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relevance, and all the other radionuclides were considered irrelevant from a radioecologic viewpoint. For the croaker (6 specimens) from the state, an identical situation occurred: <sup>226</sup>Ra was of medium relevancy and the other radionuclides were considered irrelevant. Still from the Espírito Santo state, for the mullet (7 specimens) <sup>226</sup>Ra was considered relevant and the other radionuclides were considered irrelevant. In the state Rio de Janeiro, for the croaker (10 specimens) and liza (7 specimens) <sup>226</sup>Ra was considered of medium relevancy and all the other radionuclides were considered irrelevant. The same pattern was obtained for tubera snapper (21 specimens) from the state of Ceará. In conclusion, the analysis of nine natural radionuclides in 57 specimens distributed in four species of marine fish, along the coast of three Brazilian states, showed by the use of IRR that <sup>226</sup>Ra is the most important radionuclide for all the analyzed species, in all the states. The remaining eight radionuclides did not show radioecologic relevancy, considering their IRR.

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## Natural Radionuclides and <sup>137</sup>Cs in Mosses and Lichen in Eastern Serbia

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The paper presents the results of radionuclides determination in mosses (*Homothecium sp.*, *Hypnum Cupresiforme sp.*, and *Brachythecium sp.*) and lichen (*Cladonia sp.*), sampled in the region of Eastern Serbia, during 1996 – 2010.

Activities of <sup>7</sup>Be, <sup>40</sup>K, <sup>226</sup>Ra, <sup>232</sup>Th, and <sup>137</sup>Cs were determined on an HPGe/ORTEC/Ametek detector (relative efficiency 34 %, resolution 1.65 keV at 1.33 MeV) and HPGe/Canberra detector (relative efficiency 25 %, resolution of 1.95 keV at 1.33 MeV) by standard gamma spectrometry. The average counting time was 60 000 s. The standard error of the method was 10 %. Spectral analysis was performed with the Gamma Vision 32 software package.

The majority of the <sup>40</sup>K activities measured in moss was within the range (100–500) Bq/kg dw (dry weight), while most of the <sup>226</sup>Ra and <sup>232</sup>Th activities were in the range (5–50) Bq/kg dw. The calculated "soil-to-moss" transfer factors for <sup>40</sup>K, <sup>226</sup>Ra, and <sup>232</sup>Th were 0.45, 3, and 0.3, respectively. Over the study period, the majority of the <sup>137</sup>Cs activities in moss were in the range (0–500) Bq/kg dw, with less than 10 % of the samples with the activity higher than 1000

the <sup>137</sup>Cs activity was highly non-uniform over the region. The variations in the content of natural radionuclides among the three most sampled moss species were not significant. Linear Pearson correlation coefficient was 0.68 for <sup>226</sup>Ra versus <sup>232</sup>Th, and 0.24 for <sup>137</sup>Cs versus <sup>40</sup>K.

The content of natural radionuclides in lichen was to some extent less than in moss, as lichen was collected from higher points (trees), and the effect of resuspension from soil was thus less pronounced. Still, the frequency pattern of activities of natural radionuclides in lichen resembled the pattern seen in moss. The <sup>137</sup>Cs activities in lichen were also less than in moss, with most of the concentrations below 300 Bq/kg dw.

The mean activities of <sup>7</sup>Be in moss and lichen sampled in Eastern Serbia in 2006 and 2008 were in the range (41–122) Bq/kg dw, with variations up to 71 %. The <sup>7</sup>Be concentrations were significantly (20–60 %) higher in 2008 than in 2006. The pronounced <sup>7</sup>Be variations (28–71 %) between the sites and within a year were mainly a result of its short half-life and the differences in microclimate and topology of the sites.

**Keywords:** mosses, lichen, radionuclides, Eastern Serbia



## Deactivation of the liquid radioactive waste with compounds of carbonic acid labeled $^{14}\text{C}$

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In modern hydrobiology the radiocarbon method of definition of primary production of organic matter, both in the seas, and in freshwater reservoirs is one of the cores and the most widespread. However, in the course of heavy use of labeled on carbon-14 of connections of carbonic acid there are considerable volumes of liquid radioactive waste which will be utilized according to norms of radiating safety.

Authors developed the method of the deactivation of the liquid radioactive waste of the dissolved connections of coal acid labeled by  $^{14}\text{C}$ , based on the sedimentation of the consecutive additions of equal portions  $\text{BaCl}_2$  and  $\text{Na}_2\text{CO}_3$  in water solution.

The method allows to lower radioactivity in the basic volume of liquid waste to level below admissible concentration  $^{14}\text{C}$  in potable water for the population ( $30 \text{ Bq} \cdot \text{mL}^{-1}$ ) and to minimize volume of the waste which is subject to burial place.

**Keywords:** methods, deactivation,  $^{14}\text{C}$ , liquid radioactive waste.