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A Comparison of Potential Radiological Impacts of ^{233}U and ^{239}Pu Fuel Cycles*

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Nuclear fuel cycles utilizing ^{233}U are currently the subject of considerable interest in the United States. This paper focuses on the identification of significant differences between the off-site radiological hazards posed by $^{232}Th/^{233}U$ (Th/U) and $^{238}U/^{239}Pu$ (U/Pu) fuel cycles, and represents a portion of our involvement in the Nonproliferation Alternative Systems Assessment Program (NASAP),[1] to be used in support of the International Fuel Cycle Evaluation (INFCE).

Recycle systems such as these incorporate a number of major components, each a potential source of radionuclide releases. Our research focused on those components anticipated to contribute the majority of off-site dose. The Generic Environmental Statement on Mixed Oxide Fuels[2] provides data indicating that the major contributors to radiological dose are likely to be uranium mining and milling (58.5% of total fuel cycle dose), reprocessing (33.9%), and light-water reactor power generation (7.3%). The remainder of the cycle, including enrichment processes, fuel fabrication, transportation, and waste management, contributes only 0.3% to total estimated fuel cycle dose. These latter components are therefore not further considered here.

Mining and Milling

Mining and milling activities dominate the dose commitments resulting from nuclear fuel cycle processes.[2] A study by Sears *et al.*[3] assesses dose commitments associated with milling uranium ores for U/Pu cycles. A 1978 study by Tennery *et al.*,[4] using similar models and assumptions, calculates the dose associated with mining and milling ^{232}Th for Th/U fuels. Radioactivity exists the mill sites as dust and as ^{222}Rn (U milling) or

^{220}Rn (Th milling) gas. Both facilities release similar quantities of radioactive materials. However, the decay products of ^{232}Th are relatively short-lived compared to several ^{238}U daughters (half life of ^{234}U = 2.4 x 10^5 year; ^{226}Ra = 1600 year; ^{210}Pb = 22.3 year).

Table 1 lists dose commitments for uranium and thorium mill facilities. Uranium milling Cases 1 and 2 bracket the single thorium case, in terms of level of containment assumed to reduce radioactive releases. Based on these data, it appears that thorium milling presents a generally lower hazard to off-site individuals. Additional analysis[4] indicates that post-operational doses associated with uranium tailings piles may also be significantly greater than post-operational thorium mill doses.

Fuel Reprocessing

Two recent studies allow comparison of off-site doses resulting from routine releases from large-scale U/Pu or Th/U reprocessing operations.[5,6] Dose commitments to individuals located 1 km from the plant stacks were found to be 2.9, 6.9, and 2.8 mrem to total body, bone and lungs, respectively, for U/Pu reprocessing.[5] Similarly, for Th/U fuels, the doses were estimated as 3.1, 4.1, and 3.3 mrem, respectively.[6] Major contributors to total-body doses were ^{3}H, ^{137}Cs, ^{14}C, and ^{106}Ru for both fuel types. Plutonium-238 contributes 1% to U/Pu total-body dose, ^{232}U contributes 9% to the Th/U dose. Doses were found to be moderate, and similar in magnitude for the two fuel cycles.

Reactor Operation

Analysis of the rates of release of radioactive effluents from reactors indicates few differences related directly to choice of U/Pu or Th/U fuels.[1] Releases of liquids and of airborne particulates should be near-zero for future light-water, helium-cooled or sodium-cooled reactors. Variations in production of gaseous radionuclides are anticipated among reactor types, but no apparent fuel-cycle-related differences exist with respect to radiological dose, with the possible exception of greater levels of tritium production in fast U/Pu reactors.[7]

Conclusions

We conclude that off-site hazards due to routine releases of radionuclides from both Th/U and U/Pu recycle should be acceptable compared to EPA 40 CFR 190 regulations. Dose commitments associated with ore milling facilities represent the major differences apparent in a comparison of the cycles. Moderate variations in production and release of radioactivity from other fuel cycle components are insufficient to justify decisions for or against either generic fuel cycle. We find little evidence of off-site radiological hazard recommending a choice of either cycle, and suggest that other factors, such as proliferation resistance or fuel cycle economics, play key roles in such decisions.

References

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Table 1: Estimated 50 year Dose Commitments (from one year of facility operation) to Maximally Exposed Individuals - U and Th Mills (mrem)

	Total Body	Bone	Lung
Uranium milling[a]:			
Case 1[b]	61	640	74
Case 2[c]	5.3	59	14
Case 6(c)[d]	1.7×10^{-4}	2×10^{-3}	5.1×10^{-1}
Thorium milling[e]:	0.9	2.8	26

[a]From Sears *et al.*,[3] Table 8.2, VI.

[b]Case 1 is representative of mills which will process a major fraction of uranium ore during the next twenty years.

[c]Case 2 represents recently constructed uranium mills with dust control procedures in limited current use. Tailings pile dust releases have been eliminated.

[d]Case 6(c) represents future uranium mills with a high degree of dust and radon control, estimated to increase containment costs by a factor of 40 over Case 2.

[e]From Tennery *et al.*,[4] Table 6.1, modified to reflect milling-related dose only. Normalized to allow comparison to Cases 1 and 2, uranium milling.