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BIOACCUMULATION OF TRITIUM IN NATURAL AND TECHNOLOGICAL SYSTEMS

The distribution of tritium in the soil-vegetation complex was studied on a series of combined samples taken in the area of the radioactive waste storage facility (RWSF). It is shown that bioaccumulation of tritium by vegetation is determined mainly by the position of each specific object (testing point) in relation to the predominant direction of atmospheric transport of the nuclide. In locally selected samples of herbaceous and arboreal vegetation, the content of the nuclide changes according with a high degree of correlation, and its distribution in fractions of freely migrating (transpirational) tritiated water (TW) and in the form of organically bound tritium (OBT) also changes according with a high degree of correlation. In the zones of intense and persistent atmospheric migration tritium forms radiogeochemical anomalies in the soil and vegetation. Under the conditions of stationary atmospheric migration flows, pseudo-equilibrium ratios of nuclide concentration in the components of the soil-vegetation system are established, while under the conditions of the functioning of short-term soil flows, the concentration equilibrium of the nuclide in the components of the soil-vegetation system is not observed. Higher concentrations of tritium are observed in more tightly bound forms in both soil and vegetation, which obviously reflects a large dynamic dependence of the mobile form on weather and climate conditions. The ratios of activity concentration of tritium in different forms of presence determined for different types of vegetation as concentration ratio (CR) indicate that tritium accumulates more effectively in arboreal plants - bushes, trees than in herbaceous ones (grass), it is equal to 1.10 and 1.20, respectively. Freely migrating (transpirational) tritiated water possibly due to greater mobility and greater dependence on changes in the activity concentration of tritium in the atmospheric plume and moisture saturation of the air, has a lower activity concentration of tritium than the organically fixed form (OBT), respectively 1.14 and 1.29, which does not have such temporal dependence. During the emission of tritium from RWSF there was a significant accumulation of the heavy isotope of hydrogen in an organically bound form, that is more than half of the tritium absorbed by vegetation is retained during the existence of organic matter and is temporally excluded from the biological cycle in the case of arboreal vegetation. In conditions of the forest landscape of the sanitary protection zone (SPZ) of the RWSF, root absorption of tritium by grass from the humus layer is from 20 to 31% of its total amount accumulated in the soil. The degree of absorption of tritium from the soil is almost the same in herbaceous and arboreal vegetation. This indicates that during the long-term existence of the atmospheric-radio-geochemical anomaly caused by the constant emission of tritium from the storage of RW in organic matter, an equilibrium balance of the content of transpirational HTO and OBT has been formed. In turn, the establishment of such a balance in plant matter can be used as an indicator of a prolonged regime of tritium emission from RWSF. Herbaceous and arboreal vegetation make it possible to determine the spatial position of atmogeomigratory paths of tritium distribution. Plant indicators indirectly reflect the impact of this migration flow on the direct absorption of tritium by organic matter from the air, or its absorption from the root layer of the soil, where the heavy isotope of hydrogen enters with atmospheric precipitation.

Key words: *tritium, isotopes, bioaccumulation, radioactive waste, tritiated water, fractionation.*

Introduction. Existing environmental protection technologies take into account the possibility of diluting atmospheric emissions and liquid discharges to acceptable levels of tritium concentration in the components of natural and man-made biogeosystems. Numerous studies in the zones of influence around nuclear facilities establish the accumulation of tritium in biosystems and especially in phytocenoses. Vegetation occupying large territories and forming significant plant biomass is able to accumulate a large amount of tritium with fixation in plant organic matter. Thus, in aquatic plants near the areas of underground nuclear weapons tests in the USA, a higher content of ^{3}H was found in the total organic complex of these plants than in ambient water [3].

The ratio of tritium concentration between abiotic and biotic components of the landscape is determined by the mechanisms of hydrogen distribution between different forms of presence in the biosphere. More than 90% of hydrogen incorporated in living matter is assimilated mainly by plants. Part of the tritium in vegetation in the form of HTO forms free (transit or transpiration) water (TW), and the other part is incorporated into biological structures in the form of organically bound tritium (OBT). The transit form of tritium accounts for approximately 80% of the raw mass of the plants and, as a rule, after the level of feeding activity, it approaches the external water that comes into contact with the plants. The other 20% determine the OBT or HT incorporated into biological structures. With chronic

absorption of ^{3}H by vegetation, the specific activity of tritium in the composition of free water and OBT increases over time until reaching an equilibrium state in the biogeosystem [2].

