Radioactivity is Invisible

but do the facts have to be hidden as well?

A Critique of the Strateco EIS of October 2009

for the

Underground Exploration Program of the Matoush Property

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Abstract

> ***Given the nature of the project, the impact statement must discuss, in a satisfactory manner, the environmental issues associated with uranium exploration and outline the impacts related to future phases of the project to bring a uranium mine into production.***
>
> ***Directives***

The four volumes laying out the Environmental Impact Study (EIS) for the Underground Exploration Program of the Matoush Property, published by Strateco Resources in October 2009, do not meet the most fundamental requirements, as laid out in the Directives, for informing the concerned communities of the basic concepts about radioactivity and the resulting environmental issues. In addition, the rationale for the project is not discussed in an open and frank manner.

The first part of this critique focuses on the proponent's complete failure to communicate the basic facts about radioactive materials and exposures as required by the Directives. Although the data collected may be of use in further planning, the EIS as such is entirely unacceptable as it does not even attempt to satisfy the Directives when it comes to the treatment of radioactivity.

> ***Special attention must be given to aspects of the project that are associated with radioactivity…***
>
> ***Given the specific nature of the project, the impact statement must describe the radioactivity-related aspects that make this project different from other types of mining activities.***
>
> ***Directives***

> ***Special attention should be given to the treatment of elements that may be associated with uranium based on the mineralogy and known history of uranium mining …***
>
> ***Directives***

Fundamental physical terms such as radioactivity, radioactive decay, ionizing radiation, Becquerel, half-life, decay products, decay chains, secular equilibrium, alpha particles, beta particles, gamma rays, isotopes, and radionuclides are undefined or unexplained, and in many cases hardly even mentioned, if at all.

The use of these terms and concepts is at one point so badly bungled in the EIS that one is forced to wonder whether the authors really don't know what they are talking about or whether they are merely unable or unwilling to communicate the facts correctly. In either case, such basic errors and oversights do not inspire confidence, and serve to invalidate the EIS. It is a profoundly non-compliant document.

Fundamental radiobiological concepts such as radiation carcinogensis, radiation dose, equivalent dose, relative biological effectiveness (RBE), target organ, latency period, stochastic versus non-stochastic effects, radiation-induced genetic damage, and the linear non-threshold model are likewise absent from the EIS.

Fundamental radio-ecological concepts, including such highly relevant topics as bio-concentration, particularly in the context of the *"lichen –> caribou –> human" food chain as it affects lead-210 and polonium-210 in the bodies of hunters, are also absent from the EIS.*

Fundamental facts about the 37 different radioactive materials in the ore body are likewise absent from the EIS – especially the probable pathways of these radioactive contaminants through the environment, the food chain, and the human body – despite the fact that those radioactive materials will pose a potential threat to the environment and human health for a long time – essentially forever – for hundreds of thousands of years after the mining operation has been terminated.

The long-term hazard of the uranium mill residues – called uranium tailings – is particularly important in the post-closure period when the tailings will be effectively abandoned by the proponent. From that point on, the job of preventing millions of tones of radioactive sand from contaminating the environment will fall to the surrounding communities and to the provincial and federal governments. But there will be no revenues at that point in time to pay for maintenance or decontamination efforts, so resources may be severely limited.

This long-term challenge is of particular importance since the Otish mountains are situated not only in the geographical centre of the province, but also in the hydrological centre of the province. So many important rivers flow in so many different directions from the Otish Mountains, providing perfect pathways for radioactive contamination to be spread over very large land areas, that one may easily conclude *that the Otish mountains is the worst possible place to locate a reservoir of millions of tones of finely-divided sand-like radiotoxic materials.*

The second part of this critique addresses the rationale for the project. In describing the uses of uranium, the proponent fails to mention the fact that uranium is not only used in nuclear weaponry, but it is an absolutely essential part of any nuclear weapons program.

In contrast, the non-military uses of uranium are also non-essential. Electricity can be generated in many ways that do not make use of uranium. Medical isotopes can be produced without the need for uranium, by using cyclotrons or linear accelerators. Food irradiation does not require uranium either.

But nuclear weapons cannot exist without uranium. There are only two nuclear explosive materials – highly enriched uranium (HEU), and plutonium. And plutonium is a man-made element that does not exist in nature; it is produced directly from Uranium-238 inside each and every nuclear reactor.

When addressing the reasons why nuclear power and uranium mining have been controversial, the proponent does not mention plutonium – even though the proponent advances the idea of possibly recycling used nuclear fuel in order to get more energy. The fact of the matter is that recycling used nuclear fuel always involves the extraction of the *plutonium from the used fuel, and that plutonium can be used at any time in the next 50 thousand years to make atomic bombs.*

Earlier this year, in August 2010, the International Physicians for the Prevention of Nuclear War (Nobel Peace Prize winners in 1985) called for a ban on all uranium mining throughout the world. One of the main reasons for this action on their part is their realization that even if uranium is used for peaceful purposes, the radioactive leftovers (i.e. the plutonium) can still be used to make nuclear weapons. This can happen even thousands of years after the last uranium mine and the last nuclear reactor has been shut down.

The proponent makes no mention of the many studies in the last few years that have shown that the nuclear renaissance is not happening. For example, earlier this year, the Prognos Institute in Switzerland was asked to study this question for the German Government. The conclusion was that "the world-wide renaissance of nuclear power that has so often been predicted will not take place in the next few decades. Nuclear energy will be on the decline till the year 2030, and will continue to decline in importance globally."

This is important information, because the profitability of uranium mining operations often depends upon a growing nuclear industry. Already the price of uranium has declined, as has the contribution of nuclear energy. The rationale for the Matoush project cannot be divorced from the fate of the nuclear energy program worldwide.

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Communications and Consultation: Obligation?

We begin with section 1.3 of the Directives: Communications and Consultation.

The Directives for the Environmental Assessment of the Matoush Project make it clear that the proponent has an obligation to explain the fundamental facts and risks associated with radioactive materials in terms which are understandable to the population likely to be affected by the project.

This information about "radioactivity and the environment" should be sufficiently well understood by "elected officials, groups, organizations, land users and the general population", to allow those members of the concerned communities to foresee possible dangers and to express their concerns about them. Thus the nature of the communication should be "adapted to the cultural and social context" of the community.

The fundamental facts about radioactivity and radioactive materials are needed now so that possible dangers to human health and the environment associated with "the planned mining phase following exploration" as well as with the exploration phase of the project can be "more accurately foreseen", and the community's concerns about all phases of the project from exploration to mining and beyond can be expressed and "addressed". "Risks must be discussed separately for each phase."

Communications and Consultation: Performance?

In its four-volume Environmental Impact Study of October 2009, running to over 3800 pages, the proponent Strateco fails completely to satisfy its fundamental obligation to communicate the basic facts about radioactivity and radioactive materials to the community.

For this reason the EIS should be rejected by this panel as inadequate and unacceptable, since it fails to meet one of its most basic criteria as laid down in the Directives. The EIS fails to provide the community with any accurate information about the phenomenon of radioactivity, even to the point of understanding the basic vocabulary. Instead the EIS is filled – not so much with unanswered questions, but with questions that are never even asked!

Question 1: What is atomic radiation? What is radioactivity?

This question is asked only once, by a Cree woman who is quoted on page 427 of Volume 4 of the EIS, and it is never answered by the proponent. Not anywhere. The only answer she gets is: "We are all exposed to radiation." ***[Note: all page numbers cited are from the English pdf version of the EIS.]***

Question 2: What is a Becquerel? What is a disintegration?

The Becquerel is the basic physical unit of radioactivity. One Becquerel indicates that one atomic disintegration is taking place every second.

A radioactive material is defined as one whose atoms are unstable. Most atoms are eternal and unchanging, only entering into different combinations with other atoms. That is the way with non-radioactive materials.

But a radioactive material has atoms that are unstable. An unstable atom is called a radioactive atom. Such an atom will disintegrate very suddenly, at some unpredictable moment, in a violent and energetic manner.

The energy that is given off by an atomic disintegration is called "atomic radiation". And it is precisely at the moment of atomic disintegration that biological damage can be done by the atomic radiation, possibly leading to cancer or leukemia or other diseases to the individual much later, or even damage to the unborn children of that individual.

But in the EIS, although units of "Becquerel's per gram" [sic] (Bq/g) and "Becquerels per litre" (Bq/l) are used in several tables and charts in Volume 3, the word "Becquerel" is never defined. *[Bq is the abbreviation for the word "becquerel".]* Nor is the concept of radioactive disintegration ever described – not anywhere in the four volumes of the EIS. In fact the word "disintegration" is never even used in any of the four volumes.

Yet this concept of "radioactive disintegration" is the essential property that separates radioactive materials from non-radioactive materials. It is impossible to understand atomic radiation or radioactivity or what a radioactive material is or why it is dangerous if you do not understand what an atomic disintegration is.

A search for the word "becquerel" reveals no use of that word in volumes 1 or 4. It is mentioned just twice in Volume 2, but only in the confusing and legalistic context of the Quebec Government's Directive 019 on radioactive materials. The word is used 13 times in Vol. 4, but only in tables (11 times as Bq/g; twice as Bq/l).

Question 3: What is the Half-Life of a Radioactive Material?

What does half-life mean, and why is this an important and useful concept? You would never know from the EIS.

The half-life of a radioactive material is the time required for half of its atoms to disintegrate. Thus radon gas has a half-life of almost 4 days, while radium has a half-life of 1600 years.

So if you had a gram of radon gas in a closed container, and you checked the container 4 days later, you would have about half-a-gram of radon gas left, and about half-a-gram of other materials that the radon gas has changed into. If you wait another 4 days, you will have a quarter-of-a-gram of radon gas and three quarters-of-a-gram of other materials. Every 4 days, the amount of radon gas is cut in half.

You would have to wait a long time for the amount of radon gas to be reduced by a factor of 1000 – it would take 10 half-lives, or 40 days, to see this result. After 40 days you would have only about a milligram of radon gas, and 999 milligrams of other materials.

