Technical Challenges in the Management of Spent TRISO fuel from Next Generation SMR-HTGRs

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Outline

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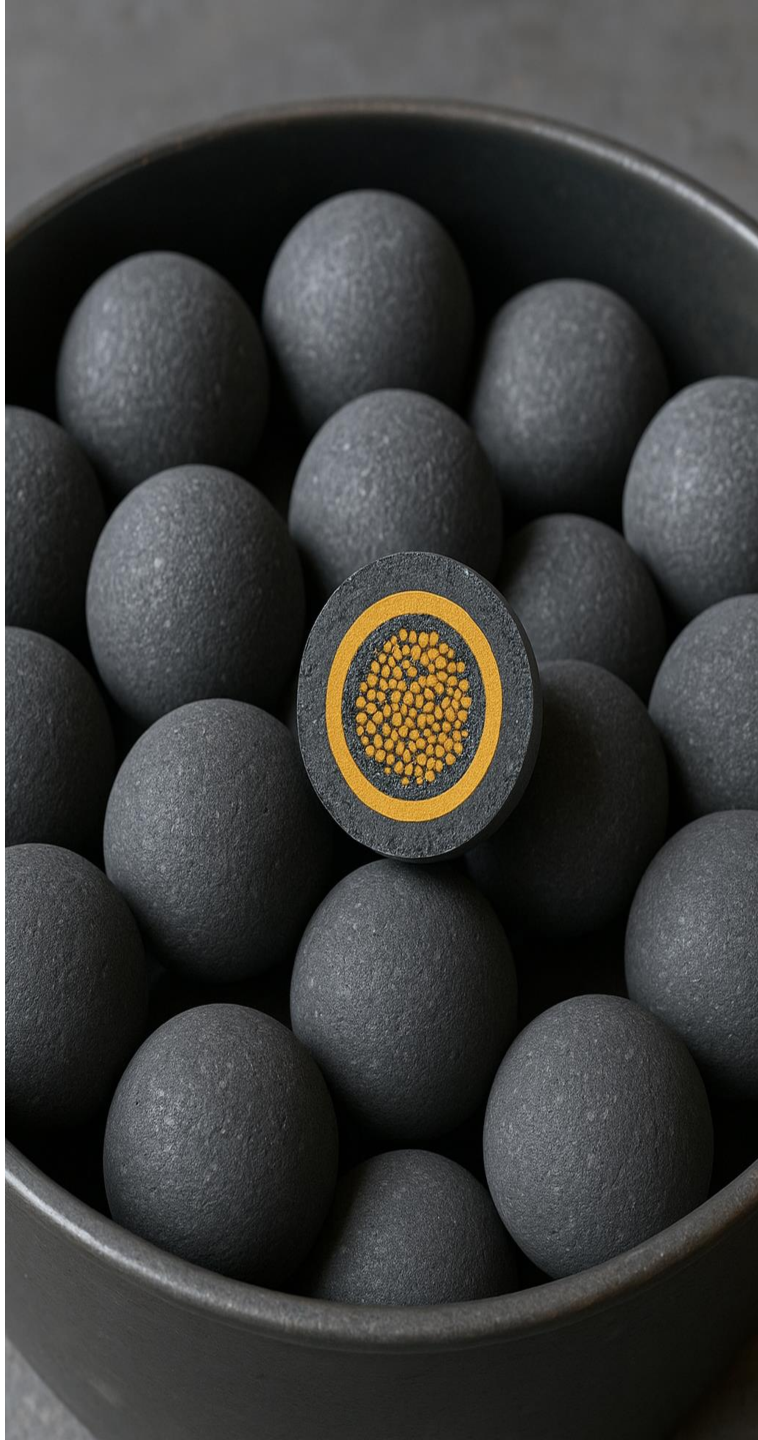


