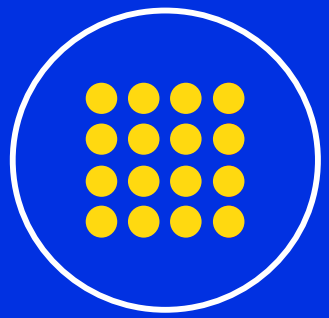

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Radiotoxicity of thorium fuel cycles in PWRs

Kevin Hesketh

ARWIF 2005

Motivation

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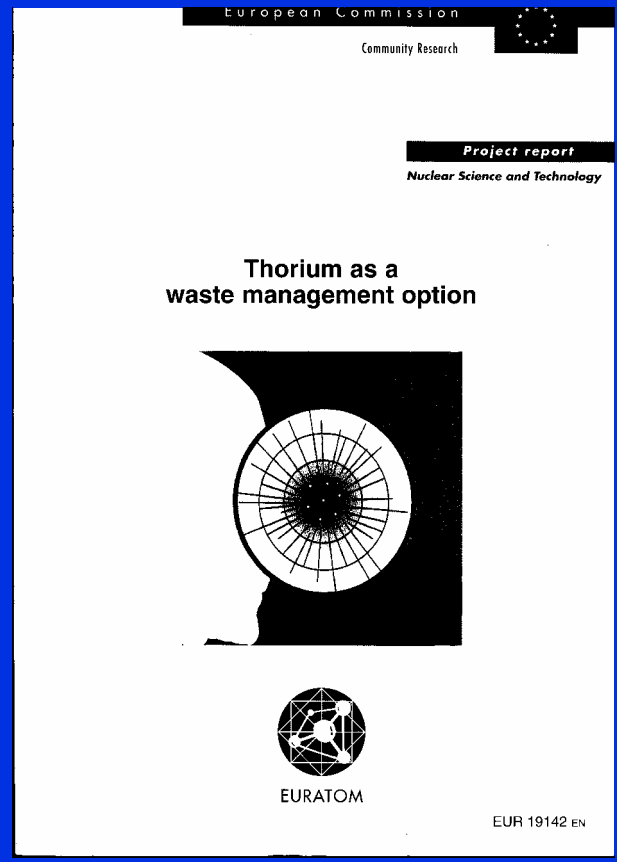
- Aim to quantify radiotoxicity of thorium fuel cycles compared with standard UO_2 once-through fuel cycle
- Complements and provides independent confirmation of earlier European 4th Framework studies
- BNFL has contributed to thorium studies in 5th Framework and will contribute to 6th Framework activities



Scope

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- Analyse thorium-uranium and plutonium-thorium fuel cycles in standard PWR fuel assemblies
- Limited to conceptual calculations of radiotoxicity without verifying practicality of core nuclear design characteristics
  - –4th Framework study has already demonstrated satisfactory reactivity coefficients for the moderate discharge burnup assumed here

Modelling method

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- JEF2.2 nuclear data
- CASMO-4 assembly spectrum calculations and 3-group cross-section condensation
- CAS2FIS processing of 3-group burnup dependent cross-sections and fluxes
- FISPIN inventory calculations
- RTOX post-processes FISPIN inventory output to calculate radiotoxicities using ICRP-72 effective dose coefficients for ingestion

PWR parameters

- Standard 17x17 fuel design
- 3-batch fuel cycle
- 57 GWd/t average discharge burnup
- THOREX reprocessing applied with ^{233}U and ^{232}Th recycled
  - –But no attempt to recycle ^{235}U and Pu

Thorium-uranium fuel cycle

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- ***UOX*** : 4.95 w/o UO_2 fuel with direct disposal cycle to act as a reference for comparison
- ***U3-Th*** : $^{233}U0_2/^{232}ThO_2$ fuel with 4.18 w/o ^{233}U and 95.82 w/o ^{232}Th recycled to extract ^{233}U and ^{232}Th
- ***U5-Th*** : $U0_2/^{232}ThO_2$ fuel with heterogeneous mix of 20 w/o enriched UO_2 rods and $^{232}ThO_2$ rods
  - Smeared composition 6 w/o ^{235}U, 24 w/o ^{238}U and 70 w/o
  - $^{232}ThO_2$ rods recycled to extract ^{233}U and ^{232}Th
  - UO_2 rods <u>not</u> recycled

Equilibrium core consists of 35%:65% mix of ***U3-Th*** & ***U5-Th*** assemblies self-sufficient in ^{233}U

