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# Radiation Risk Estimates in Normal and Emergency Situations

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# N.V. TIMOFEEFF-RESSOVSKY'S VIEWS AS THE BASIS OF RADIOECOLOGICAL STUDIES

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**Abstract.** Theoretical fundamental and methodological approach to the investigations of the radionuclide behaviour in biogeocenosis was made by the outstanding researcher N.V. Timofeeff-Ressovsky. He performed and supervised the first investigations of the radionuclide behaviour into the simple links as soil-solution, soil-plant, water-hydrobionts. Later his students and adherents started a new trend in radioecology, studying the radionuclide migration and biological effects on natural ecosystems of land and internal reservoirs. N.V. Timofeeff-Ressovsky's views and ideas are corresponded with theory of the sick plates of the Planet which is being elaborated as a part and parcel of the contemporary ecological doctrine of Russia.

**Keywords:** radionuclides, biogeocenosis, radioecology, ecosystem

In our country history of radioecology is closely connected with general history of natural science. Ideas of V.I. Vernadsky about living substance and biosphere of the Earth made a valuable contribution to development of this science. V.N. Sukachev brilliantly developed the concept of organization of biosphere. As for evaluation of the results on geochemical activity of living organisms, it became a constituent part of the doctrine on biochemistry and geochemistry of landscapes. Genetic soil science developed by V.V. Dokuchaev formed the basis for these scientific concepts. V.V. Dokuchaev paid special attention to natural and historical origin of soil. Among all factors contributing to soil origin he especially noted time factor, which plays an important role in creation of unique body of nature.



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*Radiation Risk Estimates in Normal and Emergency Situations,* 27–34.

N.V. Timofeeff-Ressovsky synthesized and summed up the achievements of the Dokuchaev school. He was the first who marked similar approach of the above naturalists in understanding nature and problems of general science. It is these natural and historical, and biosphere approaches that formed in mid - 1950s the basis for a new scientific discipline, i.e.: radiation biogeocenology later called radioecology. It was dictated by constantly increasing amount of natural and artificial radionuclides in biosphere of the Earth, which were released during large-scale nuclear weapon tests, and developing nuclear industry and power engineering. Since then the world scientific community had to recognize a new global ecological factor, i.e.: man-caused radionuclides and the related ionizing radiation. Evolution in understanding the radiation factor involved a number of sciences, a viz.: ecology, agrochemistry, geochemistry, hydrobiology, and nuclear physics. "Such method of formation of new scientific disciplines as noted by Aleksahin (2000), could lead to heterosis: a qualitatively new discipline appears due to fruitful interaction between different scientific disciplines". As a rule, to develop a new scientific discipline requires activity of "creative personalities", whose ideas form the basis for future study. Actually, two outstanding personalities, N.V. Timofeeff-Ressovsky and V.M. Klechkovsky, were founders of radioecology. Symbolically, both of them, being contemporaries of the century, in 40-50s founded new scientific schools at the Urals, which is the birthplace of home nuclear project. To treat both of them with due respect, today we dwell upon N.V. Timofeeff-Ressovsky.

After World War II Nikolai Timofeeff-Ressovsky, being a prisoner, who passed Butyrka and Karlag, run a Department in one of the "closed" cities in South Urals. In 1955 together with a group of collaborators he was deported to Institute of Biology (presently Institute of Plant and Animal Ecology, Ural Division of Russian Academy Science) located in Sverdlovsk city (now Yekaterinburg). Standing at the beginning of creation of nuclear project he noted a very serious problem of a comprehensive study of the matters related to effect of fast development of nuclear industry on biosphere. Being a follower of his promoted predecessors and with account for vast experience accumulated destructive effect of industrial wastes on environment, he stressed (1962) that "any serious problem related to influence of a human being and his activity on environment should be based on Vernadsky doctrine on biosphere as well as on the biogeocenological ideas of Sukachev".

At the first stage a large number of experiments were arrived out under the leadership of N.V. Timofeeff-Ressovsky, who worked excitedly and with great optimism. Radionuclides were treated as "radioactive tracers" to study the behaviour of chemical elements in different components of biosphere, while ionizing radiation as a convenient and easy in dosage

factor to affect organisms and their communities. Accessible investigations in accordance with scientific methodology of the author were performed with a wide range of radionuclides on such simplified systems as solution-soil-solution, water– bottom sediments, and water- hydrobionts. Investigation of these simple systems was started from the study of cause-and-effect relation. There is few number of cause-and-effect relations in a simple system. Besides, they are well-defined and more easy to study. Investigation results allowed Timofeeff-Ressovsky et.al. (1966) to classify radionuclides according to their behaviour in a primary ecological links and to find out common factors and mechanisms responsible for their capacity to migrate in them.