The analysis of the results of monitoring observations carried out within the limits of the radioactive waste storage facility of the State Interregional Special Combine (SISC) of the UkrSA "Radon" testified that the possible ways of tritium migration from RWSF the convective-diffusion exit of the gas-aerosol mixture through the overlap of the storage facilities into the atmosphere and infiltration through violation of the integrity of the walls and bottom into the geological environment. As a result of the first migration flow, an atmoradiogeochemical anomaly is formed, which further spreads according to the regularities of air transport. Its impact on the environment determines the formation of radiobiogeochemical anomalies in vegetation due to the direct absorption of radionuclide by leaves and grass directly from the air, as well as radiogeochemical anomalies in the humus part of the soil due to rain leaching of tritium from the atmosphere.

The long-term existence of an atmogeochemical migration flow determined the coordinated process of tritium accumulation in grass (herbaceous vegetation) and in the leaves of trees and shrubs (arboreal vegetation) in transpirational water and organically bound form. As a result, a biogeochemical anomaly of a heavy hydrogen isotope was formed in herbaceous and arboreal vegetation [1] within the limits of the RWSF industrial site and its sanitary protection zone.

The purpose of the performed research was to determine the effectiveness of tritium removal by vegetation from circulation within the limits of the natural and man-made system.

Materials and methods. To determine the effectiveness of tritium removal by vegetation from circulation within the natural and man-made system, the selection of paired samples (Fig. 1) of grass (herbaceous) and leaves of trees and bushes (arboreal) vegetation within the industrial site (observation points 1 PA – 9 PA) and Kyiv SPZ RWSF (observation points 1B – 27B). From the selected biomass

Table 1. Degree of absorption from the atmosphere and fixation of tritium by vegetation. Industrial site and SPZ KRWSF [1]
Таблиця 1. Ступінь поглинання з атмосфери та фіксації тритію рослинністю. Проммайданчик і СЗЗ КПЗРВ [1]

Point of observation	Activity concentration of tritium, Bq·m^{-3}				Concentration ratio (CR)			
	Grass		Leaves		Grass	Leaves	TW	OBT
	TW	OBT	TW	OBT	Kr^3	Kr^4	Kr^5	Kr^6
1 ПА	1250	1740	1040	3090	1,39	2,97	0,83	1,78
2 ПА	1100	1250	1300	1490	1,14	1,15	1,18	1,19
3 ПА	700	720	670	740	1,03	1,10	0,96	1,03
4 ПА	270	330	600	650	1,22	1,08	2,22	1,97
5 ПА	2150	2300	1940	2340	1,07	1,21	0,90	1,02
6 ПА	2010	2900	1800	3140	1,44	1,74	0,90	1,08
7 ПА	1200	1100	910	980	0,92	1,08	0,76	0,89
8 ПА	200	205	240	290	1,03	1,21	1,20	1,41
9 ПА	1300	1320	1150	1290	1,02	1,12	0,88	0,98
1 Б	65	52	73	68	0,80	0,93	1,12	1,31
5 Б	340	490	480	520	1,44	1,08	1,41	1,06
6 Б	1100	1240	970	1750	1,13	1,80	0,88	1,41
7 Б	101	120	107	125	1,19	1,17	1,06	1,04
10 Б	131	156	147	180,9	1,19	1,23	1,12	1,16
11 Б	144	168	174	202	1,17	1,16	1,21	1,20
12 Б	119	161	93	107	1,35	1,15	0,78	0,66
13 Б	64	68	99	92	1,06	0,93	1,54	1,35
15 Б	77	72	64	75	0,94	1,17	0,83	1,04
21 Б			100	130				
25 Б	45	52	50	64				
27 Б	40	44	45	58				
Average					1,14	1,29	1,10	1,20
Cor.(fr)		0,98		0,89				
Cor.(g/l)			0,98	0,95				

Notes: 1) Kr^n – Concentration ratio (CR), n = 3, 4, 5, 6; 2) Correlation coefficients calculated respectively for different moisture fractions (***Cor.(fr)***) in each type of vegetation and (***Cor.(g/l)***) – between grass and tree leaves for each of the fractions.

