Comments on the EIS for the Midwest Project

prepared for the

Inter-Church Uranium Committee

by

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to be presented

in Saskatoon, Saskatchewan

on

February 19, 2008.

Environmental Assessments – The Social Context

Spurred by the grass-roots activism of the environmental movement of the 1960s, various governments – including the Government of Canada – established Departments of the Environment around the year 1970 and ushered in the present era of Environmental Standards and Environmental Assessments.

In the intervening decades it has become ever more clear that protection of the environment is critically important for the future of our planet.

Because Environmental Impact Assessments are intended to serve a larger purpose than business-as-usual, it is important that potential environmental problems be described clearly and unflinchingly in every EIS, in language that can be understood by ordinary citizens who may lack the benefit of scientific or technical training but need to have a basic understanding of the issues at hand.

Environmental Assessment has to be an open process in order to fulfill its larger social goal. That requires that all pertinent problems be addressed frankly and acknowledged directly. Problems must not be avoided, ignored, or misrepresented just because they have not yet found a fully satisfactory solution.

A number of important deficiencies have been found in the EIS for the Midwest Project related to the failure of the proponent to address problems clearly and accurately, and to explain the underlying science in an appropriate fashion.

These deficiencies need to be rectified if the larger social goal of environmental assessment is to be achieved: to identify potential environmental impacts fully and fearlessly, to illuminate the nature of the problems by explaining the underlying scientific principles, and to describe any mitigating measures that are intended to reduce or eliminate possible adverse impacts.

Hazards of Radiation Exposure Are Not Properly Represented

The EIS provides a shallow and misleading view of the nature of the health hazards of chronic exposure to ionizing radiation. It is regrettable that none of the responsible agencies saw fit to comment on this rather evident deficiency.

Workers and northern residents need to have accurate and reliable information on a matter so important to their own long-term health and well-being. Citizens are entitled to a clear presentation of the nature of the risks associated with ionizing radiation. They do not get it from this EIS; it must therefore be revised.

In section 8.2.2 of the EIS we read:

> "The amount of radiation that a worker is exposed to is measured in terms of radiation dose. Exposure to radioactive substances, resulting in high radiation doses, has been found to cause detrimental effects, or to increase the likelihood of detrimental effects occurring. Dose limits for individuals have been developed to protect against the risk of unacceptable consequences." (EIS, p.706)

The implication here is, clearly, that although high radiation doses may cause detrimental effects, or increase the likelihood of detrimental effects, that low radiation doses will not do so. Moreover, it is stated that dose limits for individuals will prevent "unacceptable consequences" from happening.

Since any normal individual would probably consider death from a radiation-induced cancer as an "unacceptable consequence", the clear implication is that such cancers cannot be caused by radiation exposures if those exposures are below the regulatory dose limits for individuals.

But this is misinformation. All nuclear regulatory bodies operate on the basis that even low doses of radiation exposure will carry an additional risk – possibly very small, but not zero – of adverse health effects, including fatal cancers. The proponent should be required to make this clear in the EIS.

It is scientifically incorrect and morally wrong for the EIS to imply that regulatory dose limits can be counted on to provide any assurance that there will be no harmful or even fatal health consequences. In 2007, in a press release announcing the publication of the US National Academy of Sciences' BEIR-7 Report on the Biological Effects of Ionizing Radiation, we read:

> WASHINGTON (June 2007) — A preponderance of scientific evidence shows that even low doses of ionizing radiation, such as gamma rays and X-rays, are likely to pose some risk of adverse health effects, says a new report from the National Academies' National Research Council.
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> The report's focus is low-dose, low-LET — "linear energy transfer" — ionizing radiation that is energetic enough to break biomolecular bonds. In living organisms, such radiation can cause DNA damage that eventually leads to cancers. However, more research is needed to determine whether low doses of radiation may also cause other health problems, such as heart disease and stroke, which are now seen with high doses of low-LET radiation.
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> The study committee defined low doses as those ranging from nearly zero to about 100 millisievert (mSv) — units that measure radiation energy deposited in living tissue. The radiation dose from a chest X-ray is about 0.1 mSv. In the United States, people are exposed to average annual background radiation levels of about 3 mSv.
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> The committee's report develops the most up-to-date and comprehensive risk estimates for cancer and other health effects from exposure to low-level ionizing radiation. In general, the report supports previously reported risk estimates for solid cancer and leukemia, but the availability of new and more extensive data have strengthened confidence in these estimates.
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> Specifically, the committee's thorough review of available biological and biophysical data supports a "linear, no-threshold" (LNT) risk model, which says that the smallest dose of low-level ionizing radiation has the potential to cause a small increase in health risks to humans. In the past, some researchers have argued that the LNT model exaggerates adverse health effects, while others have said that it underestimates the harm. The preponderance of evidence supports the LNT model, this new report says.
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> "The scientific research base shows that there is no threshold of exposure below which low levels of ionizing radiation can be demonstrated to be harmless or beneficial," said committee chair Richard R. Monson, associate dean for professional education and professor of epidemiology, Harvard School of Public Health, Boston.

> "The health risks – particularly the development of solid cancers in organs – rise proportionally with exposure. At low doses of radiation, the risk of inducing solid cancers is very small. As the overall lifetime exposure increases, so does the risk." The report is the seventh in a series on the biological effects of ionizing radiation.

Here is some corroborating evidence on the same point from the Canadian nuclear industry, dating back some 25 years:

In November 1981 , two atomic workers at Chalk River, Ontario, were granted full pensions because of cancers which they had contracted as a result of radiation exposure on the job. "We acknowledge that it was probable that their cancers were caused by working here," said a statement issued by Chalk River Nuclear Laboratories, despite the fact that neither of the men had ever been over-exposed to radiation.
Thomas Arnold was awarded a pension of $1335 a month by the Ontario Workman's Compensation Board (WCB), on the advice of Atomic Energy of Canada Limited (AECL). Arnold credits AECL with doing all the work to get him the pension. He developed lymph cancer during his 28 years of work as a reactor maintenance man at Chalk River.

The other case involves a 31-year veteran of Chalk River who died of leukemia shortly before the WCB granted his compensation. His widow was awarded $490 a month for life, the maximum permitted under WCB rules.

A spokesman for the WCB said there is a third claim pending from Chalk River over a case of skin cancer. Meanwhile, a 50 year-old Pembroke man has also filed a claim with the WCB. Raymond Paplinskie, who has lost an eye and most of the skin on one side of his face, says that he got cancer of the sinuses from doing nuclear cleanup work following a 1958 reactor accident at Chalk River.

