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Title: Criticality Monitoring Parametric Study on 1F Fuel Debris

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Introduction

- Criticality monitoring is integral to fuel debris removal during deactivation & decommissioning
- This is challenging when fuel debris is not well characterized, i.e. the Fukushima-Daiichi Nuclear Power Station (1F) site
- A parametric study was conducted to understand how criticality changes regarding fuel debris size and water content
- Nuclear criticality is the determination of whether a fission reaction chain is critical where the self-sustaining reaction does not result in a change in the neutron population
- Supercriticality is where the neutron population increases over time
- Subcriticality where the neutron population decreases over time
- When a reaction is critical or supercritical, the number of particles released pose a significant threat to health and safety

Methods

K-effective Calculations and Neutron Moderation

- K-effective is the measure of criticality, it is a ratio of neutrons in a given generation over the number of neutrons in the previous generation
- Data for the composition of the field debris was obtained from JAEA Field Debris Composition Study [1]
- A homogeneous sphere was constructed with its radius varying from 10 to 400 cm, surrounded by a sphere of water ranging from 0 to 500 cm outside the fuel itself.
- MCNP k-code runs were completed varying both parameters
- The ratio of thermal, intermediate, and fast neutron fissions were also observed to characterize neutron interactions

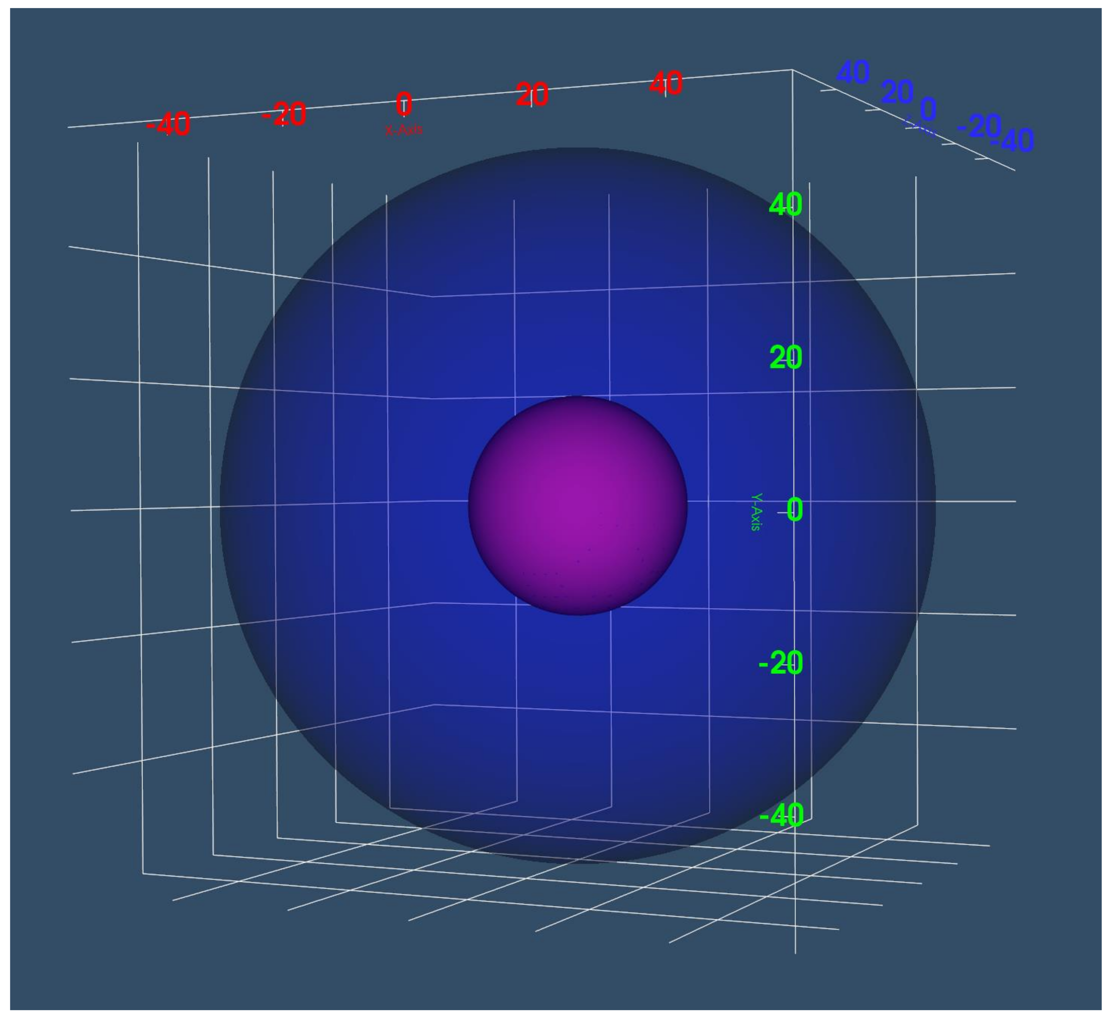

Figure 1. Fuel sphere inside water sphere

Results

- K-effective increased logarithmically before plateauing, this maximum value was approximately 0.64 for the largest radii of both fuel and water
- The percentage of slow neutron fissions changes similarly and reaches a maximum value between 30 and 40 percent of total fissions

