has seen the amount of industrial disease as we're facing. There's very little we can do. The time-bomb is ticking; it's gonna explode, it's just gonna continue well after these mines are closed."*
>
> **Ed Vance, United Steelworkers.**

There are many current research studies of hard rock miners exposed to radon and its progeny in Europe, the U.S. and Canada, all showing clearly increased lung cancer rates. The amount of cancer is dependent on the radiation exposure of the miners: the higher the exposure, the greater the number of cancer deaths. Significant increases in lung cancer due to radiation have been observed in both smokers and non-smokers.

E.7. Are the current levels of radiation exposure for miners considered safe?

There is no scientific evidence to indicate that there is any safe level of exposure to radon. Virtually all of the evidence points in the opposite direction. The only prudent assumption consistent with the evidence is that any exposure to radon will cause a proportional increase in the incidence of lung cancer. This conclusion has been echoed by every major report on the subject since the late 1970s.

This is true for anyone exposed to radon, including homeowners. In fact, radon is now considered the leading cause of lung cancer after smoking.

In the early 1980s, an independent scientific study on the risks of radon was published by the Atomic Energy Control Board (AECB, the federal regulatory body that sets standards for radiation exposure in Canada). This study, known as the Thomas/MacNeill Report, reviewed all available evidence from several countries. It concluded that the risks are very high. The study found that if uranium miners worked at AECB's maximum permissible level over their entire working lifetime, the the lung cancer incidence would likely quadruple. Instead of 54 lung cancer deaths per 1000 males, the Ontario average, there could be close to 200 lung cancers per 1000, about one in five.

> *"We get to accept death if we want economic prosperity. We get to accept death if we want what's labelled a good standard of living. It's not a good standard of living if you get sick."*
>
> **Dr. Rosalie Bertell, research scientist.**

The 1980 report of the BCMA, already mentioned, said the AECB was "unfit to regulate" because of the health risks it permits. According to the BCMA report, no other industry allows a cancer-causing substance in the workplace at anything close to the doubling dose for cancers in humans.

E.8. Can the health dangers be alleviated by using more miners for shorter periods of time?

The 1976 Ontario Ham Commission Report warned that using more miners for shorter times, without reducing the total exposure to inhaled radon, will not reduce the number of cancer victims. If anything, it could increase the number of excess lung cancers.

The Ham Commission Report, the BCMA Report, the Thomas/MacNeill Report, and the 1988 BEIR-IV report (published by the U.S. National Research Council) have all pointed out that at lower radon exposure levels the number of cancers caused per unit dose may actually increase. In other words, spreading the same total dose out over a larger population, so that each individual gets a smaller dose, may increase the total number of cancers caused. The BEIR IV Report observes that this phenomenon is well-known for laboratory animals, but is less clearly established in the case of human populations.

F. URANIUM TAILINGS

F.1. What are uranium tailings?

At a uranium mine, the uranium ore (including its decay products) buried deep in the earth is brought to the surface and crushed into a fine sand. The uranium is then chemically removed and the sand is stored in huge reservoirs. These leftover radioactive sands are called uranium tailings.

> *"If mining continues at 1988 production levels, the industry will have dumped three hundred million tonnes by the end of the century;...they are Canada's slow bombs."*
>
> **From the film narration.**

The tailings contain over a dozen radioactive materials, called the decay products of uranium, all of which are extremely harmful to living things. The most important of these are thorium-230, radium-226, radon-222 (radon gas) and the radon progeny, including polonium-210.

If this radioactive sand is left on the surface and allowed to dry out, it can blow in the wind and be deposited on vegetation far away, thus entering the terrestrial food chain. Or it can wash into rivers and lakes and contaminate them so they are unfit for human use.

F.2. What is thorium-230?

Thorium-230 is the uranium decay product with the longest lifetime. It lasts for hundreds of thousands of years: in human terms, forever. It decays to produce radium-226, which in turn produces radon gas (radon-222). So the amount of radium in the tailings, and the quantities of radon gas produced by the tailings, will not diminish for a long time. They are constantly being replenished by the decay of the very long-lived thorium-230.

Thorium is especially toxic to the liver and the spleen. It has been known to cause leukemias and other blood diseases.

F.3. What is radium-226?

Radium-226 is one of the more dangerous of the uranium decay products. It is a radioactive heavy metal, and a potent alpha emitter. As it decays, it produces radon gas as a byproduct. Radium is chemically similar to calcium, so when ingested, it migrates to the bones, teeth and breast milk. It is readily taken up by vegetation. In aquatic plants, it can be concentrated by factors of hundreds or even thousands.

In the first half of the twentieth century, radium was used to make a paint that glows in the dark. Radium is now considered too dangerous to use for such purposes. Many young women who used the paint in their work died from cancers of the bone or of the head. The bone cancers were caused by microscopic amounts of radium which were unintentionally swallowed. The head cancers resulted from radon gas generated from the ingested radium inside the women's bodies. The radon gas collected in their sinus and mastoid cavities, causing cancer.

It is even considered dangerous to wear a watch which has been painted with radium, because some of the radium decay products give off intense gamma rays, even more powerful than x-rays. This type of radiation can damage the body by sending rays right through it, even from a distance. Radium is sometimes used in cancer therapy for this very reason, to destroy unwanted tumours.

While some radium is still used for medical purposes, only small quantities are needed. Most of it is now discarded with the crushed rock left over from uranium mining, despite the fact that it is known to be an extremely dangerous material.

Several U.S. studies have reported higher rates of cancer and leukemia in communities having elevated levels of radium in the drinking water, although the cause-and-effect relationship in these cases is still a matter of dispute.

