22.251 Systems Analysis of the Nuclear Fuel Cycle
Fall 2009

Laboratory Exercise #3 Solution

a) Summary of data for normalization:

Case	BU, MWth-d/kg	Efficiency	Mass, Kg/MTHM	Energy, GWe-Y/MTHM
1	50.0	33.7	1000	4.6133E-02
2	50.0	33.7	1000	4.6133E-02
3	75.0	33.7	1000	6.9199E-02
4	7.5	33.2	1000	6.8172E-03
5	20.9	33.2	1000	1.8997E-02

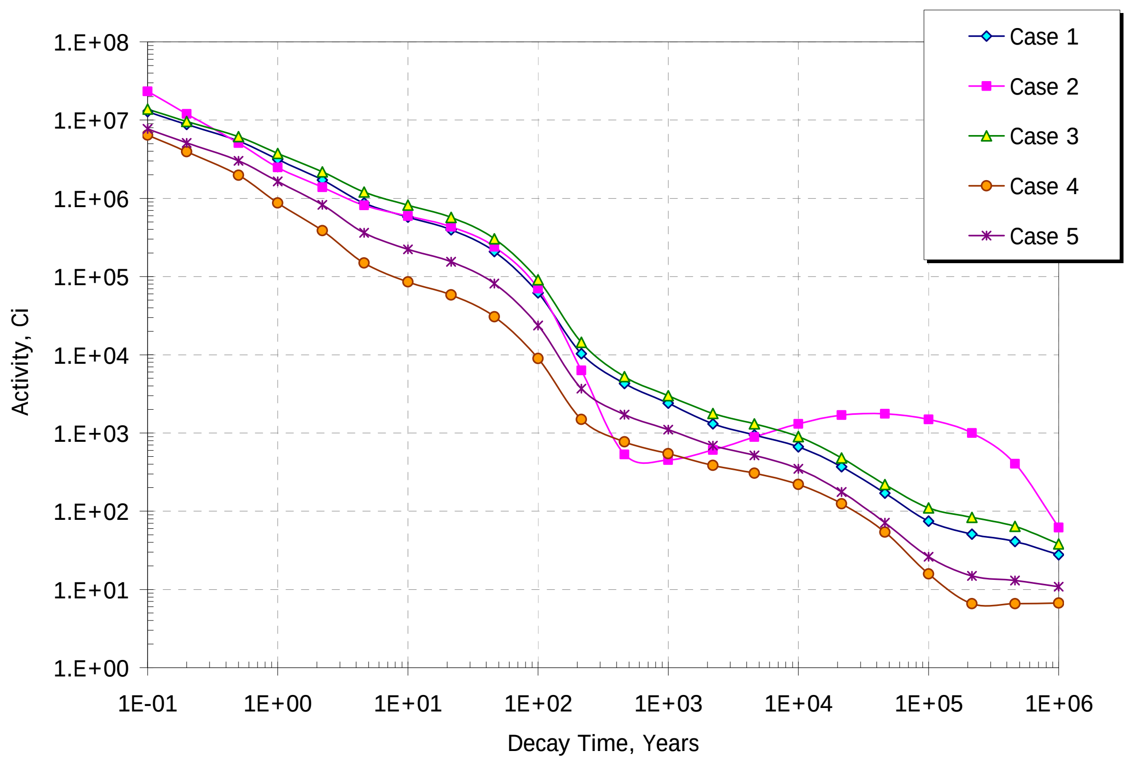

Figure 1: Activity per MTHM

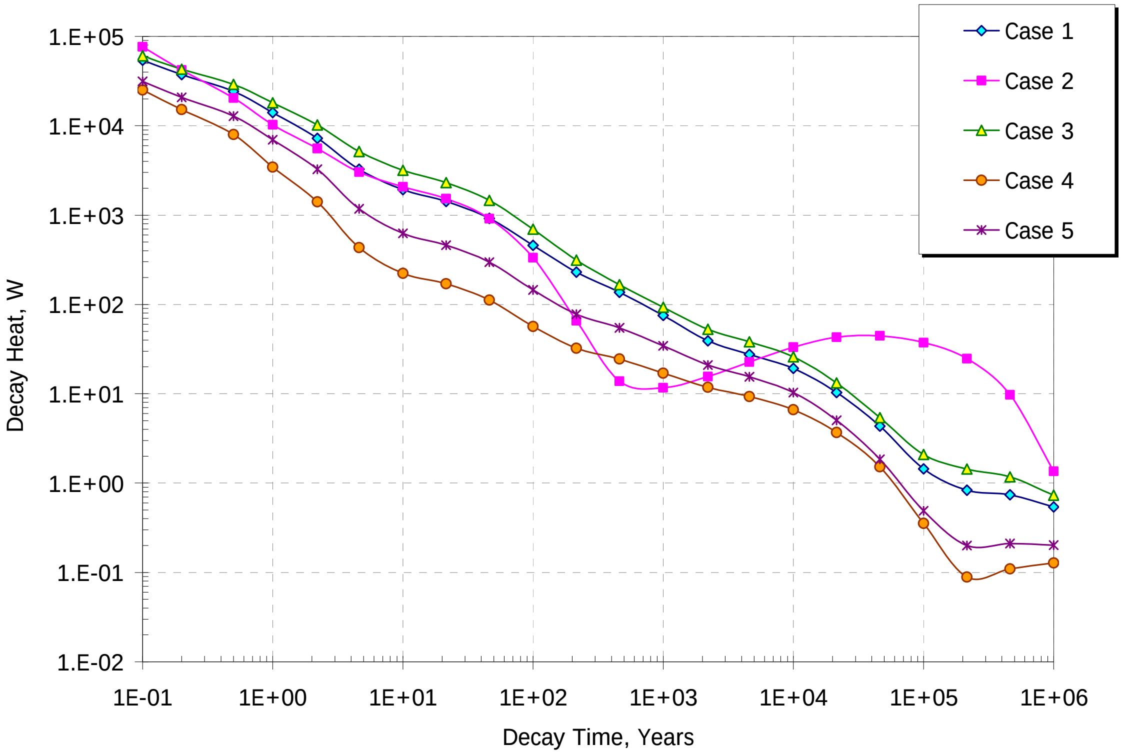

Figure 2: Decay Heat per MTHM

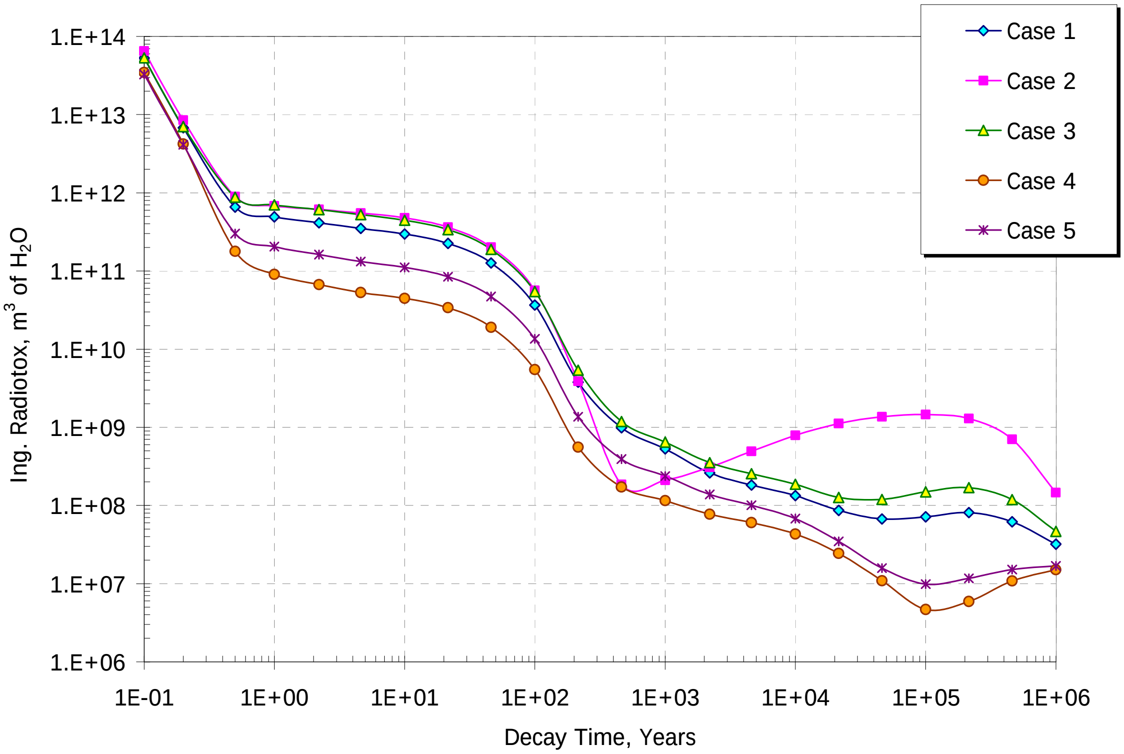

