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Current status of DEMO activated waste studies

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Previous studies of the European Demonstration fusion reactor concept (DEMO) have shown that the expected amounts of radioactive waste at reactor end of life (EOL) can be of the order of 10^4 tonnes [refs 1,2,3]. These studies also suggested that comparable amounts of waste will be classified as low level waste (LLW) and intermediate level waste (ILW) 100 years after DEMO EOL. Since these studies were performed, updated models for the DEMO reactor have been developed. To assess what effect these changes have had of the waste expectations from DEMO new waste assessments have been performed.

These followed the same methodology as the previous studies: Monte-Carlo neutron transport calculations were performed on the DEMO design geometry and the resulting cell tallied neutron energy flux spectra are used in high fidelity inventory simulations, to find the expected activation of reactor components. MCNP v6.2 [refs 4,5] was used for the transport calculations and FISPACT-II [ref 6] for the inventory simulations. Two blanket concepts have been used in this study: the Helium cooled Pebble Bed (HCPB) and the water cooled Lithium-Lead (WCLL) designs. The complete reactor model has been studied and assessed in accordance to the UK LLW criteria, with the possibility of material being Non-active waste (NAW) assessed on IAEA clearance index.

The results of the current assessments suggest that the waste performance of the DEMO reactor remains comparable to previous work, the waste mass evolution of the current DEMO model are shown in figure 1. In both models studied the majority of reactor material is expected to require disposal as radioactive waste, with 1-2$\times 10^4$ tonnes being classified as ILW, possibly needing geological disposal, 100 years after EOL. The WCLL model has greater total mass due to the Pb content of the LiPb breeder material. The LiPb also provides greater levels of neutron shielding, which is the cause of larger amount of NAW in the WCLL model.

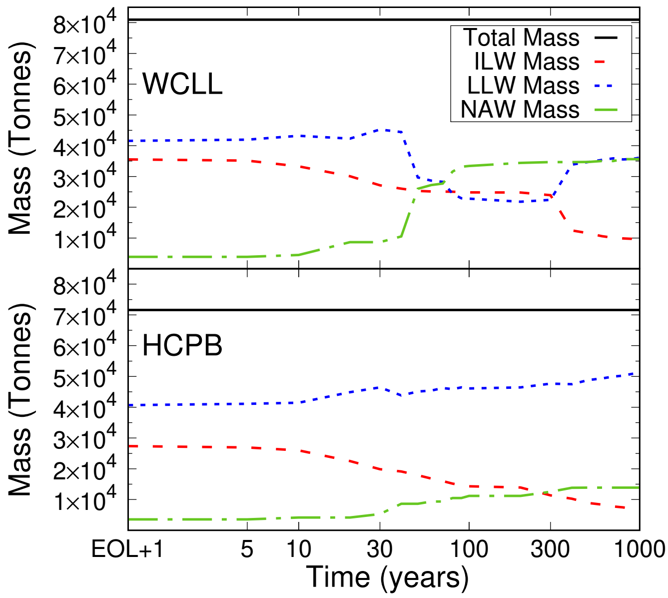

Figure 1: The expected ILW, LLW and NAW masses from each of the DEMO models studied for time after reactor EOL. While the HCPB model produces a greater proportion of LLW, the WCLL models produce more NAW. Both blanket concepts produce comparable proportions of ILW

A significant proportion of the ILW mass from DEMO arises from activated structural components in the near plasma blanket region. Current plans use Eurofer steel which is expected to produce long lived activation products. These can include ^{14}C, ^{53}Mn and ^{94}Nb, the presence of which can cause difficulties when attempting to achieve LLW waste criteria. The activation profile expected in DEMO Eurofer is shown in figure 2, revealing ^{14}C as the major cause of failing to meet the LLW limit used in this work.