The same thinking applies to any other radioactive material. If you had a gram of radium in a tightly sealed box, and waited 1600 years, you would have half-a-gram of radium and half-a-gram of other materials that the radium has changed into. If you waited another 1600 years, you would have a quarter-of-a-gram of radium left.

You would have to wait a long time for the amount of radium to be reduced by a factor of 1000 – it would take 10 half-lives, or 16 thousand years, to see this result. After 16 thousand years you would have only about a milligram of radium, and 999 milligrams of other materials.

The term “half-life” is never used in Volumes 1, 3, or 4, and only once in Volume 2, where it is applied in an absolutely incorrect manner on page 46.

On page 46 of volume 2, all radioactive decay products of uranium that have half-lives of 9 days or more are supposed to be listed – but the list includes several materials with much shorter half-lives, excludes several materials with much longer half-lives, and is hopelessly befuddled as to which of the listed materials are in fact radioactive decay products of uranium. This mish-mash of incompetent bungling in the EIS is discussed further in the next paragraphs.

But the language used on page 46 of Volume 2 brings us to another fundamental concept that is never defined or explained or described in the EIS: decay product.

Question 4: What is a Decay Product? What is a Decay Series?

The term “radioactive decay” means exactly the same thing as “radioactive disintegration”. An atom that undergoes “decay” is one that suddenly “disintegrates”. It is like an invisible explosion, very powerful and energetic at the atomic level, which throws off “atomic radiation” – a kind of subatomic “shrapnel” that can affect nearby atoms, molecules and living cells.

(Shrapnel refers to the pieces of metal that are thrown off by an exploding bomb; flying shrapnel can cause serious wounds to people nearby. The use of the word shrapnel is just to make a comparison with the pieces of the atom that are thrown off when an atom undergoes atomic disintegration.)

When a radioactive atom disintegrates, it does not disappear; instead it changes into a brand new atom that is fundamentally different from what it was before. The new atom is called a “decay product” of the original.

For example, when a radon atom disintegrates, it becomes a polonium atom. Radon is a radioactive gas, whereas polonium is a radioactive solid. They are very different materials! Radon does not chemically combine with anything else, but polonium combines chemically with many other things. These materials behave very differently in the body and in the environment! Polonium is called a “decay product” of radon, because polonium is only produced (or created) through the gradual disintegration (or radioactive decay) of radon atoms.

As another example, when a radium atom disintegrates, it becomes an atom of radon gas. So radium, which is a radioactive heavy metal (and therefore much more dangerous than any non-radioactive heavy metal), is gradually changing into a radioactive gas! Every atom of radon in fact comes from an atom of radium, so radon is a "decay product" of radium.

This is very important information, because it tells you that wherever you have radium contamination, you are also going to have radon gas building up (unless there is strong ventilation to carry the radon gas away). And wherever you have radon gas, you are going to have polonium too. Polonium is extremely dangerous – it is the most toxic element in nature.

So radium decays into radon gas, and radon gas decays into polonium. It's as if you have a mother, a daughter, and a granddaughter. This is called a radioactive "decay chain", or a "decay series". And it doesn't just stop there, because polonium is also radioactive – it decays into a radioactive form of bismuth, and that decays into a radioactive form of lead, and so on and on it goes, creating a much longer "decay chain" or "decay series".

In the past, the decay products were often called "daughters", so one could refer to the "radon daughters" when speaking about all the decay products of radon gas (radon has seven radioactive decay products). But this terminology is not used any more, because it is considered to be insulting to women (since the "radon daughters" are very nasty and dangerous materials). It is customary today to refer to the decay products as the "progeny" of a given radioactive element.

A search of the 4 volumes of the EIS reveals that the word "decay" (in the sense of radioactive decay) is never mentioned in Volumes 1 or 3, and it is only mentioned once in Volume 2 (on page 46, where it is incorrectly applied). The word occurs 3 times in Volume 4 (pages 15, 158, and 171) but without any definition or explanation whatsoever.

On the four occasions where the word "decay" is used in a radiological context in the entire 1865 pages of the EIS, it is used only as an adjective (once in "decay products", 3 times in "decay series"). The actual process of radioactive decay is never described, nor is the fact that biologically damaging atomic radiation is given off only at the instant of radioactive decay.

Question 5: What is a "radionuclide" or an "isotope"?

The EIS never defines or explains what an isotope is or what a radionuclide is, although both terms are used in the text.

In nature, uranium is always found as a blend of three different kinds of atoms, called Uranium-238, Uranium-235, and Uranium-234. These are denoted as U-238, U-235, and U-234. Chemically, these three kinds of uranium behave the same way. They are like identical triplets. But they are all different in their radioactive properties. For example, they each have a different half-life, and they each have different decay products. These different varieties of the same chemical element are called "isotopes", and if they are radioactive (as they are in the case of uranium) they are called "radio-isotopes" or "radionuclides". Most radioactive materials have different isotopes (and even non-radioactive materials can have different isotopes as well.)

Different isotopes of the same element are indicated by attaching different numbers to the chemical name of the element. The numbers represent the number of particles (called "nucleons") in the core of the atom (called the "nucleus"). Nuclear energy refers to energy that comes from the nucleus of the atom, so atomic radiation is one kind of nuclear energy (but not the most powerful kind). All the radioactive characteristics of a radio-isotope are determined by knowing the chemical name and the number that goes with it – such as the half-life, and the type of atomic radiation that is given off when the atom disintegrates. (Non-radioactive atoms also have different isotopes, and they are represented in the same manner.)

The half-life of uranium-238 is 4.5 billion years – about the same as the age of the Earth, according to scientists' best guess. That's why uranium is still around after all this time. Back at the beginning, when the Earth was first formed, there must have been twice as much Uranium-238 as there is today.

The half-life of uranium-235 (U-235) is 703 million years. A lot of it has disappeared since the Earth was formed, and now there is only a fraction left. That fraction is 0.7 percent of the total amount of uranium, and it's *the same all over the world. So in any uranium deposit, in any uranium ore body anywhere in the world, only 7 out of 1000 uranium atoms are of the U-235 variety.*

Two other radioactive materials that have been around since the Earth was formed are Thorium-232 (Th-232) and Potassium-40 (K-40). Thorium-232 has its own decay chain, but Potassium-40 does not have any radioactive decay products and therefore has no actual decay chain.

None of this is explained in the EIS. The word isotope is only used 12 times, and it is never explained or defined. The word radionuclide is used 7 times in volumes 1 and 2, and many times in volumes 3 and 4, but is never explained or defined, and is never related to the word "isotope".

Isotope

Vol. 1 – 3 times;
Vol. 2 – 5 times, twice in the text and 3 times in tables;
Vol. 3 – twice on page 33;
Vol. 4 – Twice on page 399, but only as "medical isotopes".

Radionuclide

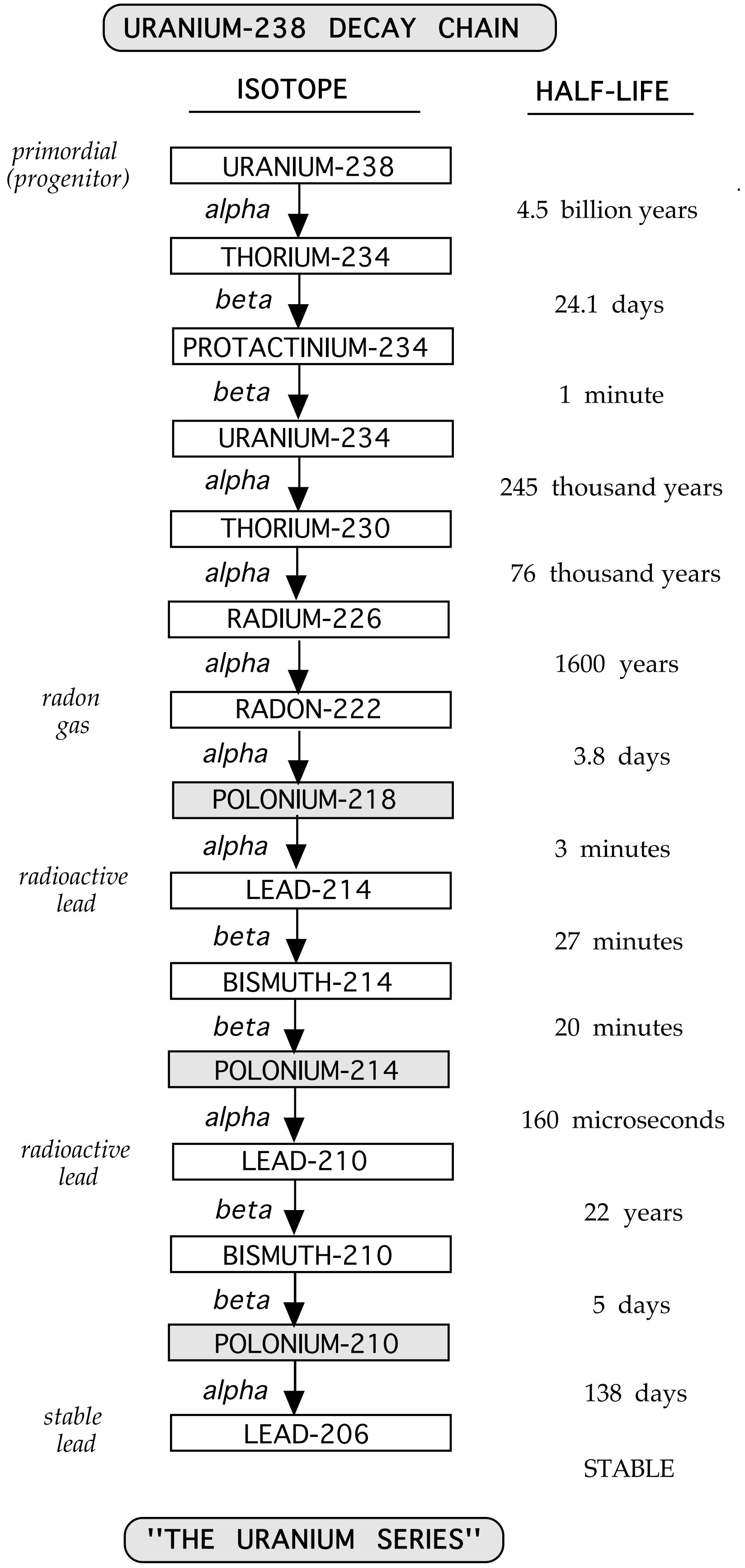
Vol 1 – 3 times, twice on p. 67 and once on p. 108;
Vol. 2 – 4 times, 19 or 20 of them listed;
Vol. 3 – Many times, with only 4, 5, or 6 listed;
Vol. 4 – Many times, with 4, 5, or 6 listed.