^{233}U balance

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- ***U3-Th*** ^{233}U discharge inventory 1.85 w/o
- ***U5-Th*** ^{233}U discharge inventory 1.23 w/o
- These discharge masses match the ^{233}U mass for fresh ***U3-Th*** at 35% core ***U3-Th*** fraction
- Compared with ***UOX*** cycle, ^{238}U conversion to plutonium is smaller and transuranic contributions to radiotoxicity reduced
- Radiotoxic contributions of U and Th decay chains removed from total on the assumption they are recycled indefinitely
  - –Overstates benefit compared with realistic finite scenario

instantaneous radiotoxicities

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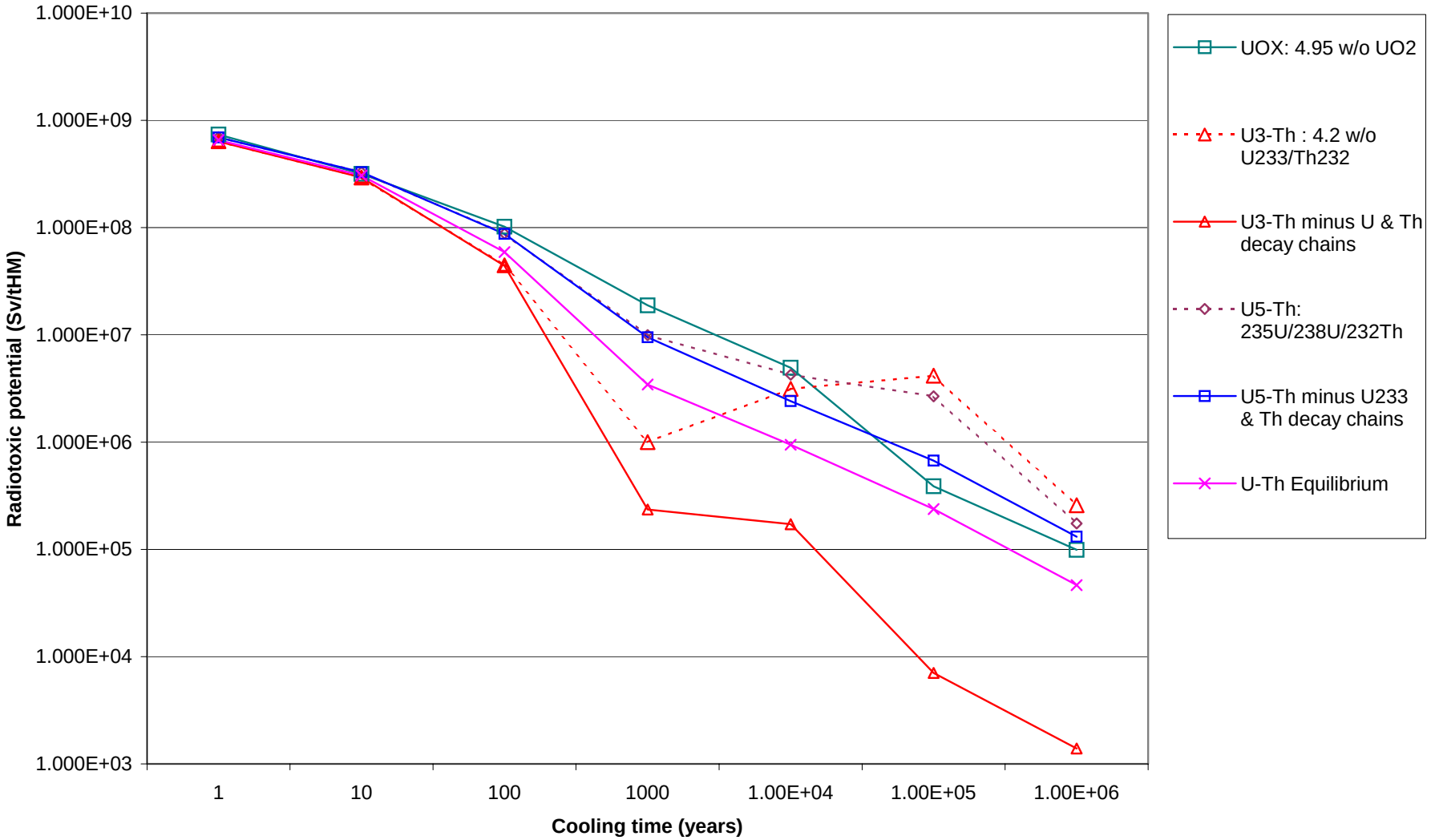