AECL spokesman Hal Tracy explained that the nuclear industry in Canada accepts the theory that there is no safe threshold limit for radiation exposure; hence, it must also be accepted that any dose at all has the potential for harm, and that eventually there will be some evidence of this harm. "Possibly there will be more cancers among our workers," said Mr. Tracy. "These first cases weren't a total surprise. Deaths due to radiation exposure had been predicted. We've always believed there was an increased risk."

Robert Potvin, a spokesman for the Atomic Energy Control Board (AECB), which regulates the Canadian nuclear industry, said that the two cases of compensation have "no implications" form the safety standpoint. They "simply confirm the long-standing expectation" that nuclear workers run a higher-than-usual risk of cancer due to years of exposure to low-level radiation, he said.

"Our limits admit that any dose can increase the risk and, on that premise, cancer deaths are not unexpected." He added that "studies say the average risk under these limits is comparable to the risk in an industry with a high safety standard -- for example, manufacturing shoes."

A spokesman for Ontario Hydro, Richard Furness, said in an interview with the Toronto Star that "no one has ever died or suffered lost-time injuries due to radiation at a Hydro nuclear plant -- or any other Canadian nuclear facility." When told about the AECL acknowledgement of two cases at Chalk River, Furness remarked: "Oh. Well, there goes that record."

Ontario Hydro's Health and Safety Director Bob Wilson said it was time the public recognized the facts. For every hundred million hours of work done under radiation exposure (at no more than the permissible limits) about 2 to 4 otherwise unexpected cancer cases will develop, Wilson said. "We have never said a radiation worker is without risk," he insisted, but added that radiation workers are 10 to 100 times less likely to die from work than such people as fishermen, forestry workers, miners or even Hydro linemen.
But a well-informed AECL worker told the Toronto Star that "this is going to open an intense debate about safety. What can we expect from all the other live or dead cancer victims who have long-term low-level radiation exposure at AECL or Ontario Hydro? It could mean that the whole system of predictions that five rems of radiation was an acceptable dose for workers is dead wrong."

Critics of the nuclear industry have argued that the industry's predictions could prove fatally wrong for many more workers than anticipated. It can take 20 years or more for cancers to develop from low-level long-term radiation exposure, and at least 250 Hydro workers and about the same number at AECL are coming up for the 20-year turning point.

In fact, a special report on the medical effects of alpha radiation published by the AECB in September 1982 indicates that the present permissible exposure limits could result in a quadrupling of the risk of lung cancer deaths among uranium miners, whether they smoke or not. This conclusion is based on actual mortality figures among uranium miners from Colorado, Sweden, Czechoslovakia, Canada, and elsewhere.

REFERENCES

Canadian Occupational Health and Safety News, v.5, n.10, March 15, 1982.
Canadian Environmental Law Association Newsletter, 1982.
Toronto Star, March 4, 5, 6, 7, 1982.
Globe and Mail, March 5, 11, 1982.
Risk Estimates for the Health Effects of Alpha Radiation, INFO-0081, AECB, Sept. 1982.

In the interest of fairness to the workers, who may be putting their lives at some small or considerable risk by working in an environment which exposes them to chronic doses of ionizing radiation, the proponent should be required to report in the EIS that many populations of uranium miners in Canada and elsewhere have shown increased incidences of radiation-induced lung cancer, and that the regulatory limits of radiation exposure for individuals do not provide a guarantee against such adverse health effects.

At the same time, the proponent may explain why such adverse effects are less likely due to mitigating measures including the difference between open-pit mining and underground mining, more stringent control over radiation exposures, etc. However, the proponent should not be allowed to imply that individual workers are protected against the possibility of such adverse health effects.

Failure to Explain Alpha and Beta Radiation

Alpha radiation is universally regarded as the principal life-threatening radiation hazard in the context of uranium mining, yet the EIS nowhere explains what alpha radiation is or how it differs from other types of radiation such as gamma radiation and beta radiation.

This is an unacceptable deficiency in the EIS and must be corrected.

On page 707 the EIS states that “radiation exposures can be divided into three components”, the first of which is gamma radiation. But there is no mention of alpha radiation at all in this context and only a cursory mention of beta radiation.

To be sure, radon and its progeny are identified on the same page as internal radiation risks along with “long-lived” radioactive dust. But there is no hint that this “internal risk” is in fact due to two other types of ionizing radiation, both of them dramatically less penetrating than gamma radiation – alpha and beta.

The word “alpha” appears in the EIS only four times (on pages 600, 605, and 616), the word “beta” appears only three times (all on the same page, 707, in two consecutive sentences), yet the word “gamma” appears 62 times.

A normal person might reasonably conclude that gamma radiation exposures are all-important – especially when workers’ risk from beta radiation is explicitly dismissed and the only references to alpha radiation in the entire EIS are in the context of radiation exposures to fish, aquatic plants, and benthic invertebrates.

The dangers of beta radiation are dismissed out of hand in two sentences on page 707 where it is stated that it (beta radiation) poses no “external” risk without clarifying that it (beta radiation) does in fact pose an internal radiation risk. This is a serious misrepresentation of the facts concerning beta radiation, which can be a very significant internal radiation risk.

But the most important oversight is the failure to deal with alpha radiation. This constitutes a major defect in the EIS. It must be remedied.

Failure to Explain the Importance of Alpha Radiation

Alpha radiation is of primary importance throughout the uranium mining and milling operations.

Uranium-238, uranium-235 and uranium-234 are all alpha emitters, as are radium-226, radon-222, polonium-218, polonium-214, and polonium-210, as well as thorium-230 and seven other radioactive materials found in every uranium ore body. These alpha emitters are by far the most dangerous radioactive materials encountered in the context of uranium mining and milling.

Alpha radiation is much more biologically damaging than either gamma or beta radiation per unit of ionizing energy deposited in living tissue. Yet the EIS never mentions this fact in the context of human exposures, and only alludes to it indirectly in the context of environmental radioactivity:

> The benthic invertebrate and aquatic plant dose assessment included the consideration of external dose from sediment (*i.e.*, the benthic invertebrate living in the sediment). The internal dose was calculated based on water to tissue transfer factors. A range of Relative Biological Effectiveness (RBE) factors (5, 10, 20 and 40) were originally utilized to reflect the range of current opinion regarding the biological impairment resulting from exposure to alpha radiation. (EIS, p. 616)

This is good, as far as it goes; but nowhere does the EIS explain what "RBE factors" of 5, 10, 20 or 40 really mean. It is a kind of scientific shorthand, and it means that internal exposure of living cells to alpha radiation energy is 5, 10, 20, or 40 times more damaging than exposure of those same cells to an equal amount of gamma-ray energy or beta-ray energy.