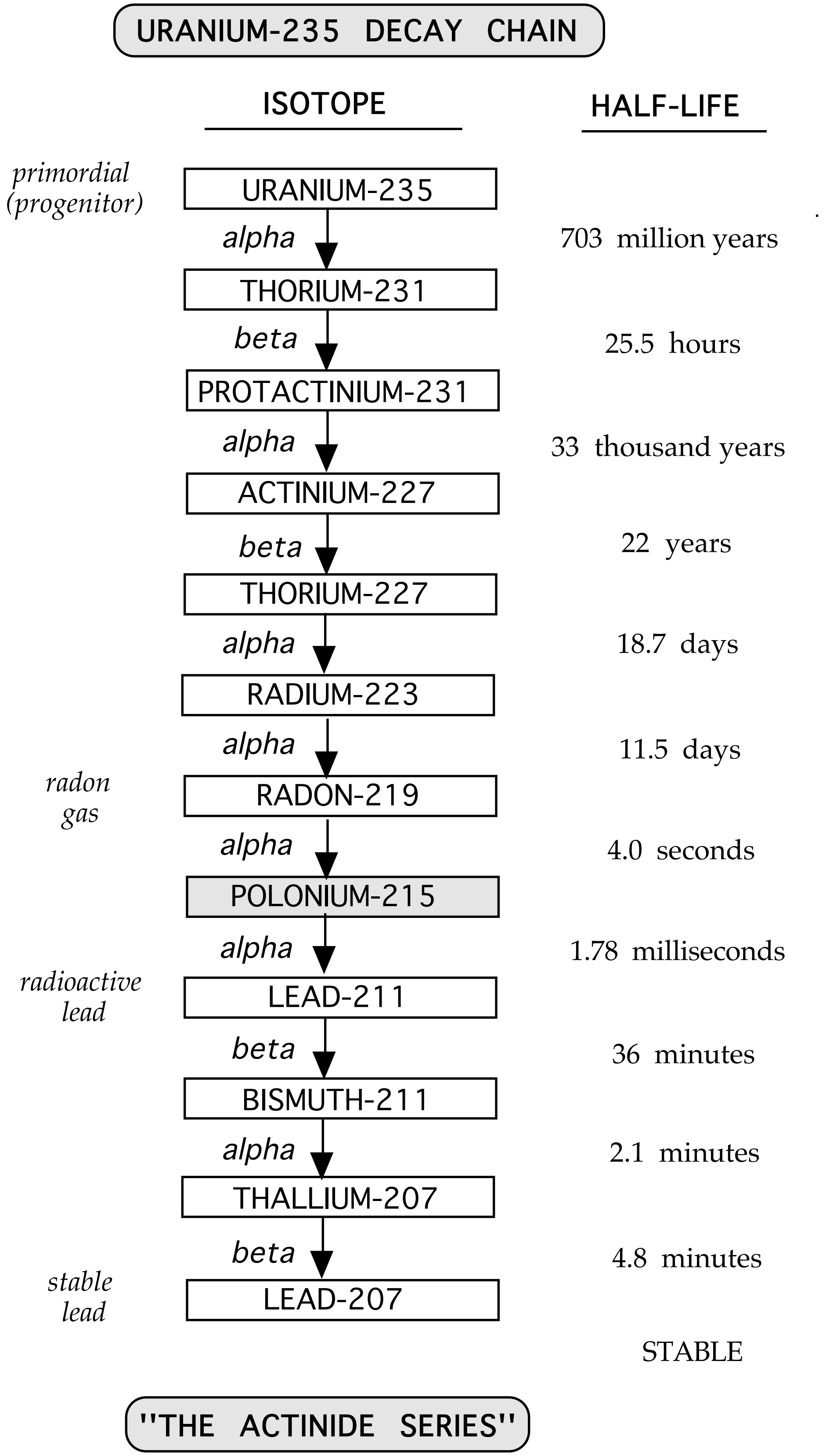
Question 6: What is "the Uranium Decay Chain (or Series)"?

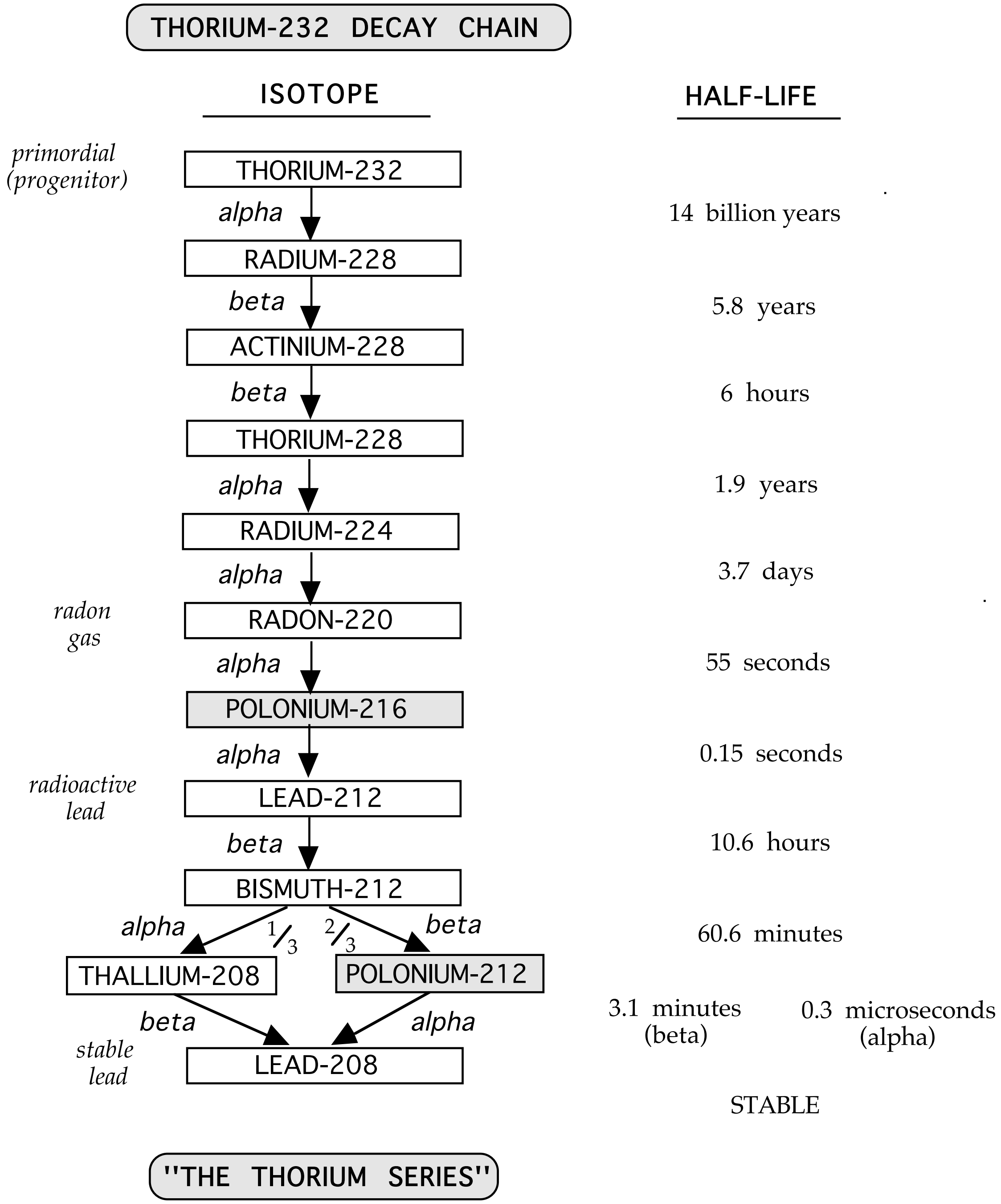
Incredibly, for an EIS about uranium exploration and mining, nowhere is the decay chain for U-238 or U-235 given in the text. This is an absolutely stunning omission, since the decay chain sets the parameters for the radiological hazards that will be associated with the exploration, the mining, and the long-term management of the mill residues (known as "uranium tailings").

The complete decay chains for Uranium-238 and for Uranium-235 are given on the following two pages. The decay chain for U-238 is called "The Uranium Series" and the decay chain for U-235 is known as "The Actinide Series".

Another decay chain that is of some importance is "The Thorium Series", which is also provided here. A radioactive ore body that contains uranium will often contain Thorium-232 as well. It is important to know that these other radioactive materials are there (from the Thorium Series), because they will end up in the waste byproducts (the uranium tailings, waste rock, effluents, sediments, etc.)