Figure 3: Radio-toxicity per MTHM

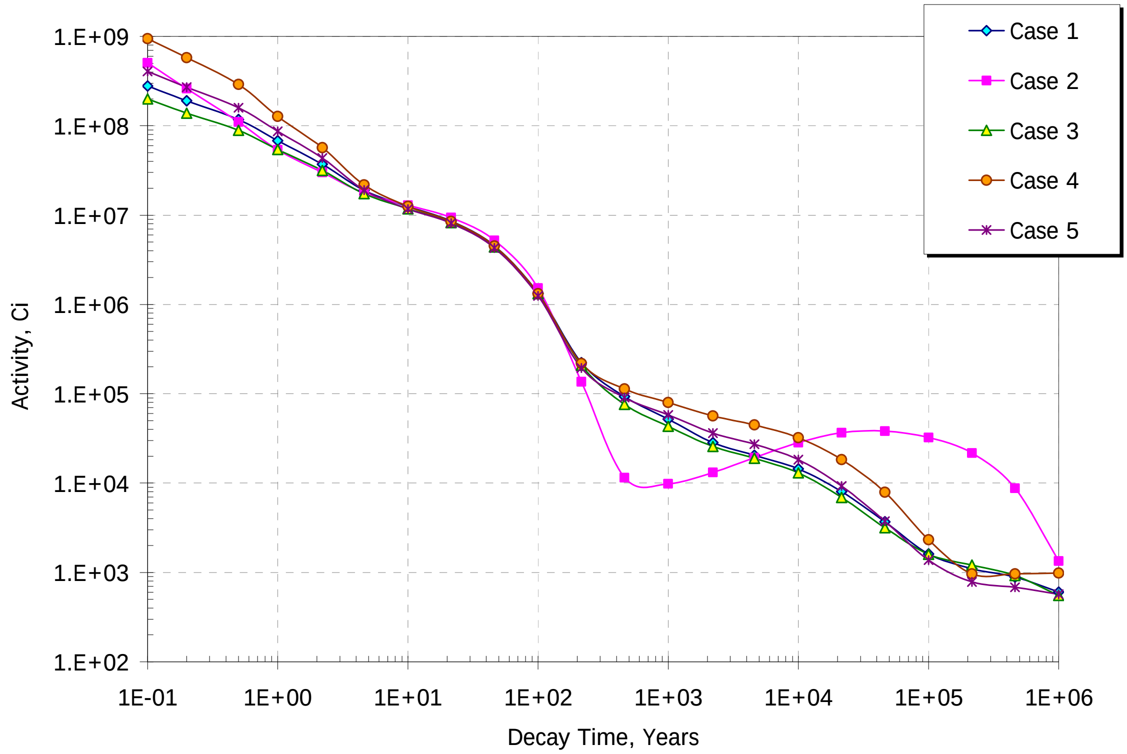

Figure 4: Activity per GWe-Y

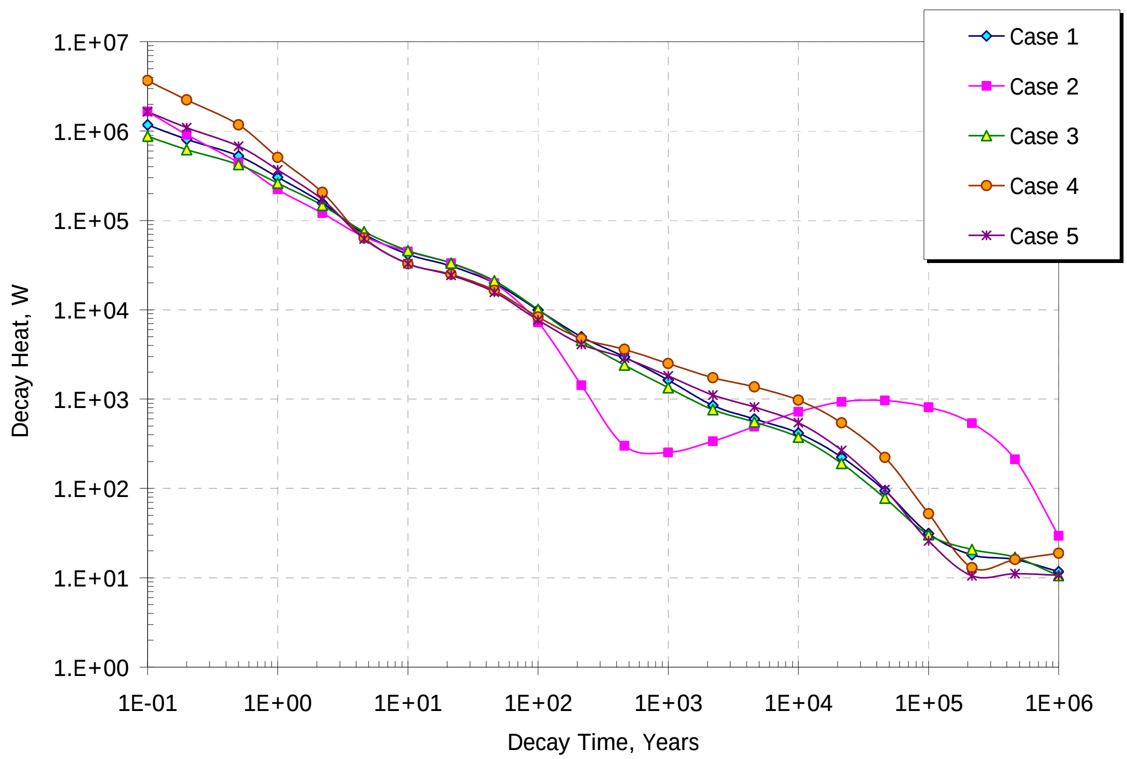

Figure 5: Decay Heat per GWe-Y

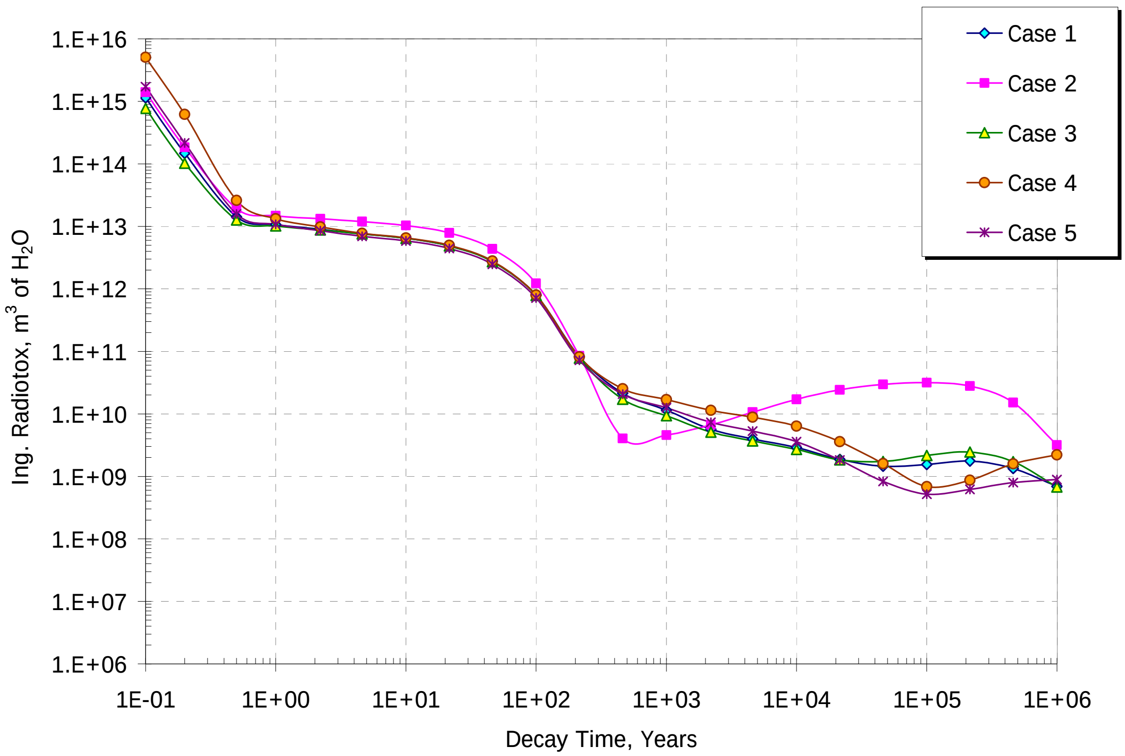

Figure 6: Radio-toxicity per GWe-Y

b)

Case	Major Nuclides	Fractional Radiotoxicity
1	Pu-239	49.8%
	Pu-240	39.9%
	Ra-226	4.3%
2	Th-229	39.8%
	Ra-225	31.8%
	Rn-219	10.0%
	Ra-226	9.3%
3	Pu-240	44.9%
	Pu-239	41.0%
	Ra-226	6.9%
4	Pu-239	60.9%
	Pu-240	38.4%
5	Pu-240	53.7%
	Pu-239	43.4%

c)

