Unit Risk Quotient (RQ) and Relative Significance of Radionuclide on Flora and Fauna to the EU-APR Optimization

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1. Introduction

In order to expand and diversify the global nuclear power market of APR1400, the EU-APR design has been developed to comply with the latest Revision D of the European Utility Requirements (EUR) aiming at development of a standard design that can be built and licensed in Europe with minor changes.

As part of the project for acquiring the certification from EUR organization, in accordance with Articles 4.8 and 5.5 specified in Section 2.20 of EUR Volume 2 [1], the effects of ionizing radiation from the standard design of EU-APR on biota and ecosystems during operation and decommissioning phases shall be assessed. This assessment must be carried out according to the ERICA (i.e. Environmental Risk from Ionizing Contaminants: Assessment and management) integrated approach.

This paper describes the evaluation results for unit risk quotient and relative significance by radionuclide derived from performing Tier 1 assessment on flora and fauna for the EU-APR design using ERICA Tool.

2. Methods and Results

2.1 Assessment Model

Under the Revision D of the EUR Requirements, the radiological impact assessment on flora and fauna was performed according to ERICA integrated approach. This approach allows for greater integration between the risk assessment sequenced in three (3) different tiers, risk characterization and decision-making aspects of ecological risk assessment.

To facilitate estimation of the radiological risk to freshwater, marine and terrestrial ecosystems, Tier 1 assessment designed to be simple and conservative was carried out using ERICA Tool, which is a software system that has a structure based upon the ERICA integrated approach.

2.2 Input Data and Assumptions

To evaluate the standard design of EU-APR, the terrestrial, marine (coastal), and freshwater (river) ecosystems were selected as the scope of assessment. Even though the radiological impact assessment on flora and fauna is strongly dependent on the on-site ecosystems, the site-specific parameters required by ERICA Tool are not known during the design stage. Accordingly, the default parameters presented in Table 2 of EUR Section 2.20 [1] were used for assessing the radiological impact. And, the assessment was carried out for a set of the ERICA reference organisms selected to be representative of all protected species in Europe.

For all default radionuclides of which databases are included in the ERICA Tool, the discharge rate of 1 Bq/sec was inputted to estimate the risk quotient (RQ) per unit activity of each radionuclide. It is assumed that the activity is discharged continuously and uniformly throughout the year.

The simple transport models taken from IAEA Safety Reports Series No.19 [2] are applied to predict media activity concentrations from discharge data for assessing dose rates to biota, which are embedded as an option in ERICA Tool.

2.3 Assessment Process

For Tier 1, the pre-defined screening dose rate is back-calculated to yield Environmental Media Concentration Limits (EMCLs) for all reference organism/radionuclide combinations. The screening criteria applied in this analysis are incremental dose rates of 10 μGy/hr for terrestrial animals, and 100 μGy/hr for terrestrial plants and all aquatic species, respectively. Subsequently, the Tool compares the input media concentrations with the most restrictive EMCL for the most limiting reference organism and determines a RQ for a given radionuclide in the released source term. That is, a formula to calculate a RQ for a given radionuclide and organism can be expressed as follows;

$$RQ = \frac{M}{EMCL} = M \times \frac{F}{SDR} \quad (1)$$

where 'M' is estimated activity concentration for a given radionuclide, 'EMCL' is environmental media concentration limit, 'SDR' is screening dose rate, and 'F' is the dose rate that a given organism will receive for a unit concentration of a specific isotope in an environmental medium.

In terms of the radiological impact, the relative significance by radionuclide for each ecosystem is derived from dividing the calculated result of RQ for each isotope of the minimum value. (In other words, the

relative significance of isotope having the minimum RQ is considered as a unity.)

2.4 Results and Discussion

RQ per unit discharge rate of radionuclide was assessed for a set of seventy-one (71) isotopes provided in the ERICA Tool as a default. Subsequently, as noted above, the relative significance of each isotope for each ecosystem is derived from dividing unit RQ for the corresponding radionuclide by the minimum value.

For the terrestrial, marine (coastal), and freshwater (river) ecosystems, the assessment results of the top and bottom 5 isotopes on the basis of unit RQ are tabulated in Tables I through III.

In addition, Figures 1 through 3 show the relative significance of radionuclide in the results of ERICA Tier 1 assessment for the each ecosystem, respectively. In each figure, isotope with the minimum value is marked with different color (or style) from all other elements.