F.4. What is radon-222?

Radon-222 is a toxic gas created by the decay of radium-226. Most of the radon is normally trapped in the ore-bearing rock deep within the earth where it can do no harm. But when the rock is excavated and crushed, a lot of radon gas is released into the air. Uranium miners breathe this radioactive gas and its progeny into their lungs.

Radon (the gas and its progeny) is a very powerful cancer-causing agent. Even small doses over a long time can cause lung cancer.

Uranium tailings are constantly producing large amounts of radon gas through the decay of radium. This gas can travel thousands of kilometers in a light breeze in just a few days. As it travels, it continually deposits solid radon progeny on the ground, water and vegetation below.

Radon also dissolves readily in water, and can be transported by ground water into wells and streams.

F.5. What are radon progeny?

Because radon gas is radioactive, it decays, producing seven radioactive decay products called radon progeny [see figure III, p. 14]. These solid radioactive materials attach themselves to tiny dust particles and droplets of water vapour floating in the air.

When breathed, radon gas is exhaled as easily as it is inhaled; but when the accompanying radon progeny are inhaled, they lodge in the lining of the lung. There they bombard the delicate tissues with alpha particles, beta particles and gamma rays. The radon progeny are various radioactive forms (or isotopes) of bismuth, polonium and lead. The bismuth and lead isotopes emit beta particles and intense gamma rays, while the polonium isotopes emit alpha particles which may irreparably damage the bronchial tissue.

When radon gas is given off from uranium tailings, the radon progeny eventually come to earth as radioactive fallout in the form of rain, snow or dust, thus entering aquatic and terrestrial food chains. A few days following deposition, the main radioactive progeny left are lead-210, bismuth-210 and polonium-210. The others have decayed away to non-radioactive atoms.

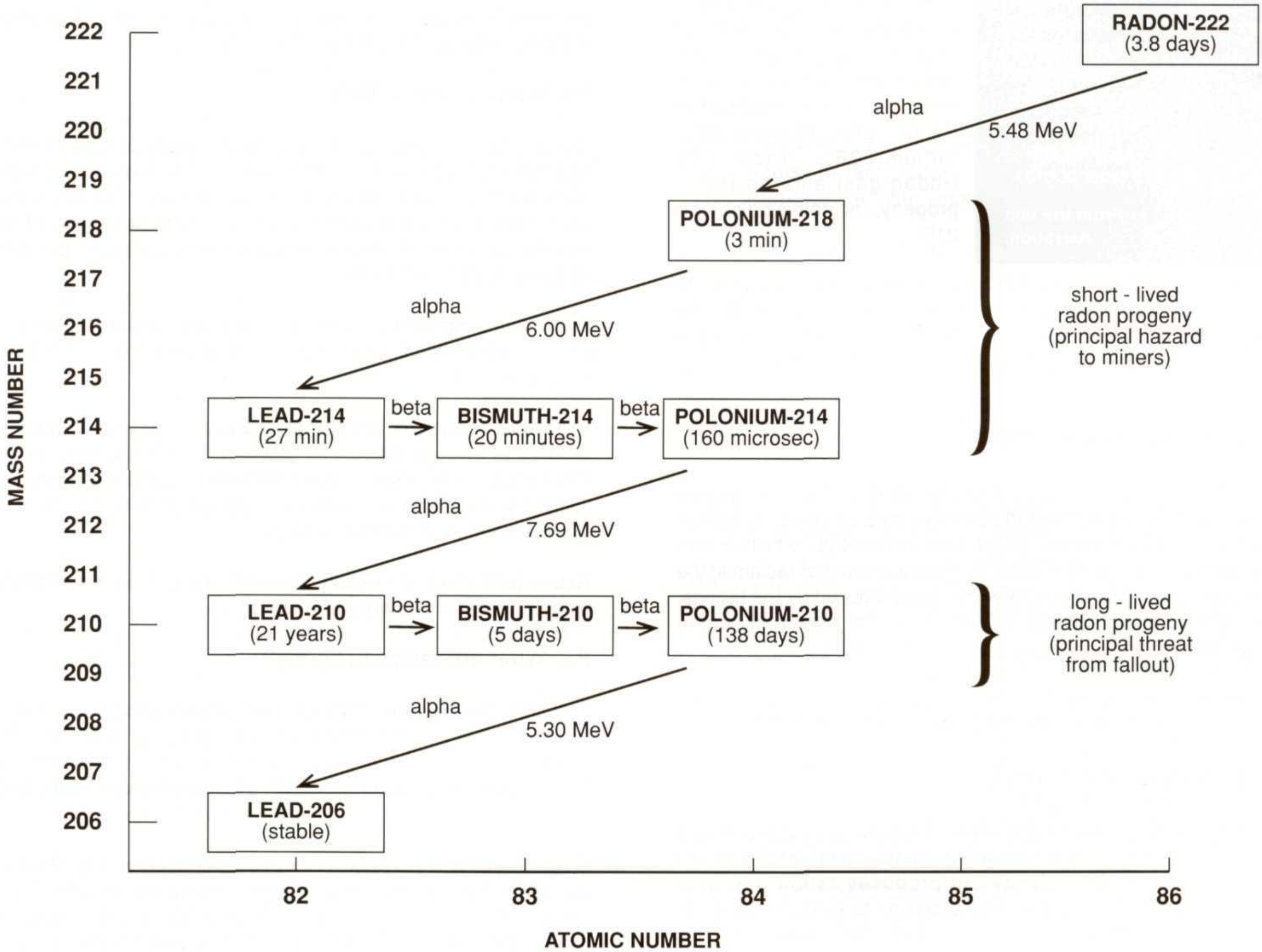
When lead-210 and polonium-210 are ingested via contaminated vegetables, fruits, fish or meat, they are incorporated into the body just like non-radioactive materials.