Heat Load – This impacts the flow of groundwater which affects the transport of nuclides. Additionally it dictates the spacing between the storage tunnels and ultimately the total physical size of the repository.

Isotope Solubility – The relative ability for a particular isotope to dissolve in water.

Waste Volume – This plays a role on the size of the storage tunnel required; or in other words how much rock must be mined to make space for the waste.

Modeling Capability – The predictive models used (along with their associated uncertainties) determine how the repository and the engineered barriers are designed.

d)

On the per energy produced basis, Th fuel is comparable to the rest of the options up to about 100 years. In the following period up to about 10000 years, Th even offers some benefits having lower decay heat power than other analyzed cases. Beyond 10000 years, Th fuel has higher toxicity and heat. However, ThO_2 matrix is somewhat more stable in oxidizing environment than UO_2, which may compensate for the higher radiotoxicity.

Thorium fuel is a comparatively less attractive material for proliferators due to the smaller amount of fissile plutonium and higher radiation barrier.

High burnup PWR has the lowest activity, decay heat and radiotoxicity of all the analyzed cases.

e)

High burnup reduces the amount of Pu generated per unit energy produced.
Pu isotopic vector becomes more proliferation resistant with higher burnup as relative fraction of "even" Pu isotopes increases thus increasing the spontaneous fission source. Pu-238 fraction also increases increasing the heat generation.