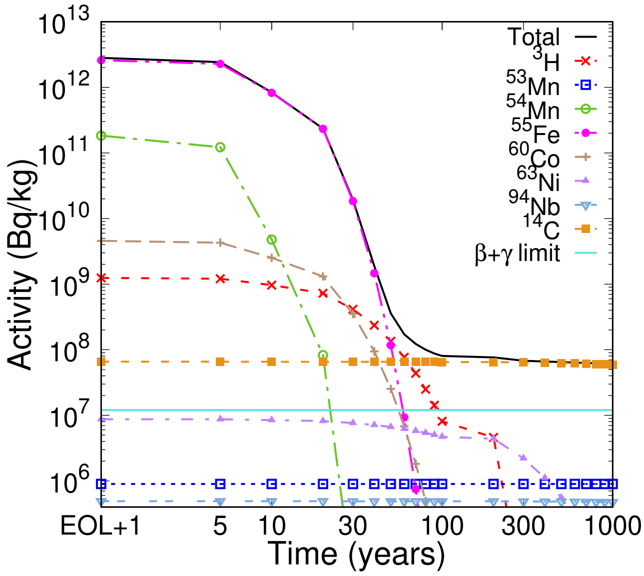

Figure 2: The expected activation profile of Eurofer steel under DEMO irradiation conditions. The nuclide contributions plotted are those which provide a significant contribution on the time-scale plotted.

It has been suggested that the Carbon content of activated steels could be reduced to 1 weight part per million via a so called decarburization process [ref 7]. The process, where Oxygen is blown across the surface of molten steel to create CO which is eventually captured as solid $CaCO_3$, has been claimed capable of reducing carbon content of steels to 1 weight part per million. The affect of such a technique has been applied to the Eurofer results from the inventory simulations and the resulting $CaCO_3$ inventory has also been estimated, the resulting ILW masses are shown in figure 3.

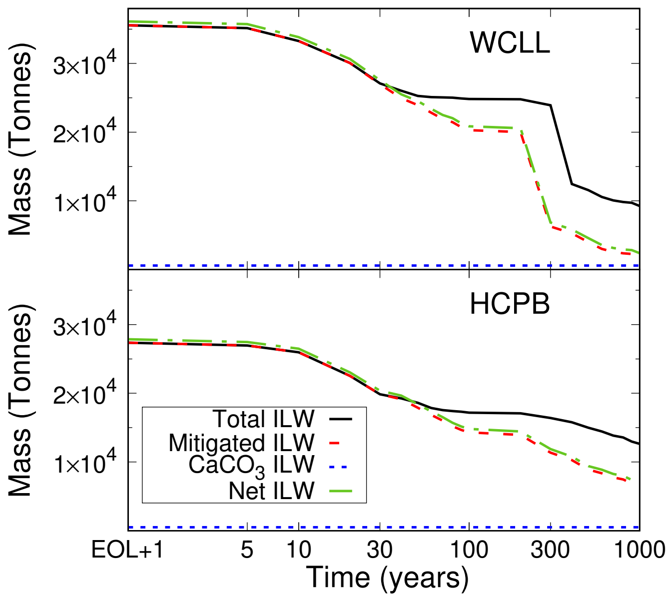

Figure 3: The level of ILW expected form each of the DEMO models before and after decarburization has been approximated. The amount of expected $CaCO_3$ appears constant as the same amount of Carbon is removed at each time step

It was found that decarburization could improve the expected waste evolution of DEMO Eurofer, but some secondary ILW $CaCO_3$ was produced. While this technique has the potential to improve the waste disposal prospects of in-vessel fusion steels, there are still a number of issues that must be resolved before it could be adopted as a DEMO waste mitigation strategy. These include proper assessment of the secondary waste burden from $CaCO_3$ and whether it can be safely applied to large volumes of activated steel (it has only previously been tested on non-active material).

The ^{94}Nb content in activated Eurofer is most commonly a result of neutron capture reactions on Nb impurities. The reduction of these impurities may also improve waste performance. Unfortunately the global activity limits used by UK criteria mean a reduction ^{94}Nb would not improve waste classification, as ^{94}Nb is dwarfed by other activity sources, see figure 2. Nb reduction can have an affect when individual nuclide limits are applied, such as those in different waste management systems. For example the French LLW system, which is based on individual nuclide activities, allows 9.2×10^7 Bq/kg of ^{14}C and 1.2×10^5 Bq/kg of ^{94}Nb. Comparing these to the activities shown in figure 2 reveals that these criteria may make decarburization unnecessary, but Nb impurity reduction could provide a significant improvement in long term waste classification. The possibility of applying waste mitigation techniques, such as decarburization or Nb-reduction, need only be considered if relevant to the waste regulations in-force at the chosen site for DEMO.

The expected levels of radioactive waste is an ongoing issue for the DEMO reactor concept. The application of waste mitigation techniques could lower the amount of ILW, but it will remain on the order of 10^4 tonnes on decommissioning (approximately 100 years post EOL) time scales. It should be noted that any waste mitigation techniques applied after EOL will produce secondary wastes which need to be included in complete reactor waste assessments.

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