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TRITIUM AND ITS PLACE IN THE OVERALL RADIATION UKRAINE TECHNOGENESIS

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Abstract. The problem of migration accumulation of tritium, as one of the radionuclides with low radiation doses, is of great value for Ukraine in our time. The current state analysis of the tritium migration accumulation in the components of eco – and bio-systems taking into account its biological effect on living organisms is the aim of the study. The paper presents a general model of ecological system state changes under the influence of tritium migration flows.

Key words: tritium, pollution sources, biological aspects, model

1. Inroduction

The study of environmental aspects of migration accumulation of radionuclides with low radiation doses is of special value for Ukraine, as for the territory with tense radiation technogenesis. One of the most biologically hazardous radionuclides in its effect on the living organisms is tritium. Tritium is a radioactive isotope of hydrogen (heavy hydrogen), denoted by the symbols T and ^{3}H, with a half-life (12,32 ± 0,02) years. Rapidly oxidized, forming tritium water HTO that tastes and smells like ordinary water, but is a very chemically active substance. Tritium is a very dangerous radionuclide in terms of its impact on environmental and biological systems and, ultimately, on humans.

2. Problem formulation

During the 1960s – the 1990s scientific literature [1–6] fairly paid much attention to the results of the research on the action of technogenic tritium on the components of the environment and biological systems. Nowadays the study of migration accumulation of technogenic tritium in the environment has become topical again because of the energy needs of mankind, leading to the expansion of nuclear power. This necessitates the analysis of the current state of radioactive contamination and the place of technogenic tritium in it.

Technogenic tritium that enters the environment comes in the links of ecological system in several ways. The amount of tritium, which enters the environment, is the main factor determining the activity of radionuclide in the ecological system links. The concentration of tritium in any link of the ecological system as a whole meets its concentration in water.

Tritium is effectively included in the biological tissue and is a mutagenic disorders potential source due to radiation of the average energy (5,8 keV) and due to molecular bonds expense, caused by a change of hydrogen (H) isotope by a neutral body (He) which was formed as a result of T β-decay.

As shown by the experiments on different animal species [1], even after a single submission of oxide tritium, the normal functioning of the body is disrupted, early significant violation of immune reactivity is caused, diffuse circulation disorders such as hemorrhage, disorders of normal tone of vessels, perivascular outflows with degeneration of cellular elements of the body and other violations develop.

Tritium can enter the living organisms in several ways. The first way is orally administered, with food and water. The process of water suction occurs in the intestine where this process takes place at high speed. Tritium is determined in venous blood after 2–9 minutes after swallowing HTO. After that the contents of tritium in venous blood increases linearly in time. The second way of tritium flow to the body is breathing. The experiments on animals showed that during the inhalation of the air, containing tritium oxide, from 85 to 100 % of HTO is sucked in the lungs. When calculating the maximum permissible levels of HTO in the air, it is accepted, that during a regular respiratory cycle, 100 % of tritium oxide is absorbed in the lungs [1].

Over the past decades, the most powerful incident technogenic tritium pollution occurred due to the accidents at nuclear power plants.

The abundance of tritium has escaped into the atmosphere in 1986 during the Chornobyl nuclear power plant (CNPP) disaster. The nature of the radionuclides scattering was determined by lots of factors: weather conditions, time of emission, temperature of radioactive cloud and others. Tritium contamination occurred both locally and globally. For example, to illustrate the globality of environmental pollution by technogenic tritium process, we can cite the observations, which were held in 1986 in Austria, where the concentration of tritium in precipitation relative to level 20–30 TE observed during winter and early spring of 1986, came to the level of more than 100 TE in the late April of that year [5, 6].

The areas adjacent to the Chornobyl NPP were subjected to tritium contamination most of all. Unfortunately assessment of the total amount of tritium, which got into the biosphere during the Chornobyl disaster, as well as calculation of radiation doses of this isotope, are unknown, but a significant increase of tritium in surface and ground waters, both in the areas surrounding Chornobyl, where its concentration was 400 Bq per liter, and at a considerable distance from the CNPP, show significant contamination of environment component by this isotope.

