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Characterization Methodology for Difficult-To-Measure Nuclides in the Type B Radwaste from the ITER

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1. Introduction

In general, it is not possible to directly detect beta rays from the radwaste in the field measurement due to their extremely low penetration through the materials. Only lab-scale measurements with proper shield and detecting system are available for the nondestructive assay. However, the disposal sites in many countries require the determination of inventories of the difficult-to-measure (DTM) nuclides in the waste before their acceptance for disposal. Many sites that generate radwastes thus are adapting the indirect method to characterize the DTM nuclides in the radwaste to be disposed.

The radwaste from the operation of an international thermonuclear experimental reactor (ITER) will be sent to the hot cell building (HCB) after packing it to the basket and they are then treated into the disposal form as well as characterized through the nondestructive assay. The radwaste properties from the ITER are that high density material such as a steel, a copper, and a tungsten accounts for the main substance and many nuclides due to the neutron irradiation including the DTM nuclides exists in that waste. Therefore, the ITER is also facing with the problem for the characterization of DTM nuclides.

The scaling factor [1] for the radiological relationship between the gamma and the beta nuclides is one of the indirect measurements to characterize the DTM nuclides in the waste. The methodology of the scaling factor to apply this method to the characterization the Type B radwaste from the ITER are presented in this paper. There are several types of the in-vessel components (IVCs) in a Tokamak which will be activated by neutron and they will be divided into different types of the radwaste such as the divertor cassette, blanket module, and port plugs. In this paper, the characterization of DTM nuclides will be focused on the radwaste from a blanket module out of IVCs.

Methods and Results

The radiological inventory documentation of the Type B radwaste from the ITER is that the primary waste such as IVCs is first sent to the HCB for a proper treatment which means cutting and tritium removal. These treated wastes are packed into a prepackaging basket and then, it is characterized with the gamma scanning system for the documentation of gamma nuclides in a basket. The scaling factors for the primary waste are then applied to the result on the representative gamma nuclide such as Co-60 in order to evaluate the DTM nuclides in a prepackaging basket. The above procedure is shown in Fig. 1.

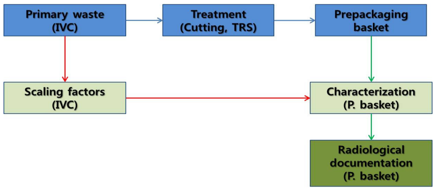

Fig. 1. Procedure for the radiological documentation of a prepackaging basket

2.1 The scaling factor

In order to calculate the scaling factor of the primary waste, the possible DTM nuclides and their activities should be first reviewed from the activation analyses for the IVCs as follows;

- Survey of material composition by the IVCs
- Calculation of the neutron spectrum and the flux in each component through the Monte-Carlo simulation such as the MCNP code
- Activation results of the material within each component through the PISPACT code or other activation code
- Survey of possible gamma and beta nuclides and their activities

From above results by the major component of the IVCs, the list for the scaling factors could be made by below equation.

$$SF_i = A_i / A_g$$

where, SF is the scaling factor, A_i is the activity of the DTM nuclide in the component, and A_g is the activity of the representative gamma nuclide in that component.

As a result, the characterization of one of the DTM nuclides in a prepackaging basket to be assayed would be done from below equation.

$$(A_i)_{basket} = SF_i' \times (A_g)_{basket}$$

where, $(A_i)_{basket}$ and $(A_g)_{basket}$ are the activity of the DTM nuclides to be analyzed and the representative gamma nuclide in a prepackaging basket, respectively, and SF'_i is the weight-averaged scaling factor for the

DTM nuclide by considering the packaging method of the component materials according to the cutting strategy.

2.2 Material composition of a blanket module

The blanket module consists of 4 kinds of materials: Be, CuCrZr, SS and Water [2, 3]. These four materials have the following combinations as shown in Fig. 2: beryllium first wall, the CuCrZr layer, the 85-% steel layer, and the 70-% steel layer. The layers with 70-% steel could be also divided into the regions with the density of about 5.89 and with the reduced density of about 4.43. As far as the waste classification is concerned, the beryllium first wall, the CuCrZr layer, and the 85-% steel layer belong to Type B radwaste and they are treated and characterized in the HCB. The rest parts of a blanket module belong to Type A radwaste.

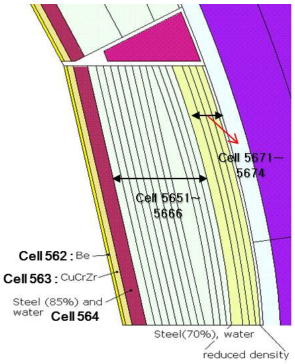

Fig. 2. Vertical section of the blanket module 14 for the MCNP modeling

2.3 Activation results on a blanket module

The activity of the blanket module was calculated to be at 3 weeks after last pulse in the cooling period from the activation results. The specific activities for the 20 most abundant nuclides in the 85-% steel layer are shown in Table 1. These dominant nuclides contribute more than 99 % of the gamma emission rate in all materials.

Table 1. Specific activities in the 85-% steel layer of a blanket module

Nuclide	Activity (Bq/kg)	Nuclide	Activity (Bq/kg)
Co-57	3.64E+11	Nb-92m	2.28E+09
Co-58	3.99E+11	Nb-93m	1.01E+09
Co-60	1.18E+11	Nb-95	1.07E+09
Cr-51	5.84E+11	Ni-63	1.43E+10
Fe-55	2.01E+12	P-32	4.28E+08
Fe-59	9.77E+09	Sc-46	3.72E+08
H-3	5.85E+08	Ta-182	3.73E+10
Mn-54	2.84E+11	Ta-183	5.36E+08
Mo-99	1.56E+09	Tc-99m	1.51E+09
Nb-91m	2.46E+09	V-49	1.36E+10

The DTM nuclides in the Be first wall were surveyed to be H-3, C-14, Ca-45, Fe-55, Ni-63, and Ta-179. And they were also surveyed to be H-3, Fe-55, Mo-99, Ni-63, Tc-99m, and V-49 for the CuCrZr layer and H-3, Fe-55, Mo-99, Nb-93m, Ni-63, P-32, Tc-99m, and V-49 for the layer with 85-% steel and 15-% water.

A Co-60 was elected as a representative gamma nuclide in a blanket module. Since the thickness and the densities of layers in a blanket module are different by the layer, it is advisable to use the weighted average of the scaling factors based on the areal densities of the layers in the blanket module, as multiplying the thickness and the density in the layer.

$$(SF)_i = \frac{\sum_{l=1}^{n} \left(SF_i\right)_l \times (AD)_l}{\sum_{l=1}^{n} (AD)_l}$$

where, i is the DTM nuclide, l is the layer number, AD is the areal density in the unit of g/cm^2.

3. Conclusion

The characterization methodology for the DTM nuclides was established by adopting the concept of the scaling factor. The possible beta emitting nuclides as well as low-energy gamma emitting nuclides which mean it is not possible to directly measure those activities with the field measurement were first surveyed in the Type B radwaste through the material composition of IVCs. The scaling factors by the component were then calculated by using the activities of DTM nuclides and Co-60 from the activation results. As a result, the characterization strategy of the DTM nuclides in a prepackaging basket was established using the scaling factors for major components of IVCs.

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