FIGURE III: RADON PROGENY

The vertical axis measures the **MASS NUMBER** while the horizontal axis measures the **ATOMIC NUMBER**.

DIAGONAL ARROWS: denote alpha decay and **HORIZONTAL ARROWS:** denote beta decay

MeV = MILLION ELECTRON-VOLTS, is a measure of the **ENERGY** of the alpha radiation; the more energetic it is, the more damaging it is.



What are the mass number and the atomic number?

All the atoms of a given element are identical. Each atom has a tiny core called a "nucleus", containing even smaller paricles called "protons" and "neutrons". The number of protons in the nucleus is the **atomic number**, while the number of protons and neutrons together is the **mass number**. These numbers are characteristics of the particular element.

Elements having the same atomic number are chemically indistinguishable, even if the mass numbers are different. They are called "isotopes". For example, polonium 218, polonium 214 and polonium 210 are three isotopes of the same element. They have different mass numbers - as indicated by their names - but they share the same chemical properties because they all have the same atomic number, 84.

During "alpha decay" the nucleus gives off an alpha particle, which is made up of two protons and two neutrons. Thus the atomic number goes down by two and the mass number goes down by four.

During "beta decay" one of the protons in the nucleus spontaneously turns into a neutron, giving off a high-velocity electron in the process. Thus the atomic number increases by one, and the mass number is unchanged. The escaping electron is called a beta particle.

F.6. What is polonium?

Three different isotopes of polonium are included among the radon progeny. These pernicious substances are responsible for most of the biological damage attributed to radon. In particular, polonium-214 and polonium-218 when inhaled, can deliver massive doses of alpha radiation to the lungs, causing fibrosis of the lungs as well as cancer.

Animal studies have confirmed that polonium is extremely harmful, even in minute quantities. The 1988 BEIR-IV report states that polonium-210 is far more dangerous than plutonium at high exposure levels, more or less equivalent to plutonium (which is five times more damaging than radium) at intermediate exposure levels, and approaches the toxicity of radium at very low chronic exposure levels.

Because of the lichen-caribou food chain (mentioned in C.3), caribou in the arctic and in northern Saskatchewan have much higher levels of polonium-210 in their flesh than any other animals in North America. As a result, the Canadian Inuit have up to 80 times more polonium-210 in their bodies than other North American people. Uranium mining can only exacerbate this situation, because increased amounts of airborne polonium-210 will be deposited on the lichen as fallout from the tailings and from abandoned ore bodies.

There is growing evidence that polonium-210 inhaled in tobacco smoke is responsible for much of the biological damage caused by cigarettes. Autopsies show that smokers have higher levels of polonium-210 in their lungs than non-smokers. Animal studies show that polonium-210 in the lungs is a superb carcinogen. From the lungs, polonium can also enter the bloodstream and it appears that the resulting radiation damage to blood vessels can eventually lead to blocked arteries, causing strokes and heart attacks.

G. URANIUM AND THE ENVIRONMENT

G.1. What are the greatest environmental risks from a uranium mine?

The greatest risks to the environment are: (1) contamination of groundwater, river systems and lakes with dissolved radioactive materials; (2) catastrophic failures of tailings containment; (3) the dispersal of radioactive dust, which finds its way into water, plants, animals, fish and humans; (4) releases of radon gas into the air, which will deposit radon progeny on the ground for many kilometres in all directions; (5) pollution of surface and ground water by chemical pollutants in tailings, notably heavy metals, acids, ammonia and salts.

In the short term, chemical pollution has caused by far the most damage. Whole groups of organisms have disappeared downstream from some old uranium tailings areas because of acidification. Radiation hazards are more subtle and will take longer to become manifest.

Unless the tailings are properly disposed of, these hazards will continue unabated for thousands of years. On abandoned minesites, tailings hazards will probably get worse as time goes on because of erosion, neglect and climatic change. On decommissioned minesites, monitoring will have to continue for many years, decades or even centuries. Performance of the protective containment measures over periods of thousands of years is unknown.

G.2. Does uranium mining cause water pollution?

Even during normal mine and mill operation, radioactive substances, sulphuric acid and other chemical contaminants will get into the water.

By the late 1970s, the entire Serpent River system in Ontario, including a dozen lakes, was contaminated for 80 kilometres downstream of the old uranium mines which operated in the Elliot Lake area in the 1950s and 1960s. At that time the International Joint Commission identified the Serpent River system as the largest single contributor of radium contamination to the Great Lakes. The situation has improved since then but acidification and ammonia are still a problem at Elliot Lake.

In case of a failure of the containment system for tailings, rivers and lakes can be ruined completely as a source of water for humans and animals. In the Elliot Lake area, there have been over thirty tailings dam failures.

"About 1978, we found that there were high radium contents in the river. And we pressured the government, through various tactics, into building a radium removal plant, which you see here. Now the unfortunate part about that is that they wouldn't provide the water for the Indians on the other side of the river, who take their water from here too. They only provided it for the white settlement. That didn't make an awful lot of sense, so when we argued and investigated that, they said, 'Well, Indians are a federal matter. And white people are a provincial matter.' "

Homer Sequin, United Steelworkers.

