Background: July 8 2021

It is alarming that Canada would allow and even encourage reprocessing of irradiated nuclear fuel to extract plutonium from CANDU used fuel without any public hearings, independent review, or parliamentary debate. It has long been recognized that plutonium extraction poses even more of a proliferation risk than uranium enrichment – because all reactor-produced plutonium (extracted from irradiated nuclear fuel) is immediately weapons-usable and needs no enrichment.

The Moltex pyroprocessing operation proposed for New Brunswick is designed to extract plutonium (Pu) + minor actinides (MA) + lanthanides (Ln) – all blended together in a molten salt mixture. Because the plutonium is mixed with the minor actinides and the lanthanides, Moltex claims the plutonium is not "weapons usable". But that is just playing with words. Plutonium cannot be used for weapons unless it is separated from the rest of the radioactive garbage in irradiated nuclear fuel anyway, and most of that separation work has been accomplished by pyroprocessing -- the remaining last steps are relatively simple by comparison.

The nuclear weapons proliferation potential of plutonium is not diminished but enhanced by Moltex technology. A critical mass of plutonium, needed to make an atomic bomb roughly equivalent to the Nagasaki bomb, would require about 10 kilograms of plutonium. To extract 10 kilograms of plutonium one would need 2600 kilograms of CANDU used fuel to begin with -- but one would only need 57 kilograms of used Moltex fuel to acquire the same 10 kilograms of plutonium, and only 22 kilograms of fresh Moltex fuel for the same purpose. Most of the work has already been done by Moltex. Such considerations have led US government non-proliferation agencies to declare that pyroprocessing is no different from any other kind of reprocessing in terms of the weapons proliferation potential.

Moreover, the Moltex technology does not alter the need for very long-term isolation of nuclear waste. According to the Moltex company's own projections, a bit more than 38 percent of the recovered plutonium remains unfissioned in the Moltex spent fuel. So the plutonium that is to be extracted from the irradiated CANDU fuel (less that 1/2 of 1 percent of the total) will by no means be eliminated, and the long-term storage requirement for spent fuel will remain fundamentally the same.

Moreover, when the Moltex reactor uses the “recycled” fuel, fissioning it with fast neutrons, many of the plutonium atoms and many of the MA atoms are fissioned, while many others absorb neutrons without fissioning, thereby transmuting into other isotopes — which may in some cases offer some benefits in terms of reducing radio-toxicity characteristics including reduced longevity. However the lanthanides are largely unaffected, and a great many more intensely radioactive fission products are created as a result of the fissioning of plutonium and MA atoms. This new crop of fission products includes the very long-lived fission products such as iodine-129 (16 million years), technetium-99 (210,000 years), cesium-135 (3.5 millon years) and a few others that are listed below.

Numerous detailed studies of the post-closure safety case for buried nuclear waste have shown that these long-lived fission products pose a greater environmental and health hazard in the long run (in contrast to the plutonium and MA) because they are much more mobile in the enviornment and much more bio-available than the actinides. Also the chlorine atoms in the salt-fuel matrix of the proposed Moltex reactor fuel, as well as in the molten salt coolant, will “breed” a long-lived radioactive activation isotope, Chlorine-36, with a 300,000 year half-life, to accompany the other very long-lived neutron activation products such as nickel-59 (76,000 year half-life). So the nuclear waste problem is not “solved” or even “eased” significantly (if at all) by the Moltex technology, while the proliferation potential is greatly exacerbated. Canadians who care about the Fate of the Earth should not be sitting on their hands while this travesty unfolds.

Gordon Edwards

Notes from Wikipedia : Long-Lived Fission Products (LLFP)

(https://en.wikipedia.org/wiki/Long-lived_fission_product#Long-lived_fission_products)

1. Technetium-99 produces the largest amount of LLFP radioactivity. It emits beta particles of low to medium energy but no gamma rays, so has little hazard on external exposure, but only if ingested. However, technetium's chemistry allows it to form anions (pertechnetate, TcO_4^-) that are relatively mobile in the environment.

2. Iodine-129 has the longest half-life, 15.7 million years, and due to its higher half life, lower fission fraction and decay energy it produces only about 1% the intensity of radioactivity as ^{99}Tc. However, radioactive iodine is a disproportionate biohazard because the thyroid gland concentrates iodine. ^{129}I has a half-life nearly a billion times as long as its more hazardous sister isotope ^{131}I; therefore, with a shorter half-life and a higher decay energy, ^{131}I is approximately a billion times more radioactive than the longer-lived ^{129}I.