Uranium-thorium integrated radiotoxicities

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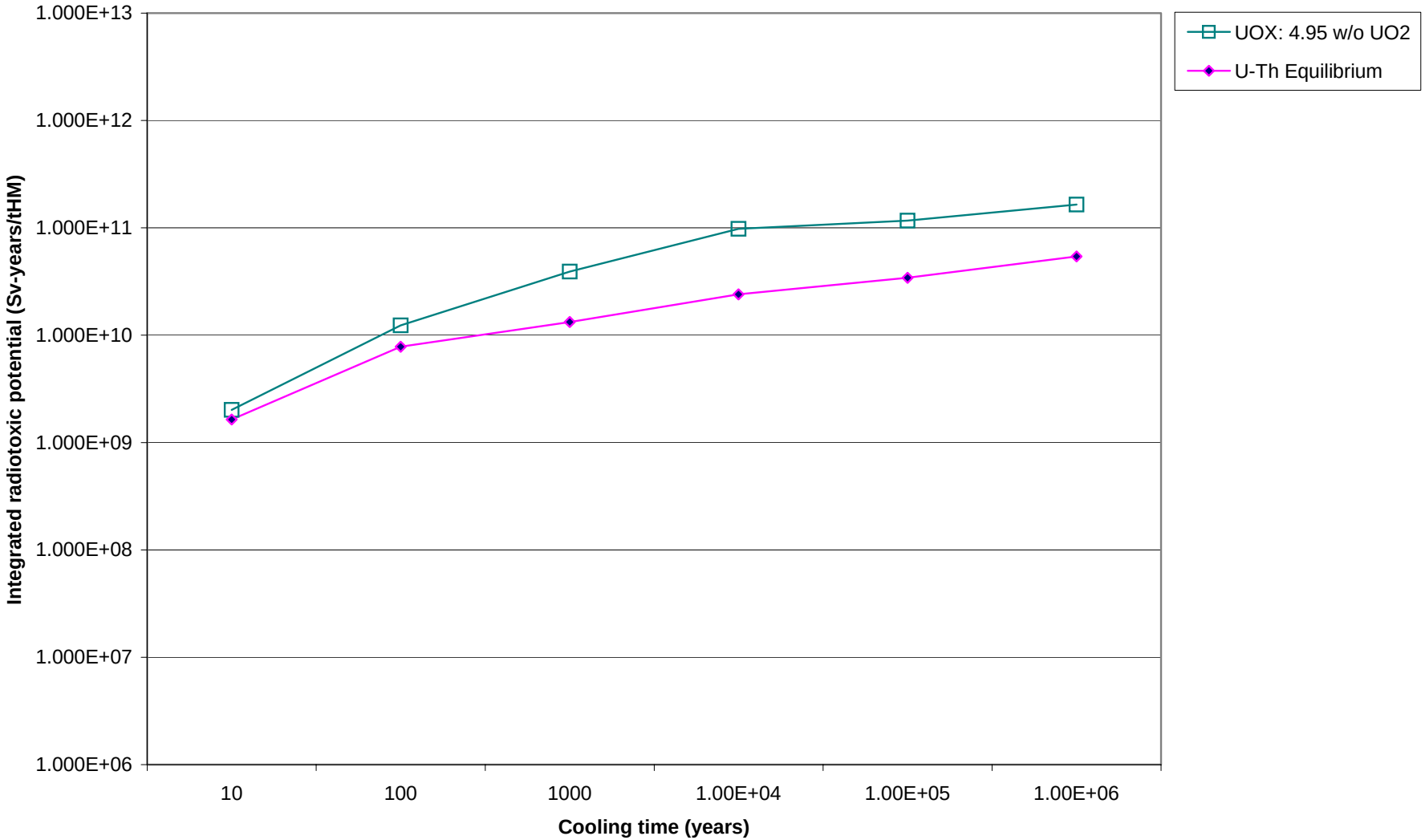

Uranium-thorium results

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- Equilibrium uranium-thorium cycle has lower radiotoxicity by factor ~5 after 1000 years
  - Integrated radiotoxicity lower by factor ~3 after 1E6 years
  - ^{233}U contribution peaks at ~1E5 years in uncorrected radiotoxicity curves
- European 4th Framework study indicated factor ~ 2 reduction for a very similar scenario, but with only 2 recycle steps
  - ^{233}U peak at 1E5 years also noted
  - Results considered consistent within limitations

Plutonium-thorium fuel cycle

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- Aim is to compare relative merits of conventional MOX fuel and Pu-Th fuel for plutonium disposition
- 17x17 conventional PWR assembly design, 57 GWd/t average discharge burnup 3-batch fuel cycle
- Once-through fuel cycle, so Pu assemblies undergo geological disposal