In 1979, a new tailings dam built with the latest technology suddenly collapsed in Churchrock, New Mexico. The resulting spill was the greatest accidental release of radioactive material into the environment prior to the Chernobyl nuclear disaster.

At modern mines in Canada, the short-term environmental impacts are often caused by non-radioactive parameters. For example, increased levels of salts may have caused a shift in species downstream of one uranium mine in Saskatchewan. Construction, exploration and road building in areas previously untouched by industrial activity often cause the most severe short-term impacts.

The Saskatchewan Spill Control Program recorded one hundred and fifty spills at the three operating mines in the province between 1981 and 1989. More than ninety of these spills involved radioactive materials.

To date, no major environmental impacts have been asssociated with these spills because the spills were either small, happened to flow into natural containments (such as a small bog), or were diluted by the bodies of water that received them. This is due as much to good luck as to good management.

G.3. What are the dangers of uranium mine tailings to humans, wildlife and the environment?

Unless uranium tailings are perfectly contained in some kind of storage system which has yet to be devised, humans and animals who come close to the tailings cannot help ingesting or inhaling some of this radioactive material, which seeps into the air, the food and the water. In this way, damage can be done to the lungs, skin, kidneys, blood, bones and reproductive organs. Over a period of years, that damage can lead to many types of illnesses, including cancers and leukemia. It can also lead to diseases and malformations in children, even before they are born.

A major study of Navajo Indians who worked as uranium miners, and those living near uranium tailings on the Colorado plateau, is almost finished. The children of these people have a very high rate of birth defects. A study in Malaysia is currently documenting blood changes and ill health among children exposed to thorium and uranium waste.

Radioactive materials in the tailings can also be carried very far away in the bodies of animals, fish or birds. Anybody eating the meat from these contaminated animals will get the radioactive material inside his or her own body.

G.4. Is there a way to avoid this kind of radioactive contamination?

Since people have to breathe and eat and drink, it is impossible to avoid the radioactive material once it is released from the deep rock, brought to the surface and crushed, and spread into the environment. The only remedy is prevention. Either the crushed rock should not be allowed to get into the environment, or the radioactive material should not be brought to the surface.

G.5. How long will the tailings be radioactive?

The uranium which is taken away and sold represents only about one seventh of the total radioactivity in the rock. The rest will be left in the tailings, which will remain radioactive for hundreds of thousands of years, far longer than the span of recorded human history.

In fact, the amount of radium in the tailings, and the amount of radon gas given off by the tailings, will not diminish much for the first 5,000 or 10,000 years (The Egyptian pyramids are about 5,000 years old). Even after 80,000 years, these quantities will have diminished by only one half.

G.6. How long will it take to get rid of the hazards associated with uranium mine tailings?

Unless a great deal of money is spent on engineered deep storage of the mine and mill tailings, they will be left at the mine site forever. No mine or mill site has yet been cleaned up in a permanently satisfactory way anywhere in the world although some attempts at long-term decommissioning of mines are underway.

New stringent laws for covering (but not burying) mine and mill tailings in the U.S. have encouraged mining companies to move their operations to other jurisdictions. Canada does not yet have detailed laws requiring the removal or covering of mine and mill tailings by the mining companies, nor does the Canadian government require deep burial in rock.

The provincial government in Saskatchewan requires that conceptual decommissioning plans be filed for all new uranium mines as a condition of licensing. When a mining company serves notice of intent to close a uranium mine, it is expected to file detailed decommissioning plans. Responsibility for decommissioned sites eventually reverts to the government.

G.7. Can modern science eliminate atomic radiation from radioactive tailings?

Modern science has no way to eliminate this radiation. There is no practical way to neutralize radioactive materials, nor to destroy them, nor to render them harmless.

Attempts are underway to try to put radioactive mine and mill tailings back into the ground, where they were less harmful to animals and humans. The volume increase resulting from crushing the ore makes this a very difficult task, however, and we do not know how to put the sand back together as a rock, nor do we know how to retrieve all the radon gas, the liquid effluents and the radioactive dust which have been released into the environment.

Also, because the tailings will remain dangerous for a period of time which exceeds the span of recorded human history, it is difficult to judge whether our storage methods will be adequate.

> *"We have three important sources of food here; fish, caribou and moose. If they are destroyed, what are the mining companies gonna supply us with instead? When they eventually destroy the lake, are they gonna bring us another lake we can live on?"*
>
> **Martin Josie, Wallaston Post, Saskatchewan.**

G.8. What do scientists know about the long-term effects of uranium mining on the environment?

What is known:

- Radionuclide content in aquatic biota (fish, insects, clams, plants) has been shown to increase downstream of uranium mine tailings; this increase is especially pronounced near older mines.

- Radionuclide content in terrestrial plants near uranium mines and mills increases; again this increase is more pronounced near older mines.

- Uranium series radionuclides do concentrate in plants low on the food chain but they do not biomagnify; that is, they do not increase in concentration as they are passed to successive steps in a food chain. Thus, they do not behave like mercury. This is fortunate for top predators, such as people; however, it does not mean that people or other animals at the top of the food chains get no radiation dose at all; just that it is much lower than it could have been had the radionuclides behaved like mercury. Furthermore, effects on biota at the bottom of food chains (where doses are higher) may have long-term ecological consequences.

- Significant levels of radionuclides released during atmospheric bomb tests were found in caribou and reindeer in arctic regions in the late l960s. Since then, data have shown the levels to be in steady decline. However, there have been no studies specifically focussing on animals who migrate into uranium mining areas and no recent studies tracking uranium-series radionuclides in sensitive arctic foodchains.