Nor does the EIS explain that internal exposure of humans to alpha radiation is also much more effective (about 20 times more effective) in causing cancer and other diseases than exposure to the same amount of gamma-ray energy or beta-ray energy.

Workers and non-workers alike need to understand that although alpha radiation is a non-penetrating form of ionizing radiation, which can be stopped by a single sheet of paper or by the dead layer of cells on the outside of the skin, and therefore poses no hazard outside the body, nevertheless it can be exceedingly hazardous when an alpha-emitting material is inhaled, ingested, or otherwise absorbed into the body, and thereby comes into close contact with living cells.

Indeed, during the first half of the twentieth century it has been the alpha emitters – specifically radium, radon, polonium, and uranium – which have posed the greatest radiological threat to human health.

To this day, it is the alpha emitters – specifically radon, an alpha-emitting radioactive noble gas, and its alpha-emitting progeny – which have caused the greatest number of deaths among uranium miners, and even among ordinary citizens (the US EPA currently estimates that about 20,000 Americans die each years as a result of breathing radon gas in their own homes – at dose levels far below the regulatory dose limits for workers).

The proponent must be required to explain what alpha radiation is, and why it is especially dangerous once it is inside the body. The concept of RBE must be explained in simple terms, so that people can understand that an RBE greater than one indicates a proportionately higher degree of biological damage than would be the case if the more penetrating gamma radiation were involved.

This is vital information for workers and members of the neighbouring communities. It underscores the importance of preventing the inhalation or ingestion of contaminated materials. It explains why radioactive dust may pose little threat outside the body, even if it has settled on the skin, compared with inhaling that dust into the lungs or ingesting it through food or drink. It is true in the case of alpha contamination, and also in cases of beta contamination.

Understanding the non-penetrating nature of alpha radiation, yet the high danger level associated with internal alpha contamination, underscores the importance of workers and others washing very thoroughly and very carefully in situations where surface contamination of skin or clothing may have occurred, so that alpha contamination does not enter the body through open cuts or sores or through transferring the material to the mouth by touch.

The proponent should be obliged to discuss these matters in the EIS.

Radioactive Progeny Are Not Properly Explained

The EIS does not explain how one radioactive material can be transformed into another radioactive material through the process of atomic disintegration. Thus the reader is left to grapple with frequent references to "radon progeny" and "uranium progeny" without any clear understanding of what is meant by those words. This results in mystification rather than understanding.

It was 1896 when Henri Becquerel discovered that uranium ore is radioactive. The ore gives off a kind of invisible light capable of exposing a photographic plate – even one that is wrapped in thick brown paper.

Shortly thereafter, Marie Curie crushed a large amount of uranium ore and chemically separated the uranium from the residues. She found that, while uranium is radioactive, the residues are much more so. She intuited that there must be other intensely radioactive materials contained in the residues.

In this way she soon discovered two previously unknown elements, both of them millions of times more radioactive than uranium. She named them polonium (after her native country Poland) and radium. For this she won the Nobel Prize.

She didn't know at that time that radium and polonium are transformed versions of uranium. Uranium atoms actually change into atoms of radium and polonium, through a process known as radioactive decay or radioactive disintegration.

Uranium atoms are unstable. Each uranium atom eventually disintegrates, giving off a burst of energy (called atomic radiation) in the process. But the atom doesn't disappear when this happens; instead, it is transformed into an atom of a brand new kind, which – as it happens – is also radioactive, and therefore it too will disintegrate, producing a third radioactive atom, then a fourth, then a fifth, until eventually a completely stable atom – a non-radioactive atom – is obtained.

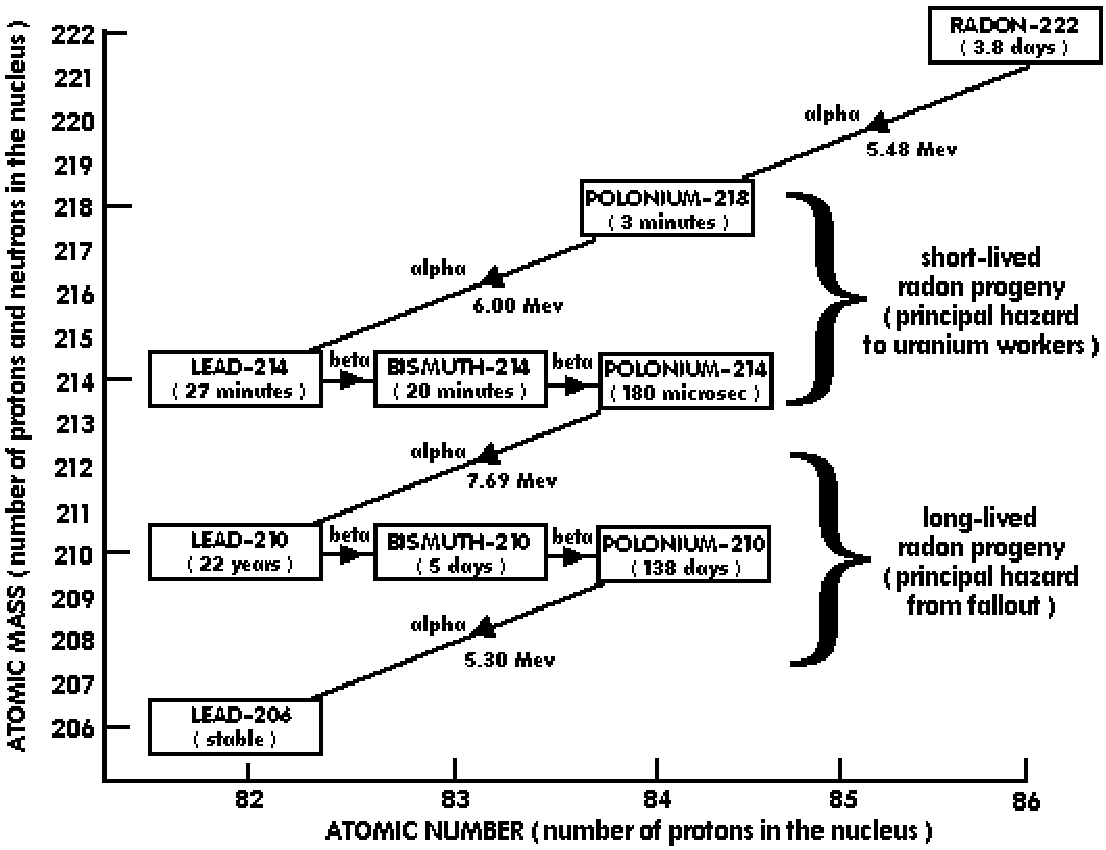
Thus we obtain the so-called "radioactive decay chain" of uranium, which includes about a dozen other materials called the "progeny" of uranium. See appendix 1 for the decay chains of uranium-238, uranium-235, and thorium-232. These three (U-238, U-235, Th-232) are called "primordial radionuclides" since they have been buried in the Earth's crust for billions of years.