URANIUM-238 DECAY CHAIN
ISOTOPE
HALF-LIFE
primordial (progenitor)
URANIUM-238
alpha
4.5 billion years
THORIUM-234
beta
24.1 days
PROTACTINIUM-234
beta
1 minute
URANIUM-234
alpha
245 thousand years
THORIUM-230
alpha
76 thousand years
RADIUM-226
alpha
1600 years
radon gas
RADON-222
alpha
3.8 days
POLONIUM-218
alpha
3 minutes
radioactive lead
LEAD-214
beta
27 minutes
BISMUTH-214
beta
20 minutes
POLONIUM-214
alpha
160 microseconds
radioactive lead
LEAD-210
beta
22 years
BISMUTH-210
beta
5 days
POLONIUM-210
alpha
138 days
stable lead
LEAD-206
STABLE
"THE URANIUM SERIES"


URANIUM-235 DECAY CHAIN
ISOTOPE
HALF-LIFE
primordial (progenitor)
URANIUM-235
alpha
703 million years
THORIUM-231
beta
25.5 hours
PROTACTINIUM-231
alpha
33 thousand years
ACTINIUM-227
beta
22 years
THORIUM-227
alpha
18.7 days
RADIUM-223
alpha
11.5 days
radon gas
RADON-219
alpha
4.0 seconds
POLONIUM-215
alpha
1.78 milliseconds
radioactive lead
LEAD-211
beta
36 minutes
BISMUTH-211
alpha
2.1 minutes
THALLIUM-207
beta
4.8 minutes
stable lead
LEAD-207
STABLE
"THE ACTINIDE SERIES"



Note: 33 % of the stable lead-208 is produced from thallium-208 by "beta decay" , and 67 % is produced from polonium-212 by "alpha decay" .

The Panel's Directives state that "Special attention should be given to the treatment of elements that may be associated with uranium. . . ." Yet the only place decay series elements are identified as such is in Volume 2, on page 46, where we read:

> Since Directive 019 does not specify the radionuclides to be tested, these were selected based on the daughter products of the host ore mineral of the Matoush deposit : uraninite (UO_2). The radioactive elements belonging to the uranium decay series with a half life of greater than 7 days were analyzed including the following isotopes: actinium 228, bismuth 212 and 214, lead 210, 212 and 214, polonium 210, potassium 40, radium 223 and 226, radon 219, thallium 208, thorium 227, 228, 230 and 234 and uranium 234, 235 and 238.

There are many things wrong with this paragraph.

First, as a point of law, Directive 019 is supposed to be applied to all relevant radionuclides, whether they are measured directly or inferred indirectly. The proponent's interpretation is simply wrong; one is not allowed to "select" the radionuclides to be included.

Second, a number of those listed do not have a half life of "greater than 7 days": actinium-228 has a half life of 6 hours, bismuth-212 has a half life of one hour, bismuth-214 has a half life of 20 minutes, lead-212 has a half life of 10.6 hours, lead-214 has a half life of 27 minutes, radon-219 has a half-life of 4 seconds. This reveals the proponent's lack of competence on radioactive matters.

Third, the radioactive elements listed are not "belonging to the uranium decay series". Only 10 of the 19 are from the uranium-238 decay chain (the one commonly known as the "uranium decay series", p. 8), while an additional 4 of the 19 are from the uranium-235 decay chain (the "actinide decay series", p. 9). And of the remaining 5 radionuclides listed, one is potassium-40 (which does not belong to any of the 3 main decay chains) and the other 4 are from the thorium-232 decay chain (p.10) – even though thorium-232 itself is not even listed!

Fourth, there are two radioactive elements belonging to the uranium-235 decay series, each having half lives of more than 7 days, which are not listed at all – protactinium-231 has a half life of 33 000 years, and actinium-227 has a half-life of 22 years. Two more radioactive elements that are not listed, each with a half life of more than 7 days, are thorium-232 (half life 14 billion years), and radium-228 (half life 5.8 years).

The muddled thinking that this list reveals once again calls into question the proponent's competence in matters of radioactivity. But the most significant aspect of the error is that 18 radionuclides are entirely missing from the list.

There is a total of 36 radionuclides in the decay chains of U-238, U-235 and Th-232, and the proponent only lists half of them (along with potassium-40). Eighteen of the relevant radioactive species are simply left out.

For the record, the missing radionuclides are: protactinium-234, radon-222, polonium-218, polonium-214, bismuth-210, thorium-232, radium-228, radium-224, radon-220, polonium-216, polonium-212, thorium-231, protactinium-231, actinium-227, polonium-215, lead-211, bismuth-211, and thallium-207.

All these missing isotopes are likewise excluded from *Table 3.4: Radiologic Parameter Concentrations* (Vol. 2, page 79) and *Table 3.5: Radiological Classification of Samples* (Vol. 2, pages 80-81) – except for lead-211 and thorium-232, which, although missing from the proponent's list quoted above, appear in both Tables. Strangely, uranium-238 is in the list but not in the Tables.

What is the significance of all this? Well, it is the only section in the entire four volumes of the EIS where the concepts of radioactive decay products and radioactive half-lives are used together in any meaningful way. The result is an incompetent mess that would earn a failing grade from any accredited college. Either the proponent doesn't know enough about radioactivity, or is not sharing the necessary information with the panel and the community. Either way, the proponent has shown itself not to be a competent and/or trustworthy authority on matters of radioactivity for the purpose of satisfying the EIS Directives.

Incidentally, even if the proponent had correctly listed just those elements of the uranium decay series with half lives of more than 7 days, three of the most deadly ones would have been omitted: radon-222 (radon gas, with a half life of 3.8 days), polonium-218 (with a half life of 3 minutes), and polonium-214 (a half life of 180 microseconds). It has been confirmed that about 85 percent of the lung damage attributed to radon gas is actually caused by these two short-lived isotopes of polonium, leading to lung cancer; so the three short-lived isotopes above are the ones responsible for the deaths of hundreds of underground uranium miners:

> Alpha particles released by 2 radioisotopes in the radon-decay chain, polonium-218 and polonium-214, deliver . . . the energy that is considered to cause radon-associated lung-cancer.
>
> *Page 21-22, Health Effects of Exposure to Radon (BEIR VI)*
> *U.S. National Academy of Sciences, 1999.*

Question 7: What is "Radioactive Equilibrium"?

The concept of radioactive equilibrium is crucially important for understanding the relationships between the radioactive decay products in an ore body (or in any closed containment). Yet this concept is nowhere mentioned in the EIS.

A radioactive element is said to be in radioactive equilibrium when it is produced at the same rate at which it is disintegrating, so that the number of atoms of that particular radionuclide remains constant over time.

In a state of radioactive equilibrium, a radioactive element will maintain a constant number of becquerels over quite long periods of time, no matter how short its half life might otherwise be. That's because the disintegrating atoms are constantly being replaced by new ones, so the process of radioactive decay is unable to reduce the overall population of its atoms; new ones keep arising to replace the ones that have disintegrated.

Suppose, for example, we start with 1000 becquerels of radium-226 inside a sealed container (such as an undisturbed rock). As can be seen from the "uranium decay series" (p. 8), radon-222 is the immediate decay product of radium-226; so every second, 1000 atoms of radium-226 are disintegrating and turning into 1000 atoms of radon-222 (also known as radon gas).

Since 1000 new atoms of radon-222 are being created every second, the amount of radon gas begins to increase. The more radon there is, the more atoms of radon are disintegrating every second; in other words, the number of becquerels of radon-222 inside the container is rising – for a while.

But the number of disintegrating radon atoms can't keep increasing forever. Eventually it reaches the point where 1000 radon atoms are disintegrating every second – precisely balancing the 1000 radon atoms that are being created every second. When that happens, the radon gas inside the container has reached a state of radioactive equilibrium: its atoms are now being produced at the same rate that those atoms are disintegrating.

So beginning with 1000 becquerels of radium, we now have 1000 becquerels of radon as well. The total radioactivity has increased dramatically!

Note that radioactive equilibrium is achieved when the number of becquerels of radon-222 is exactly the same as the number of becquerels of radium-226. That's because the first number tell us how fast radon is disintegrating and the second number tells us how fast radon is being produced. In the example above, we used 1000 becquerels – but we could have used any other number.

So how long do we need to wait for this "balancing act" to occur?
How long before the radioactive equilibrium of radon-222 takes place?

It requires about a month of undisturbed containment – that's about 8 times the half-life of radon-222. (Radon-222 has a half-life of 3.8 days, and 8 x *3.8 = 30.4 days.) After that time, the number of becquerels of radon inside the container will remain the same for many, many years – despite the fact that radon-222 has a half-life of only 3.8 days!*

This calculation works because the "parent element", radium-226, has a very long half-life of 1600 years; therefore the amount of radium-226 does not diminish to any perceptible degree in the span of a few months, years or even decades. And it keeps on producing radon all the time at a steady rate.

The radioactivity of radium-226 isn't constant – but it's almost constant. In truth, the number of becquerels of radium-226 does gradually diminish over time, and so therefore does the number of becquerels of radon gas, even under "equilibrium" conditions. But it takes centuries for this to be noticeable. So, although we can never achieve "perfect" radioactive equilibrium, we have "almost perfect" radioactive equilibrium!

The key point here is that radioactive materials with short half lives will persist for an exceedingly long time if they are being replenished by a long-lived progenitor. The amount of short-lived decay product will build up over time to reach equilibrium with its long-lived progenitor, at which point the becquerels of each – the progenitor and the decay product – are the same.

In the case of a so-called "primordial" radionuclide – uranium-238, uranium-235, or thorium-232 – it is a well-known fact (never mentioned in the EIS) that any ancient undisturbed geological deposit containing one of these materials will contain all the other radionuclides in the same decay chain, and all of them will be in radioactive equilibrium. So the number of becquerels for each radionuclide in the same decay chain will be exactly the same, from top to bottom.

The concept of equilibrium is important because it allows one to accurately predict how much thorium-230, radium-226, and polonium-210 to expect in a given ore deposit, based on the amount of uranium-238 that is found there. Similarly one can predict how much radium-228, thorium-228, and lead-212 to expect, based on how much thorium-232 is present in the ore.

In each case, knowing how many becquerels of the primordial radionuclide are present, one can confidently predict that each of the decay products in the same decay chain will have that same number of becquerels.