- There are several other contaminants released by uranium mines; these can include arsenic, nickel and unnaturally high levels of salts. Some uranium tailings are also very acidic, leading to the release of more metals into the environment.

- Improved treatment of uranium tailings at mines opened since 1980 has significantly decreased the rate of release of radionuclides and metals into the environment.

- Estimated radiation doses to people eating fish once a week from a lake contaminated by an older uranium mine are 1 to 2 percent of the annual radiation dose limit for the general public. These are worst case estimates. The significance of such doses is subject to debate because it involves judgment as to the acceptability of any risk from radiation, as well as disagreement over the science used to derive the dose.

What is unknown:

- We do not know what effects chronic exposure to low level radiation has on biota and ecosystems as a whole. We can guess, based on laboratory experiments using higher dose radiation of a different quality; however, we have no real data from the field.

- Until recently, protection of people from radiation has been assumed to protect all other forms of life. This premise is now being questioned. A more ecosystem-centred approach may be preferable.

- We do not know enough about radionuclide levels in game animals routinely consumed by people living near uranium mines.

- We do not know how to decommission uranium mines so as to minimize radionuclide migration for millennia; uranium mines that have been decommissioned need further detailed study.

- We do not know the significance of other contaminants released by uranium mining. They may be more damaging to indigenous biota than radiation.

One of the central problems in the debate about the nuclear fuel cycle is ignorance. Scientists simply do not know what the effects of chronic exposure to low-level radiation are, either in people or in other biota. We can guess, based on extrapolations from victims of high-level radiation such as atomic bombs and nuclear reactor accidents like Chernobyl. We will only begin to know for sure after several more decades have passed and a large population of exposed people has been studied. In the meantime, we have to ask: 'Do we really want to live with this uncertainty? What risks are we willing to accept as a society?'

H. REGULATING TAILINGS MANAGEMENT

H.1. Who is responsible for regulating tailings management in Canada?

As long as the uranium mine/mill complex is operating, the management of the tailings is regulated by the Atomic Energy Control Board (AECB) and by the appropriate provincial authorities. However, once the tailings have been abandoned, particularly when the owner/operator ceases to exist as a corporate entity, there is considerable confusion as to who is responsible for managing the tailings, although one government or another is the likely inheritor.

There have been numerous cases in Canada and elsewhere where thousands of tonnes of radioactive mine tailings or refinery wastes, neglected by the authorities, have been used in the construction of homes and schools, resulting in unacceptably high levels of radiation exposure in those buildings. There is a real possibility that this will occur again.

In Canada, there have been several cases of abandoned uranium tailings not properly fenced or posted with adequate warning signs. These dangerous radioactive deposits are freely accessible to unsuspecting people and animals.

H.2. What are the current regulations?

Currently, the regulations require the design, construction, maintenance and monitoring of an engineered facility for storing tailings as long as the mine/mill complex is operational. There are also requirements for treating effluents and limiting access to the site, and there are close-out criteria to be followed in preparing the tailings for abandonment.

During the operational phase, the tailings must be physically contained. There are provisions for controlling the atmospheric spread of radioactive dust and radon gas, limiting the seepage of chemicals and radionuclides into the underlying soil, and reducing the levels of dissolved and undissolved radioactivity in the liquid run-off. Special provisions may be required for storing tailings in which the concentration of radioactivity is unusually high.

Before abandonment, the regulations require that tailings be immobilized and covered. Close-out criteria stipulate that off-site levels of radioactive pollution from the tailings should not be significantly greater than the background levels of radioactivity found in nature. Moreover, the regulations require that no human intervention should be needed to maintain the integrity of the containment.

H.3. Are the regulations effective?

Over all, tailings management during the operational phase has greatly improved in the last fifteen years. Nevertheless, even at the newest mines, radioactive spills are frequent (as discussed in section G.2).

At Rabbit Lake, Saskatchewan, in November of l989, 2 million litres of radioactive liquid was spilled into a creek that feeds Wollaston Lake. This was followed in January of l990 by a 90 thousand litre radioactive spill at the same minesite.

At Key Lake, Saskatchewan in January of 1984, an over-filled containment dam failed, allowing 100 million litres of radioactive water to spill into a nearby bog. This was one of more than half a dozen radioactive spills at Key Lake within six months of the mine's startup in 1983. The main operating problem at Key Lake is that the tailings containments were built without consideration for the possibility of tailings freezeup, even though it was claimed to be a state-of-the-art mine.

At Cluff Lake, Saskatchewan, in the early l980s, efforts to store highly radioactive tailings in thousands of concrete vaults ended in dismal failure. The Cluff Lake Board of Inquiry had approved the storage of these wastes in underground concrete vaults intended to last at least a century. The Atomic Energy Control Board rejected this method of storage so the mining company placed the wastes in hundreds of concrete pots above ground. After less than five years of use, the pots started to leak. The company responded by reprocessing the wastes to recover gold, and dumped the remaining (still radioactive) wastes into the above-ground, open-air, tailings ponds - precisely what the Cluff Lake Board of Inquiry had wanted to avoid in the first instance.

"Even if there weren't these dramatic failures ...you would still have the long-term consequences to deal with ....When we're talking state-of-the-art, we're talking state-of-the-art to protect us, but not state-of-the-art to protect future generations."

Dr. Robert Woollard.

The long-term containment of uranium tailings remains a major unsolved problem. Once uranium tailings have been abandoned, it is doubtful whether any regulations can be effective in preventing large-scale contamination of the environment. The levels of radioactivity in the tailings, and the amount of radon gas produced by the tailings, will not noticeably diminish for more than 10 thousand years. How can the natural forces of erosion, migration, dispersion and dissolution be held in abeyance? Who will monitor the wastes and take corrective action? Who will pay for the future effort needed to do all this?

