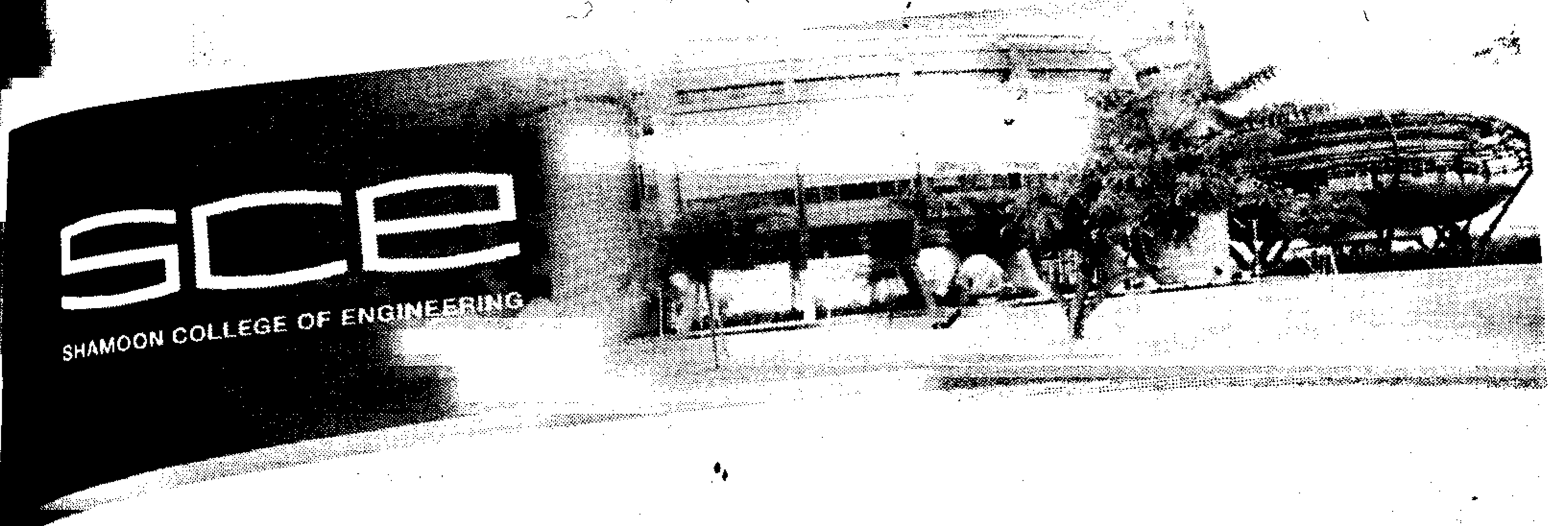

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Theory of Reliability in Radiation Ecology

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Abstract

For twenty years after Chernobyl catastrophe, we have studied capability of plants of different kinds to store and retain the radionuclide tracer ^{137}Cs as the measure of stability and reliability of the ecosystem biota exposed to gamma-radiation and chemical pollutants. We introduced two parameters to quantify the ecosystem reliability. First, radiocapacity is defined as the upper level of radionuclide contamination, above which the ecosystem biota species begin to manifest depression and/or suppression of growth. Then, factor of radiocapacity is defined as probability of the biota constituents to retain the radionuclide tracer. The more is the factor of radiocapacity the higher is reliability of the relevant biota components. With knowledge of the ecosystem structure and these parameters, it is possible to estimate ability of ecosystems to provide the proper distribution and redistribution of the tracer. In particular, we showed that ecosystems of the serious type of organization, like slope and mining ones that are incapable to provide the proper pollutant migration, exhibit low radiocapacity and, thus, low reliability. Using this approach along with the data of geoinformational analysis, we can predict the principal seats of location of pollutants in the specific ecosystems and estimate the appropriate dose loads and risks.