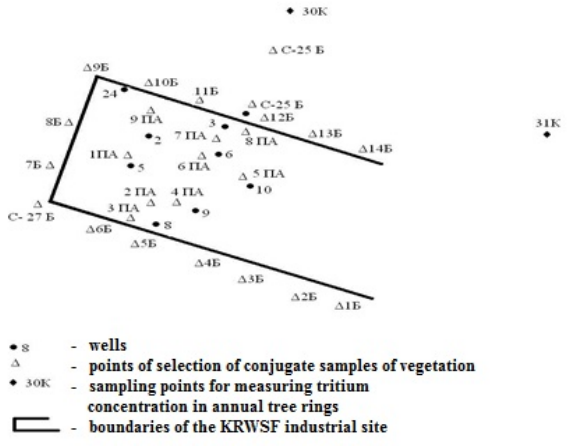


Fig. 1. Location of vegetation sampling points. Kyiv's RWSF (KRWSF)
Рис. 1. Розташування точок відбору проб рослинності. Київський пункт збереження радіоактивних відходів (КПЗРВ).

at temperatures up to 150ºC and 240-650ºC, fractions of HTO corresponding to transpiration water (TW) and organically bound form (OBT) were removed.

The selected samples after cleaning from organic impurities (oxidation with an anhydrous oxidizer) and distillation were mixed with a Hi Sife 3 Wallac scintillator in a ratio of 8:12. The tritium content in the emulsions prepared in this way was measured on a liquid low-background scintillation α-β spectrometer Quantulus 1220 (LKW Wallac) according to the standard method.

Obtained results and their discussion

To assess the efficiency of tritium extraction by different types of vegetation (herbaceous or arboreal) and the ratio of the specific activity of tritium in all analyzed forms, proportionality coefficients were calculated according to the formulas:

$$Kr^3 = A_G^{2F} / A_G^{1F} \quad (1)$$

$$Kr^4 = A_L^{2F} / A_L^{1F} \quad (2)$$

$$Kr^5 = A_{1F}^{L} / A_{1F}^{G} \quad (3)$$

$$Kr^6 = A_{2F}^{L} / A_{2F}^{G} \quad (4)$$

where: A_G^{1F}– specific activity of tritium in the 1st fraction of grass, A_G^{2F} – specific activity of tritium in the 2nd fraction of grass, A_L^{1F} – specific activity of tritium in the 1st fraction of leaves, A_L^{2F} – specific activity of tritium in the 2nd fraction of leaves

The ratio of the content of tritium in different forms of presence in vegetation and their indicator capabilities are shown in Figures 2 and 3. The correlation coefficients between the content of tritium in the forms of TW and OBT for grass are equal to 0.98, and for leaves – 0.89 (Table 1).

The ratios of the specific activity of tritium in different forms of presence determined for different types of vegetation as proportionality coefficients (Table 1) show that tritium is more efficiently accumulated by perennial plants - bushes, trees than by grass, respectively $Kr^5 = 1{,}10$, $Kr^6 = 1{,}20$. Freely migrating water, possibly due to greater mobility and greater dependence from changes in the specific activity of tritium in the atmospheric plume and moisture saturation of the air, has a lower specific activity of tritium than organically fixed (respectively, $Kr^3 = 1{,}14$, $Kr^4 = 1{,}29$), which has no such temporal dependence. The obtained calculated values of the proportionality coefficients indicate that during the emission of tritium from RW storage facilities, there was a significant accumulation of the heavy isotope of hydrogen in an organically bound form, that is, more than half of the tritium absorbed by the vegetation is retained during the existence of organic matter and is excluded temporally from the biological cycle.