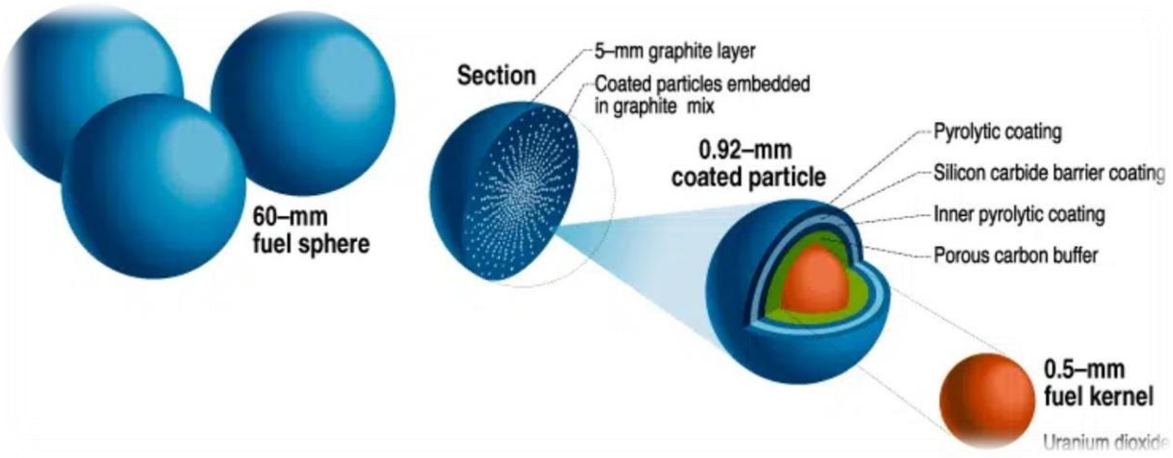
1. Objectives

- Neutronics safety parameters for HTGR-SMR design will be calculated and analyzed
- Address the complexity of characterizing and modeling spent TRISO fuel behavior.
- Identify the unique characteristics of spent TRISO fuel from SMR-HTGRs using the Monte Carlo simulation code, MCNP6 .
- Research and Development of the technical challenges gaps in managing Spent TRISO

2. TRISO & Spent fuel Management

TRISO stands for TRi-structural ISOtropic particle fuel; TRISO fuel kernel made up of a mixture of Uranium and Oxygen or Uranium OxiCarbide that is then coated with three layers:

1. An inside layer of high strength pyrolytic carbon
2. Silicon carbide,
3. An outer layer of pyrolytic carbon.



TRISO unique characteristics are

- Resistant to neutron irradiation, corrosion, oxidation and high temperatures due to robust coating layers
- High fission product retention and structural integrity due to its own containment triple-coated layers
- High BU.

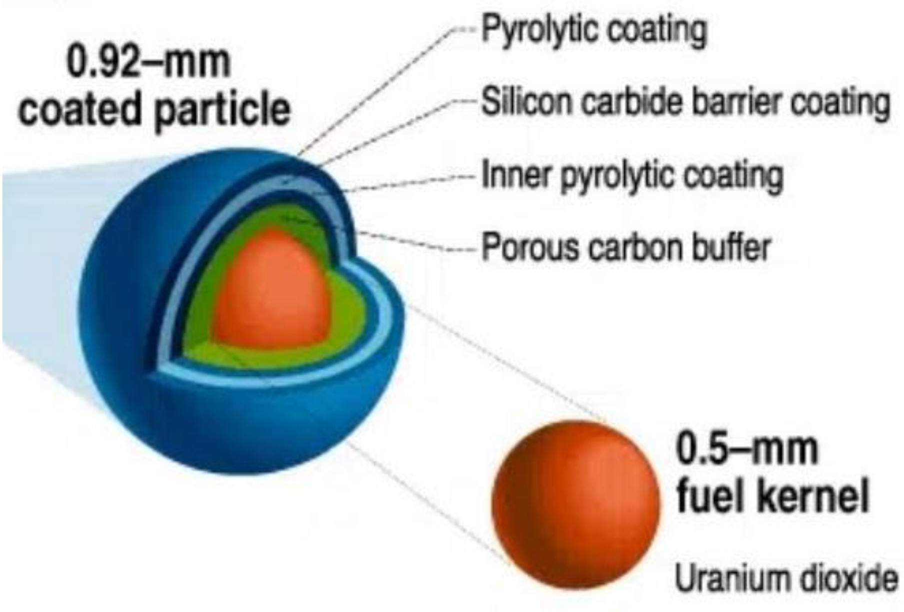
TRISO & Spent fuel Management, cont.

