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Model for migration of ^{137}Cs in lake ecosystems and its application to the lake highly contaminated by the Chernobyl fallout

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A dynamic model has been developed to evaluate the ^{137}Cs migration in lake ecosystems. The model includes three interconnected parts: hydrological model, which calculates the radionuclide dynamics in water and bottom sediments; radioecological model, which is responsible for estimation of the radionuclide accumulation in aquatic biota; dose assessment model, which allows calculation of doses to aquatic organisms and to men from the use of the water body. Results of calculation in the first part of the model are used as the input data in second and third parts of the model. Dynamics of the radionuclide accumulation and elimination is calculated taking into account the ecological and physiological characteristics of an aquatic organism, such as growth and metabolic rates, position in the food chains of the aquatic ecosystem. It was shown, that the biological elimination of ^{137}Cs from the freshwater fish is proportional to the metabolic rate of the fish. The inverse relationship between the concentration factor of ^{137}Cs in fish and concentration of K^+ in water was taken into account.

The model was applied for reconstruction of the long-term dynamics of ^{137}Cs in the food chain "goldfish – pike" from Lake Kozhanovskoe (Bryansk Region, Russia). This lake was contaminated in 1986 as a result of the Chernobyl fallout. Lake Kozhanovskoe is located in the territory contaminated up to $1.5 \cdot 10^6$ Bq/m^2 with ^{137}Cs. Activity concentrations of ^{137}Cs in water of the Lake Kozhanovskoe are comparable with those in water bodies located in the 10-km area around the Chernobyl NPP. It is caused by the specific content of bottom sediments in this lake, which have low fixing

capacity for ^{137}Cs. Low concentration of stable potassium in the lake water ([K^+]= 1.4 mg/L) is the reason for high accumulation of ^{137}Cs in the lake organisms, including fish. Radioecological studies on the Lake Kozhanovskoe in 1992 – 1999 showed maximum activity concentrations of ^{137}Cs in goldfish 21 kBq/kg, in pike as high as 66 kBq/kg.

Activity concentrations of ^{137}Cs in water and fish were selected as endpoints for the model testing. For testing the adequacy of results of the model reconstruction, the calculations have been compared with the dataset on the activity concentrations of ^{137}Cs in water and different fish species (predatory and non-predatory), obtained within the framework of the many-years radioecological monitoring of the Lake Kozhanovskoe. Such comparison showed that the developed model allows to adequate evaluation of the levels and dynamics of ^{137}Cs in all components of the lake ecosystem. Although the observed seasonal dynamics of the radionuclide in fish has some higher amplitude than modelled, the most part of the calculated values is within the range of the test data for the long time period (more than 10 years). The model correctly described the observed radioecological phenomena in the radiocaesium accumulation in aquatic organisms, such as “trophic level effect” and “size-effect”. The developed model can be useful for the tasks of reconstruction and prognosis of the ^{137}Cs behavior in lakes after the pulse contamination.