Key words: reliability, ecosystems, radiation ecology, radiocapacity, 137Cs-tracer, geo-information technologies

1. Tracer ^{137}Ce as the factor of radiocapacity of biota and the parameter of reliability of the ecosystems biota

Owing to the Chernobyl reactor accident in 1986, radionuclide ^{137}Cs, as the tracer, was "generously" strewn over the world. As a consequence, we can use this case to elucidate the laws of redistribution of the tracer over ecosystems of different types. Any sharp changes in the content of the tracer in the ecosystem biota can serve as indicators of the collisions, the biota must have endured. In essence, the tracer performs the function of "ecological thermometer " that monitors the condition and reliability of the biota. For example, in the case of lake ecosystems, any decrease in aqueous pH results in the desorbtion of radionuclides from the ground adjournments into water along with the reduction of radiocapacity of the ground biota and the relevant growth of amount of the tracer in the water. As a result, it brings about the additional dose loads to the biota water and people who use the lake water for drink and irrigation (Korogodin 1960, Kutlakhmedov etc. 2003).

In our experiments with the culture of water plants we have shown that the dynamics of the factor of radiocapacity of the ecosystem biota, under the influence of gamma-irradiation and the salts of heavy metal (cadmium), is essentially in line with the dynamics of the biological parameter, i.e. – the growth rate. This support our assertion that behaviour of the ^{137}Cs, as the analogue of mineral feed element K (potassium), displays the extent of the biota well-being. It can be concluded that the more is the ability to accumulate and keep the tracer, the more comfortable is the state of the ecosystems biota and, thus, the higher is its reliability (Kutlakhmedov 2006).

Assessment of the biota dose loads on biota at accumulation of the tracer in ecosystems of ferent types.

The admitted limits of dose loads have been determined in *(Polikarpov 1995)*. The typical results of e studies are displayed in Table 1.

Table 1. The dose commitment scale for some ecosystems

ZONE	ABSORBED DOSE RATE (Gy y^{-1})
Zone of radiation well-being	< 0.001-0.005
Zone of physiological masking	0.005 - 0.05
Zone of ecological masking: for terrestrial animals for hydrobionts and terrestrial land plants	 0.05 - 0.4 0.05 - 4
Zone of evident ecological changes: Dramatic: for terrestrial animals for hydrobionts and terrestrial plants Catastrophic: animals and plants	 >> 0.4 >> 4 >> 100

To assess the biota dose loads, we apply the dose coefficients from the model of Amiro (Amiro 1992), that makes it possible to calculate doses for every components of the ecosystem (Table 2).

Table 2.Mean values of the dose coefficients induced by some kinds of radionuclides.

Radionuclides Internal irradiation Gy/year/Bq/kg		External irradiation			
		Water Gy/ year /Bq/m^3	Air Gy/y Bq/m^3	Soil Gy/ year /Bq/ kg	Vegetation Gy/year /Bq/kg
137Cs	4.1 E -6	2,7 E-9	1,72E-6	4,02 E-6	1,72 E-6
^{3}H	2.88 E-8	0	0	0	0
^{40}K	3.44 E-6	1.76 E-9	1.43 E-6	2.64 E-6	1.43 E-6
^{32}P	3.52 E-6	1,57 E-9	1.43 E-6	2.36 E-6	1.43 E-6
^{241}Am	2.86 E-5	1.48 E-10	7.73 E-8	2.22 E-7	7.73 E-8
^{239}Pu	2.64 E-5	3.72 E-12	2.35 E-9	5.58 E-9	2.35 E-9
^{90}Sr	9.92 E-7	3.07 E-10	2.83 E-7	4.61 E-7	2.83 E-7
^{222}Rn	1.12 E-4	8.91 E-9	6 E-6	1.43 E-5	6 E-6
^{14}C	2.5 E-7	6.51 E-12	6.01 E-9	9.77 E-9	6.01 E-9

For example, from the data of Table 2 one can see that the dangerous limit, i.e. – 4 Gy/year, is achieved at 600 kBq of ^{137}Ce per kg of biomass. Moreover, it was shown that the reliability decreases linearly from 1 to 0 for the dose range up to 4 Gy. Furthermore, we assessed the radiocapacity of the biotic components of the ecosystem in case when the biota reliability is close to 0 (≈ 600 kBq/kg). Thus, the parameter of radiocapacity can serve the measure of the ecosystems biota reliability.

The block diagram on Figure 1 demonstrates the example of the slope ecosystem consisting nine chambers (Petrusenko, Kutlakhmedov, 2006).