H.4. Are the regulators independent of the industry?

The Atomic Energy Control Board (AECB) is supposed to be independent of the nuclear industry. However, it reports to the federal Minister of Energy, Mines and Resources, the same Minister who is responsible for (1) Atomic Energy of Canada Limited, a crown corporation that designs, builds and sells nuclear reactors and (2) Canada's interest in CAMECO, a Canada/Saskatchewan-owned corporation that owns and operates uranium mines and refineries and is one of the world's largest uranium producers.

Moreover, many AECB staff members are recruited from various sectors of the nuclear industry, including the uranium mining companies, which the AECB is meant to regulate.

The five member board of AECB is currently (fall, 1990) comprised of a nuclear physicist, an engineer, a metallurgist, a geologist and a pediatrician. AECB's critics argue that because the nuclear industry draws staff members from many of these same disciplines, the Canadian public would be better served if a majority of AECB's board members were drawn from disciplines such as epidemiology, genetics, ecology, public health, law, ethics and the social sciences, not to mention representatives of the interested general population.

Formal public hearings to accompany licensing applications for uranium mines, mills and other nuclear facilities are not required as part of AECB's licensing process, nor have they ever been held.

"And I guess I could sum the whole thing up by saying that I believe that the regulatory agencies and the industries and the politicians are just playing pretty dangerous games with people's lives."

Ed Burt, farmer. Manitoulin Island, Ontario.

J. THE HEALTH EFFECTS OF ATOMIC RADIATION

J.1. Can the human body protect itself from radioactive materials?

The body has no way of protecting itself from radioactive substances in food or air. It takes them in and stores them in the lungs, muscles, bones and other organs, just as if they were natural foods.

Inside the body, when the radioactive material decays, it explodes (microscopically), causing damage to the tiny living cells. When many of these cells are damaged, the body is less able to fight off a variety of infectious diseases.

J.2. How does atomic radiation cause cancer?

Chronic illnesses, including leukemia or cancer, can be caused by atomic radiation. When cells are damaged in such a way that they begin to reproduce in an abnormal and uncontrolled fashion, they have become cancer cells. As the cancer spreads, it destroys healthy tissue. Unless arrested, it eventually kills the host organism. Leukemia is a cancer of the bone marrow or other blood-forming organs, which results in the uncontrolled overproduction of white blood cells to the detriment of other blood cells.

It takes time for a cancer to grow, so the effect is not apparent immediately. It often takes many years before cancer caused by breathing radioactive air or eating contaminated food can be spotted by a doctor. Even then, it is usually impossible for the doctor to tell whether that specific cancer was caused by atomic radiation.

"That is where I worked and that is where I got this cancer. I inhaled this poison air. That's what the doctor has told me. 'That's where you got your sickness from,' the doctor said. And that is true. Where I worked there were many other Indian people and also many white people. I guess most of us will be dying in a short time."

Martin Assinewi, former mine worker. Elliot Lake, Ont.

J.3. How does atomic radiation cause genetic defects in children?

Radiation damage to the father's sperm or the mother's eggs can result in a damaged child. Atomic workers take the greatest risk of having a damaged child because they are in closest contact with radioactive materials. A child suffering from genetic damage can pass that damage on to future generations.

Since the father's sperm is replaced every three or four months, he could theoretically wait for some time after working in a radiation environment before fathering a child. However, if his body is contaminated with long-lived radioactive materials, his sperm could continue to be damaged by internal exposure to radiation even after quitting his job.

Women carry in their bodies from birth, all the eggs they will ever have. Damage to a woman's eggs at any one time can result in a damaged baby many years later.

J.4 How do we know that atomic radiation causes genetic damage?

Radiation induced genetic damage has been observed and documented in every laboratory species that has so far been studied, including mammals, insects, micro-organisms and plants.

Genetic damage sometimes results in an unviable organism, leading to spontaneous abortion or premature death. Some kinds of genetic damage result in gross abnormalities or deformities whereas other types involve subtle differences which are difficult to detect. In fact, some forms of genetic damage are not seen in the first or second generations but only appear later, after several generations have passed.

Among human populations, there is little direct evidence of genetic damage. For example, several scientific studies have found a significant increase in the incidence of a genetic disease known as Down's syndrome (also known as mongolism) following irradiation of the mother, but other studies have not shown a comparable increase. An unusually high incidence of Down's syndrome has also been reported from some geographical regions where background radiation levels are unusually high, but these results are also controversial. Thus, while there is evidence that radiation may cause Down's syndrome, the evidence is not conclusive.

Since genetic damage has been clearly demonstrated in other species, most genetic scientists consider it virtually certain that similar damage will occur in human populations exposed to atomic radiation. In the absence of reliable human data, however, the level of risk can only be estimated by using animal data.

J.5. How else can atomic radiation damage unborn children?

A recent British study (the Gardner Report, published in the Journal of the British Medical Association in February, 1990) shows that the children of men who work in the Sellafield nuclear plant in northern England experience a much higher rate of leukemia than other children. The radiation exposure of the father appears to play an important role. It may be that damage to the sperm before conception causes leukemia in the children born later on, but no one knows exactly how or why.

Even if the father and the mother conceive a healthy baby, that baby is vulnerable to radiation while it is growing in the mother's womb. Whatever the mother eats can travel through the umbilical chord to the baby and damage it so that it is born with a disease or a deformity. Sometimes when a baby is seriously damaged before birth it is spontaneously aborted or it dies at the time of birth.