On the basis of biogeocenological studies of water reservoirs Timofeeff-Ressovsky (1962) made the following conclusion: “In water reservoirs, as distinct from soil with important role of soil formation and relation between soils and drainage, element concentration in bottom sediment is of special importance. It depends on flow conditions, climate, biological productivity and composition of biocenoses in water reservoir”. This thesis was supported by a number of studies, in which general distribution of radionuclides over main reservoir components (i.e.: water, bottom sediments, and biomass) and accumulation of various radioactive elements by freshwater animals and plants as well as decrease in radiation of water passing through low-running reservoirs was discussed in detail. It is to be noted that E. Timofeeffa-Ressovskaya (1963) was the key person in these studies. It is worth mentioning that these studies were of acute importance because of the practical matters related to purification of water from radioactive contaminations. Generally the first-stage phenomenological studies in hydrobiology outlined the program in radioecology of freshwater reservoirs further successfully developed by the followers and students of Timofeeff-Ressovsky.

At the first stage studies special attention was paid to ability of living organisms to accumulate radionuclides. To qualitatively estimate and compare accumulative ability of organisms a formal criterion- accumulation coefficient- was used. This coefficient shows the ratio between concentration of the given radionuclide in organism and environment under equilibrium condition. It was shown that the accumulation limits are very wide for different types of radionuclides and elements. Those with the highest accumulative factors were named specific accumulators. To determine these accumulators the following criterion was proposed: more than a 4 $\sigma$ deviation from the average value for the corresponding variational series. To define “concentrators” of radionuclides special attention was paid to organisms-pioneers that form residual soil and initial soil, i.e. bacteria, fungi and lichens. Later these organisms, “specific accumulators” of this or that radionuclide, were used as bioindicators of

radioactive contamination of natural ecosystems. Later owing to these studies a specific scientific branch appeared, a viz.: lichen- and brio-indication of environment, one of the tasks of which was to trace the status of natural ecosystems in highly man-caused zones. The advantage of such a monitoring is as follows: high concentration ability and sensitivity of living organisms to pollutions allow to exclude labor-intensive analysis of the ecosystem components with low concentration of pollutants.

On top of this, in 50-60s of the previous century a numerous experiments on comparative radiosensitivity for more than 100 types of plants were performed by Timofeeff-Ressovsky and Poryadkova (1956) and Timofeeff-Ressovsky (1957). The obtained data supported stimulation effect of radiation on growth and evolution of plants. First attempt was made to explain this phenomenon. Experiments on artificial communities of terrestrial plants and fresh water periphiton showed that a comparatively low radiation doses result in negligible stimulation of the communities, without definite transformation. Alternatively, high radiation doses result in deep damage of composition and structure of the communities.

Timofeeff-Ressovsky (1962) analyzed huge analytical material obtained and presented it as thesis for his Doctor's degree. This thesis contains quintessence of the author's views on the novel field of knowledge, its general basis, and enumeration of problems, which are still of acute importance. They are as follows:

− migration mechanisms, distribution and biological effect of radioactive elements in various biogeocenoses (ecosystems);

− scientific prognosis on the consequences of radioactive pollutions of biosphere;

− ecological regulation of these pollutions in nature components and means of weakening their harmful effect.

In Autumn 1957, 74 PBq were polluted into atmosphere as a result of the accident at "Mayak" plant, later called Kyshtym accident. As a result of the Kyshtym accident a trace of radioactive contamination was left over the territory of 23,000 sq. km. This territory was called the East-Ural Radioactive Trace (EURT), which became a unique testing area for radio- ecological studies. With this aim in 1958 upon supervision by V.M. Klechkovsky was arranged Experimental scientific-research laboratory at "Mayak" plant. He was a scientific leader and coordinator of all studies done at this laboratory under strict secrecy. As a result, in 1974 V.M. Klechkovsky together with a group of scientists involved in radioecological studies was awarded the State Prize.

Unfortunately, Timofeev-Ressovsky was not allowed to guide studies of the accident consequences in 1957. He was pushed aside and deeply disappointed. But he continued the so-called "open" studies on this theme with all his enthusiasm and energy at the biological station "Miassovo" and

in the Institute of Biology that belonged to the Ural Division of the Academy of Sciences USSR (Sverdlovsk). Even then he foresaw the possibility of global contamination of environment and in this connection he stressed the following acute problems:

– to trace the behaviour of radionuclides in various biogeocenoses, a viz.: routes and scale of migration from contamination centers;
– to study effect of ionizing radiation on living organisms;
– to develop measures to fight harmful radioactive pollutions.

At the same time Timofeeff-Ressovsky (1962) noted that «the problem of biosphere protection as well as all the problems connected with development of conservancy measures belong to a problem of biogeocenology. And to solve this problem one should introduce the present-day ideas on biosphere of the Earth and biogeochemical processes, especially to technicians."