All of this is important to know if one wants to understand the radiological hazards associated with uranium mining and milling. Since the mill only extracts uranium from the ore, the crushed rock that is left behind is far more radioactive than the uranium that has been extracted. The mill tailings contain not only all of the radium and polonium that was present in the ore, but lots of other radioactive materials as well. In fact 85 percent of the radioactivity that was originally in the undisturbed ore body ends up in the tailings.

Similarly, radon gas (one of the uranium progeny) is radioactive; when it disintegrates it produces seven other radioactive materials called the "radon progeny". When one inhales radon gas that has been hanging around for a while, one is also breathing in the solid radon progeny. These solid radioactive particles lodge in the lung and do most of the radiation damage to the delicate living lung tissue, in some cases leading to lung cancer many years later.

Nowhere in the EIS is there a complete tabulation of the decay chain for uranium-238 or any of the other primordial radionuclides. Nowhere in the EIS is there a listing or a discussion of the decay chain of radon gas. Nowhere in the EIS is there a discussion of the mechanism by which the progeny are created, and as a result there is no clear understanding offered of what the progeny are.

The proponent should be required to include such information in the EIS, and to explain associated concepts such as radioactive equilibrium between the parent radionuclide and its progeny, whether the parent be uranium-238 in the ore, or thorium-230 in the mill tailings, or radon-222 in a confined unventilated space.



Uranium Mill Tailings

Without an understanding of the uranium decay chain and uranium progeny, it is not possible to understand the radiological legacy of the long-lived wastes brought to the surface by uranium mining activities. These toxic residues must be contained for a period of time that dwarfs the span of human history.

It is sobering to realize that, given perfect containment of the mill tailings, the amount of each radionuclide in the tailings is only reduced by 50 percent after about 76,000 years, due to the longevity of thorium-230 which continuously replenishes the inventory of other radionuclides lower down in the decay chain.

It is also sobering to realize that each of the uranium progeny has the same degree of radioactivity (measured in becquerels) as the parent uranium isotope, due to the "secular equilibrium" that is characteristic of old uranium ore bodies.

Although great strides have been taken in recent decades to improve the short-term management of uranium mill wastes, the problem of keeping these wastes out of the environment for hundreds of thousands of years is still unresolved.

What kind of warning or notification will be provided for generations thousands of years hence? In what language will those notices be written? What assurance do we have that any of our existing languages will not have become extinct within the next few thousand years? What assurance do we have that the wastes will not be washed into the environment by floods, spread far and wide by tornadoes, or even excavated and used in construction by future generations of humans in ignorance of the toxic nature of the wastes?

Yet this staggering environmental problem is not discussed at all in the current EIS. This is an unacceptable deficiency in the document. A very serious long-term environmental problem has gone unarticulated. This should not be.

At the very least, there has to be a meaningful acknowledgment of the problem, so that people can judge the mitigating measures that are planned to cope with that problem. And there should be continual pressure to seek better alternatives.

For example, our society has spent considerable sums of money on the concept of geological disposal of the high-level radioactive wastes produced by a nuclear reactor in the form of irradiated fuel elements. There is still a considerable residuum of uncertainty as to whether this is the best way to proceed, but in any event, the search for a permanently acceptable solution continues. Is the same true for uranium mill tailings?

Under cross-examination at the Royal Commission on Electric Power Planning in Toronto, back in 1978, Dr. Kenneth Hare, co-author of the Government of Canada's green paper on the Management of Canada's Nuclear Fuel Wastes, stated that if there are sufficient quantities of actinides and other radio-toxic materials in uranium mill tailings, then serious consideration should be given to geologic disposal of mill tailings as well.

For example, polonium-210 is one of the constituents of mill tailings, and it is billions of times more toxic than cyanide. It is one of the most deadly naturally-occurring substances known. Most people had never heard of this incredibly toxic material until quite recently; it was the poisonous agent used to murder the ex-KGB agent Alexander Litvinenko in London England. Because it is a pure alpha emitter, polonium-210 can be safely transported in a sealed vial posing no danger to the assassin and offerring no chance of detecion. But once uncorked and ingested by the victim, polonium-210 attaches itself to the red blood cells and is transported to each of the body's vital organs in turn, causing untold damage along the way.

Radium-226 is also a constituent of uranium mill tailings. It is a deadly material, described by the British Columbia Medical Association as "a superb carcinogen". Back in the 1920s, radium-226 sold for $100,000 per gram. But by the 1940s so many people had been killed because of rapid anemia, bone cancer, and other diseases caused by ingesting minute quantities of radium-226 – microgram quantities – that the market for this radioactive material all but disappeared.

Nowadays, radium-226 and polonium-210, along with a host of other radioactive materials, are routinely discarded as waste by-products in tailings containment areas such as the JEB pit. And the number of becquerels of each of these materials is equal to the number of becquerels in the uranium-238 that has been extracted, due to the principle of radioactive equilibrium (so-called "secular equilibrium") in very old ore bodies.

Yet in this EIS, there is no discussion of the toxicity of mill tailings, the longevity of the hazard, or alternative approaches to the long-term management of mill tailings. Such a discussion should be required. What about advanced milling techniques? In the Joint Panel Report on the McArthur River Project, mention was made of the possibility of extracting the thorium and radium from the ore as well as the uranium, thereby drastically reducing the long-term radiological hazard of the tailings. Once separated, the radium and thorium could then be immobilized and subjected to something akin to geologic disposal.

Radiological Importance of the Lichen-Caribou Food Chain

Caribou are one of the most important living resources for past, present and future residents in the north , especially aboriginal people. In particular, the barren-land caribou are identified in the Project-Specific Guidelines and Scoping Document as requiring special attention in the EIS.