Technical note: A slight modification to this rule arises when there are two different modes of radioactive decay, as in the case of bismuth-212 – a radionuclide in the thorium-232 decay chain (see p. 10). In that case, under equilibrium conditions, the number of becquerels of the "parent" is equal to the sum of the numbers of becquerels of its two immediate "progeny".

Bismuth-212 has not one, but two immediate decay products – thallium-208 and polonium-212. Scientists have found that when equilibrium is attained, the number of becquerels of thallium-208 is only about one-third the number of becquerels of bismuth-212, while the number of becquerels of polonium-212 is about two-thirds of that for bismuth-212. When taken together, they add up to the total number of becquerels of bismuth-212.

Using the concept of radioactive equilibrium, we can understand why the numbers in Table 3.4 (in becquerels per gram) should be virtually identical for radionuclides that come from the same decay chain (in almost all cases, bearing in mind the slight modification discussed in the previous two italicized paragraphs). And this should be true in each one of the rock samples tested.

In the following 3 pages, the entries in Table 3.4 are separated out according to the three major decay chains involved: first U-238, then U-235, and finally Th-232.

The first striking observation is the number of radionuclides that are simply not listed. That of course represents a major error on the part of the proponent.

The second striking observation is the failure of some of the reported radiological concentrations to agree with the principle of radioactive equilibrium. That is another error, based on inaccurate measurements or inaccurate reporting.

The Uranium-238 Family

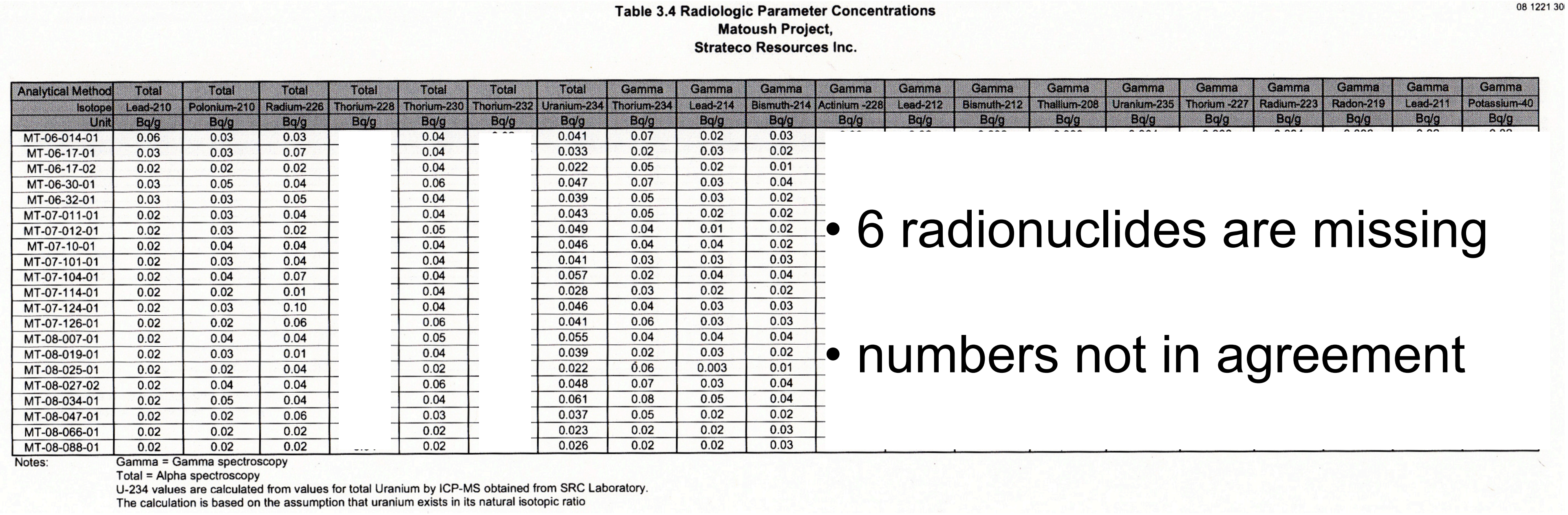


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Table 3.4 Radiologic Parameter Concentrations
Matoush Project,
Strateco Resources Inc.

Analytical Method	Total	Total	Total	Total	Total	Total	Total	Gamma	Gamma	Gamma	Gamma	Gamma	Gamma	Gamma	Gamma	Gamma	Gamma	Gamma	Gamma	Gamma
Isotope	Lead-210	Polonium-210	Radium-226	Thorium-228	Thorium-230	Thorium-232	Uranium-234	Thorium-234	Lead-214	Bismuth-214	Actinium -228	Lead-212	Bismuth-212	Thallium-208	Uranium-235	Thorium -227	Radium-223	Radon-219	Lead-211	Potassium-40
Unit	Bq/g	Bq/g	Bq/g	Bq/g	Bq/g	Bq/g	Bq/g	Bq/g	Bq/g	Bq/g	Bq/g	Bq/g	Bq/g	Bq/g	Bq/g	Bq/g	Bq/g	Bq/g	Bq/g	Bq/g
MT-06-014-01	0.06	0.03	0.03		0.04		0.041	0.07	0.02	0.03										
MT-06-17-01	0.03	0.03	0.07		0.04		0.033	0.02	0.03	0.02										
MT-06-17-02	0.02	0.02	0.02		0.04		0.022	0.05	0.02	0.01										
MT-06-30-01	0.03	0.05	0.04		0.06		0.047	0.07	0.03	0.04										
MT-06-32-01	0.03	0.03	0.05		0.04		0.039	0.05	0.03	0.02										
MT-07-011-01	0.02	0.03	0.04		0.04		0.043	0.05	0.02	0.02										
MT-07-012-01	0.02	0.03	0.02		0.05		0.049	0.04	0.01	0.02										
MT-07-10-01	0.02	0.04	0.04		0.04		0.046	0.04	0.04	0.02										
MT-07-101-01	0.02	0.03	0.04		0.04		0.041	0.03	0.03	0.03										
MT-07-104-01	0.02	0.04	0.07		0.04		0.057	0.02	0.04	0.04										
MT-07-114-01	0.02	0.02	0.01		0.04		0.028	0.03	0.02	0.02										
MT-07-124-01	0.02	0.03	0.10		0.04		0.046	0.04	0.03	0.03										
MT-07-126-01	0.02	0.02	0.06		0.06		0.041	0.06	0.03	0.03										
MT-08-007-01	0.02	0.04	0.04		0.05		0.055	0.04	0.04	0.04										
MT-08-019-01	0.02	0.03	0.01		0.04		0.039	0.02	0.03	0.02										
MT-08-025-01	0.02	0.02	0.04		0.02		0.022	0.06	0.003	0.01										
MT-08-027-02	0.02	0.04	0.04		0.06		0.048	0.07	0.03	0.04										
MT-08-034-01	0.02	0.05	0.04		0.04		0.061	0.08	0.05	0.04										
MT-08-047-01	0.02	0.02	0.06		0.03		0.037	0.05	0.02	0.02										
MT-08-066-01	0.02	0.02	0.02		0.02		0.023	0.02	0.02	0.03										
MT-08-088-01	0.02	0.02	0.02		0.02		0.026	0.02	0.02	0.03										

Notes: Gamma = Gamma spectroscopy
Total = Alpha spectroscopy
U-234 values are calculated from values for total Uranium by ICP-MS obtained from SRC Laboratory.
The calculation is based on the assumption that uranium exists in its natural isotopic ratio

- 6 radionuclides are missing
- numbers not in agreement

Missing: uranium-238, protactinium-234, radon-222, polonium-218, polonium-214, bismuth-210

Concentrations: thorium-230 and radium-226 should be about equal
lead-210 should not be smaller than polonium-210

The Uranium-235 Family

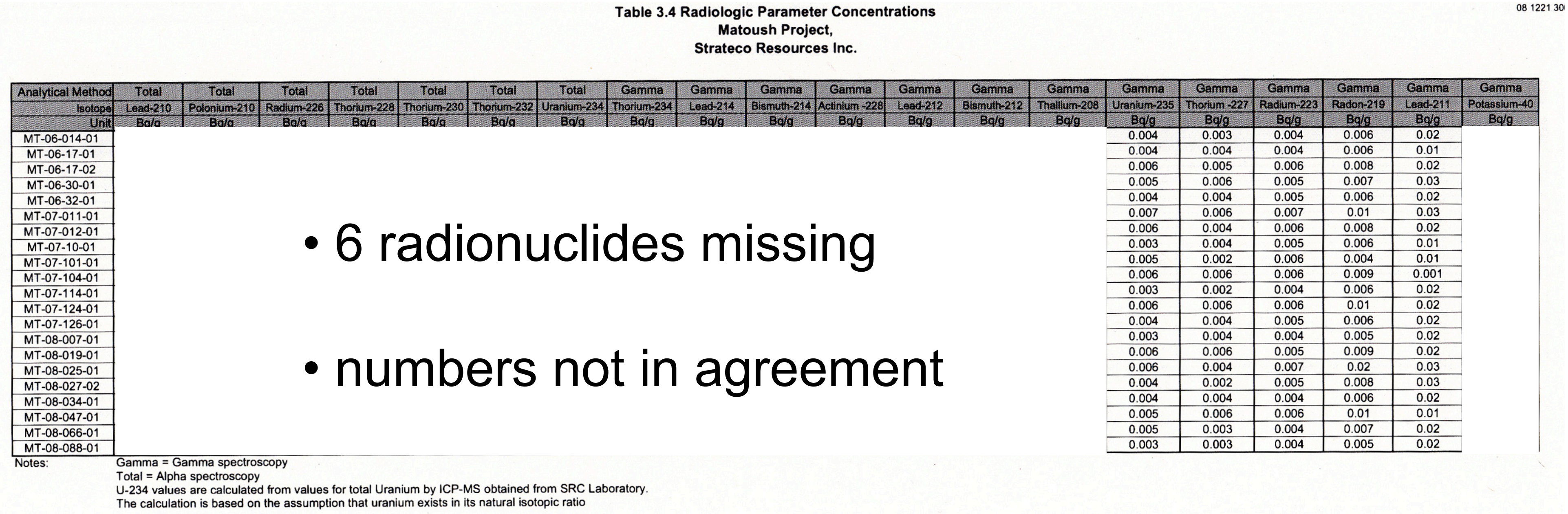

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Table 3.4 Radiologic Parameter Concentrations
Matoush Project,
Strateco Resources Inc.

