Background: **February 26 2019**

In 2016, I made a non-technical presentation in Narsaq, Greenland, aimed at a general audience, outlining medical concerns associated with the proposed mining of a massive radioactive ore deposit at Kvanefjeld (or Kuannersuit). I was sent to Narsaq by Physicians for Global Survival, the Canadian Chapter of International Physicians for the Prevention of Nuclear War, in response to a request from local citizens for health-related information.

See www.ccnr.org/Narsaq_Edwards_2016.pdf and. www.ccnr.org/Narsaq_Edwards_2016_show.pdf .

Shortly after my presentation in Narsaq, I was interviewed by Anne Albinus, a Danish researcher and blogger who has been following the Kvanefjeld story for years. She subsequently posted my 2016 responses to questions on 3 topics:

1. *Why are some medical professionals opposed to uranium mining?*
   https://atomposten.blogspot.com/2016/06/uranium-mining-interview-with-dr-gordon.html
2. *Is Cluff Lake is a good example of satisfactory remediation of a uranium mining site?*
   https://atomposten.blogspot.com/2016/07/uranium-mining-interview-with-dr-gordon.html
3. *Could Greenland's uranium end up in nuclear weapons?*
   https://atomposten.blogspot.com/2016/07/uranium-mining-interview-with-dr-gordon_15.html

On January 21, 2019, Ms. Albinus forwarded to me an email from James Eggins challenging the scientific credibility of my views on radioactive waste from uranium mining and the links to nuclear weapons. Mr. Eggins is the man in charge of Uranium Marketing for the Australian-based company "Greenland Minerals and Energy" (GME), the company that is seeking approval to exploit the Kvanfjeld ore body*. [Its name has been shortened to "Greenland Minerals".]*

Although I was not asked to do so, I wrote the following response to Mr. Eggins' email. I have also copied Eggins' email and Anne Albinus' email, written on February 21 and February 20 respectively, just below my response of February 24.

Gordon Edwards.

Email from Gordon Edwards to Anne Albinus, February 24, 2019.

. . . I am now responding to the email from James Eggins *[see below].* There is one point he makes that I accept without argument : that the radioactivity in the uranium mine wastes (called tailings) will diminish from 85% to about 70% of the original total radioactivity in the ore body in about one year (assuming that there is very little thorium-232 in the ore). But the radioactivity left over in the tailings will stay relatively constant after that short initial time period. In fact, for the next 11,000 years, the radioactivity left behind in the waste is more than four-and-a-half times greater than the radioactivity of all the uranium that is extracted from the ore body.

However I disagree with Eggins' other comments, especially on the nature of the hazard. The perception of hazard depends on circumstances. If all radioactive materials are safely contained for a million years, then there is no actual harm done. But the question is, how does one guarantee the safe containment of 112 million tonnes of radioactive sand for a million years? This is not hyperbole, this is realism.

Also, how does one prevent the unremitting emissions of radon gas from the tailings, given that radon cannot be inhibited by any chemical means, being a "noble gas" that does not enter into any chemical reactions whatsoever? Moreover, whatever escape of radon gas does occur (and it will!) leads to the deposition of solid radon decay products on the soil and vegetation over a wide area — radioactive isotopes of bismuth, lead and polonium, including polonium-210.

The Los Alamos nuclear labs in the USA estimate that polonium-210 is 250 billion times more toxic than cyanide; it was the agent used to murder Alexander Litvinenko in London. I am not sure how precise the Los Alamos figure is, as they do not reveal their mode of calculation, but there is no doubt that polonium is by far the most toxic element that occurs in nature. It is ONLY produced by the disintegration of radon atoms, and radon is ONLY produced by the disintegration of uranium and thorium atoms.

Eggins is on shaky ground when he talks about the relative contribution of uranium decay products to the overall level of hazard. It is certainly true that the amount of radioactive material in the tailings is "minute" in terms of mass and volume, but not necessarily in terms of biological hazard. For example, in the Elliot Lake region of Ontario, where uranium mining took place for decades, the ore grade was about 0.05 percent. That means that the mass of uranium in a tonne of ore was only about half a kilogram of uranium-238 (500 grams). The mass of thorium-230 in that same tonne of ore, and hence in one tonne of tailings, would be about 8.68 milligrams. And the mass of radium-226 in that same tonne of ore, or tailings, would be even lower: 0.165 milligrams = 165 micrograms. These numbers are so small that one can rightly call them "minute" — if measured in terms of mass.

But it's not the mass that makes them dangerous!! Mass is not a measure of radioactivity. Each of the above-mentioned masses of uranium-238, thorium-230, and radium-226, has exactly the same amount of radioactivity, which is about 6 million becquerels. So in each tonne of Elliot Lake tailings

there are 6 million disintegrations per second (dps) from uranium-238 atoms, another 6 million dps from thorium-230 atoms, another 6 million dps from radium-226 atoms, and the same number of disintegrations per second from all the other uranium-238 decay products in the tailings.