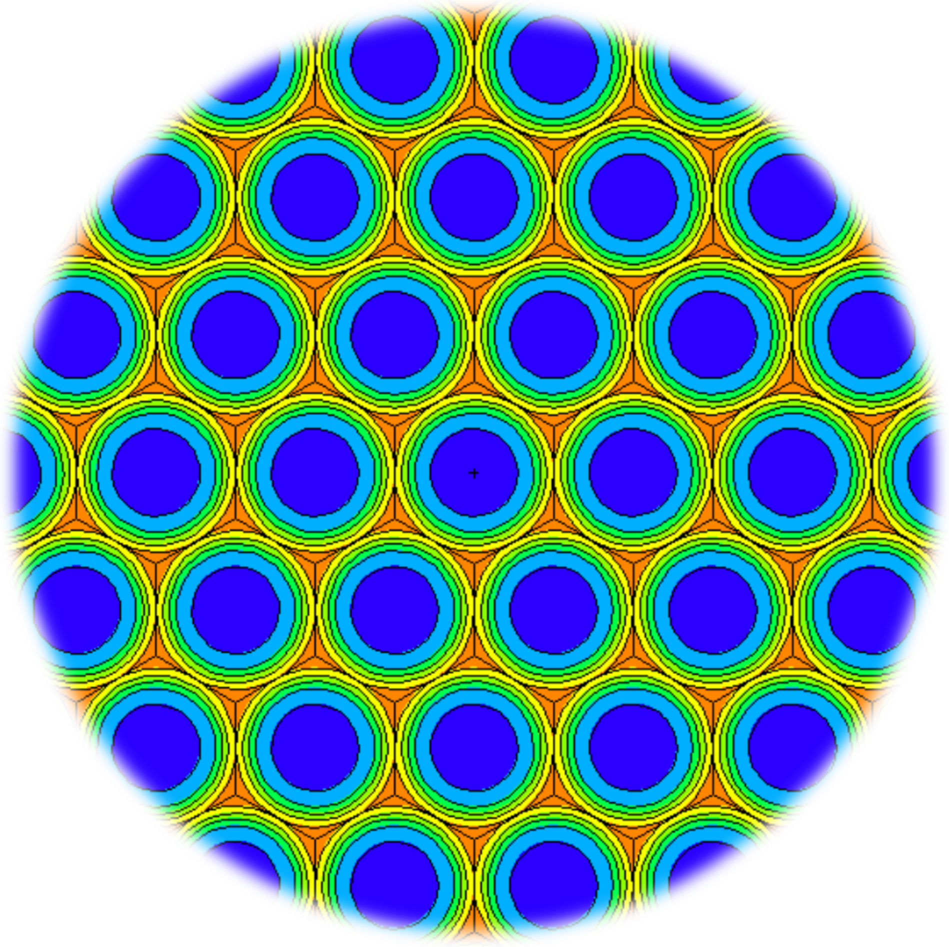
As TRISO robustness offers an excellent solution for HTGRs, it addresses technical difficulties in spent fuel management such as:

- The decay heat generated inside TRISO is high and that made cooling system design more complicated for interim storage and casks.
- The coating layers are radiation-resistant, which is perfect for FPs retention yet it's a technical challenge for chemical dissolution in reprocessing facilities.
- Volatile radionuclides as Cs-137 and Ag-110m may leak through the fuel coatings under stress or over time and that remarks as a radiological characterization challenge and for that additional shielding is required during handling, storage, and transportation.