Plutonium-thorium fuel cycle

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- ***Pu-Th*** : PuO_2/ThO_2 assembly with 11.5 w/o Pu^{tot}
- ***MOX*** : Conventional PuO_2/UO_2 assembly with 10.5 w/o Pu^{tot} to act as a reference

instantaneous radiotoxicities

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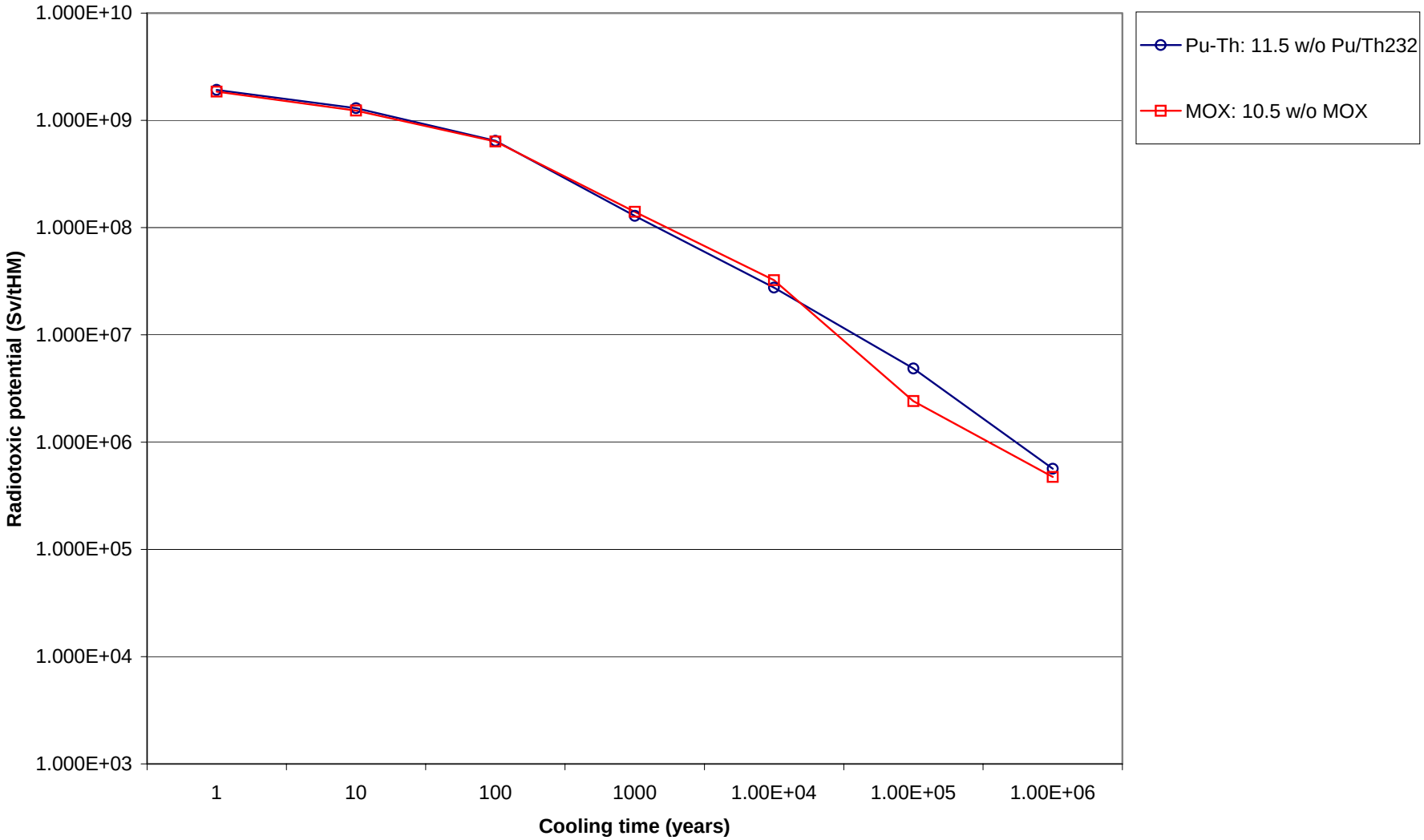