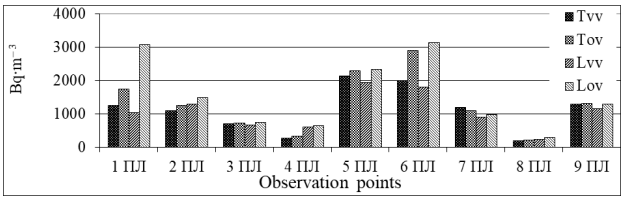


Fig. 2. Ratio of forms of tritium in vegetation. The zone of strict regime of the KRWSF. The location of the monitoring points is shown in Figure 1. **Tvv, Tov** – specific activity of tritium in the TW and OBT of the grass; **Lvv, Lov** – specific activity of tritium in TW and OBT in leaves

Рис. 2. Співвідношення форм знаходження тритію в рослинності. Зона суворого режиму ПЗРВ Київського ПЗРВ. Розташування пунктів спостереження наведено на рисунку 1. **Tvv, Tov** – питома активність тритію у транспіраційній воді (ТВ) і органічно зв'язаній формі (ОЗТ) трави; **Lvv, Lov** – питома активність тритію у ТВ і ОЗТ у листях

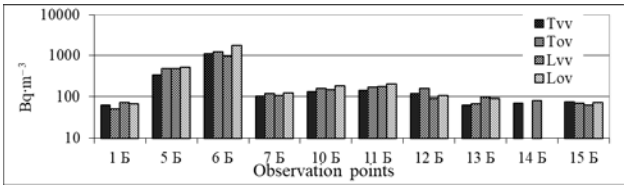


Fig. 3. Ratio of forms of tritium in vegetation. Kyiv SPZ KRWSF (for conventional designations, see Fig. 2)
Рис. 3. Співвідношення форм знаходження тритію у рослинності. Санітарно-захисна зона (СЗЗ) КПЗРВ (умовні позначення див. рис. 2)

Thus, herbaceous and arboreal vegetation allow us to determine the spatial position of the atmogeomigratory paths of tritium distribution. Plant indicators indirectly reflect the effect of such migration flows on the direct absorption of tritium by organic matter from the air, or its absorption from the root layer of the soil, where the heavy isotope of hydrogen enters with atmospheric precipitation.

In the conditions of the forest landscape of the SPZ KRWSF, root absorption of tritium by grass from the humus layer is from 20 to 31% of its amount accumulated in the soil (Tables 2, 3).

Table 2. The degree of root absorption of tritium by herbaceous vegetation from the soil
Таблиця 2. Ступінь кореневого поглинання тритію трав'яною рослинністю з ґрунту

Pit	Activity concentration of tritium, Bq·m^{-3}		Concentration ratio (CR)
	Soil (layer 0–25 cm)	Grass	Grass/Soil (0–25 cm layer)
14	1300	358	0,28
15	917	241	0,26
17	1160	356	0,31
19	1286	311	0,24
Average			0,27

Tritium absorption is more effective from a deeper horizon, where the absorbing part of the plant root system is more developed. Thus, for the 5–25 cm horizon, the proportionality coefficients for herbaceous and arboreal vegetation range from 0.35 to 0.49, i.e. from 35 to 49% of tritium that has entered the soil can be removed by vegetation. At the same time, from 40 to 49% of ^{3}H is fixed in the form of OBT (Table 3).

It should be noted that the degree of absorption of tritium from the soil is almost the same in for herbaceous and arboreal vegetation. This indicates that during the long-term existence of the atmospheric-radio-geochemical anomaly caused by the continuous emission tritium from RAW storages has been accumulated in organic matter, an equilibrium balance of the content of mobile HTO and OBT has been formed. In turn, the establishment of such a balance in plant matter can be used as an indicator of a prolonged regime of tritium emission from RWSF.

Analytical data on the content of tritium in plants make it possible to evaluate the biogeochemical immobilization properties of the phytocenoses. Taking into account the averaged data on the biological productivity of grass and tree leaves, which correspond to the conditions of the location of the SPZ KRWSF, the specific reserves of tritium absorbed by vegetation (Table 4) per unit area were calculated. The calculation was made on the basis of data on

Table 3. The degree of root absorption of tritium by for herbaceous and arboreal vegetation from the soil. SPZ KRWSF
Таблиця 3. Ступінь кореневого поглинання тритію однорічною та багаторічною рослинністю з ґрунту. СЗЗ КПЗРВ

Interval, sm	Activity concentration of tritium, Bq·m^{-3}					Concentration ratio (CR)			
	Soil	Grass		Leaves		Grass/ Soil		Leaves/ Soil	
	1 frac.	TW	OBT	TW	OBT	TW	OBT	TW	OBT
	Well 21								
0–5	849			100	130			0,12	0,15
5–25	283							0,35	0,46
	Well 25								
0–5	230	45	52	50	64	0,20	0,23	0,22	0,28
5–25	130					0,35	0,40	0,38	0,49

Note: 1 fr. – pore water and surface adsorbed water (release temperature 16–120°C).