The concentrations of tritium in natural waters within the boundaries of the 30 km zone after the Chornobyl accident can be regarded as a superposition of global nature factors, native activity of Chornobyl in pre accident period and the release during the accident with the dominance of the role of the latter factor. In the hydrogeological cycle, a major source of global tritium pollution is the atmosphere. Precipitation forms isotope composition of rivers, lakes, groundwater and interstratal waters, seas and oceans. Deep groundwater and perennial glaciers serve as a global reservoir for runoff, where the radioactive tritium decays. The concentration of tritium in surface waters is close to its concentration in precipitation (in the absence of other sources of pollution) [7, 8].

In 2011 there was a strong accident at Japanese nuclear power plant “Fukushima-1”, provoked by the earthquake and tsunami. This caused a meltdown of the reactor core at blocks 1,2 and 3. As a result there was contamination of surrounding areas by radionuclides and transboundary migration of tritium, both by air and by water, almost around the globe. In the summer of 2013 the level of tritium in the waters adjacent to the NPP (within 25 m) increased almost 10 times, and 17 times in groundwater. In September 2015 the work on ocean dumping of 850 tons of liquid, free from radioactive substances was performed. But the level of tritium was 600 Bq/l. Permanent discharges of tritium water to the ocean resulted in its getting into biological objects (ocean fish, marine animals and plants). This caused the transition of tritium by food chain to human body [9, 10].

Nuclear power engineering, even in its regular work, is traditionally considered to be one of the constant sources of technogenic tritium that enters the environment. The content of tritium in liquid discharges during the regular operation of nuclear power plant far exceeds the absolute value of the contents of all other radionuclides, and in gaseous emissions to the environment it is the second after the amount of inert radioactive gases. Due to the chemical equivalence to ordinary hydrogen tritium in the form of HTO accumulates in NPP technological waters and enters the reservoir-cooler and then the nearby ponds, groundwater, surface layer of the atmosphere. In Ukraine there are four nuclear power plants, which have 15 blocks with VVER-type reactors that are the most powerful sources of technogenic tritium, compared with other types of reactors. VVER-type reactors emit tritium into the atmosphere and hydrosphere to 33 GBq / MW (e) / a year. [11–13].

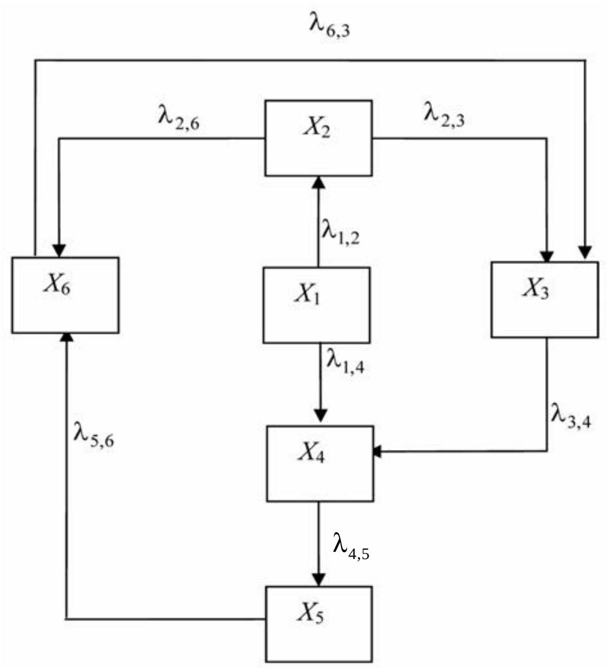
The most powerful technogenic pollution sources are the plants for processing spent nuclear fuel. Until recently, Ukraine had no such plants, but if, as planned, the following sources of technogenesis are built, it will have bad influence on the general state of environmental situation and genetics of the future generations of Ukrainian population.

For many years the study of migration of tritium in the environment did not take into account the impact of radioactive waste disposal points (RWDP) including tritium solid waste (TSW). As tritium pollution sources, they were considered only in recent decades, due to emergency incidents at RWDP in Kharkiv and Pirogovo near Kyiv.

The experience of operation of tritium-containing waste disposal points shows that it is impossible to completely locate the waste in conventional ground vaults. Every year RWDPs become a constant source of tritium supply in the environment components. Thus, depending on the geological structure of the underground system of species, watersheds and specific water horizons, tritium can contaminate even deeper aquifers [14–16].