ORIGEN predicts Pu isotopes buildup reasonably well if proper cross-section library is used. For 50MWd/kg case, the discrepancy is below 20%. For the high burnup case however, no suitable library exists for ORIGEN. Consequently, the discrepancy in Pu isotopic vector prediction is much larger especially for the higher isotopes. For example, Pu-242 fraction differs by almost a factor of two between the CASMO and ORIGEN predictions.

	Bd = 50 MWd/kg			Bd = 75 MWd/kg		
	CASMO, fractional	ORIGEN, fractional	Kg/GWe-Y	CASMO, fractional	ORIGEN, fractional	Kg/GWe-Y
Pu-238	0.027	0.031	8.5	0.051	0.056	13.1
Pu-239	0.511	0.533	147.3	0.469	0.478	112.2
Pu-240	0.237	0.253	70.0	0.230	0.308	72.3
Pu-241	0.150	0.126	34.8	0.155	0.105	24.7
Pu-242	0.075	0.057	15.6	0.095	0.054	12.7
Total	1.000	1.000	276.1	1.000	1.000	235.0

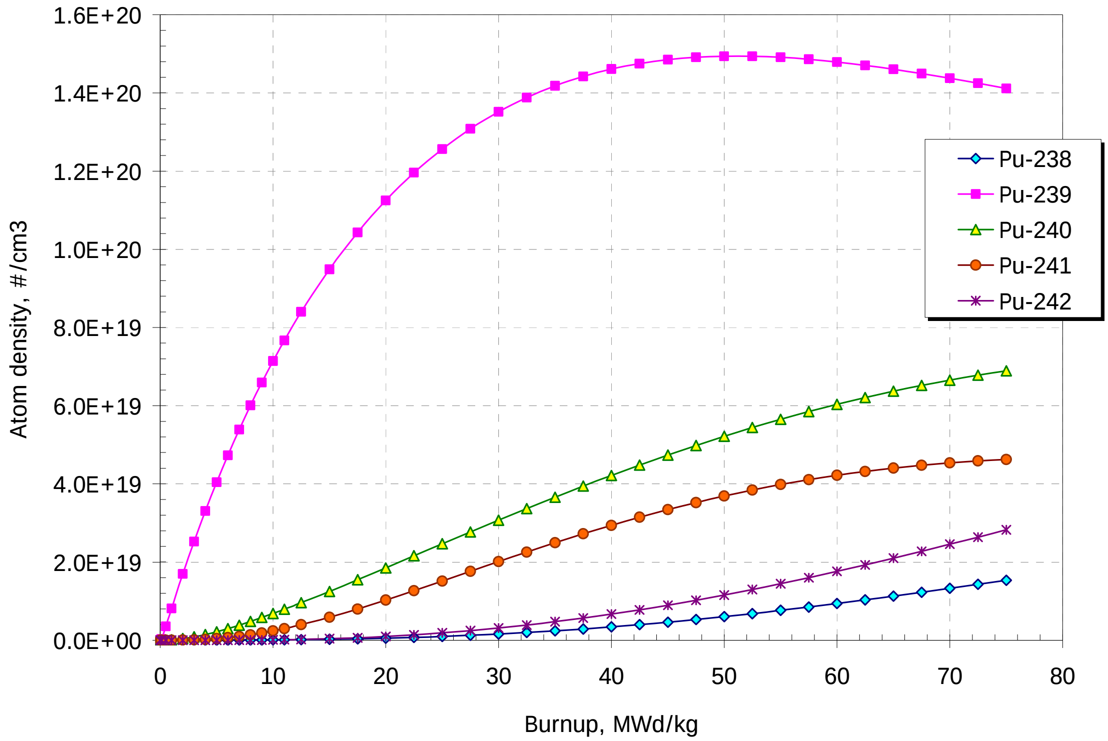

Figure 6: Pu isotopes buildup in PWR assembly