3. TRISO Modelling & Characterization

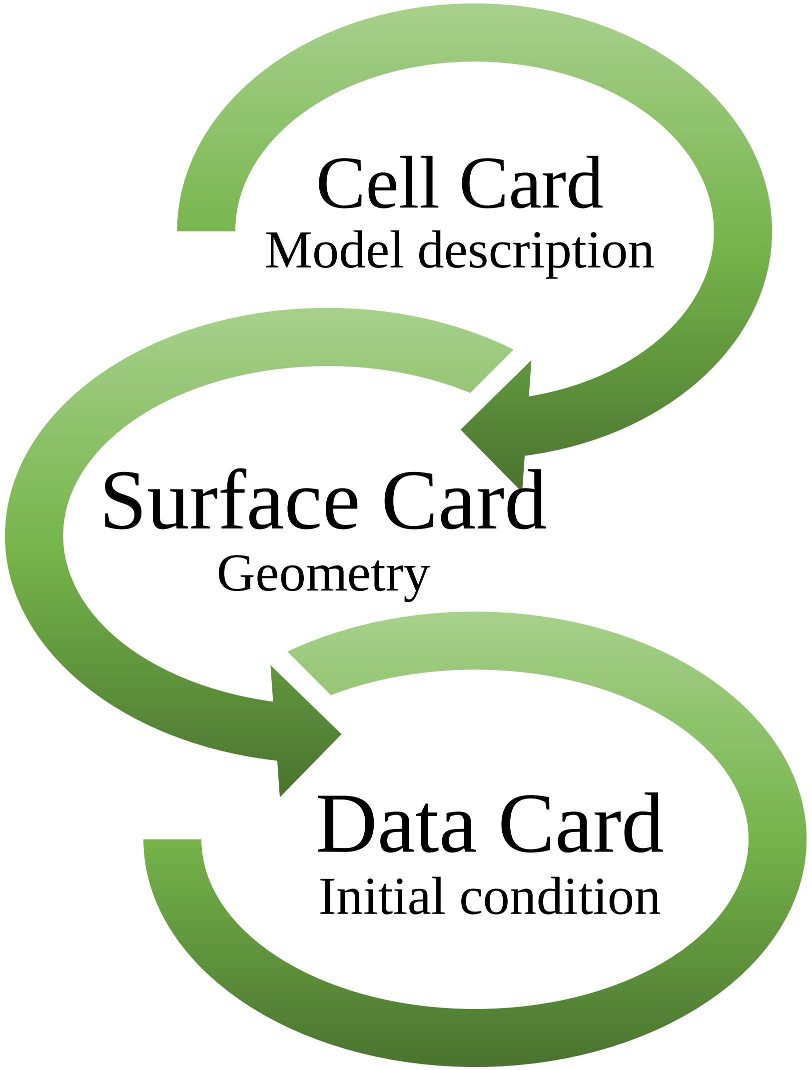
MCNP input of one Pebble bed particle model is represented with 8335 TRISO particles dispersed in graphite matrix and the particle composed of 5 layers.