Mental retardation due to brain damage is the most likely form of developmental abnormality resulting from exposure to atomic radiation if the foetus is exposed during the critical period when the child's brain is being formed. Radiation-induced mental retardation has been observed and documented in animals as well as humans.

J.6. Is there a cure for radiation victims?

Some of the damage caused by radiation is healed by the body's own power to heal itself. Rarely is the healing perfect. Medical treatment can relieve some of the side effects of radiation damage and can prolong life through cancer surgery or treatment.

J.7. Can radioactivity be detected by human senses?

In concentrated form, radium or thorium or polonium can give a person a severe burn. Also, when uranium is exploded in an atomic bomb or "burnt" in a nuclear reactor, many of the radioactive substances produced give off atomic radiation intense enough to kill a person very quickly with burning pain.

"They are very small particles that we can't see or feel; and they come in - they're like minute bullets - and they do damage to the body. But you can't see them. So, until you begin to realize we're being polluted, you don't object."

Dr. Rosalie Bertell, research scientist.

However, at much lower doses, such as those experienced in uranium mining, atomic radiation cannot be detected by any of our human senses. Special instruments are needed. Alpha radiation, the kind associated with radon gas and most of the other uranium decay products, is difficult to detect even with instruments.

J.8. Are medical and dental x-rays free of risk?

Although x-rays are often useful and sometimes necessary, they do cause damage to living cells, slightly increasing the risk of both cancer in the individual exposed and genetic damage to his or her subsequent offspring. That's why lead aprons or shields are now used to protect the patient's gonads.

As with all forms of atomic radiation, the risk from x-rays is cumulative; it increases with each additional dose. That's why doctors, nurses and technicians often leave the room or duck behind a wall while a patient is being x-rayed.

Although the risk from one x-ray is small, the public health consequences of routine exposures can be serious because of the large numbers of people exposed to that small extra risk. That's why x-ray machines in shoe stores (letting kids see their toes wiggle) have been disallowed. Mass chest x-rays programs have also been discontinued.

Twenty-five years ago, Dr. Alice Stewart (a British M.D.) showed that a single diagnostic x-ray to the abdomen of a pregnant woman increased by fifty percent the chance that the child would later develop leukemia. It is no longer acceptable to x-ray unborn babies unless there is a compelling medical reason to do so.

K. THE REGULATION OF RADIATION EXPOSURES

K.1. What is an acceptable level of exposure to atomic radiation?

There is no convincing scientific evidence that there is a safe dose of atomic radiation. The evidence points strongly to the opposite conclusion; that every dose of atomic radiation administered to a large population, no matter how small it may be, will cause a corresponding increase in the numbers of cancers, genetic defects in offspring and other diseases.

The increase in the incidence of cancers and genetic defects seems to be roughly proportional to the total radiation dose received by the entire population. If the radiation dose is cut in half, the increase in the number of people dying of cancer or having defective children will also be cut in half, but the degree of damage to each affected individual is undiminished. Lowering the dose reduces the frequency but not the severity of the medical consequences. Every regulatory body in the world uses this principle as the basis for regulating radiation exposures.

Since no dose can be proven safe, there is no objective or scientific way to decide what dose is acceptable. It is a social or political choice, not a technical or scientific one.

Science can only help us to estimate the risks: how many people are likely to get cancer, how many children are likely to be born defective, or what other types of illnesses might increase as a result of a given exposure to radiation. But to judge whether or not these consequences are acceptable is beyond the scope of science.

The situation is further complicated when the people who receive the financial or other benefits of nuclear power or uranium mining are not the only ones exposed to the risks.

K.2. Who is responsible for regulating radiation exposure in Canada?

The Atomic Energy Control Board (AECB), in cooperation with the Radiological Protection Bureau of the federal Department of Health and Welfare, is responsible for regulating radiation exposure in Canada. Since the AECB has little medical or epidemiological expertise, it depends heavily on research and recommendations by agencies outside Canada.

In particular, it relies on the advice of the International Commission on Radiological Protection (ICRP), an self-appointed international advisory body consisting of prominent scientists who work in the field of atomic radiation. Critics have charged that ICRP members are in a conflict-of-interest because their careers are based on jobs where people are inevitably exposed to 'man-made' radiation.

The AECB sets maximum permissible levels of radiation exposure for atomic workers and for members of the general population. These levels are not regarded by the ICRP as acceptable levels for continuous exposure, but as upper limits beyond which radiation exposure becomes clearly unacceptable. Attempts are made to keep actual exposures to a small fraction of the maximum permissible limits, but there is no guarantee that this will always be the case.

The industry and the regulators claim to follow the ALARA principle, which means keeping radiation exposures "As Low As Reasonably Achievable, social and economic factors being taken into account." But who decides what is reasonable? Critics of the industry claim that current acceptable levels of occupational and general population exposures in Canada are unreasonably high, particularly in the light of recent scientific studies (notably, the 1989 BEIR-V report) which indicate that the risks from low-level radiation are from two to eight times as great as previously thought.

Canadian regulatory authorities have never held public hearings to decide on radiation standards, despite numerous official recommendations that they do so.

K.3. What is the basis for setting radiation standards?

In a very real sense, radiation standards are arbitrary. While maximum permissible levels of radiation exposure have been defined for workers and the general population, these exposures should not be regarded as safe or even acceptable. The International Commission on Radiological Protection (ICRP) warns that it would be unacceptable for workers or for members of the general population to be exposed continuously to the maximum permissible dose levels.