Because of the potential medical harm that can be caused by these levels of radioactivity, a federal government-appointed Environmental Assessment Panel in Canada concluded in the 1990s that these uranium tailings – ground to a very fine consistency, more like flour than like sand — will have to be subject to active monitoring and maintenance forever in order to protect the environment and public health. The executive summary states:

> ***"Given the permanent nature of the hazards presented by the tailings, the panel recommends that an adequate containment system must be supported in perpetuity by effective care and maintenance programs. Such programs must include vigilant monitoring, maintenance, repair and, as necessary, system modification in the light of experience and technological advances. There should also be a capability to repair promptly major failures caused by exceptional unforeseen events."***

In the 1970s, due to neglect, the entire Serpent River system that drains into Georgian Bay after winding for 58 miles through a network of 18 lakes in the Elliot Lake region, was terribly contaminated from uranium tailings and had degenerated into what was described in an Ontario government report at that time as a “biological desert”. This radioactive and chemical contamination was the cumulative result of over 30 tailings dam failures in the Elliot Lake region. Since that time a lot of remediation has been carried out and the Serpent River system has been restored to a considerable extent, but the amount of radioactive radium-226, thorium-230, and polonium-210 in the tailings will remain virtually unchanged for many thousands of years. And radon gas will continue to be produced at an undiminished rate. Radon is the primary cause of lung cancer among non-smokers.

It doesn’t matter how small the masses are. What matters is how much "subatomic shrapnel” (alpha particles, beta particles, and gamma rays) are being given off each and every second. Each individual subatomic projectile has the potential to cause a fatal or non-fatal cancer or a harmful genetic defect that can damage future generations. The number of such adverse effects will be zero if no humans are exposed, but if the radioactive material

finds its way into the drinking water, the food chain, the soil, or the atmosphere, these harmful biological effects (and others) are correspondingly more likely to occur. The larger the population exposed, the greater the number of detrimental effects that will occur.

See “The Harm Caused by Radioactivity”, www.ccnr.org/Pikwakanagan_3.pdf

The term “secular equilibrium” means that each of the 14 radionuclides in the decay chain of uranium-238 have the same level of radioactivity, so in one tonne of Elliot Lake ore there are 6 x 14 = 84 million disintegrations every second, and in the Elliot Lake tailings there will be about 72 million disintegrations per second (a bit more than 85% of the radioactivity in the ore body). After about a year, the number of disintegrations per second (per tonne of Elliot Lake tailings) will decrease to about 60 million disintegrations per second (due to the gradual month-by-month disappearance of thorium-234 and protactinium-234) but it will not decrease to any significantly lower level for many thousands of years. In fact it will take about 38,000 years for the radioactivity in one tonne of Elliot Lake tailings to diminish from 60 million dps to 30 million dps.

Eggins is naive in his discussion of the proliferation of nuclear weapons. In fact, the military in the USA and other nuclear weapons states use cast-off U-238 (“depleted uranium” or DU) in order to manufacture the plutonium-239 that is used as the primary nuclear explosive in almost all nuclear warheads. Most of this DU is civilian in origin.

In specialized “military production reactors”, the military uses highly enriched “driver rods” as a nuclear fuel and a source of neutrons, while hollow cylindrical “target rods” made of depleted uranium surround the driver rods. As the U-238 atoms in the targets are bombarded by neutrons from the U-235 driver rods, they are transformed into plutonium-239 atoms.

The metallic DU target rods are MUCH less radioactive than the irradiated nuclear fuel (i.e. the driver rods) and so they are MUCH more easily dissolved in boiling nitric acid to create a liquid solution from which the plutonium is chemically separated, re-solidified, and machined into spherical metallic plutonium implosion devices (“pits”) needed to “trigger” the H-bombs or to be used as smaller fission bombs akin to the Nagasaki bomb.

By the way, DU is also used in the casing of every H-bomb, and the MAJOR PORTION (way more than 50%) of the explosive power of the resulting

nuclear weapon comes from the FORCED FISSIONING of the DU atoms by the extremely energetic fusion neutrons (14 MeV instead of 4 MeV for the typical fission neutron). Although U-238 cannot sustain a nuclear chain reaction on its own, it can be fissioned if there is an external source of neutrons to do the work. An H-bomb will do quite nicely for that purpose.

The enormous stockpile of depleted uranium found in the back yards of enrichment plants is overwhelmingly civilian in origin, but the uranium suppliers (such as Canada) have no desire to retain ownership of these commercially useless DU drums, so ownership reverts to the USA or whatever other country is performing the enrichment service. Therefore the military suppliers have no need to purchase uranium, they just help themselves to the leftovers of the civilian enrichment traffic. The fact that this DU has utility in the nuclear weapons business is indicated by the fact that the US government forced Canada (certainly in the pre-Gorbachev years) not to allow any left-over DU from civilian enrichment to remain in the USSR in those few instances where a customer for Canadian uranium requested/required that its uranium be enriched not in the USA but in Riga, Latvia -- at that time part of the USSR.