Analytical Method	Total	Total	Total	Total	Total	Total	Total	Gamma	Gamma	Gamma	Gamma	Gamma	Gamma	Gamma	Gamma	Gamma	Gamma	Gamma	Gamma	Gamma
Isotope	Lead-210	Polonium-210	Radium-226	Thorium-228	Thorium-230	Thorium-232	Uranium-234	Thorium-234	Lead-214	Bismuth-214	Actinium -228	Lead-212	Bismuth-212	Thallium-208	Uranium-235	Thorium -227	Radium-223	Radon-219	Lead-211	Potassium-40
Unit	Bq/g	Bq/g	Bq/g	Bq/g	Bq/g	Bq/g	Bq/g	Bq/g	Bq/g	Bq/g	Bq/g	Bq/g	Bq/g	Bq/g	Bq/g	Bq/g	Bq/g	Bq/g	Bq/g	Bq/g
MT-06-014-01															0.004	0.003	0.004	0.006	0.02	
MT-06-17-01															0.004	0.004	0.004	0.006	0.01	
MT-06-17-02															0.006	0.005	0.006	0.008	0.02	
MT-06-30-01															0.005	0.006	0.005	0.007	0.03	
MT-06-32-01															0.004	0.004	0.005	0.006	0.02	
MT-07-011-01															0.007	0.006	0.007	0.01	0.03	
MT-07-012-01															0.006	0.004	0.006	0.008	0.02	
MT-07-10-01															0.003	0.004	0.005	0.006	0.01	
MT-07-101-01															0.005	0.002	0.006	0.004	0.01	
MT-07-104-01															0.006	0.006	0.006	0.009	0.001	
MT-07-114-01															0.003	0.002	0.004	0.006	0.02	
MT-07-124-01															0.006	0.006	0.006	0.01	0.02	
MT-07-126-01															0.004	0.004	0.005	0.006	0.02	
MT-08-007-01															0.003	0.004	0.004	0.005	0.02	
MT-08-019-01															0.006	0.006	0.005	0.009	0.02	
MT-08-025-01															0.006	0.004	0.007	0.02	0.03	
MT-08-027-02															0.004	0.002	0.005	0.008	0.03	
MT-08-034-01															0.004	0.004	0.004	0.006	0.02	
MT-08-047-01															0.005	0.006	0.006	0.01	0.01	
MT-08-066-01															0.005	0.003	0.004	0.007	0.02	
MT-08-088-01															0.003	0.003	0.004	0.005	0.02	

Notes:
Gamma = Gamma spectroscopy
Total = Alpha spectroscopy
U-234 values are calculated from values for total Uranium by ICP-MS obtained from SRC Laboratory.
The calculation is based on the assumption that uranium exists in its natural isotopic ratio

- 6 radionuclides missing
- numbers not in agreement

Missing: thorium-231, protactinium-231, actinium-227, polonium-215, bismuth-211, thallium-207

Concentrations: lead-211 should be about the same as all the others
radium-223 cannot be smaller than radon-219

The Thorium-232 Family

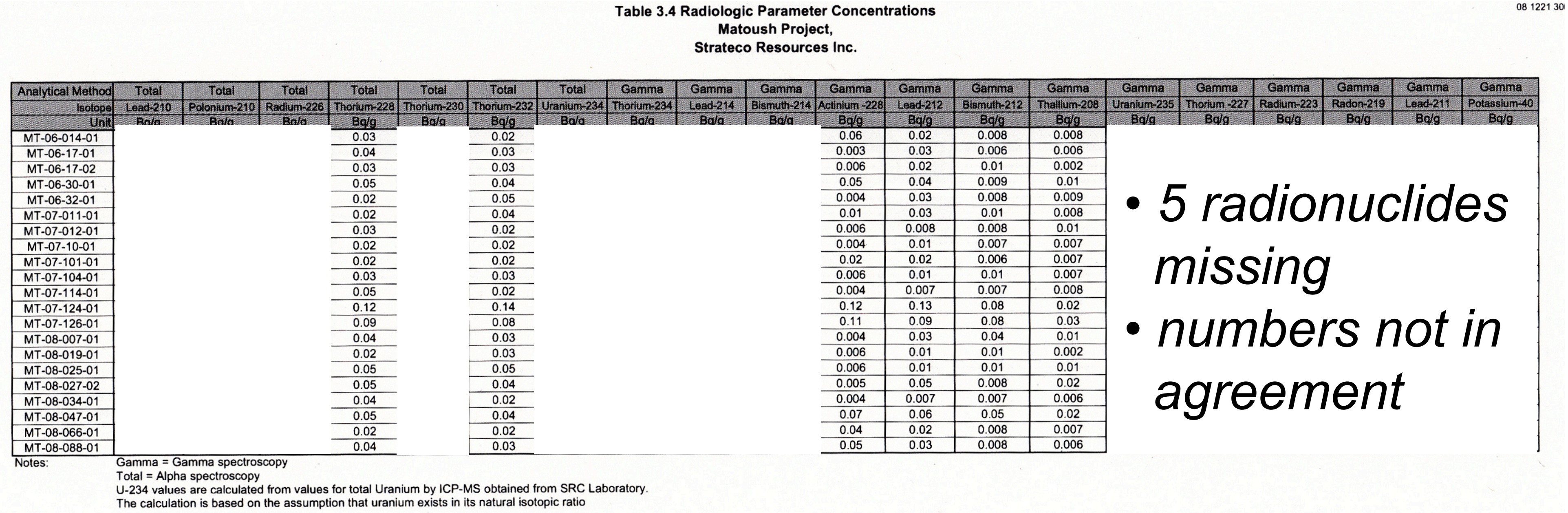

Table 3.4 Radiologic Parameter Concentrations
Matoush Project,
Strateco Resources Inc.

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Analytical Method	Total	Total	Total	Total	Total	Total	Total	Gamma	Gamma	Gamma	Gamma	Gamma	Gamma	Gamma	Gamma	Gamma	Gamma	Gamma	Gamma	Gamma
Isotope	Lead-210	Polonium-210	Radium-226	Thorium-228	Thorium-230	Thorium-232	Uranium-234	Thorium-234	Lead-214	Bismuth-214	Actinium -228	Lead-212	Bismuth-212	Thallium-208	Uranium-235	Thorium -227	Radium-223	Radon-219	Lead-211	Potassium-40
Unit	Bq/g	Bq/g	Bq/g	Bq/g	Bq/g	Bq/g	Bq/g	Bq/g	Bq/g	Bq/g	Bq/g	Bq/g	Bq/g	Bq/g	Bq/g	Bq/g	Bq/g	Bq/g	Bq/g	Bq/g
MT-06-014-01				0.03		0.02					0.06	0.02	0.008	0.008						
MT-06-17-01				0.04		0.03					0.003	0.03	0.006	0.006						
MT-06-17-02				0.03		0.03					0.006	0.02	0.01	0.002						
MT-06-30-01				0.05		0.04					0.05	0.04	0.009	0.01						
MT-06-32-01				0.02		0.05					0.004	0.03	0.008	0.009						
MT-07-011-01				0.02		0.04					0.01	0.03	0.01	0.008						
MT-07-012-01				0.03		0.02					0.006	0.008	0.008	0.01						
MT-07-10-01				0.02		0.02					0.004	0.01	0.007	0.007						
MT-07-101-01				0.02		0.02					0.02	0.02	0.006	0.007						
MT-07-104-01				0.03		0.03					0.006	0.01	0.01	0.007						
MT-07-114-01				0.05		0.02					0.004	0.007	0.007	0.008						
MT-07-124-01				0.12		0.14					0.12	0.13	0.08	0.02						
MT-07-126-01				0.09		0.08					0.11	0.09	0.08	0.03						
MT-08-007-01				0.04		0.03					0.004	0.03	0.04	0.01						
MT-08-019-01				0.02		0.03					0.006	0.01	0.01	0.002						
MT-08-025-01				0.05		0.05					0.006	0.01	0.01	0.01						
MT-08-027-02				0.05		0.04					0.005	0.05	0.008	0.02						
MT-08-034-01				0.04		0.02					0.004	0.007	0.007	0.006						
MT-08-047-01				0.05		0.04					0.07	0.06	0.05	0.02						
MT-08-066-01				0.02		0.02					0.04	0.02	0.008	0.007						
MT-08-088-01				0.04		0.03					0.05	0.03	0.008	0.006						

Notes:
Gamma = Gamma spectroscopy
Total = Alpha spectroscopy
U-234 values are calculated from values for total Uranium by ICP-MS obtained from SRC Laboratory.
The calculation is based on the assumption that uranium exists in its natural isotopic ratio

- *5 radionuclides missing*
- *numbers not in agreement*

Missing: radium-228, radium-224, radon-220, polonium-216, polonium-212

Concentrations: lead-212 and bismuth-212 should be approximately equal
bismuth-212 should be about three times thallium-208

To understand why the numerical entries in Table 3.4 do not always make sense, we will study one particular example. Other examples could easily be given.

Look at the numbers reported on p. 17 for radium-223 and radon-219 – both part of the uranium-235 decay series. Note that the numbers of “becquerels per gram” reported for radon-219 are larger than those reported for radium-223 in every case but one. This can’t be right. It must be an error, and here’s why.

Since radium-223 is the immediate “radioactive parent” of radon-219, it is not logical that the number of becquerels of radium-223 are smaller than the number of becquerels of radon-219. That would imply that radon-219 atoms are disintegrating faster than they are being created: it describes a state of profound disequilibrium.