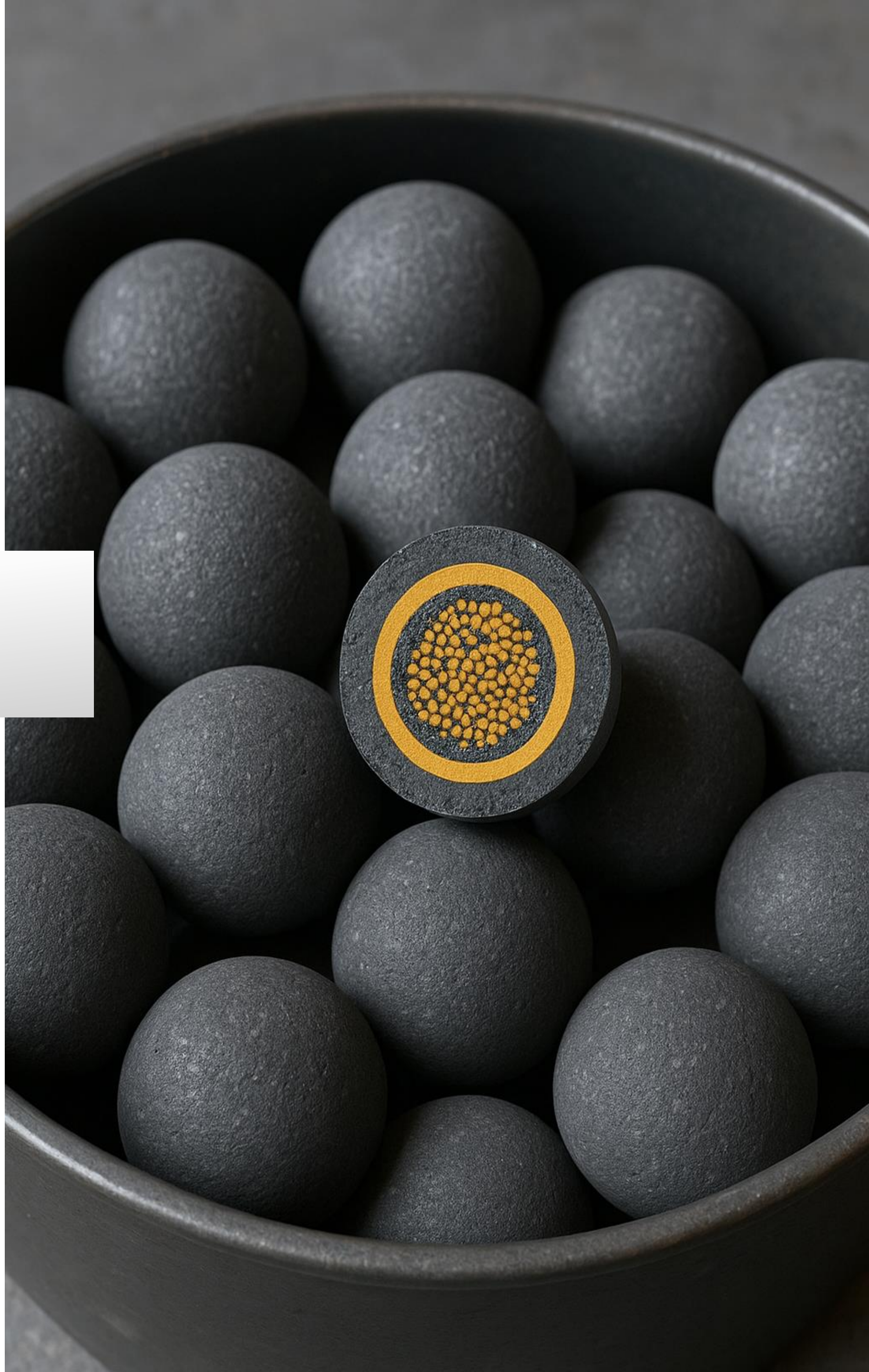


Methodology

- MCNP6 code is Monte Carlo N-Particle ver.6 code, it's a general-purpose, continuous-energy, generalized-geometry, time-dependent, developed at Los Alamos National Laboratory. Designed to track many particle types over broad ranges of energies from birth till it's lost from the system.
- It has the capability of material depletion and BU calculations. It includes cross-section, and library tools through the CINDER′90.