Plutonium-thorium integrated radiotoxicities

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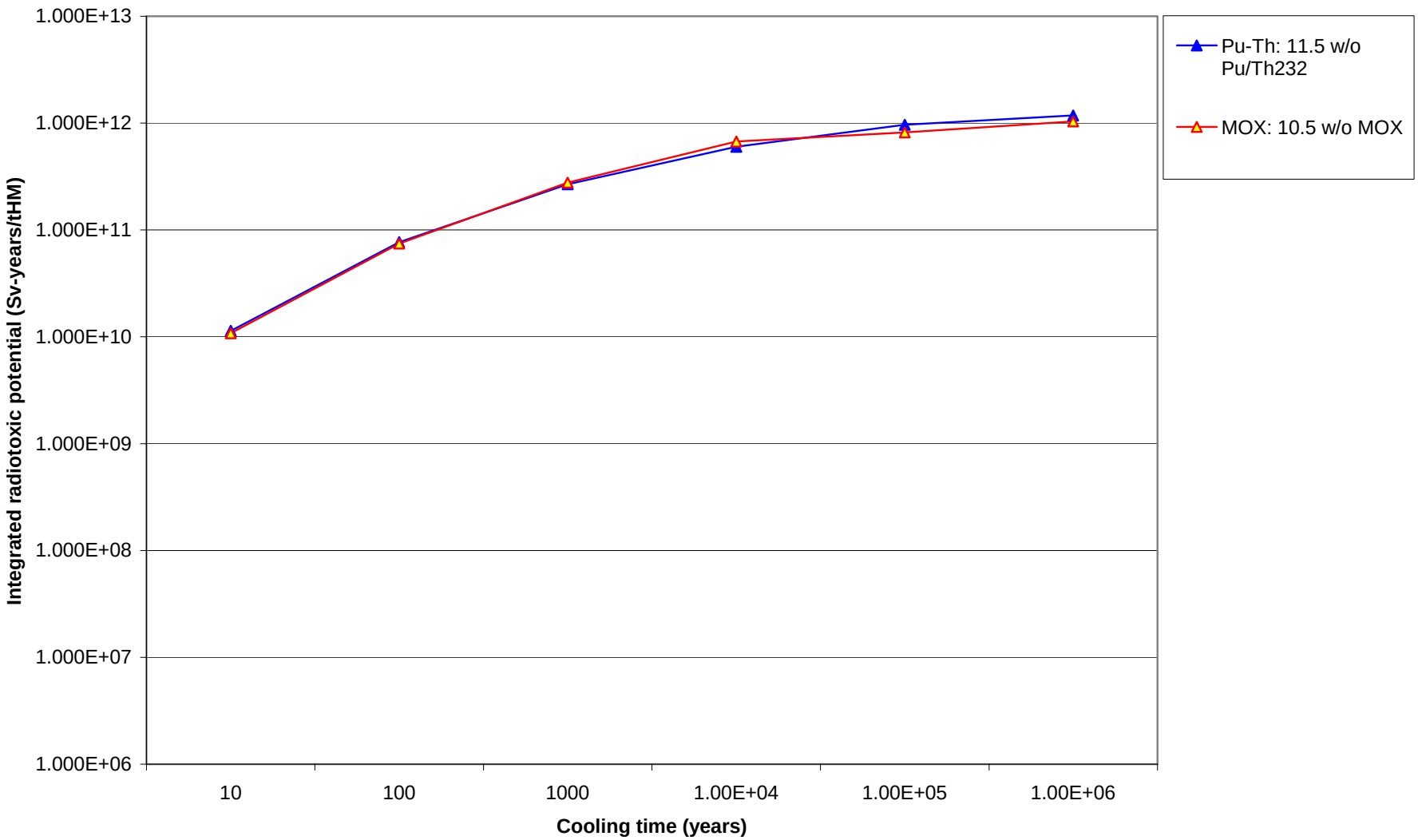

Plutonium-thorium results

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- Very little distinction between Pu-Th and MOX instantaneous and integrated radiotoxic inventories
  - –identical result noted in 4th Framework study
- However, net Pu destruction in Pu-Th is 122 kg/TWhe (compared with 64 kg/TWhe for MOX) and Pu isotopic quality is significantly poorer
  - –Lower proliferation risk for Pu-Th
  - –Offset by ^{233}U inventory

Conclusions

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- The self-generated equilibrium ***U3-Th*** & ***U5-Th*** cycle shows a modest reduction in radiotoxicity by a factor of ~5 wrt once-through UO_2 cycle
- The full benefit would not be obtained with a finite number of recycle steps
- ***Pu-Th*** fuel radiotoxicity is very little different from conventional ***MOX*** assembly, although discharge Pu mass is significantly lower
- Whether ***Pu-Th*** fuel represents a reduced proliferation risk is debatable, because of ^{233}U