But radon-219 has a half life of 4 seconds, so no state of disequilibrium can last for even one minute! Radioactive equilibrium for radon-219 must be achieved after eight half-lives of radon-219, and that’s a time lapse of only 8 x 4 = 32 seconds.

Look at the numbers in the first row of Table 3.4 (on p. 17) for example. Radium-223 is reported at 0.004 becquerels per gram. Radon-219 is reported at 0.006 becquerels per gram. So in each kilogram of rock, are 4 atoms of radium-223 decaying into radon-219 atoms each second, while 6 atoms of radon-219 are decaying each second?

No. As already pointed out, radioactive equilibrium for these two radionuclides must be achieved in 32 seconds. After that time the number of becquerels for each one must be equal. Once radon-219 is in equilibrium, you can’t have 4 atoms being created and 6 atoms decaying each second – not in the same kilogram of rock. It makes no sense.

If anything, the radiological concentration of radon-219 could be measured as less than that of radium-223 if some of the radioactive gas is allowed to escape during the process of crushing the sample and testing it – but it certainly can’t be greater!

Question 8. How Does One Apply Quebec Directive 019?

Naturally, these errors on the part of the proponent have led to errors in the calculation of the radioactivity index according to Quebec Directive 019. This is a rather technical matter, but it reveals once more the proponent’s lack of competence in radioactive matters. While the miscalculation does not have great practical significance in this early exploration phase, such miscalculations could become very significant in later phases of the Matoush project.

It turns out that the proponent's calculated value of "S" – a numerical index defined in Quebec Directive 019, used to legally classify the radiological character of radioactive material residues – is too low by a considerable margin.

Using the figures reported by the proponent in Table 3.4 and applying the precautionary principle based on the concept of radioactive equilibrium, we find that the proponent's calculated value of S (reported in Table 3.5, pages 80-81 of Vol. 2) is too low by a rather large factor – one that lies somewhere between 3.5 and 7.5 .

We begin by noting that there are four primordial radionuclides involved here: uranium-238, uranium-235, thorium-232, and potassium-40. Due to radioactive equilibrium, all the radioactive decay products in any given decay chain should have the same number of becquerels per gram in each sample.

Also, within each decay chain, the maximum recorded radiological concentration (among all the decay products tested) is the value most likely to be correct for all the other decay products in that same decay chain. That's because the measured number of disintegrations is not likely to be smaller than the actual number of disintegrations.

Now we use the recipe from Quebec Directive 019 to calculate a revised value of "S" – that is, we add up the quantities C/A for all of the radionuclides in each of the four decay chains, and then add those answers to get the total value of S . The revised value, denoted S_{rev}, is then compared with the proponent's value, denoted S_{EIS}.

The symbol "C" represents the radiological concentration of each radionuclide in becquerels per gram. The symbol "A" represents a regulatory number associated to each radionuclide, having the value 4 in some cases, 40 in other cases, and 400 in the case of potassium-40. All of this is spelled out in Directive 019.

On the next page there is a tabulation giving the results of the revised calculation. The columns labeled "C" list the maximum reported radiological concentrations for each decay chain, taken from Table 3.4. But the revised calculation takes into account all the missing radionuclides and also utilizes the principle of radioactive equilibrium, making the becquerel-counts equal where appropriate. The value obtained is S_{rev}.

On average, the revised value for S (denoted S_{rev}) is five-and-a-half times greater than the proponent's incorrectly calculated value for S (denoted S_{EIS}) .

As a matter of fact, in every sample, the proponent's calculation of S is lower than the revised calculation of S by a factor that lies somewhere between 3.7 and 7.5.

Recalculation of the radioactivity index "S" according to Quebec Directive 019

Sample Number	U-238 (C-1)	U-235 (C-2)	Th-232 (C-3)	K-40 (C-4)	Srev Σ (C/A)	SEIS table 3.5	Ratio
MT-06-014-01	0.07	0.02	0.06	0.82	0.236	0.042	***5.62***
MT-06-17-01	0.07	0.01	0.04	0.76	0.203	0.042	***4.84***
MT-06-17-02	0.06	0.02	0.03	1.10	0.188	0.025	***7.50***
MT-06-30-01	0.07	0.03	0.06	1.80	0.253	0.047	***5.37***
MT-06-32-01	0.06	0.02	0.06	1.60	0.217	0.040	***5.41***
MT-07-011-01	0.06	0.03	0.04	1.80	0.213	0.036	***5.90***
MT-07-012-01	0.06	0.02	0.03	1.50	0.189	0.029	***6.50***
MT-07-10-01	0.048	0.01	0.02	0.79	0.138	0.034	***4.05***
MT-07-101-01	0.04	0.01	0.02	0.75	0.120	0.032	***3.76***
MT-07-104-01	0.067	0.009	0.03	0.97	0.187	0.043	***4.34***
MT-07-114-01	0.04	0.02	0.05	1.20	0.163	0.022	***7.42***
MT-07-124-01	0.046	0.02	0.14	1.10	0.259	0.061	***4.25***
MT-07-126-01	0.06	0.02	0.11	1.00	0.261	0.046	***5.68***
MT-08-007-01	0.055	0.02	0.04	1.60	0.187	0.039	***4.80***
MT-08-019-01	0.039	0.02	0.03	1.60	0.144	0.026	***5.52***
MT-08-025-01	0.06	0.03	0.05	0.97	0.220	0.030	***7.32***
MT-08-027-02	0.07	0.03	0.05	0.82	0.241	0.039	***6.17***
MT-08-034-01	0.061	0.02	0.04	0.82	0.198	0.039	***5.08***
MT-08-047-01	0.06	0.01	0.07	1.60	0.212	0.041	***5.16***
MT-08-066-01	0.03	0.02	0.04	0.92	0.132	0.024	***5.49***
MT-08-088-01	0.03	0.02	0.06	1.20	0.151	0.026	***5.81***

Srev = revised calculation of the radioactivity index; SEIS= proponent's calculation.

Clearly the proponent has not displayed the necessary degree of competence in dealing with radioactivity to be able to satisfy the Panel's Directives.

Question 9. Are radioactive materials carcinogenic?

Chronic exposure to even low doses of radioactive materials over a long period of time can – and does – cause an increase in the number of cancers and leukemias in the exposed population. This has been amply demonstrated in the case of radium, radon, thorium, and polonium.

Yet there is no discussion of this fact in the EIS. Indeed the words "cancer" and "carcinogenic" (cancer-causing) are never used by the proponent in the context of radioactive materials as a causative factor in any of the 4 volumes of the EIS.

In Volume 1, the word "carcinogenic" is used 4 times, but only in connection with *non-radiological* contaminants, never in connection with radioactive materials:

> page 218, "**Non-Radiological** Benchmarks:
> carcinogenic COPC toxicity reference values";
>
> page 232, under "5.6.7.2 **Non-Radiological** COPC Reference Values"
> "Carcinogenic potential must also be taken into account in the human risk assessment"
>
> page 233, under "5.6.7.4 Risk of Exposure to **Non-Radiological** COPC"
> ". . . the risk characterization of **non-radiological** COPC . . . considers non-carcinogenic and carcinogenic effects."
>
> page 236, under "5.6.7.4 Risk of Exposure to **Non-Radiological** COPC"
> "In this evaluation, nickel is the only carcinogenic COPC and only through the inhalation pathway**."** ***[Emphasis added in each case]***

The word "cancer" is not used at all in Volume 1; and in Volumes 2 and 3, there are no uses of the words "cancer" or "carcinogenic".

In Volume 4 the words "cancer" and "carcinogenic" [cancer-causing] are used often in section 5.2.2, entitled "**Non-Radiological** Benchmarks", and in section 7.3.1, labelled "**Non-Radiological**" (under the heading of Risk Assessment Results).

The use of medical *isotopes for diagnosing and treating cancer* is mentioned several times in Volume 4, but the concept of radiation-induced cancer arises just three times. Exactly three times. It is raised once by a Cree tallyman on page 420, once again in answer to a Cree woman's question on page 427, and once on page 471 in response to a question raised at an "Atelier de discussion" held in Chibougamau.

So the topic of radiogenic cancer comes up in the EIS only when raised by members of the local population, and then it is treated as a thing of little or no importance.

In the two extra volumes of Answers to the Panel's Questions, dated August 2010, the proponent only mentions cancer twice – in two consecutive sentences on page 5 of Volume 1 of the Answers.

With no further explanation, the proponent describes the "discovery of the link between lung cancer and the exposure to radon" as a thing of the past, declaring that "the current exposures to radon in Canadian mines do not present the same risk to miners anymore." In other words, the risk of radon-induced lung cancer is introduced just long enough – in one sentence on p. 5 – to deny that it is a problem.

The proponent's failure to discuss carcinogenic properties of radioactive materials such as radon, radium, thorium, and polonium is a clear violation of the Directives.

Question 10. Is radon gas responsible for the deaths of miners?

Thousands of miners have died prematurely from lung cancers contracted due to radon exposures underground – and this, over a period of centuries. Yet the relevant historical facts are not presented or discussed in the EIS.

The grim toll from radon includes a great many silver and cobalt miners from Schneeberg in Germany and Joachimsthal in Czechoslovakia; the Navajo uranium miners working on the Colorado Plateau; the Newfoundland fluorspar miners; uranium miners at Port Radium in NWT, Uranium City in Saskatchewan, Elliot Lake and Bancroft in Ontario; and non-uranium miners in South Africa and Sweden.

> Radon-222, a noble gas resulting from the decay of naturally occurring uranium-238, was the first occupational respiratory carcinogen to be identified. As early as the 1500s, Agricola chronicled unusually high mortality from respiratory disease among underground metal miners in the Erz Mountains of eastern Europe (Hoover and Hoover 1950). In 1879, Harting and Hesse (1879) described autopsy findings that documented pulmonary malignancy in miners in that region and by early in the 20th century the malignancy was shown to be primary carcinoma of the lung (Arnstein 1913) . . . .
>
> The committee has drawn on 11 major studies of underground miners, which together involved about 68 000 men, of whom 2 700 have died from lung-cancer. The committee statistically analyzed the data to describe how risk of death from lung-cancer depended on [radon] exposure.
>
> *Health Effects of Exposure to Radon (BEIR VI)*
> *U.S. National Academy of Sciences, 1999*

The proponent completely ignores this history and fails to discuss the topic of radon-induced lung cancer. That is an abdication of its responsibility to the local population and to the men and women who might be potential workers in the exploration ramp or at the mine site later on.