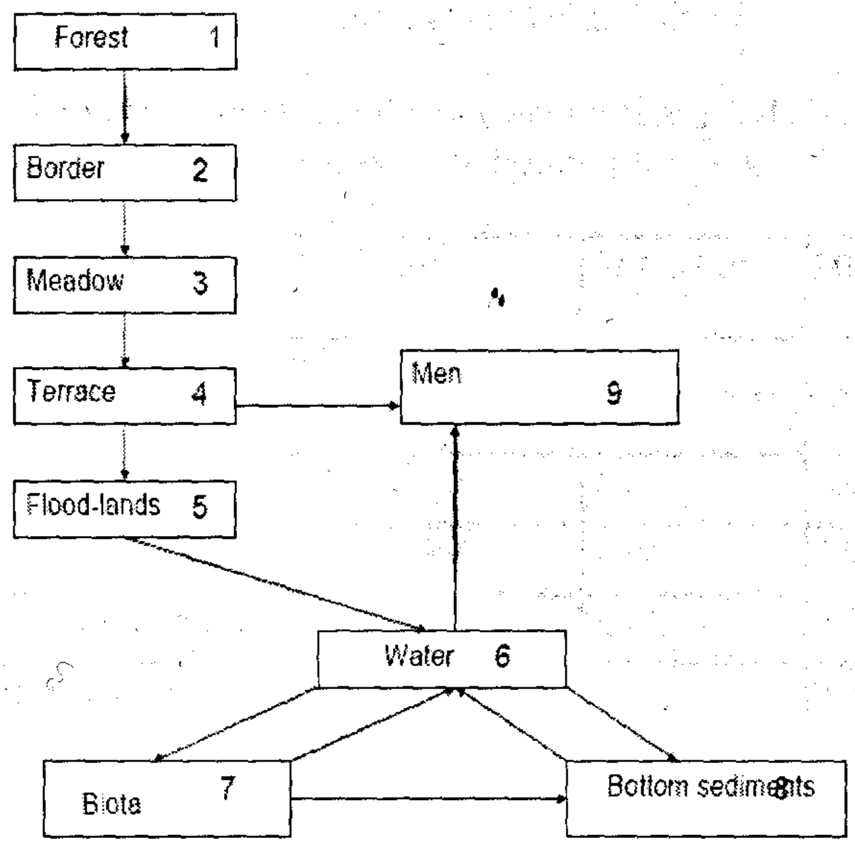

Figure 1. The block-scheme of typical slope 9-chamber ecosystem.

The mathematical model developed in our previous papers allowed to get the graphs of dynamics of redistribution of the tracer in this slope ecosystem (Figure 2).