3. Zirconium-93 is produced at a relatively high yield of about 6%, but its decay is 7.5 times slower than Tc-99, and its decay energy is only 30% as great; therefore its energy production is initially only 4% as great as Tc-99, though this fraction will increase as the Tc-99 decays. ^{93}Zr does produce gamma radiation, but of a very low energy, and zirconium is relatively inert in the environment.

4. Caesium-135's predecessor xenon-135 is produced at a high rate of over 6% of fissions, but is an extremely potent absorber of thermal neutrons (neutron poison), so that most of it is transmuted to almost-stable xenon-136 before it can decay to caesium-135. If 90% of ^{135}Xe is destroyed, then the remaining ^{135}Cs's decay energy per unit time is initially only about 1% as great as that of the ^{99}Tc. In a fast reactor, less of the Xe-135 may be destroyed.
   ^{135}Cs is the only alkaline or electropositive LLFP; in contrast, the main medium-lived fission products and the minor actinides other than neptunium are all alkaline and tend to stay together during reprocessing; with many reprocessing techniques such as salt solution or salt volatilization, ^{135}Cs will also stay with this group, although some techniques such as high-temperature volatilization can separate it. Often the alkaline wastes are vitrified to form high level waste, which will include the ^{135}Cs.

5. Tin-126 has a large decay energy (due to its following short half-life decay product) and is the only LLFP that emits energetic gamma radiation, which is an external exposure hazard. However, this isotope is produced in very small quantities in fission by thermal neutrons, so the energy per unit time from ^{126}Sn is only about 5% as much as from ^{99}Tc for U-235 fission, or 20% as much for 65% U-235+35% Pu-239. Fast fission may produce higher yields. Tin is an inert metal with little mobility in the environment, helping to limit health risks from its radiation.

6. Selenium-79 is produced at low yields and emits only weak radiation. Its decay energy per unit time should be only about 0.2% that of Tc-99.

7. Palladium-107 has a very long half-life, a low yield (though the yield for plutonium fission is higher than the yield from uranium-235 fission), and very weak radiation. Its initial contribution to LLFP radiation should be only about one part in 10,000 for ^{235}U fission, or 2,000 for 65% ^{235}U+35% ^{239}Pu. Palladium is a noble metal and extremely inert.

Here is some information about the lanthanides -

Description of Transmutation Library for Fuel Cycle System Analyses
Steve Piet, Samuel E. Bays, Edward A. Hoffman

https://www.researchgate.net/publication/255218152_Description_of_Transmutation_Library_for_Fuel_Cycle_System_Analyses

Pr = praseodymium; Ce = cerium; Pm = promethium; Eu = europium; Sm = samarium; Ho = holmium;

