Reshaping the Fusion Radwaste Management Approach: Avoid Geologic Disposal Through Recycling and Clearance

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Executive summary of proposed strategic element:
Proper handling of radioactive materials is important for the future and public acceptability of all nuclear systems, including fusion. The potential problem of fusion radwaste has been overlooked in early fusion studies and/or relegated to the back-end as only a disposal issue. In recent decades, fusion designers have become increasingly aware of the challenging problem facing fusion, as the large amount of mildly radioactive materials generated during operation and after decommissioning will fill the US repositories rapidly. Concerns about the environment stimulated the search for alternative approaches to keep the radioactive volume to a minimum via the development of recycling (reuse within the nuclear industry) and clearance (unconditional release to the commercial market if materials contain traces of radioactivity) [1]. The fusion program should be set up to change what is now impractical and costly waste disposal option for fusion radioactive materials into a valued commodity through the further development of fusion-specific recycling and clearance approaches.

Scientific and/or engineering opportunity:
In recent decades, fusion designers paid much attention to the waste management issue associated with the large volume of radioactive materials discharged from fusion power plants compared to fission reactors. This has been accomplished since the late 1980s by efforts in the US and throughout the world [1-28].

To put matters into perspective, we compared in Figure 1 the power core volumes of the ITER experimental device [29], the advanced ARIES power plants (ARIES-ACT-1&2) [2,3] and the European Power Plant Conceptual Study (PPCS) [30] to ESBWR [31] (Economic Simplified Boiling Water Reactor) – a Gen-III$^+$ advanced fission reactor. We propose reshaping the waste management approach for fusion and reduced the occupational dose in order to possess an inherent advantage for benign environmental impact, reclaim valuable resources, free ample space in repositories, and, in the long run, save millions of dollars for the high disposal cost.

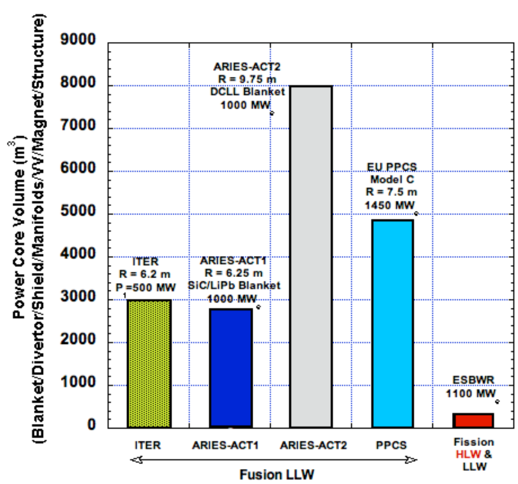

Figure 1. Comparison of radioactive waste from power core of fusion and fission designs (actual components volumes, not compacted, no replacements, no plasma chamber) [3].

If the proposed strategy is integrated properly at an early stage of the design process, fusion will eventually reach the ultimate goal of radwaste-free energy source. Currently, there is no official regulation in the US for recycling and clearance. Even though the current US experience is limited, it will be augmented significantly by advances in fission reactor dismantling, used fuel reprocessing, and bioshield clearing before fusion is committed to commercialization in the second half of the 21st century. In addition, lessons learned from other nuclear fields are valuable resources for fusion as approaches and concepts for handling mildly activated materials remain the same for particle accelerators and medical procedures [1]. While there is no US official recycling and clearance regulation, there has been some progress made in the US and in other countries [32-41]. Such developments will be of great importance to fusion, but adaptation is necessary to fusion needs (radiation level, component size, weight, etc.). In our opinion, it is just a matter of time to develop the recycling and clearance technologies and their official regulations that are essential to support fusion deployment. As a step forward, we identified several key issues and needs for recycling and clearance to provide a broader perspective of the requirements involved in both processes [1-3]. A dedicated R&D program should tackle these issues/needs to help optimize the integral fusion radwaste management strategy and maintain lifestyle in a technologically advanced society with minimal environmental impact. In the mean time:

- Fusion designers should:
  - Minimize radwaste volume by clever designs
  - Integrate the recycling and clearance approaches at an early stage of fusion designs
  - Continue addressing the critical issues for recycling and clearance
  - Examine the technical and economical aspects before selecting the most suitable radwaste management approach for fusion components.
- National labs, nuclear industry, and regulatory organization should:
  - Continue developing advanced radiation-resistant remote handling equipment capable of handling > 10,000 Sv/h
  - Develop radiochemical or laser isotopic separation processes for fusion materials
  - Accept recycled materials from dismantled nuclear facilities
  - Issue official guidelines for fusion clearable materials and address discrepancies between proposed US-NRC and IAEA clearance standards [42,43]
  - Continue national and international efforts to convince industrial and environmental groups that clearance can be conducted safely with no risk to public health by researching and refuting the linear no-threshold model.

Lastly, we describe how the proposed strategic element addresses the four NAS charge factors:

1. **Ensuring U.S. leadership in a field of plasma physics and/or fusion development:** Fusion development requires researchers to build and operate experiments. The proposed integral radwaste management strategy supports fusion development by allowing researchers to clean up and dispose of these experiments without undue public concern over radioactive waste burden to future generations.
2. **Impact on present and future international activities and collaborations by U.S. scientists:** The IEA ESEFP agreement has a specific task on fusion radwaste management. The US participation (with El-Guebaly as the US representative) has been strong in this task. To maintain our international competitiveness, collaboration in this area of research (with EU, RF, Japan, China, S. Korea, and others) is important, given the regularly worldwide resale of clearable metals from decommissioned facilities.
3. **Impact on the health of domestic fusion research at universities, national labs, and industry:** The proposed strategy provides the opportunity to engage diversity of activities at universities, national labs, industry, and US regulators (NRC), as outlined above.
4. **Impact of/from unanticipated events or innovations requiring programmatic re-direction:** The proposed radwaste management strategy would be relatively unaffected by unanticipated events in fusion research or innovations to improve the fusion development. It is applicable to all fusion concepts (tokamaks, spherical torii, stellarators, etc.) with any fuel cycle (D-T, D-D, or D-^{3}He).

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