Table 4. The stock of tritium absorbed by vegetation from a unit area of the earth's surface at the industrial site and in the SPZ KRWSF
Таблиця 4. Запас тритію поглинутий рослинністю з одиничної площі земної поверхні на проммайданчику та в СЗЗ КПЗРВ

Point observations	Tritium stock, Bq·m^{-2}				Point observations	Tritium stock, Bq·m^{-2}			
	TW		OBT			TW		OBT	
	Grass	Leaves	Grass	Leaves		Grass	Leaves	Grass	Leaves
1 ПА	152	201	211	598	1 Б	8	14	6	13
2 ПА	134	252	152	288	5 Б	41	93	60	101
3 ПЛА	85	130	87	143	6 Б	134	188	151	339
4 ПА	33	116	40	126	7 Б	12	21		24
5 ПА	261	375	279	453	10 Б	16	28	19	35
6 ПА	244	348	352	608	11 Б	17	34	20	39
7 ПА	146	176	134	190	12 Б	14	18	20	21
8 ПА	24	46	25	56	13 Б	8	19	8	18
9 ПА	158	223	160	250	14 Б	9	16		
21/Б-1				25	15 Б	9	12	9	15
25/Б-1			6	12					
27/Б-12			5	11					

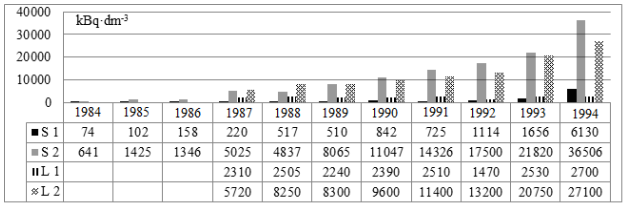
the analyzed weight of plant biomass, the volume of moisture extract obtained from it, the specific activity of tritium in this extract and the average annual productivity of plant biomass per 1 m^2 of area according to the equation (5):

$$Z = A*V*B*P^{-1} \quad (5)$$

where: Z – stock of tritium in biomass, Bq, A – activity concentration of tritium, $Bq \times cm^{-3}$. V – volume of the obtained moisture extract, cm^3, B – average annual productivity of plant biomass, $g \times m^{-2}$, P – weight of the analyzed sample, g.

Annual tree rings are an effective indicator of the dynamics of tritium atmospheric migration flows. Occupying a permanent location for a long time and having a developed root system, trees retain this dynamic in each site. In the studied perennial trees (lindens, o.p. 30k and pines, o.p. 31k, Fig. 1.), the approximate age of which is about 50 years, the well-developed crown probably ensured a very intensive transpiration circulation of moisture through the trunk and leaves.

Pumping significant volumes of soil moisture through the xylem of the trunk leads to a constant supply of HTO from the soil to the organic matter of the trees. At the same time, as a result of the exchange reactions, tritium is immobilized with the TW cells of the plant with the formation of OBT and its accumulation in the wood phytomass with the temporal exclusion of this radioisotop from the migration cycle (Fig. 4).



	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994
S 1	74	102	158	220	517	510	842	725	1114	1656	6130
S 2	641	1425	1346	5025	4837	8065	11047	14326	17500	21820	36506
L 1				2310	2505	2240	2390	2510	1470	2530	2700
L 2				5720	8250	8300	9600	11400	13200	20750	27100

Fig. 4. Tritium deposition in annual tree rings. S1, S2 – TV and OST in pine; Lp1, Lp2 – the same in linden. SPZ KRWSF. From 1984 to 1994 – the formation of the corresponding rings

Рис. 4. Депонування тритію в річних кільцях дерев. S1, S2 – ТВ і ОЗТ в сосні; Lp1, Lp2 – те саме в липі. СЗЗ КПЗРВ. З 1984 по 1994 рік – утворення відповідних кілець

The water absorbed by the plant through the roots is only partially used directly for the phytomass accumulation. The rest of it (99–99.5%) is lost through transpiration, which, by changing the osmotic pressure in the cells, ensures the movement of water from the roots to the shoots. Water absorbed by the roots from the soil with the help of osmosis moves up in the xylem together with substances dissolved in it. The movement of water from the roots to the leaves is partially provided by the capillary effect, but mainly occurs due to decrease of hydrostatic pressure in the upper parts of the plant due to the diffusion of water through the stomata of the leaves into the atmosphere.