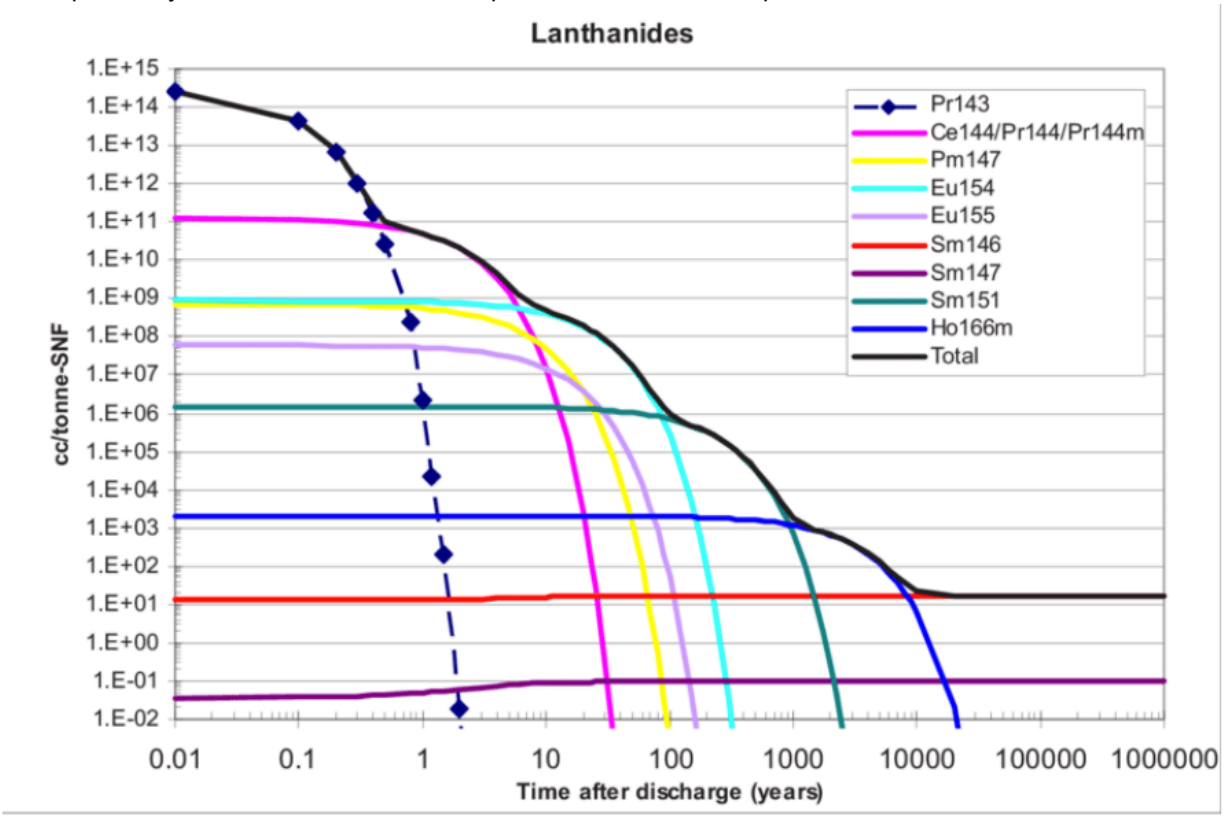

Figure A-6. Radiotoxicity of lanthanide fission products from UOX-51. (Tracked isotopes shown via solid lines, untracked isotopes shown with dashed lines.)

Notice that the three samarium isotopes remain radioactive for more than 1000 years. Because samarium-151 has a half-life of 90 years, it diminishes by a factor of 1000 only after 900 years. Moltex claims that fission products only have to be stored for 300 years.

"This report documents the Transmutation Library that is used in Fuel Cycle System Analyses. This version replaces the 2008 version. [Piet2008] The Transmutation Library has the following objectives:
• Assemble past and future transmutation cases for system analyses.
• For each case, assemble descriptive information such as where the case was documented, the purpose of the calculation, the codes used, source of feed material, transmutation parameters, and the name of files that contain raw or source data.
• Group chemical elements so that masses in separation and waste processes as calculated in dynamic simulations or spreadsheets reflect current thinking of those processes. For example, the CsSr waste form option actually includes all Group 1A and 2A elements.
• Provide mass fractions at input (charge) and output (discharge) for each case.
• Eliminate the need for either fission product other or actinide other while conserving mass. Assessments of waste and separation cannot use fission product other or actinide other as their chemical behavior is undefined.

• Catalog other isotope-specific information in one place, e.g., heat and dose conversion factors for individual isotopes.
• Describe the correlations for how input and output compositions change as a function of UOX burnup (for LWR UOX fuel) or fast reactor (FR) transuranic (TRU) conversion ratio (CR) for either FR-metal or FR-oxide.

"This document therefore includes the following sections:
• Explanation of the data set information, i.e., the data that describes each case. In no case are all of the data presented in the Library included in previous documents. In assembling the Library, we return to raw data files to extract the case and isotopic data, into the specified format.
• Explanation of which isotopes and elements are tracked. For example, the transition metals are tracked via the following: two Zr isotopes, Zr-other, Tc-99, Tc-other, two Mo-Ru-Rh-Pd isotopes, Mo-Ru-Rh-Pd-other, four other specific TM isotopes, and TM-other. Mo-Ru-Rh-Pd are separated because their content constrains the loading of waste in glass, so we have to know the mass of those elements independent of others.
• Rules for collapsing long lists of isotopes (~1000) to the 81 items in the library. For each tracked isotope, we define which short-lived isotopes mass (at t=0) is included with the mass of the tracked isotope at t=0, which short-lived radioactive progeny must be accounted for when the tracked isotope decays, and to which of the other 80 items the mass of the tracked isotope goes when it decays.
• Explanation of where raw data files can be found on the fuel cycle data portal.
• Explanation of generic cross section sets
• Explanation of isotope-specific parameters such as heat and dose conversion factors
• Explanation of the LWR UOX burnup and FR TRU CR correlations."