On page 427 of Volume 4, there is a description of a Focus Group organized by the proponent that was "meant to be held with Social, Security, Health and Education representatives". The one Cree representative who attended asked "What is radiation? I read about the Navaho. What protection is there?" The proponent not only failed to answer her question about radiation, but also gave her false information about the Navajo miners who worked on the Colorado Plateau.

The proponent's representative is quoted as saying that "The lung cancer rates with the Navaho are related to bad mining and smoking." Besides misspelling the word "Navajo", the proponent provides an inaccurate and misleading characterization of the well-known epidemic of radon-induced lung cancers among Navajo miners.

The Navajo were for the most part non-smokers. In fact the number of non-smoking Navajo miners was so great that this population offers a striking example of the carcinogenic properties of radon in a non-smoking population.

It appears that the proponent not only fails to provide factual information about carcinogenesis due to exposure to radioactive materials, but simply makes things up in answer to serious questions posed by members of the local community. This is the height of irresponsible behaviour.

Question 11: Do mining regulations make radon exposures safe?

Although the word "radon" frequently occurs in the EIS (41 times in Volume 1, 27 times in Volume 2, 5 times in Volume 3, 162 times in Volume 4) the proponent *never* mentions the health dangers of chronic radon exposure.

In the proponent's Answers to the Panel's Questions, the topic comes up only once – Vol. 1, page 5. Here is the sum total of information made available by the proponent about the health effects of radon exposures:

> Regarding health, the workers of the first Canadian uranium mines have had health problems since the harmful effects of exposure to high concentrations were not known at that time. The discovery of the link

> between lung cancer and the exposure to radon has allowed to establish a series of measures to protect workers and the population. The Eldorado study, which consisted in monitoring the health of Canadian uranium mine workers over the last 50 years, contains information that is important to understand the relation between exposure to radon and the risk for lung cancer. Thanks to this study, the current exposures to radon in Canadian mines do not present the same risk for miners anymore because of the improved and strict standards that regulate the health and safety aspects.
>
> *Strateco Document 75-752-A-1-001, p. 5*

This four-sentence summary of one of the most important health issues related to uranium mining is not only inadequate, but profoundly misleading.

First, the proponent is disseminating misinformation by saying that the "harmful effects of exposure . . . were not known" in the early days of uranium mining. As early as 1931, the Canadian Department of Mines published a series of reports on the harmful effects of low levels of exposure to radioactive materials, including radon, which at that time was called "emanation".

> The hazards involved in the handling of high-grade radioactive materials make necessary the adoption of certain precautions. Recent investigations in the field of radium poisoning have led to the conclusion that precautions are necessary even in the handling of substances of low radioactivity. The ingestion of small amounts of radioactive dust or emanation [i.e. radon] over a long period of time will cause a building up of radioactive material in the body, which eventually may have serious consequences. Lung cancer, bone necrosis, and rapid anaemia are possible diseases due to the deposition of radioactive substances in the cell tissue or bone structure of the body. . . .
>
> *Precautions for Workers in the Treating of Radium Ores*
> *Investigations in Ore Dressing and Metallurgy*
> *Department of Mines, Canada, 1931*

W. R. McLelland, the government engineer who wrote the words quoted above, also filed two memoranda on the subject. On February 8 1932, in a memorandum to the Chief of his Division at the Department of Mines, he referred to "recent information that a large number of the miners of the Bohemian Mines [exposed to uranium-bearing ores in Czechoslovakia] have developed sarcoma of the lung."

McLelland went on to say "It is necessary to adopt very rigorous regulations regarding precautions and a careful check on all workers [must be] maintained. The writer has very full data on this subject obtained from careful observation, personal discussion and a number of published reports and papers."

Second, the proponent is providing misinformation by implying that the current so-called "strict standards" on radon exposures for miners eliminates the danger of radiation-induced lung cancer. That is simply untrue.

In 1982, the Atomic Energy Control Board (AECB) published an ambitious study they had commissioned, entitled Health Effects of Alpha Radiation, by Duncan C. Thomas and K. G. McNeill. One of the objectives was to ascertain the lung cancer risk associated with permissible levels of radon exposure. The authors were told to use the best data available from various countries around the world.

The regulatory limit for workers at that time was the same as it is today: 4 WLM per year for workers (cited on page 15, Vol. 4 of the EIS). [The unit WLM stands for "working-level-months"; it is a unit of accumulated exposure to radon gas and its radioactive decay products over a specified period of time.]

The Thomas-McNeill report stated its results with a high degree of confidence:

> This report provides risk estimates . . . based solely on human data for lung cancer, [based] on miners in the Colorado plateau, Czechoslovakia, Sweden, Ontario and Newfoundland . . . . Our best estimate of excess relative risk is 2.28 ± 0.35 [lung cancers] per 100 WLM. [That represents] a doubling dose [for lung cancer] of 44 WLM.
>
> Our best estimate of the effect of a 50-year occupational exposure to 4 WLM per year is 130 excess lung cancer deaths per 1000 persons . . . with a range from 60 to 250 [extra lung cancers] per 1000 persons.
>
> *AECB Research Report INFO-0081 September 1982*

Thus , an accumulated dose of 44 working-level-months (WLM) of radon will double a worker's risk of dying from lung cancer. Under the existing regulatory limit – 4 WLM per year – a worker could legally accumulate this dose in 11 years.

Since the normal rate of lung cancer deaths among Canadian males over a lifetime is about 54 per 1000, it follows that 44 WLM of radon exposure will double this number – it will cause an *additional* 54 lung cancer deaths per 1000 men exposed, for a total of 108 lung cancers per 1000 men exposed.

This is hardly to be considered a safe exposure level!

For the sake of clarity, it must be noted that miners do not generally work at the maximum permitted level of radon exposure in a well-run mine. Typically, a miner's average annual exposure is 1 WLM per year or less. But even an exposure to 1 WLM for 11 years would cause an extra 5 or 6 lung cancer deaths per 1000 men exposed, over and above the 54 lung cancers normally expected.

The proponent fails in its duty to inform the local population adequately about the health risks of radon, giving no data on the incidence of excess lung cancers associated with various levels of radon exposure. This is of great importance, given that radon exposure is the leading cause of lung cancer among non-smokers, and that every atom of radon gas begins as an atom of uranium (it is one of the uranium decay products).

Such information is of particular importance in the context of the Matoush project. Radon exposures to workers doing exploration drilling at the 300 metre level in the proposed exploration ramp could be as high as 3.4 WLM per year, as indicated on page 198 of Volume 2 of Strateco's answers to the panel's questions.

That level of radon exposure is close to the regulatory limit of 4 WLM per year. It is a far cry from the minimal occupational exposures promised by the proponent.

Question 12: Is there a safe level of exposure to atomic radiation?

After many decades of study, the overwhelming scientific consensus is that there is no safe level of exposure to atomic radiation when it comes to cancer, leukemia, and some other types of biological damage caused by atomic radiation – particularly genetic damage. This important observation is nowhere found in the EIS.

Scientific evidence strongly supports the view that if a sufficiently large population of people is exposed to even very low levels of atomic radiation, some of those exposed individuals will develop cancer or leukemia as a result. It is impossible to predict which individuals will be stricken, but the number of victims can be predicted with considerable accuracy.

In particular, medical authorities around the world have concluded that there is no "safe" dose of radon exposure. The US Environmental Protection Agency reports that about 20,000 Americans die every year from radon exposures in their own homes, although the radon levels are generally much lower than they are in any uranium mine. [See http://www.epa.gov/radon/]

For radon exposures in homes and other buildings, the regulatory limit in Canada is now set at 0.02 WL of radon and its decay products. That's about 150 bequerels per cubic metre of air. The Thomas-McNeill Report says:

> *A 0.02 WL maximum [radon level] for homes could increase the lifetime lung cancer risk [of the occupants] by about 40 percent.*
>
> *AECB Research Report INFO-0081 September 1982*

Similarly, a 1998 report entitled Le Radon à Oka indicates that for a household exposure level of 0.02 WL of radon and its radioactive decay products – equivalent to 150 becquerels per cubic metre of air –the lifetime lung cancer risk will be increased by about 47 percent over the background lung cancer rate. (See page 19 of that report, published by the Direction régionale de la santé publique of the Régie régionale de la santé et des services sociaux des Laurentides.) That's an extra 25 lung cancer deaths per 1000 men exposed.

Evidently, the regulatory limit for radon is not a "safe" limit in the sense that no harm is done; it represents a compromise between the biological damage that results and what can be reasonably achieved in the way of prevention.

The International Commission on Radiological Protection (ICRP) makes the same point in a publication that is featured on their current web site:

> *Both low and high doses [of atomic radiation] may cause stochastic, i.e. randomly occurring, effects (cancer and hereditary disorders).... The probabilistic nature of the stochastic effects makes it impossible to make a clear distinction between 'safe' and 'dangerous', a fact that causes problems in explaining the control of radiation risks. The major policy implication of a non-threshold relationship for stochastic effects is that some finite risk must be accepted at any level of protection. Zero risk is not an option.*
>
> *International Commission on Radiological Protection:*
> *History, Policies, Procedures*
> *http://www.icrp.org/docs/Histpol.pdf*

A "stochastic effect" refers to any kind of biological damage caused by radiation whereby the number of victims can be reduced by reducing the exposure, but the severity of the damage is in no way reduced. The proponent communicates none of these important concepts to the local population. By failing to do so, it is clearly violating the Panel's Directives.