Determination of the tritium content in annual tree rings made it possible to establish the spatial distribution of hydrogeochemical anomaly formation in the sediment deposits of the aeration zone of the SPZ KRWSF and the dynamics of its development. Thus, the growth of the tritium hydrogeofiltration flow in the near-surface part of the layer of loess loams and sandy loams from 1987 to 1994, when the trunks were cut, is clearly established.

The degree of absorption of tritium by plant biomass depends on the intensity of its accumulation and is an indicator of its biogeochemical barrier properties. This parameter indirectly takes into account the interaction of various factors, such as the concentration of tritium in atmospheric precipitation and their amount, the degree of accumulation of tritium on the surface of the soil and in its root layer, etc. Given this property of vegetation, migration flows of tritium in the surface air can be recorded using biogeochemical testing. This method has been elaborated in great detail in exploratory geochemistry [4]. With its help, at potentially emergency facilities (such as nuclear weapons testing at the early 1960s), the predominant directions of atmospheric flows along which air migration of tritium can be detected.

At facilities where the concentrated release of tritium into the atmosphere is already taking place, the distribution area of tritium-contaminated vegetation can be established with a reflection on the biogeochemical map with gradations of the nuclide content, and the most dangerous direction of radiation contamination of the territory by air transport can be found. According to the biogeochemical mapping of the territory of the SPZ and taking into account the data on the growth of plant biomass, an estimate can be given of the share of tritium that is removed from the hydrogen cycle, and thus its inclusion to the trophic chains is prevented for a long time in the case of arboreal vegetation.

Conclusions. Man-made tritium entering the biosphere from the facilities of the nuclear fuel complex and radioactive waste storage facilities is included in the natural geochemical processes of dispersion in the air and water environment and immobilization in organic matter and the geological environment.

Bioaccumulation by plant biomass is an important factor in tritium immobilization. During the emission of tritium from the sources of its generation, from 18 to 50% of tritium absorbed by vegetation is retained during the existence of organic matter and is temporally excluded from the biological cycle in the case of arboreal vegetation.

Tritium that has reached the soil, that is, to the upper layers of the lithosphere, is absorbed by vegetation due to root nutrition. Herbaceous and arboreal vegetation can remove up to 40–49% of tritium that has reached the horizon of root nutrition.

Annual tree rings are an effective indicator of the dynamics of tritium atmospheric migration flows. Occupying a permanent location for a long time and having a developed root system, trees record the prolonged dynamics of migration flows of tritium in this particular place. Pumping significant volumes of soil moisture through the xylem of the trunk leads to a constant supply of HTO from the soil to the organic

matter of the trees. The immobilization of tritium from the mobile HTO by plant cells leads to its accumulation in the wood and the exclusion of this hydrogen isotope from the biogeochemical cycle.

Herbaceous and arboreal vegetation make it possible to determine the spatial position of atmogeomigratory paths of tritium distribution. Plant indicators indirectly reflect the effect of such migratory flows on the direct absorption of tritium by organic matter from the air, or its absorption from the root layer of the soil, where the heavy isotope of hydrogen enters with atmospheric precipitation. Tritium emitted into the air is absorbed by herbaceous and arboreal vegetation. At the same time, tritium is taken up by organic biomass in the form of freely migrating water (TW), which largely evaporates back into the air from grass and leaves as a result of transpiration, and in the tightly bound form of plant cellulose. Both the first and second forms remove tritium from the hydrogen cycle, but the first form only for the period of the vegetation process with a partial return to the air due to transpiration and after the fall and subsequent decomposition of leaves and grass. In the second form, tritium is fixed during the existence of plant cellulose. The ratio of weakly and strongly bound forms of tritium in vegetation ranges from **0.8** to **2.97**, on average **1.14** for grass and **1.29** for leaves. At the same time, the correlation coefficients between the content of tritium in different fractions of moisture and in different types of vegetation are equal to **0.89–0.98**.