Since there is no relevant technical solution for the localization of tritium-containing wastes and the existing surface storages are not able to completely prevent the release of hazardous radionuclides into the environment, they become permanent sources of technogenic tritium, which determines not only local, but global pollution of the biosphere. In addition, considering the significant contribution of NPP into the nuclear energy of Ukraine and that the increase of a number of VVER-type reactors at existing nuclear power plants is planned, it can be argued that the amount of technogenic tritium in water resources and soil of Ukraine will grow.

For the study, analysis and forecast of migration processes in ecosystems it is proposed to apply the following approach. Let's consider migration scheme of tritium movement, which corresponds to the iconographic model (see. Figure). A generalized model of appropriate changes in ecosystem conditions is built on its basis. The process of changing conditions of ecological systems under the influence of technogenic load of the migration flows of tritium in the environment links is a stochastic process that can be represented as a Markov's process. Stochasticity in considering this process arises due to the presence of uncertainties caused by the lack of information about the process in real natural conditions and its insufficient study.



Migration of tritium in the components of the environment

Where $\lambda_{i,j}$ – density of the flow of events that transform the system from state *i* into state *j*; X_i – those states which can be (in our case, these states are characterized by the relevant components of the environment, in which tritium was, respectively: X_1 – tritium pollution source; X_2 – tritium in the air; X_3 – tritium in soil; X_4 – tritium in the area aeration; X_5 – tritium in groundwater; X_6 – tritium in surface waters).

Migration flows can be considered as some stationary flows of events, whose impact on corresponding environment component transforms the entire system into another state. Then a generalized model of ecological system state changes under the influence of migration flows of tritium can be represented as a system of Kolmogorov-Chapman equations (1) corresponding to the ecosystem graph of states (topological model) (Figure).

$$\begin{cases} \frac{dp_1(t)}{dt} = -(\lambda_{1,2}+\lambda_{1,4})\,p_1(t); \\ \frac{dp_2(t)}{dt} = \lambda_{1,2}p_1(t) - (\lambda_{2,3}+\lambda_{2,6})\,p_2(t); \\ \frac{dp_3(t)}{dt} = \lambda_{2,3}p_2(t) + \lambda_{6,3}p_6(t) - \lambda_{3,4}p_3(t); \\ \frac{dp_4(t)}{dt} = \lambda_{1,4}p_1(t) + \lambda_{3,4}p_3(t) - \lambda_{4,5}p_4(t); \\ \frac{dp_5(t)}{dt} = \lambda_{4,5}p_4(t) - \lambda_{5,6}p_5(t); \\ \frac{dp_6(t)}{dt} = \lambda_{5,6}p_5(t) + \lambda_{2,6}p_2(t) - \lambda_{6,3}p_6(t); \end{cases} \quad (1)$$

$$\sum_{i=1}^{6} p_i = 1,$$

where $p_i(t)$ – the probability that at time *t* the system is in a state X_i.

The initial conditions for differential equations system (1) integration reflect the state of the system at the time before tritium contamination.

In our case the event is defined by tritium activity in migration flow at some point of time. The density (intensity) of events flow is the average number of events that occur one after another at random times.

If, for example, the system at $t = 0$ was in some state X_k, we suggest that $p_k(0) = 1$,, $p_i(0) = 0$, with $i \neq k$. Note that the limit mode for the system is a random process that is installed in the system at $t \to \infty$. If we assume that the number of states of the system includes at least one critical state of the ecosystem (state without output), then at $t \to \infty$ system with practical reliability certainty will be in it.

If all the streams of events that transform the system from state to state are stationary (λ_{ij} = const), and the total number of states is finite, and no states without output, then there is a limit mode characterized by limiting state probabilities $p_1, p_2, ..., p_N$, and $(\sum_{j=1}^{N} p_j = 1)$.

The resulting model allows an approximate estimation of the ecological system states changes, according to the observations of the monitoring system on the migration routes of tritium in the components of the environment.

3. Conclusions

1. The basic sources of technogenic tritium in the environment were analyzed.

2. The data on migration accumulation of tritium in biological systems, described in the literature, were researched and analyzed.

3. A generalized model of ecological system state changes under the influence of migration flows of tritium was synthesized.

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