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Estimated absorbed dose rate in the non-human biota in different environmental scenarios

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Introduction: In the past, the levels of exposure to ionizing radiation was mainly focused on humans, considering that biota and the environment were also protected if human beings were adequately protected. In the last decades, this statement was proven to fail and is no longer accepted [1].
In order to implement the current philosophy guiding the international recommendations for non-human biota radiation protection, efforts have been made on the development of radiological models, frameworks and approaches meeting present-day criteria applicable to non-human biota and in the last decade several models for assessment to non-human biota to ionizing radiations were developed [2].
Assessing potential effects of exposure to ionizing radiation is very important to obtain recommended reference values below which the risk of the deleterious effects for non-human biota can be excluded. International Commission on Radiological Protection (ICRP) recommends derived consideration reference levels in the dose rate range of 0.1 mGy d^{-1} to 100 mGy d^{-1} (recommended values depend on the reference organism) [3]. United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) recommends dose rate reference levels of 400 μGy h^{-1} (10 mGy d^{-1}) for terrestrial plants and aquatic organisms, and less than 40 μGy h^{-1} (1 mGy d^{-1}) for terrestrial animals, considering the most exposed individual in a population [4].
The main objective of the paper is to estimate the absorbed dose rate in three different environmental scenarios considering the terrestrial biota and aquatic biota (freshwater and marine) using the ERICA Tool version 1.3.1.33 and RESRAD-BIOTA code version 1.8. The three environmental scenarios used in the dose rate estimation were: First environmental scenario – NORM: Nisti et al. [5] determined the activity concentrations of natural radionuclides in typical Brazilian soils, phosphogypsum (PG) and soils amended with PG; Second environmental scenario – Soil: Nisti et al. [6] determined the activity concentrations of radionuclides in soil around IPEN facilities; and Third environmental scenario – Sediment: Saueia et al. [7] determined the activity concentrations of radionuclides in the sediment of the Baixada Santista, an estuarine system complex in southeastern Brazil.
Methodology: Estimated absorbed dose rates to the biota in the three environmental scenarios were calculated using ERICA Tool version 1.3.1.33. The estimated absorbed dose rate was run using Tier 2. Tier 2 is a detailed assessment which requires further input for estimate absorbed dose rates in each organism and ecosystem of interest (freshwater, marine and terrestrial) [8]. Default values of the ERICA Tool were used for the absorbed dose rate estimation, namely: dose conversion factors, radioecology parameters (distribution coefficient (Kd) and concentration ratio (CR)), occupancy factors, radiation weighting factors (α: 10, β: 3 and γ: 1), exposure configuration and reference organism geometries.
The Level 3 was used for estimated absorbed dose rate in the RESRAD-BIOTA code version 1.8. In level 3 a kinetic/allometric model is employed to conduct a more rigorous analysis and realistic with site-representative evaluation, the parameters are used in the estimated absorbed dose rate [9]. The values used in the estimated absorbed dose rate were: for the radiation weighting factors: α: 10, β: 3 and γ: 1. The Kd and external dose conversion factors were obtained from DOE STANDARD and were used to calculate the estimated absorbed dose rate (external, internal and total) [9]. The default parameters of the RESRAD-BIOTA code with internal dose conversion factors, CR, occupancy factors, exposure configuration and reference organism geometries were used in the estimated absorbed dose rate. Detailed explanation in relation to the default parameters used in the RESRAD-BIOTA code could be found in the literature and in the user's guide [9, 10].
Results: First environmental scenario – NORM residue: The highest contribution to the estimated absorbed total dose was the internal dose, with contribution of about 94% for ERICA Tool and of more than 91% for RESRAD-BIOTA code; the results in the contribution of the estimated absorbed total dose were very similar for both programs. Regarding the external, internal and total doses rate calculated by ERICA Tool were similar than those calculated by RESRAD-BIOTA code in the environmental scenario for terrestrial ecosystem using the PG, soil and soils amended with PG. Second environmental scenario – soil: The highest contribution to the estimated absorbed total dose was the internal dose, with contribution of about 94% for ERICA Tool and of about 76% for

RESRAD-BIOTA code; the results in the contribution of the estimated absorbed total dose were similar for both programs. Regarding the external dose rate calculated by ERICA Tool was similar than those calculated by RESRAD-BIOTA code, but the internal dose rate calculated by the ERICA Tool was about four times that of the RESRAD-BIOTA code. Third environmental scenario – sediment – (1) Aquatic ecosystem (freshwater biota): The highest contribution to the estimated absorbed total dose for freshwater ecosystem was the internal dose, with contribution of about 75% for ERICA Tool and of about 98.5% for RESRAD-BIOTA code; the results in the contribution of the estimated absorbed total dose were very similar for both programs. The results obtained in the RESRAD-BIOTA code were: external dose rate about 2.4 times, internal dose rate 47 times, resulting in an average value of the total dose rate of 36 times higher than the values of the ERICA Tool. (2) Aquatic ecosystem (marine biota): The highest contribution to the estimated absorbed total dose for marine ecosystem was the internal dose, with contribution of about 83% for ERICA Tool and of about 98.5% for RESRAD-BIOTA code; the results in the contribution of the estimated absorbed total dose were very similar for both programs. Regarding the external, internal and total dose rate obtained in the ERICA Tool showed results differences compared to the doses calculated by RESRAD-BIOTA code. The results obtained in the RESRAD-BIOTA code were higher for all estimated doses, being the external dose rate about 2.8 times, internal dose rate 32 times, resulting in an average of the estimated total absorbed dose rate of 27 times higher than the values of the ERICA Tool for aquatic ecosystem (marine) using the sediment from Baixada Santista.

Conclusions: Estimated internal absorbed dose rate was significantly higher than estimated external absorbed dose rate for all environmental scenarios studied in this paper; this finding is mainly attributable, for radionuclides in the first environmental scenario, to ^{226}Ra, ^{228}Ra and ^{210}Po; second environmental scenario, to ^{228}Th, ^{226}Ra and ^{228}Ra; third environmental scenario, to ^{226}Ra and ^{228}Ra. Considering the respective parameters used for both programs in the environmental scenarios studied, the total absorbed dose rates obtained by ERICA Tool were similar, in most cases, to those obtained with RESRAD-BIOTA code, except for the third environmental scenario, in which the resulting discrepancy was about of an order of magnitude for the absorbed dose rate.

Finally, we would like to note that all tools used in the present estimations of absorbed dose rate in non-human biota, showed excellent performance, fast processing and good usability. Models and approaches are important tools for comparing the estimated absorbed dose results with the reference levels recommended by international organizations of environmental radiation protection.

The biota assessment has an important role for environmental protection and is considered as one of the Sustainable Development Goals of United Nations.

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