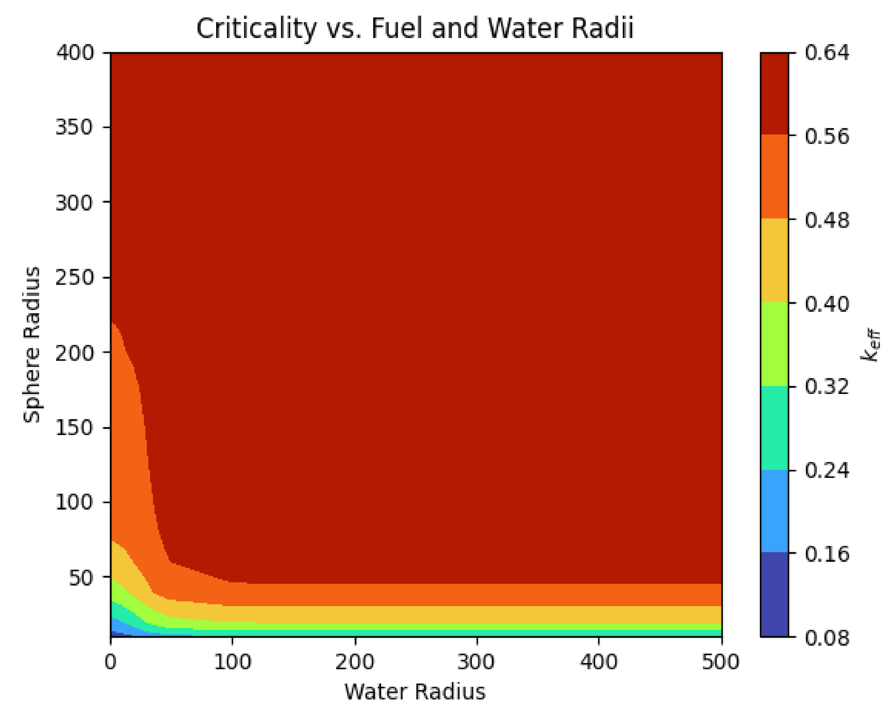

Figure 2. Heat map of k_{eff} vs. Fuel radius vs water radius for Unit 2 debris at Year 10

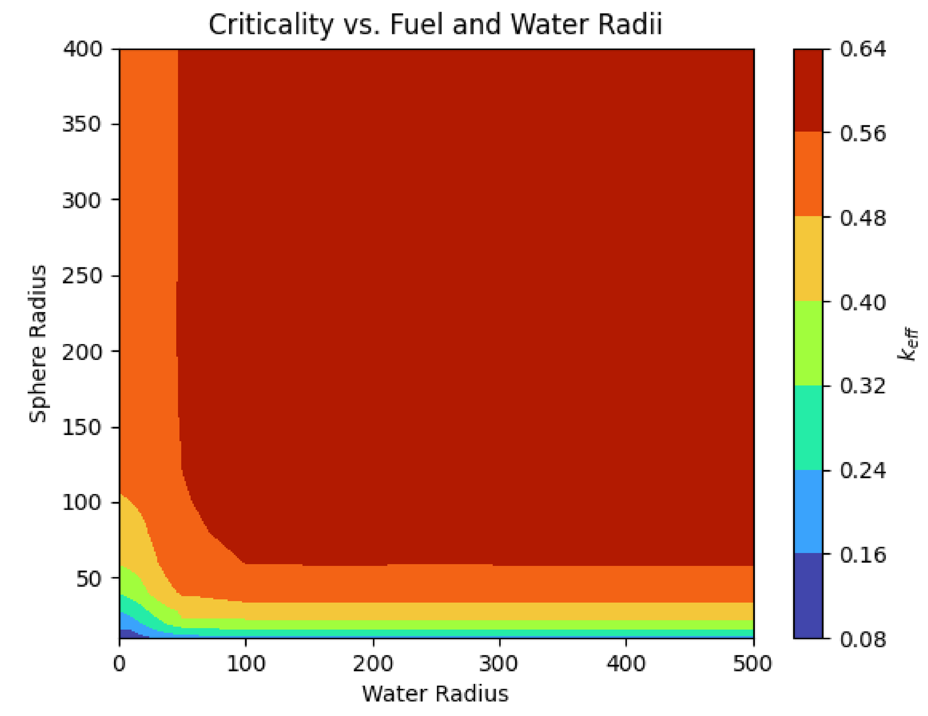

Figure 3. Heat map of k_{eff} vs. Fuel radius vs water radius for Unit 3 debris at Year 10