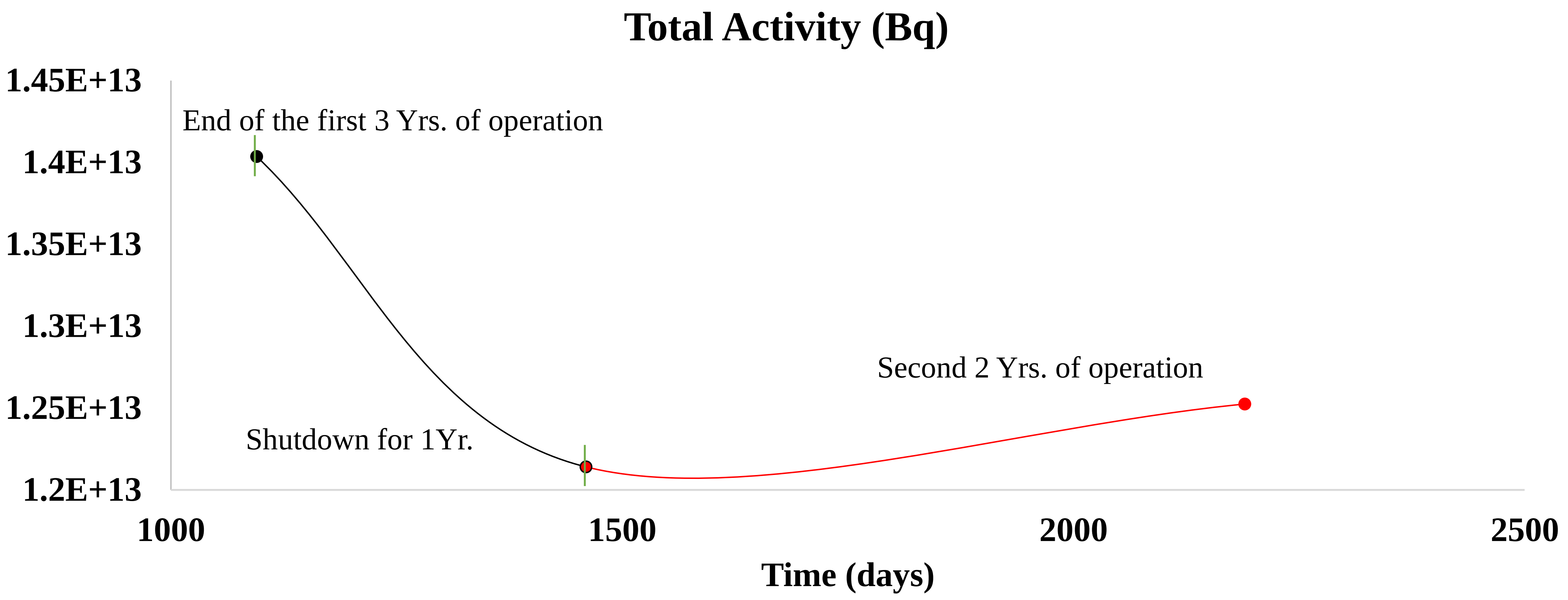
TRISO Characterization



TRISO Characterization

Spent TRISO after the first cycle operation	
EFPD	3 Yrs
BU	81 GWd/ MTU
$K_{eff-BOC}$	1.740
$K_{eff-EOC}$	1.404
$Activity_{shutdown}$	1.40E+13 Bq
Actinides mass	4.579gm

Spent TRISO after the second cycle operation	
EFPD	2 Yrs.
Cumulative BU	166 GWd/MTU
$K_{eff-BOC}$	1.542
$K_{eff-EOC}$	1.079
$Activity_{shutdown}$	1.25E+13Bq
Actinides mass	4.523gm



- The Rise in activity during 2nd cycle is expected as BU increases.
- Re-irradiated fuel generates new highly radioactive fission products:
  - Iodine (I), Cesium (Cs), Xenon (Xe), Barium (Ba)
- Minor actinides from 1st cycle (Np, Am, Cm) absorb neutrons:
  - Transmute into more radioactive isotopes and its cumulative buildup drives activity to increase

4. Technical Challenges in Management

Address several key areas as; Radiation, Corrosion, Reprocessing, Storage, Handling and Disposal and Safety and Regulatory Considerations

➢Radiation

TRISO fuel is exposed to high neutron and gamma irradiation, which affects the microstructural of the multilayer coatings, (PyC) and (SiC).

These effects can result in swelling, embrittlement, and microcracking, mostly in PyC layers, which affects the mechanical containment of the fission products.

Also, the accumulation of volatile FPs (Ag-110m, Cs-137, and Sr-90) may create internal pressure over time in the fuel kernel and if radionuclide migration happens then TRISO retention is exposed .

➢Corrosion

The SiC layer known for its corrosion resistance but may degrade under specific conditions as exposure to groundwater, oxygen, or acidic environments which present in some geological disposal settings.

Over prolonged storage periods, gradual corrosion processes may undermine the integrity of the coated particles, potentially releasing radionuclides and interacting with the surrounding geological environment.

➢Reprocessing

Separating high radioactivate radionuclide from graphite is challenging due to robust particle structure of the coating.

➢Storage, Handling and Disposal

Large waste volumes due to the graphite matrix (~92% of spent fuel), therefor, separation of TRISO from graphite is needed and that adds to technical complexity and the risk of particle damage.

➢Safety and Regulatory Considerations

Safety of TRISO handling and storage will comply with regulatory frameworks relate to the criticality and cask efficiency; Shielding and containment systems to account for both radiation dose rates and decay heat.

The challenge here is to ensure the safe disposal in geological repositories as high graphite content is stored.

Conclusion

1. Spent TRISO fuel presents unique technical challenges through heat removal, radionuclide migration, and waste management.

2. Addressing these challenges is essential to fully realizing the potential of HTGRs and ensuring a safe, complete fuel cycle .

3. Innovative solution for disposal strategies are needed for long-term management along with strong/ clear regulatory frameworks.

4. International collaboration are essential for long-term solutions

5. Expand our knowledge about TRISO as SNF from HTGR-SMRs.

Thank you