The lichen → caribou → human food chain is undoubtedly the most significant radiation exposure pathway for residents of Northern Canada. Although the EIS notes the importance of this food chain in general, it does not emphasize its importance as a vehicle for human exposure to radioactive contaminants.

Any radioactive solids which are widely dispersed in the atmosphere as microscopically small particles (aerosols) will gradually settle onto the lichen over a period of decades. Because lichen have no functional roots but take their mineral nutrition directly from the air, they are particularly efficient in capturing and retaining these radioactive materials.

Caribou herds graze on lichen over very large areas of land, especially during the winter months. As a result, caribou incorporate concentrated amounts of radioactive materials into their bodies. Some of these materials go to the bones and teeth of the animal, and so are not generally consumed by humans. Other materials go into the meat and the soft organs, and these materials are of course ingested by humans who eat caribou meat.

Over the last half-century, the major radioactive exposure of northern residents who eat caribou meat has been (1) due to radioactive cesium, released into the atmosphere by the above-ground explosions of nuclear weapons, and from the Chernobyl nuclear reactor accident in the Ukraine; and (2) due to polonium-210, released into the atmosphere by the radioactive disintegration of uranium and those uranium progeny which happen to be very close to the surface o the Earth.

The most intense period of atmospheric testing of nuclear weapons was in the late 1950s and the early 1960s. As a result, hundreds of radioactive materials were released into the atmosphere, including two types of radioactive cesium (cesium-134 and cesium-137) which were previously not encountered in nature. Due to its chemical properties, cesium is stored up in the muscle tissue and the soft organs of the caribou's body.

Shortly after the peak period of atmospheric testing of nuclear weapons, northern residents who regularly consumed caribou meat were exposed to as much as five millisieverts of extra radiation dose each year due to the cesium-137 that had been created by the fissioning of uranium atoms in the exploding bombs, dispersed into the upper atmosphere as a radioactive aerosol, and ultimately ended up in caribou meat. Incidentally, cesium-134 and cesium-137 are both beta-emitters.

These five millisieverts of radiation exposure were in addition to the normal background radiation exposure experienced by humans everywhere, which is about 2.4 millisieverts per person each year on average (according to the United Nations Scientific Committee on Atomic Radiation, 1993). Thus the caribou meat-eaters of northern Canada ended up with radiation doses about three times higher than those experienced by other Canadians as a result of radioactive fallout from the atmospheric testing of atomic bombs in the American southwest and elsewherein the world.

Despite their historic importance in terms of radiation exposure to northern wildlife and northern residents, there seems to be no mention of these data in the EIS. This is a serious deficiency in the EIS, since the same basic mechanism provides a significant biological pathway by which uranium mining and mill residues could contribute to the radiation exposure of northern wildlife and northern residents.

As already noted, testing for radioactivity levels in caribou and in northern residents did not begin to take place until the 1960s. It began as a result of scientific curiosity regarding the nature and the extent of radioactive fallout from bomb testing.

As an unanticipated result of this testing in the 1960s, it was observed for the first time that both caribou and those northern residents who eat caribou meat have dramatically elevated levels of polonium-210 in their tissues, compared with other Canadian residents. Polonium-210 is a radioactive byproduct of naturally occurring uranium in the soil.

How does polonium-210 find its way into the meat and soft organs of the caribou? The answer is found in the migration of radon gas, an invisible radioactive gas which cannot be tasted or smelled. Radon is chemically inert (it is a "noble gas") and so it does not form molecules with other atoms. It can therefore travel long distances unimpeded. Radon is much heavier than air so it tends to stay close to the ground, which is close to where the lichen are growing.

At source, every atom of polonium-210 in nature begins as an atom of uranium. But uranium atoms don't change directly into polonium atoms, they first change into atoms of radium and then into atoms of radon gas. The radon drifts over the surface of the earth and slowly deposits its own solid radioactive progeny, including lead-210 and polonium-210, onto the lichen below. The caribou eat the lichen. The polonium-210 accumulates in their meat and internal organs, while the lead-210 is stored up in the bones, the teeth, and the milk of nursing mothers. Consequently humans who eat caribou meat end up with elevated levels of polonium-210 in their bodies, but not a large amount of lead-210.

It is unacceptable that the EIS does not document this mechanism for radiation exposure of humans from naturally ocurring uranium. As Tracy Bliss of Health Canada wrote:

> "Previous studies have shown that alpha radiation from ingested polonium-210 is one of the most significant sources of radiation exposure to northern caribou herds and to the human populations who are dependent on caribou. Polonium-210 and its precursor, lead-210, result from the decay of natural radon gas in the atmosphere. These radionuclides gradually settle onto slowly-growing lichens which are the principal food source of caribou, especially during the long Arctic winters. Lead-210 accumulates mainly in the bones of the animals and is not passed on to human consumers. Polonium-210, on the other hand, accumulates in muscle tissue and organs, which are consumed by

> humans. Furthermore, polonium-210 emits pure alpha radiation, which is more damaging that other types of radiation such as beta, gamma, and x-rays. Radiation exposure levels in northern communities from ingested polonium-210 can be several times higher than levels in the rest of Canada."
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> **Effects of Polonium-210 Alpha Radiation on Human and Animal Systems**
> **Principle Investigator:** Tracy Bliss, Radiation Protection Bureau, Health Canada, 775 Brookfield, 2nd Floor, Radiation Protection Building, Tunney's Pasture, AL 6302D1, Ottawa, ON, K1A 1C1

Yet the EIS only alludes to these data in an indirect way, obscuring the fact that the elevated radiation exposures are intimately associated with the behaviour of uranium progeny in the northern environment and therefore potentially of great relevance to the long-term environmental impact of the radon-generating uranium residues.

On page 728 of the EIS we read:

> It is noted that Caribou meat, which is typically harvested outside the assessment area, constitutes a significant portion of meat consumed by northerners. Exposure to naturally occurring radiation from eating caribou meat has been estimated, using the Hatchet Lake Band dietary survey (CanNorth 2000) as a basis. Radionuclide concentrations measured in 15 caribou harvested from four natural sites in northern Saskatchewan (Thomas 1999) were used to characterize background radionuclide concentrations in caribou meat. The use of these background concentrations resulted in a dose estimate of about 1,800 µSv/year for an adult and 2,600 *µ*Sy/year for a child, which is not related to project effects. It is noted that the predicted incremental dose from the project is a small fraction of the dose received from naturally occurring radiation associated with eating caribou meat.