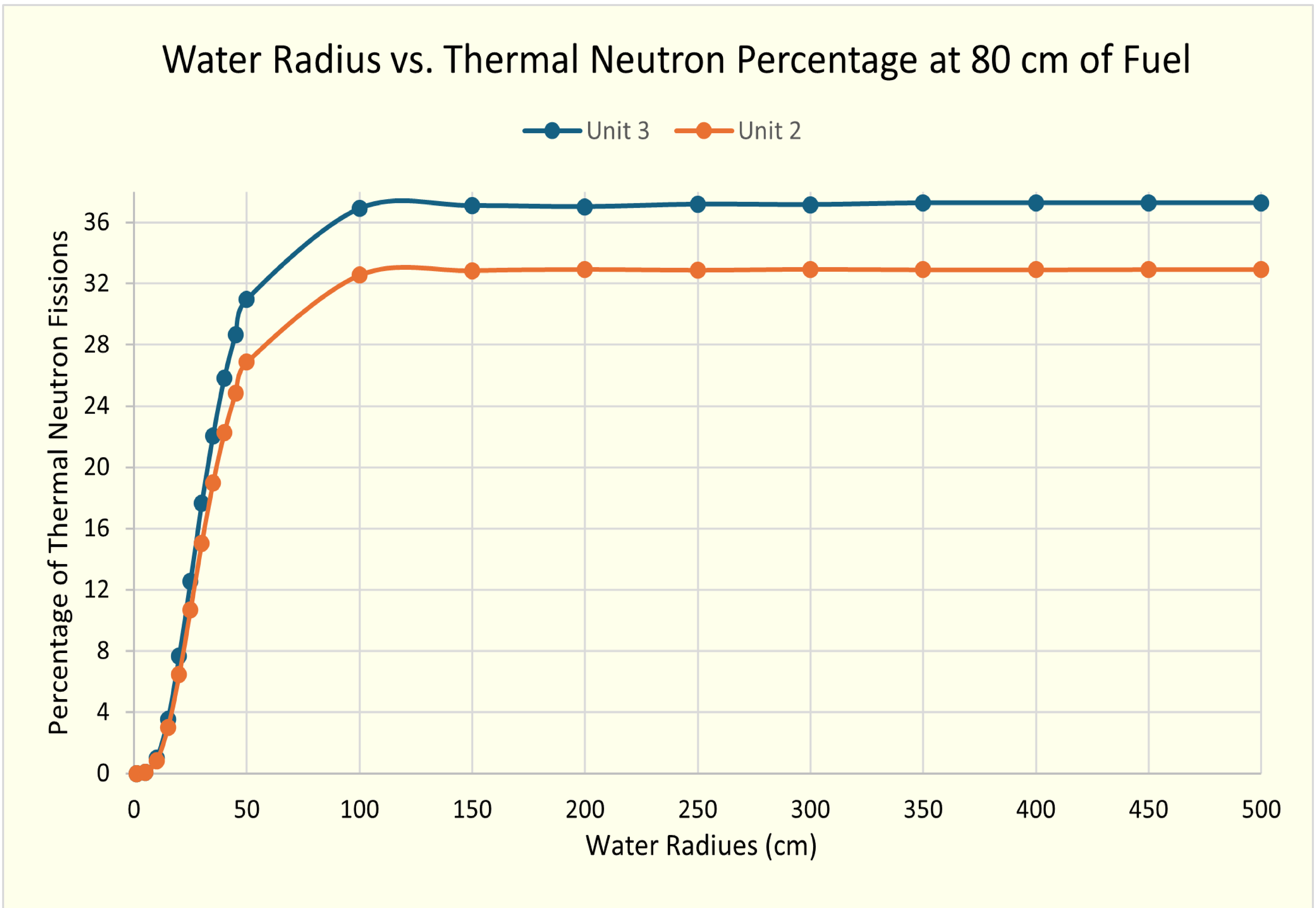

Figure 4. Graph of Slow Neutron Fission Percentages of Total Neutron Vs. Water Radius at 80 cm Radius of Fuel for Units 2 and 3

Radius of Water (cm)	Percentage of Thermal Neutrons	Percentage of Intermediate Neutrons	Percentages of Fast Neutrons
1	0	36.53	63.47
25	12.55	34.55	52.89
50	30.96	27.5	41.54
100	36.9	25.14	37.96
150	37.08	25.14	37.78
200	37.01	25.13	37.73