The huge biogeochemical circulation of substances including radionuclides is caused by interaction of living organisms and inert components of the medium as well as by interaction between living communities and more or less independent objects of the nature. According to the concept of life organizational levels Timofeeff-Ressovsky and Tyuryukanov (1966), suggested that biogeocenoses, i.e. elementary links of current biosphere, belong to such objects. Biogeocenotic level of life being determined, Timofeeff-Ressovsky together with his students made qualitative estimation of radionuclides distribution over components of natural biogeocenoses. Even then he marked the role of forest litter, aboveground mass and root system of plants as well as physical and chemical peculiarities of radionuclides in their behaviour in biogeocenoses. Timofeeff-Ressovsky was keen on quantitative studies that finally led him to mathematical simulation of radiation-induced ecological processes. Thus, the problem to mitigate effect of contaminated biogeocenoses on a human being was set and successfully solved by changing its structure. Later the models obtained were used for agricultural radioecology as well as to characterize global processes in atmosphere induced by nuclear explosion.

Large-scale tests of nuclear weapon performed in 60s of the previous century resulted in global radioactive contamination of terrestrial and water ecosystem components. To study natural systems along with reduction-analytical principle, systems approach was widely used. Systems approach is based on the idea that all objects, though being independent, interact between each other. This interaction may occur, for instance, via geochemical flow of substances. Proceeding from this point of view Timofeev-Ressovsky treated migration of substances in a biogeocenoses chain as a series of conjugate processes of dissipation and concentration of substances in organisms, soil, water, bottom, and atmosphere. Later this

became the ground to develop methods and principles for radioecological and geochemical studies of landscapes. They consist in the following: one determines certain objects of landscape (e.g. watershed, slopes, river flood plains, swamped low lands) located at contiguous by flow off areas to study routes and migration rates of chemical elements and radionuclides. With this method first data about contamination rate of soil - vegetative cover within the former USSR were obtained by Tyuryukanova (1968); Pavlotskay (1974), Aleksahin and Naryshkin (1977). On top of this, the distribution zone and zones of secondary accumulation of radionuclides in natural conditions were found; and dependence of radionuclide migration rate and their occurrence in a human body via digestive chains on local ecological conditions was evaluated by Rassel (1971); Tyuryukanova (1974); Moiseev and Ramzaev (1975). Technique to study freshwater ecosystems was developed and distribution of radionuclides over basic components was calculated by Trapeznikov and Trapeznikova (1979); Kulikov and Chebotina (1988); Chebotina et al. (1992).

The accumulated data on peculiar behavior of radionuclides depending on habitat of living organisms resulted in differentiation within radioecology and appearance of a number of independent scientific branches, such as: agricultural, forest, freshwater and marine radioecology, each branch with its separate specific problems. In 70s on the basis of Timofeeff-Ressovsky studies and vast accumulated experimental data a concept of continental radioecology was formulated with the aim to study terrestrial ecosystems and internal water reservoirs. At the same time it was underlined by Kulikov and Molchanova (1975) that natural environment cannot be considered as passive diluent of radioactive contaminants. In some links of ecosystem radionuclide concentration may be fairly high. Thus, hydrobiontes and lowest-order plants accumulate such amounts of radionuclides that are by orders higher than in environment.

Actually, the so-called “closed” results on contaminated territories in the Urals received publicity only after Chernobyl accident. “State Program of Russian Federation on Radiation Rehabilitation of the Ural Region” has been developed, in which one of the authors of this report (A. Trapeznikov) took part. Within this Program large-scale radioecological investigations have been started in Sverdlovsk, Chelyabinsk, and Kurgan regions. Researchers from Department of Continental Radioecology, the successor of Timifeeff-Ressovsky laboratory, also took an active part in these studies. Thus, with mathematical models concentration and integral reserves of radionuclides in terrestrial ecosystems and freshwater reservoirs, being under radioactive contamination, were verified and estimated. Of special importance are investigation results on transcontinental transfer of radionuclides in flood plain - river systems of Ob - Irtysh’ basin executed by Trapeznikov et al. (1993; 2005a; 2005b).

Global character of Chernobyl accident put forward the problem at which Timofeeff-Resovsky had concentrated his scientific attention for the whole of his life, and that is the problem called “Biosphere and Humanity”. Timofeeff-Ressovsky made a great contribution to world science by formulating and investigating this problem and hence, took a well-deserved place among outstanding Russian naturalistic scientists. Nowadays mankind has to account for the parameters responsible for stability of biosphere under increasing man-caused conditions. Thus, Ecological Doctrine of Russia aimed at support of biosphere stability includes as noted Chereshnev (2002), “a conception about the necessity not only to know all the hot points of the Planet, but to elaborate international transregional collaboration strategy for protection”.

N.V. Timofeev-Ressovsky was creating radiation biogeocenology as the science about regularities of radionuclide behaviour in biosphere. Hence, the problems of radioecology fall under the formulated global problem “Biosphere and Humanity”. And its priority (i.e. biospheric imperative of human behavior) is the main scientific testament left for us by the outstanding scientist.

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