The EIS should be explicit about the nature of this "naturally occurring radiation", the prercise identity of these "radionuclide concentrations", and the intimate relationship between this phenomenon and the decay chain of uranium. It should be made clear that these are exactly the same naturally occurring radioactive matyerials that are encountered in the context of uranium mining and milling, and that they are among the same radio-nuclides that figure prominently in the long-term environmental impact assessment of radioactive waste management associated with the proposed uranium mining operation.

Notice how much more frank and informative is the text of the 1999 paper that was cited in the previous passage from the EIS:

> The richest uranium ore bodies ever discovered (Cigar Lake and McArthur River) are presently under development in northeastern Saskatchewan. This subarctic region is also home to several operating uranium mines and aboriginal communities, partly dependent upon caribou for subsistence. Because of concerns over mining impacts and the efficient transfer of airborne radionuclides through the lichen-caribou-human food chain, radionuclides were analyzed in tissues from 18 barren-ground caribou (*Rangifer tarandus groenlandicus*) . Radionuclides included uranium (U) , radium (^{226}Ra = radium-226) , lead (^{210}Pb = lead-210) , and polonium (^{210}Po = polonium-210) from the uranium decay series; the fission product (^{137}Cs = cesium-137) from fallout; and naturally occurring potassium (^{40}K = potassium-40) .
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> Natural background radiation doses average 2 to 4 millisieverts per year from cosmic rays, external gamma rays, radon inhalation, and ingestion of food items. The ingestion of ^{210}Po [polonium-210] and ^{137}Cs [cesium-137] when caribou are consumed adds to these background doses. The dose increment was 0.85 millisieverts per year for adults who consumed 100 grams of caribou meat per day and up to 1.7 millisieverts per year if one liver and 10 kidneys per year were also consumed. We discuss the cancer risk from these doses.
>
> **Radionuclides in the Lichen-Caribou-Human Food Chain Near Uranium Mining Operations in Northern Saskatchewan, Canada, 1999**
> **Patricia A. Thomas[1] and Thomas E. Gates[2]**
>
> **http://www.ehponline.org/docs/1999/107p527-537thomas/abstract.html**
>
> [1]Toxicology Centre, University of Saskatchewan, Saskatoon.
> [2]Saskatchewan Environment and Resource Management, Prince Albert.

The porponent should be rerquired to be equally frank in discussing this important food chain mechanism for delivering significant amounts of ionizing radiation to wildlife and humans.

These secondary materials are called the “uranium decay products”. Taken together, they are much more radioactive and much more toxic than the uranium by itself.

Almost all of the uranium decay products are solids, except for radon gas. Radon is an invisible radioactive gas which cannot be tasted or smelled. It is about 8 times heavier than ordinary air, so it tends to stay close to the ground. Its atoms disintegrate much more quickly than uranium atoms do; in only four days, more than half of the radon atoms have disintegrated and changed into atoms of radioactive bismuth, radioactive lead, and radioactive polonium.

Uranium is a naturally-occurring material. Trace amounts are found in the soil all over the earth, usually in very small concentrations. But in some places the uranium is much more concentrated. If the concentration is high enough it is called a uranium "deposit", and if the price of uranium is high enough, it may be profitable to mine the deposit.

Naturally, wherever there is a higher concentration of uranium, one also encounters a higher concentration of uranium decay products – thus more radium, more radon gas, and more radioactive polonium.

When uranium is mined, enormous quantities of rock are brought to the surface, crushed into a very fine powder, and the uranium is separated out using sulfuric acid and other chemicals. But the uranium decay products are left behind as waste byproducts of no commercial value. These sand-like residues contain 85 percent of the radioactivity that was originally present in the uranium deposit, and they will continue to generate new radioactive decay products – especially radium, radon gas, and polonium – for hundreds of thousands of years to come.

, uranium slowly transforms itself into a series of other radioactive materialsWhen a uranium atom disintegrates, it throws of a part of itself with great force and is instantly transformed into a completely different kind of atom – an atom of a different substance. , but the process is so slow that only half of the atoms disintegrate in4.5 billion years. changing into atoms of many different radioactive materials called the "decay products" of uranium. Almost all of the decay products of uranium are solids except for radon, which is a tasteless, odourless, colourless radioactive gas, about 8 times heavier than ordinary air.

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Residents of Northern Canada who consume significant quantities of caribou meat have higher levels of polonium-210 in their bodies than other residents of Canada.

According to UNSCEAR (the United Nations Scientific Committee on the Effects of Atomic Radiation) the average "background" dose of radiation for most residents is about 2.4 millisieverts per year.

Radioactive Exposures of Caribou and Northern Residents

Lichen – caribou on page 609, no mention of radioactivity., in "Assessment of Residual Effects"

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Panel recommends tougher radon gas standards

Updated Wed. Jun. 14 2006 11:20 AM ET

CTV.ca News Staff

A panel of experts has recommended a vast reduction in the level of radon gas that is considered acceptable in homes and schools in Canada, according to a report in The Globe and Mail.

The advisory panel, comprised mostly of experts from Health Canada, as well as their provincial counterparts, recommends the government lower acceptable standards by 75 per cent.

Canada's standards are currently some of the most lax in the world -- less stringent, even, than in some developing nations, according to the report to the federal and provincial governments. .

The panel claims that radon gas -- which is caused by the decay of uranium -- is responsible for 10 per cent of all lung cancer deaths, second only to deaths caused by tobacco smoke.

The gas is a colourless and odourless radioactive gas. It often finds its way into the basements of houses and schools through cracks in foundations, or holes drilled for plumbing.

Canada's current standard permits 800 becquerels per cubic metre of air. A becquerel is the unit used to measure radon gas content in the air.

The advisory panel wants the standard dropped to 200 becquerels per cubic metre to match the standards of other nations such as Britain, Sweden and Norway.

China is applying the same standard to new construction projects.

The panel estimates that about 175,000 homes are currently above the panel's target guidelines, and homeowners are advised to take action to lower levels in their own homes.

This is commonly done through the installation of ventilation systems, or by sealing cracks and gaps in concrete foundations.

As many as 450 schools and 20 hospitals across Canada are above the panel's recommended levels. That would cost about $560 million to fix.