Two approaches have been used to justify the existing radiation standards. The first involves estimating the risks of death and genetic damage from a given dose of radiation, and comparing these radiation risks with other risks (e.g., deaths from car accidents, hazardous work, fires, earthquakes, spontaneous birth defects, over-eating, etc.) in an effort to make these two kinds of risk more or less comparable.

The second approach involves comparing the permissible levels of 'man-made' radiation to the levels of naturally-occurring background radiation.

These approaches are the subject of much criticism. The first depends on an accurate appreciation of the true risks of low-level radiation exposure and there is a growing scientific consensus that these risks have been seriously underestimated for decades. The second approach ignores differences between naturally-occurring radiation and 'man-made' radiation. The latter sometimes involves radioactive substances or biological mechanisms which may not be characteristic of naturally occurring radiation.

Both approaches assume that it is acceptable to add the risks of technologically enhanced radiation exposure to all the other risks to which we are already exposed, or to multiply the risks from background radiation by some arbitrary factor.

Furthermore, radiation standards are for people only. Other species are ignored. The standards assume that if humans are protected, so are non- humans. This assumption is now being seriously questioned.

K.4. What is background radiation?

Some radiation exposure is unavoidable, even in the absence of uranium mining and nuclear technology. This background radiation is due to small quantities of radioactive materials in the natural environment - food, water and air - as well as penetrating rays from outer space to which we are all exposed.

Background radiation is higher in some places than in others depending on the altitude, the nature of the soil, and the type of building materials used.

In recent years, it has become clear that the largest and most dangerous single source of exposure to background radiation is in the form of naturally-occurring radon gas produced by the radioactive decay of uranium in the soil. Radon is responsible for more than 50 percent of all human exposure to background radiation.

Most scientists consider that a fraction of the spontaneous cancers or birth defects that occur in human populations are caused by our unavoidable exposure to background radiation. Radon is thought to be the most potent cancer causing agent in the natural environment.

K.5. Is background radiation increasing?

Because of human activities, background radiation exposure is gradually increasing as greater quantities of naturally ocurring radioactive materials are being released into the biosphere (for example, through uranium mining).

"...when our water is destroyed; when our water is radioactive... when our people start dying from cancer, that's exactly the same thing that's gonna happen to them white people..."

Winona LaDuke, native rights activist.

We have added significantly to the unavoidable radiation exposure of all people on earth because of fallout from nuclear weapons testing and nuclear power plant discharges, particularly in the case of a large-scale accident like Chernobyl.

The medical profession has significantly added to our average radiation exposure through the use of x-rays. In addition, small quantities of medical and industrial radioisotopes ('man-made' radioactive substances used for tracers or therapeutic purposes) often end up in soil, water or air.

Although the term background radiation is not meant to include bomb fallout, reactor discharges, medical exposures or environmental contamination from radioisotopes, it is a fact that people all over the world are exposed to increased doses of radiation because of all these factors.

K.6. Is radon in homes a problem?

In the U.S., the U.K. and Sweden (but not Canada), the governments have recently urged all citizens to measure the radon in their homes for their own safety.

The radon in homes is produced from tiny amounts of radium found in the soil or in the building materials. Radon can also enter homes dissolved in tap water. A certain amount of radon is natural and unavoidable. It is nonetheless dangerous. The more radon, the greater the problem. In uranium mines and tailings, of course, the amount of radon is far greater than that found in most homes.

In places such as Port Hope, Ontario, and Grand Junction, Colorado, elevated radon levels in homes and schools resulted from the careless use of abandoned uranium tailings or other uranium wastes in construction. In other places such as Oka, Quebec and St. Johns, Newfoundland, other radium-contaminated materials have been sold to unsuspecting builders, leading to high radon levels in many homes.

A recent British medical study (published in The Lancet in April, 1990) has found a significant correlation between elevated radon levels in homes and serious illnesses such as myeloid leukemia, kidney cancer, melanoma, and a variety of cancers among children. The study uses published data from fifteen countries, including Canada.

K.7. Are Canadian exposure standards being made more stringent?

In recent years, Canadian authorities have been accused of relaxing exposure standards for atomic radiation rather than tightening them. Indeed, within the last decade, the maximum permissible concentration of radium in Canadian drinking water was increased by a factor of three. The maximum permissible concentration of uranium in water is also being increased. New regulations, proposed by the AECB over the objections of organized workers affected by the regulations (and not yet passed into law as of October, 1990) will increase the maximum permissible intake of many radioactive substances in the workplace.

Meanwhile, in other countries, the standards are being tightened because of new scientific evidence which indicates that the risks from low-level exposure to atomic radiation are considerably higher than was thought just a few years ago. The 1989 BEIR V Report stated that its own past estimates of the risk of fatal radiation-induced cancers were underestimated by a factor of two to eight. This would imply that existing permissable levels of radiation exposure for workers and the general population should be significantly reduced.

It is ironic that radiation standards now being legislated in Canada are based on an antiquated report published by the International Commission on Radiological Protection in 1977, rather than on the best scientific evidence currently available.

[In late 1990, the AECB announced it is considering the possibility of making Canadian radiation exposure standards more stringent.]

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Back cover photo: The black star shows the tracks made over a 48 hour period by alpha rays emitted from a radioactive particle lodged in the lung tissue of an ape. In living lung tissue, if one of the cells adjacent to the particle is damaged in a certain way, it can become a cancer cell later on, spreading rapidly through the lung and eventually through the body, causing almost certain death.

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