From Tables and Figures as below, it is found that the most significant isotope is Pa-231 for the terrestrial and Th-228 for the marine/freshwater ecosystems, and those radionuclides are relatively more significant than isotope having the least impact on flora and fauna by about 7 to 10 orders of magnitude.

Table I: Unit RQ and relative significance of radionuclide for the ERICA Tier 1 assessment on the terrestrial ecosystem

Rank	Isotope	RQ/(Bq/sec)	Relative Significance
High	Pa-231	3.542E-03	3.980E+07
	Np-237	3.384E-03	3.803E+07
	Ra-226	2.850E-03	3.203E+07
	Cm-243	2.236E-03	2.512E+07
	Cm-244	1.642E-03	1.845E+07
Low	Cr-51	2.321E-09	2.608E+01
	S-35	1.611E-09	1.810E+01
	H-3	1.385E-09	1.556E+01
	I-132	7.663E-10	8.611E+00
	Th-231	8.899E-11	1.000E+00

Table II: Unit RQ and relative significance of radionuclide for the ERICA Tier 1 assessment on the marine ecosystem

Rank	Isotope	RQ/(Bq/sec)	Relative Significance
High	Th-228	1.291E+01	1.520E+10
	Th-227	2.311E+00	2.720E+09
	Th-230	1.853E+00	2.181E+09
	Th-232	1.579E+00	1.858E+09
	La-140	1.298E+00	1.528E+09
Low	Cs-135	2.097E-06	2.469E+03
	Ca-45	9.030E-07	1.063E+03
	S-35	9.532E-09	1.122E+01
	Cl-36	8.897E-09	1.047E+01
	H-3	8.495E-10	1.000E+00

Table III: Unit RQ and relative significance of radionuclide for the ERICA Tier 1 assessment on the freshwater ecosystem

Rank	Isotope	RQ/(Bq/sec)	Relative Significance
High	Th-228	3.594E-01	3.827E+09
	Th-227	5.362E-02	5.709E+08
	Th-234	4.252E-02	4.528E+08
	Ra-226	4.067E-02	4.331E+08
	Th-230	3.883E-02	4.134E+08
Low	Ni-59	5.768E-07	6.142E+03
	Ni-63	1.627E-07	1.732E+03
	S-35	1.394E-07	1.484E+03
	Tc-99	5.990E-08	6.378E+02
	H-3	9.392E-11	1.000E+00

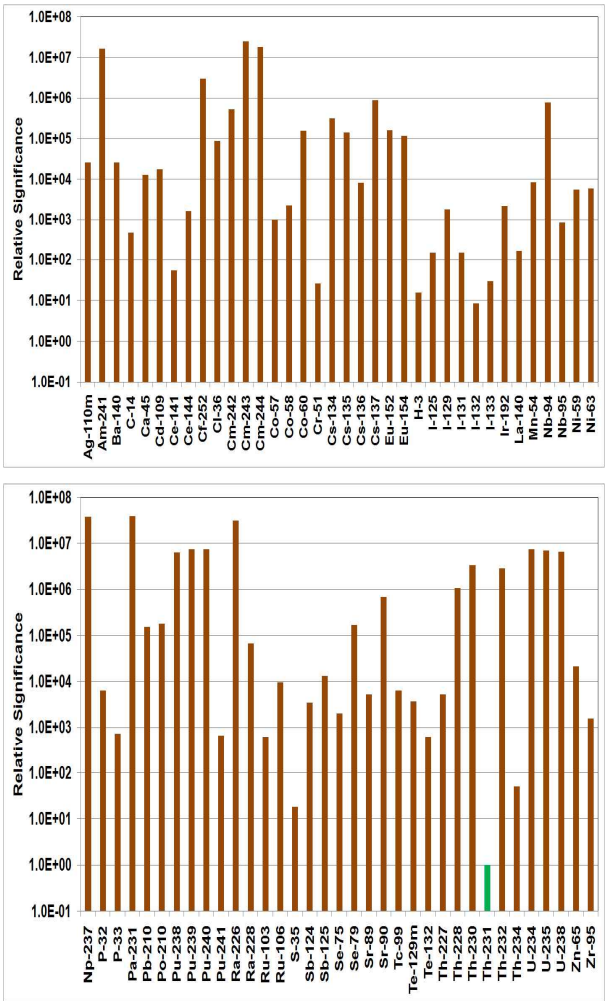

Fig. 1. Relative significance of radionuclide in ERICA Tier 1 assessment resulton terrestrial ecosystem