Effects of Polonium-210 Alpha Radiation on Human and Animal Systems
Principle Investigator: Tracy Bliss, Radiation Protection Bureau, Health Canada, 775 Brookfield, 2nd Floor, Radiation Protection Building, Tunney's Pasture, AL 6302D1, Ottawa, ON K1A 1C1

"When estimating radiation risks from alpha emitters, such as polonium-210, the absorbed dose is generally multiplied by a radiation weighting factor to account for the greater effectiveness of alpha particles in causing damage. A weighting factor of 20 has been adopted for humans, where cancer is the most significant endpoint. However, there is considerable uncertainty over an appropriate value for non-human species, where cell or reproductive effects may be more important endpoints. Previous studies have shown that alpha radiation from ingested polonium-210 is one of the most significant sources of radiation exposure to northern caribou herds and to the human populations who are dependent on caribou. Polonium-210 and its precursor, lead-210, result from the decay of natural radon gas in the atmosphere. These radionuclides gradually settle onto slowly-growing lichens which are the principal food source of caribou, especially during the long Arctic winters. Lead-210 accumulates mainly in the bones of the animals and is not passed on to human consumers. Polonium-210, on the other hand, accumulates in muscle tissue and organs, which are consumed by humans. Furthermore, polonium-210 emits pure alpha radiation, which is more damaging that other types of radiation such as beta, gamma, and x-rays. Radiation exposure levels in northern communities from ingested polonium-210 can be several times higher than levels in the rest of Canada."

8.3.2 Results of the Human Health Risk Assessment
8.3.2.1 Radiation Dose Effects

p.727

Regardless of where people live or work, they are exposed to radiation from natural sources, such as: cosmic rays; radionuclides in air, water and food; and gamma radiation from radioactive materials in the soil, rocks, and building materials used in homes. Table 8.3-7 lists exposure to radiation to some of the common sources of naturally occurring radiation for those living in Canada (AECB 1995), which can add up to 1,000 to 2,000 µSv/year. This information is also illustrated in Figure 8.3-4.

The incremental annual radiation dose resulting from the Midwest Project and the McClean Lake Operation activities for the eleven receptors is summarized in Table 8.3-8. The highest predicted incremental dose to the public is 50 µSv/year (Midwest Project Base Case) and 63 µSv/year (Midwest Project Cumulative Case) for Wollaston Lake trapper child receptor. This is well below the recommended incremental dose limit of 1,000 µSv/year, and well within the range of variability of radiation dose from natural sources. The incremental dose to on-site JEB camp worker is predicted to be about 116 µSv/year, primarily from inhalation, which is also well below 1,000 µSv/year.

It is noted that Caribou meat, which is typically harvested outside the assessment area, constitutes a significant portion of meat consumed by northerners. Exposure to naturally occurring radiation from eating caribou meat has been estimated, using the Hatchet Lake Band dietary survey (CanNorth 2000) as a basis. Radionuclide concentrations measured in 15 caribou harvested from four natural sites in northern Saskatchewan (Thomas 1999) were used to characterize background radionuclide concentrations in caribou meat. The use of these background concentrations resulted in a dose estimate of about 1,800 µSv/year for an adult and 2,600 *µ*Sy/year for a child, which is not related to project effects. It is noted that the predicted incremental dose from the project is a small fraction of the dose received from naturally occurring radiation associated with eating caribou meat.

An assessment was also carried out to evaluate the effects of replacing daily caribou meat consumption (harvested outside the affected area, and thus not affected by the project) with moose harvested from the S/V TEMS area. S/V TEMS is located immediately downstream of treated effluent release from the Midwest Project combined with the McClean Lake Operation. The Midwest Project Base Case results indicate that for the Wollaston Lake resident adult and child consuming 131 kg and 88 kg of moose per year, respectively, the incremental dose associated with this diet is estimated at 139 µSv/year for an adult and 310 µSv/year for a child. The total project related incremental dose is thus 145 µSv/year for an adult and 354 µSv/year for a child, which are both far below the recommended incremental dose of 1,000 µSv/year. For the Midwest Project Cumulative Case, the Wollaston Lake resident adult and child the incremental dose associated with this diet is estimated at 236 µSv/year for an adult and 543 µSv/year for a child. The total project related incremental dose is thus 243 µSv/year for an adult and 590 µSv/year for a child, which are both below the recommended incremental dose of 1,000 µSv/year.

8.3.2.2 Carcinogenic Effects

Over a lifetime, daily arsenic intake is also considered to present some risk of developing skin cancer (carcinogenic risk). For an adult living in Canada, the incremental risk associated with trace amounts of arsenic naturally present in water and in many foods range from seven in ten thousand (7 in

10,000) to one in one thousand (1 in 1,000) (Environment Canada 1993). In comparison, the incremental risk for skin cancer from exposure to ultraviolet rays is about 1 in 100 (Canadian Cancer Statistics 2004, www.cancer.ca).

For caribou habitat, about 30,250 ha were considered to have high potential to support caribou, ***p.774.***

In the assessment of potential effects to the caribou and wolf VECs, no constituents of concern were identified based on the CNSC benchmarks. Thus adverse effects are not anticipated. P.782

caribou and wolf are not anticipated

northern Saskatchewan consume a significant amount of caribou meat; incremental dose from eating caribou meat, due to naturally occurring radiation, is estimated to be about 1,800 uSv/year for an adult Eating the same quantity of moose harvested from the S/V TEMS area will result in an incremental dose of 139 uSv/year for an adult and 310 uSv/year for a child (Base Case); 236 uSv/year for an adult and 543 uSv/year for a child (Cumulative Case) Arsenic naturally present in market food and in drinking water represents a carcinogenic health risk of 7 in 10,000 to 1 in 1,000 for an adult living in Canada

The maximum incremental radiation dose for the member of the public is estimated

at 50 µSv/year (Base Case) and 63 uSv/year (Cumulative Case); for on-site JEB camp worker, it is 116 µSv/year (Base and Cumulative Case)
where people live, they are exposed to radiation from natural sources; in Canada, it ranges from about 1,000 to 2,000 µSv/year

The operating principles of radiation protection are founded in the ALARA (As Low As Reasonably Achievable) principle whereby the facilities, processes, equipment, and work practices are designed to minimize radiation doses to workers, and the public.