At sites where, as a result of the concentrated release of tritium into the atmosphere, an area of tritium-contaminated vegetation has already been formed, the display of nuclide content gradations on the biogeochemical map can allow to find the most dangerous direction of air spread of emergency radiation contamination of the adjacent territory.

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БІОАКУМУЛЯЦІЯ ТРИТІЮ У ПРИРОДНО-ТЕХНОГЕННИХ СИСТЕМАХ

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На серіях сполучених проб, відібраних у зоні розміщення пункту зберігання радіоактивних відходів, досліджено характер розподілу тритію в ґрунтово-рослинному комплексі. Показано, що біоакумуляція тритію рослинністю визначається здебільшого позицією кожного конкретного об'єкта (точки опробування) щодо переважного напрямку атмосферного переносу нукліда. У сполучених по місцеві добору пробах однолітньої і багаторічної рослинності вміст нукліда змінюється узгоджено з високим ступенем кореляції, а його розподіл у фракціях вільно мігруючої води й органічно зв'язаній формі також змінюється узгоджено з високим ступенем кореляції. У зонах інтенсивної і стійкої атмогеоміграції тритій формує в ґрунті і рослинності радіогеохімічні аномалії. В умовах стаціонарних атмогеоміграційних потоків установлюються псевдорівноважні співвідношення концентрації нукліда в компонентах ґрунтово-рослинної системи, а в умовах функціонування короткочасних ґрунтових потоків концентраційної рівноваги нукліда в компонентах ґрунтово-рослинної системи не спостерігається. У більш міцно зв'язаних формах і в ґрунті, і в рослинності відзначаються більш високі концентрації тритію, що, очевидно, відображає велику динамічну залежність рухливої форми від погодно-кліматичних умов. Співвідношення питомої активності тритію у різних формах знаходження, визначені для різних типів рослинності як коефіцієнти пропорційності, свідчать про те, що більш ефективно тритій накопичують багаторічні рослини – кущі, дерева, ніж однорічні (трава), його кількість становить 1,10 і 1,20 відповідно. Вільно мігруюча (транспіраційна) тритійована вода (НТО), можливо, внаслідок більшої мобільності і більшої залежності від змін питомої активності тритію в атмосферному шлейфі і насиченості вологою повітря, має меншу питому активність тритію, ніж органічно фіксована форма (ОЗТ), відповідно 1,14 і 1,29, яка не має такої темпоральної залежності. За час емісії тритію зі сховищ РАВ відбулося суттєве накопичення важкого ізотопу водню в органічно зв'язаній формі, тобто більше половини поглинутого рослинністю тритію затримується на час існування органічної речовини і надійно виключається з біологічного кругообігу. В умовах лісового ландшафту санітарно-захісної зони пункту збереження РАВ кореневе поглинання тритію травою з гумусованого шару становить від 20 до 31 % від його кількості, накопиченій у ґрунті. Ступінь поглинання тритію з ґрунту майже не відрізняється в однорічної і багаторічної рослинності. Це свідчить, що за довготривалий час існування атморадіогеохімічної аномалії, обумовленої постійною емісією тритію зі сховищ РАВ, в органічній речовині утворився рівноважний баланс вмісту транспіраційної НТО і ОЗТ. Зі свого боку, встановлення в рослинній речовині такого балансу може використовуватися як індикатор пролонгованого режиму емісії тритію зі сховищ РАВ. Однорічна і багаторічна рослинність дають змогу визначати просторове положення атмогеоміграційних шляхів розповсюдження тритію. Рослинні індикатори опосередковано відображають вплив цього міграційного потоку на пряме поглинання тритію органічною речовиною з повітря або ж всмоктування його з кореневого шару ґрунту, куди важкий ізотоп водню надходить з атмосферними опадами.

Ключові слова: *тритій, ізотопи, біоакумуляція, радіоактивні відходи, тритійована вода, фракціонування.*