Of course Eggins is also very naive in suggesting that civilian plutonium, mass-produced in all civilian nuclear power reactors worldwide, does not pose an agonizing and ever-growing threat of nuclear weapons proliferation for the next 100,000 years. By mining uranium (a material that is not immediately weapons-usable without enrichment), and using that uranium in civilian nuclear reactors, we are creating stockpiles of plutonium -- a human-made nuclear explosive materials that requires no enrichment. Any regime in the future, even 10 or 20 thousand years from now, can use that civilian plutonium to construct an arsenal of nuclear weapons if desired.

Email from James Eggins to Anne Albinus, February 21, 2019.

. . I read the material you attached from Dr Edwards. It contains a lot of graphic language and some extraordinary, I think grossly exaggerated, claims, but is otherwise largely fact-free.

There is a vast amount of literature on old uranium mining rehabilitation – not just in Canada, but also in most countries where there is a legacy of mining for cold war purposes. None of it is relevant to modern mining operations (in Canada, Australia,

Namibia, Kazakhstan - the large producers) where current practices ensure radiological exposures are very low – which is really the point.

The extract from your interview with Dr Edwards which you quote below is totally bereft of science but is very long on hyperbole. I know our Australian authorities would be astonished by claims that "medical hazards will last for hundreds of thousands of years" or the assertions about radon generation. It is just plain wrong.

This is a statement from the *Office of the Supervising Scientist, (* http://www.environment.gov.au/science/supervising-scientist) -- a federal government independent supervisor of uranium mining in the Northern Territory of Australia -- explaining the nature of *uranium* tailings:

> ***"About 95% of the radioactivity in the ore is from the U-238 decay series, totalling about 150 kBq/kg in ore with 0.1% U_3O_8. The U-238 series has 14 radioactive isotopes in secular equilibrium, thus each represents about 11 kBq/kg (irrespective of the mass proportion). When the ore is processed, the U-238 and the very much smaller masses of U-234 (and U-235) are removed. The balance becomes tailings, and at this point has about 85% of its original intrinsic radioactivity. However, with the removal of most U-238, the following two short-lived decay products in the uranium decay series (Th-234 and Pa-234) soon disappear, leaving the tailings with a little over 70% of the radioactivity of the original ore after several months. The controlling long-lived isotope then becomes Th-230 which decays with a half-life of 77,000 years to radium-226 followed by radon-222."***

[GE Note: Bq = Becquerel = one disintegration per second; kBq = 1000 Becquerels. U-234, 235, 238 = three isotopes of uranium, Th = thorium; Pa = protactinium]

l I have highlighted the 85% number because it occurs in the Dr Edwards interview. What does not occur in the Dr Edwards interview is the rest of the science.

The truth is that there are no long term radiological hazards to the public or the environment from uranium mining because the additional doses attributed to the mining, milling, processing and tailings management of a uranium ore body are trivial compared to natural background. In the case of Kvanefjeld, total increase in radiation exposure for people in Narsac [sic] from all sources is calculated to be about 1% *on top of background*. Total tailings volume for the **37 year mine life** will be less than 112 million tonnes of which a minute part is radioactive.

Email from Anne Albinus to James Eggins, February 20, 2019

Thank you for your kind answer

I got interested in the Kvanefjeld project since I have followed the Danish plan for disposal of the Danish radioactive waste at Risø since 2012.

At Risø 1130 tonnes of tailings are stored under water in 2 basins, and after many years, the Danish authorities still do not have a plan for a longterm management.
The uranium ore from Kvanefjeld has contaminated the underlying soil and also the Fjord of Roskilde. This gave me in interest in the Kuannersuit project.

Concerning the long term hazards, it would be of great importance to have the long terms hazards elaborated. Does GME have a report on that subject?

Who will safeguard the environment after the mining operations have been terminated? As Dr Gordon Edwards points out in my interview with him?

> *While improvements have been made in the handling and storing of uranium tailings during the operational phase, such results depend on having a strong, competent, and independent regulatory authority that has the power to implement tough regulations. It must be politically accountable to a vigilant government and a well-informed public. But even under the best circumstances, there comes a time when these voluminous long-lived radioactive wastes will be abandoned. Who then will have the authority, the knowledge, and the resources to safeguard the environment for countless millennia after the mining operations have been terminated and the mining company has moved on or disappeared? The medical hazards will last for hundreds of thousands of years, and will long outlive any government or regulatory agency. Who knows how to keep hundreds of millions of tonnes of radioactive sand out of the environment forever? Eighty-five percent of the radioactivity in the ore body will remain in the uranium wastes, producing vast amounts of radon gas for hundreds of millennia.*