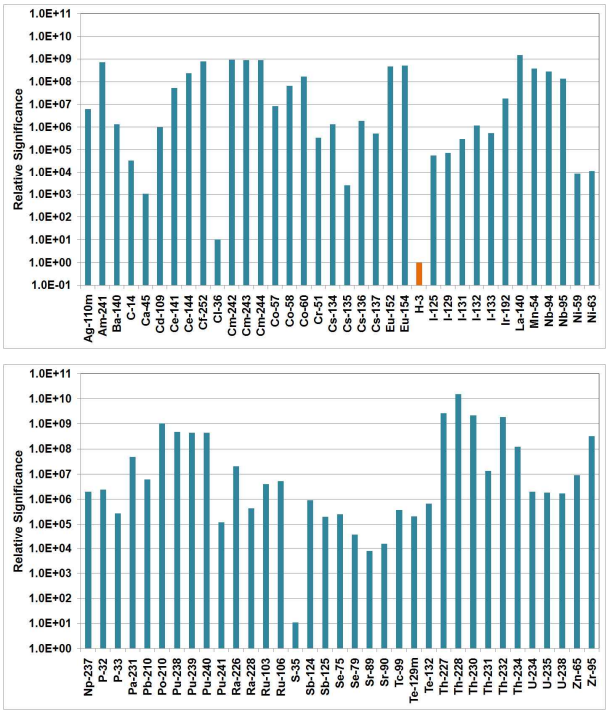

Fig. 2. Relative significance by radionuclide in the results of ERICA Tier 1 assessment on marine (coastal) ecosystem

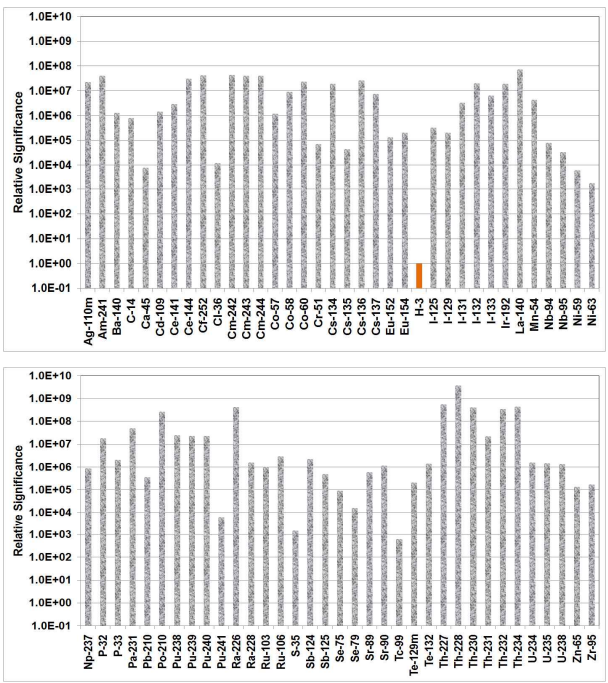

Fig. 3. Relative significance by radionuclide in the results of ERICA Tier 1 assessment on freshwater (river) ecosystem

3. Conclusions

In this paper, for a default set of seventy-one (71) isotopes of which databases are included in the ERICA Tool, RQ per unit discharge rate(also referred to as 'unit RQ') and relative significance of radionuclide were assessed for the terrestrial, marine (coastal), and freshwater (river) ecosystems. These results are tabulated in Tables I through III and shown in Figures 1 through 3.

As specified previously, Pa-231 and Th-228 are the most significant for the terrestrial and for the marine/freshwater ecosystems, respectively. And, in terms of environmental risk, those radionuclides having the most impact on flora and fauna are relatively more significant than isotope having the least impact by about 7 to 10 orders of magnitude.

In the ERICA Tier 1 assessment on flora and fauna for the specific exposure scenario during operation and decommissioning phases, RQ of a given radionuclide and sum of RQs for each ecosystem are directly derived from the calculation result of 'unit RQ' by isotope providing that information on radionuclides discharged from the EU-APR design is available. In addition, it is judged that the results obtained from this study could be applicable to development of the discharge control strategy for the standard design of EU-APR considering the relative significance to reduce environmental impact.

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[2] IAEA, Generic Models for Use in Assessing the Impact of Discharges of Radioactive Substances to the Environment, Safety Reports Series No. 19, 2001.