Table 1. Percentage of Thermal, Intermediate and Fast Neutrons compared to Radius of Water at 80 cm Radius of Fuel

Conclusion and Future Work

- Varying the parameters did not result in achieving criticality
- A future study will be conducted with more complex geometries to get more accurate results and model potential storage of fuels
- An additional study of the compositions of past years and future years will be conducted to identify an ideal time of lowest criticality for potential remediation efforts

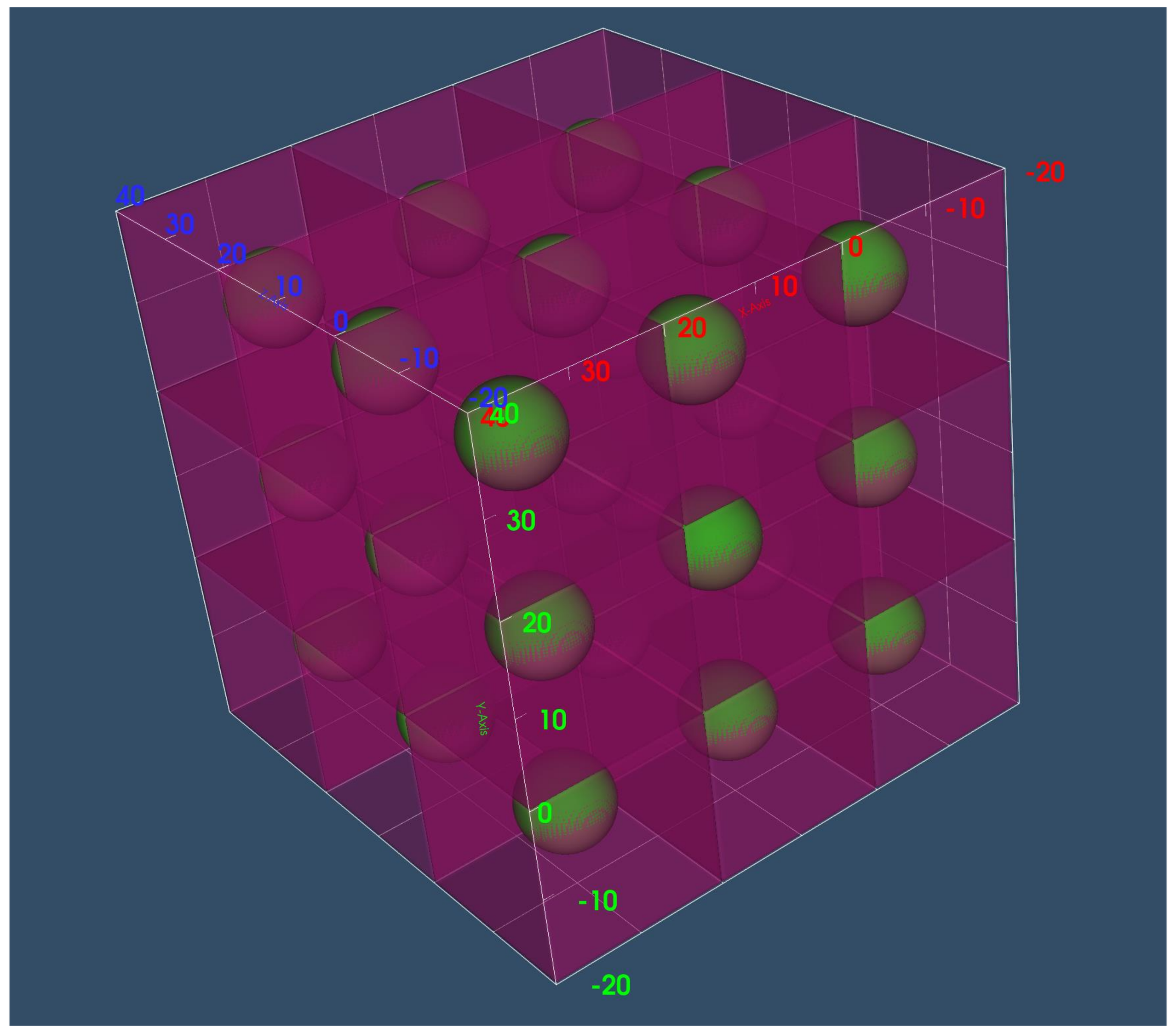

Figure 5. Lattice Structure of Fuel Spheres Surrounded by Water

References

[1] Kenji Nishihara, Hiroki Iwamoto, and Kenya Suyama, "Estimation of Fuel Compositions in Fukushima-Daiichi Nuclear Power Plant," Japan Atomic Energy Agency, Tokai-mura, Naka-gun, Ibaraki-ken 319-1195 Japan, JAEA-Data/Code 2012-018, 2012.

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