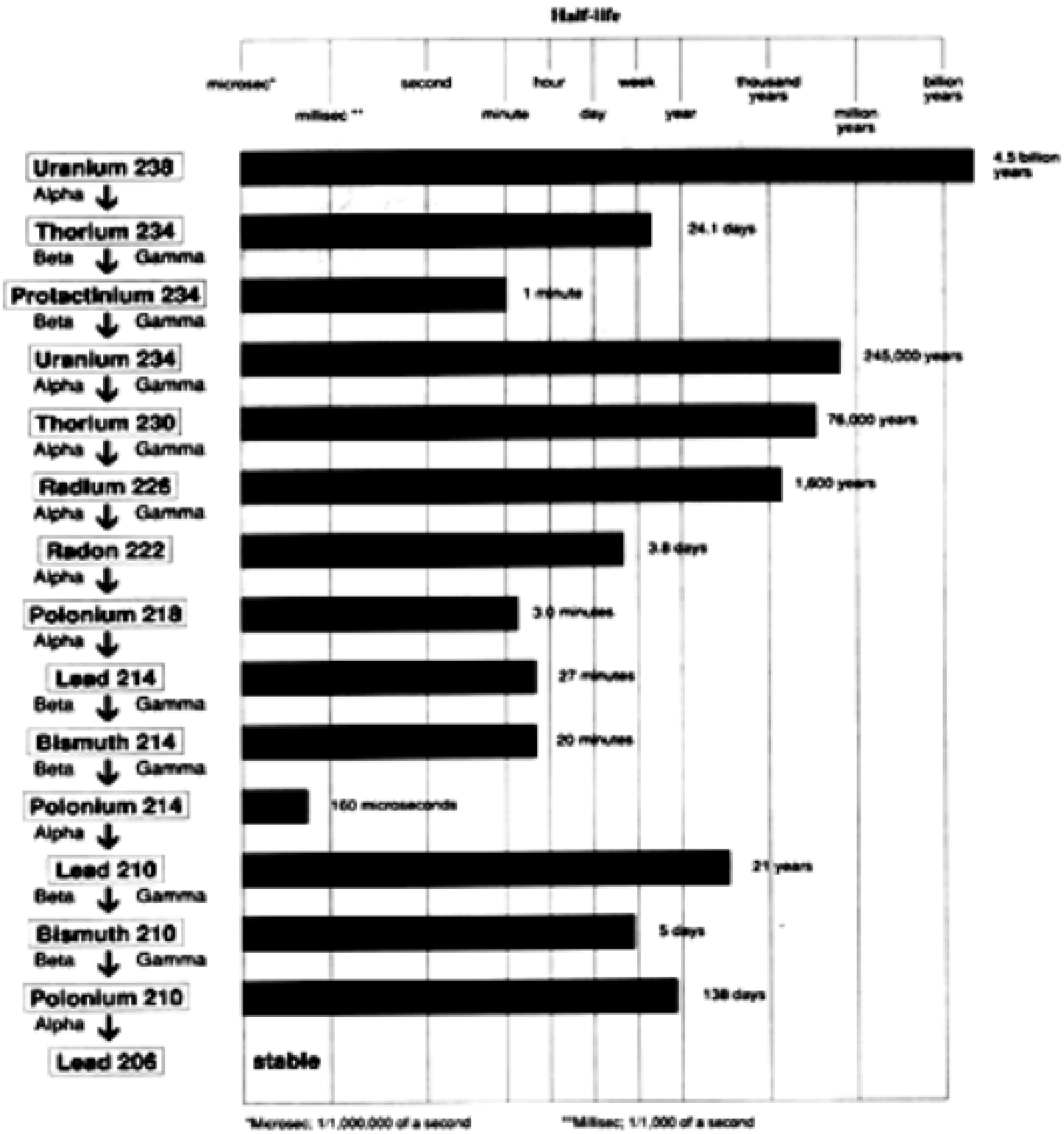
The amount of radiation that a worker is exposed to is measured in terms of radiation dose; dose limits have been developed to protect workers
Radioactive materials that transform spontaneously into other materials through the process of radioactive decay emit energy and/or particles known as radiation

At the McClean Lake Operation, radiation exposures can be divided into three components:
1. ***Gamma radiation***: Gamma rays emitted by uranium and its radioactive progeny giving the recipient an external exposure.
2. ***Radon and radon progeny***: Radon is a gaseous decay product of uranium which is released when the ore is crushed and dissolved in the milling process. Radon and its progeny can be inhaled, giving the recipient an internal exposure.
3. ***Long-lived radioactive dusts***: These are dusts (fine materials that can become airborne) that contain radioactive materials, and may be

inhaled or ingested, giving the recipient an internal exposure.
Any beta radiation released from the ore is stopped by the walls of the pipes
and tanks containing the ore. Hence, external beta radiation is not a significant source of occupational radiation exposure.

exposures can be divided into gamma radiation, radon and radon progeny, and long-lived radioactive dusts External beta radiation is not a significant source of radiation

Of course, polonium-214 and polonium-218 are even more toxic than polonium-210, but they have such short half-lives that they are


Half-life
second
hour
week
thousand years
billion years
minute
day
year
million years
Uranium 238
Alpha
4.5 billion years
Thorium 234
Beta
Gamma
24.1 days
Protactinium 234
Beta
Gamma
1 minute
Uranium 234
Alpha
Gamma
245,000 years
Thorium 230
Alpha
Gamma
76,000 years
Radium 226
Alpha
Gamma
1,600 years
Radon 222
Alpha
3.8 days
Polonium 218
Alpha
3.0 minutes
Lead 214
Beta
Gamma
27 minutes
Bismuth 214
Beta
Gamma
20 minutes
Polonium 214
Alpha
160 microseconds
Lead 210
Beta
Gamma
21 years
Bismuth 210
Beta
Gamma
5 days
Polonium 210
Alpha
138 days
Lead 206
stable

Radon, being a radioactive gas, has its own family of radioactive progeny. These include two other varieties of polonium, both short-lived, called polonium-214 and polonium-218. These materials are even more deadly than polonium-210, which is also one of the progeny of radon. In the lung, 85% of the biological damage that is done by breathing radon is due to the two isotopes of polonium mentioned here. So radon is a health hazard primarily because it acts as a delivery system for getting these polonium isotopes into the lungs.

From a longer-term environmental perspective, however, radon also produces a relatively long-lived form of radioactive lead, called lead-210. Lead-210 has a 22-year half-life, so it remains in the environment for several decades after it is deposited on vegetation or on soil or in the water. Lead-210 atoms disintegrate directly into polonium-210 atoms. Thus radon gas migration is one of the main vehicles for getting lead-210 and polonim-210 into the environment and into the food chain. (The other is through dust dispersal under dry conditions.)

None of these connections are explained in the EIS report. It therefore becomes impossible for an ordinary citizen to achieve any clear comprehension of the mechanisms by which these materials are disseminated in the environment – or how these radionuclides come to exist in the first place.

The proponent should be required to explain these connections in as clear and simple a fashion as possible, so that the various environmental pathways and the various hazards to human health can be better understood by all involved. This will make it easier to understand and judge the efficacy of any mitigating measures.