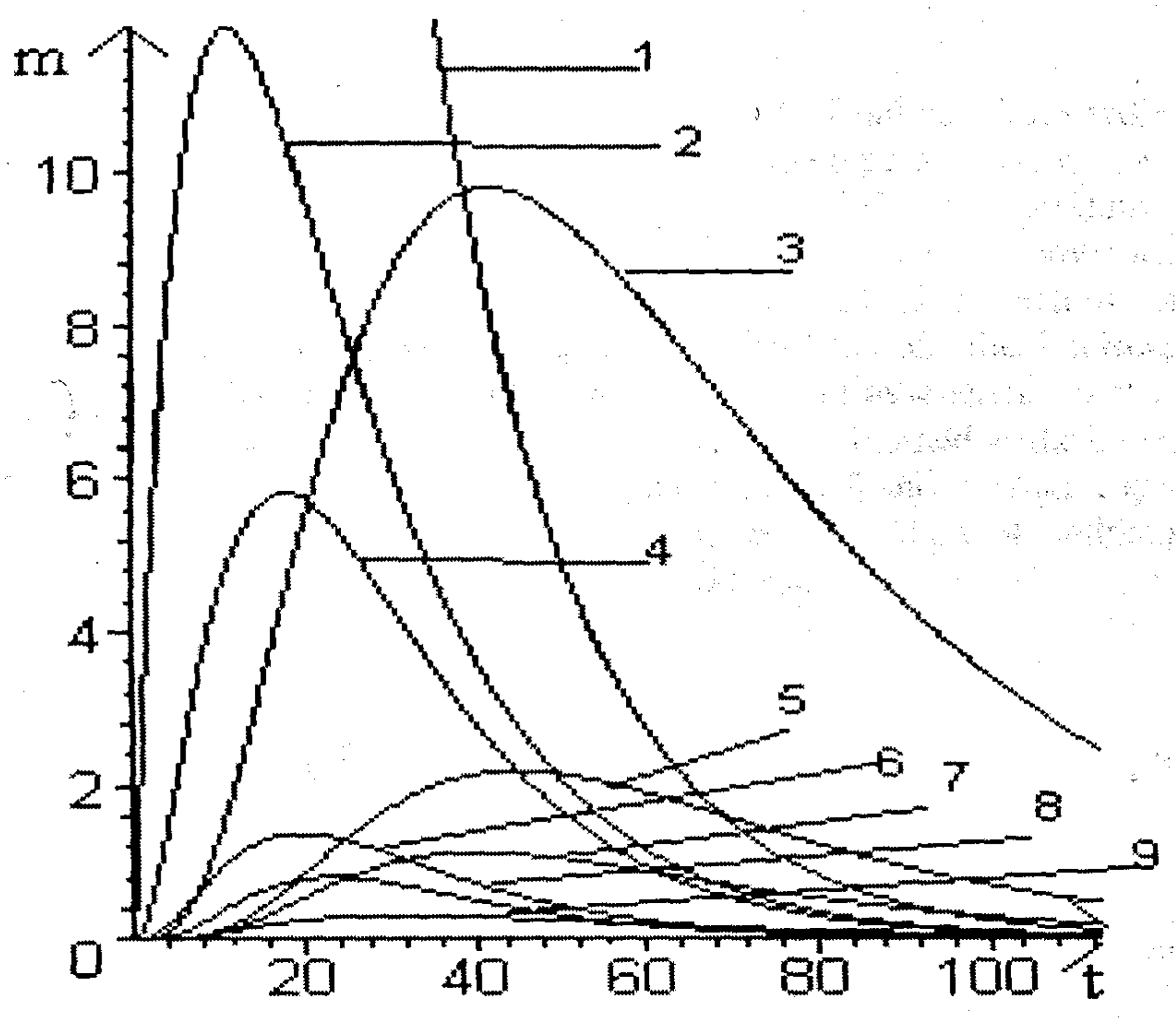

Figure 2. Dynamics of the content of the tracer in different chambers of the ecosystems (m - percentage from the initial amount, t - years).

The obtained data make it possible to assess the doze loads in the different biota components of the slope ecosystem depending on the total amount of the tracer (^{137}Cs) in the ecosystem and to assess the reliability of the biota. In the calculations, the consecutive model have been used (Petrusenko, Kutlakhmedov, 2006). The results are presented in Table 3.

Table 3. The assessment of reliability of the typical slope ecosystem for different levels of pollution of the top site (forest) with radionuclide ^{137}Cs.

Level of contamination by the radionuclide	**10 Ci/km^2**	**50 Ci/km^2**	**100 Ci/km^2**
1.Forest	0,93	0,67	0,34
2.Border of forest	1	1	1
3. Meadow(6%)	0,99	0,99	0,99
4.Agricultural terrace (1,4%)	0,99	0,99	0,99
5.Flood-lands of lake (0,82%)	1	0,99	0,99
6.Biota of bottom sediments (1,16%)	0,95	0,75	0,5
General reliability of ecosystem	0,87	0,49	0,165

It was recognized that, even for low values of the stock (10 Ci/km^2), reliability of the ecosystem is essentially reduced. For high values of the radionuclide stocks, there is the drastic decrease of the ecosystems reliability.

3. Application of GIS-technology to analysis of radiocapacity of real landscape ecosystems

The results of the analysis show that the rate of movement of radionuclides within the landscape is mainly defined by the extent of steepness of the slope (P_1), the type of cover of the slope (P_2), the type of dismemberment of the landscape (P_3) and the rates of vertical (P4) and horizontal (P5) migration of the radionuclide. The analytical procedure is based on the rank analysis of probabilities of the impacts of these parameters of the landscape on the radionuclide redistribution. Each of these parameters has been estimated to range from 0 to 1. To a good approximation, the landscape parameters are considered to be independent from each other and the general assessment of the probability of the radionuclide migration among the elements of the landscape is obtained as the curtailed probability by the formula $P = P1 \times P2 \times P3 \times P4 \times P5$. With the analytical GIS and the radiocapacity models, it has been possible to estimate and predict the dynamics of redistribution of pollutants within the real landscapes, like polygon "LESNIKI" near Kiev (*Kutlakhmedov 2006*).

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