SCIENTIFIC HORIZONS

Journal homepage: https://sciencehorizon.com.ua

Scientific Horizons, 25(1), 68-75

UDC 546.36/027*137:582.912.46:504.456(477.1-924.82/.84)

DOI: 10.48077/scihor.25(1).2022.68-75

Dynamics of ^{137}Cs Accumulation by Cranberry on Sphagnum Bogs of Polissia of Ukraine

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Article's History:
Received: 16.02.2022
Revised: 18.03.2022
Accepted: 20.04.2022

Suggested Citation:
Krasnov, V., Ivaniuk, I., Zhukovskyi, O., Kurbet, T., & Orlov, O. (2022). Dynamics of ^{137}Cs accumulation by cranberry on sphagnum bogs of Polissia of Ukraine. *Scientific Horizons*, 25(1), 68-75.

Abstract. Oligotrophic and mesotrophic bogs are common ecosystems in Polissia of Ukraine. After the Chernobyl accident, these ecosystems were contaminated with radionuclides. A common berry plant in these bogs is the cranberry, which is widely used in food industry. The aim of research is to establish dynamics of migration of ^{137}Cs in cranberries during the last 30 years. The obtained results of monitoring studies are necessary for prognosis of radioactive contamination of cranberry. Investigation was conducted on stationary experimental plots (SEP) in Zhytomyr Polissia. ^{137}Cs specific activity was measured on spectrum analyzers with scintillation and semiconductor detectors. Obtained results testify about intensive ^{137}Cs migration on sphagnum bogs of Polissya of Ukraine. Results of investigation conducted after 34 years of Chornobyl accident showed low values of ^{137}Cs specific activity in cranberry (*Vaccinium oxycoccus* L.) on all stationary experimental plots. This index in 2020 in fresh berries hesitate from 871±82.6 to 286±16.9 Bq/kg (at the permissible level 500 Bq/kg), and in dry shoots – from 1492 (SEP 15) to 6197 Bq/kg (SEP 12). It was found that in the first period (1991-1996) rather significant decreasing of ^{137}Cs specific activity was observed in fresh berries of cranberry – from 3.8 times on SEP 11 to 2.2 times on SEP 12. In the next period (1996-2002) this decreasing was in the limits 1.4-2.9 times that is lower than in previous one. In the following period decreasing of ^{137}Cs specific activity in berries was significantly lower. Revealed regularities of decreasing of ^{137}Cs specific activity in berries during 1991-2020 also confirmed by decreasing of this index in the plant shoots. Total decreasing of this index in dry shoots on the whole period of investigation was: on SEP 11 – from 94590±4236 to 6099±366 Bq/kg (15.5 times), on SEP 12 – from 31800±2325 to 6197±242 Bq/kg (5.1 times), on SEP 15 – from 12120±898 to 1492±112 Bq/kg (8.1 times), on SEP 18 – from 14732±1126 to 1854±112 Bq/kg (7.9 times). Continuation of monitoring on stationary experimental plots will allow to predict levels of radioactive contamination of cranberry on the base of mathematical modeling

Keywords: specific activity, radionuclide, *Vaccinium oxycoccus* L., sphagnum, dry shoots, fresh berries

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INTRODUCTION

Features of relief and complex of climatic conditions caused appearance in Polissya of Ukraine of oligotrophic and mesotrophic bogs, which, as is known, are characterized by specific conditions of moistening, flow of geochemical processes, and phytocenotic features. In these conditions, a phytogenic medium is created, in which its leading importance is its edificator– a sphagnum (different species), which has a large hygroscopic capacity. Water, on such bogs, is characterized by excessive acidity, low content of nutrients and oxygen. These circumstances, as well as the absence of bacterial decomposition of organics, lead to significant accumulation and formation of peat. At the same time, the fast-growing bogs play a significant role in maintaining the hydrological regime of the territories, water level in rivers, delay a considerable amount of dust and harmful substances (including radioactive). It's generally accepted that they reduce the amount of carbon dioxide in the atmosphere due to the concentration of a large amount of organics. In view of this, in the middle of the last century, radio-ecologists suggested that swamp ecosystems could play a role in the redistribution of radionuclides in significant areas (Mroz *et al.,* 2017).

After the Chornobyl disaster, researchers began to study the migration of some radioactive elements that came into the environment in different natural and artificial ecosystems and their accumulation in different species of plants that were the most representative or characteristic of the latter. For the study of migration of radionuclides on oligotrophic and mesotrophic bogs such plant sometimes was a cranberry (*Vaccinium oxycocus* L.). Perhaps this was primarily due to the fact that the berries of this plant are widely used in food by locals for their own consumption and for sale. Cranberry is one of the important resource plants of Ukrainian Polissia and requires constant research of levels of radioactive contamination. In addition, it can serve as an indicative view for the sphagnum bogs of this region, as it has specific biological adaption, characterized by plants growing in these ecological conditions (Kaletnik *et al.,* 1990; Krasnov & Orlov, 2004).

The problems of ^{137}Cs biogeochemical migration in the ecosystems of oligotrophic bogs are focused on fragmented studies carried out mainly in the countries of Northern Europe, in particular, Sweden (Galán, 2006; Rosen *et al.,* 2009; Vinichuk *et al.,* 2010) and Finland (Vetikko *et al.,* 2010). In Ukraine, the laws of ^{137}Cs distribution in the systems of sphagnum bogs were studied in Polissia (Orlov & Dolin, 2010; Holovko, 2012; Holovko & Orlov, 2019, Maloshtan *et al.,* 2019). However, in the given publications the results of researches which scientists have received mostly during 1 year, less – 2-3 years are given.

The purpose of the research was to establish modern levels of radioactive contamination of the cranberry and to detect dynamics of ^{137}Cs specific activity in its berries and shoots during the last 30 years.

The scientific novelty of the research is that for the first time established dependence of dynamics of ^{137}Cs specific activity in berries and the shoots of cranberries during 30 years (1991-2020), which can be used for forecasting of their radioactive contamination in the next period.

LITERATURE REVIEW

In different periods since the Chernobyl disaster, researchers have studied the role of various food products in the radiation of the population in different regions of Polissia of Ukraine, including food products of forests (wild plant berries, edible mushrooms). Thus, scientists who carried out complex radiation-hygienic monitoring in some settlements of Rokytne Raion of Rivne Oblast in 2017 confirmed that wild plants of berry plants (including cranberry) continue to make a significant contribution to annual effective doses of radiation exposure to locals (Vasylenko *et al.,* 2018). Similar monitoring studies were conducted on the territory of the SOE "Polissya Forest Management", which is located in the western direction from the Chornobyl NPP (Chobotko *et al.,* 2018). In general, scientists have concluded that food products of forest origin (including wild berries) make a significant contribution to obtaining an additional dose of internal irradiation (Skrkal *et al.,* 2017), which is observed a significant increase in effective doses of internal irradiation during periods of wild berries and appearance of edible mushrooms. The authors of the above publications say about the necessity of continuation of monitoring of the contents of radio-cells in wild berry plants and mushrooms (Andric & Gajic-Kvascev, 2021). Radio-ecologists, who are currently studying the redistribution of radionuclides in the soil of forest-based automorphic and hydromorphic landscapes, confirm the generalization previously made by numerous researchers that in recent landscapes there is a more intensive migration of ^{137}Cs in soil and its inflow to plants (Imamura *et al.,* 2020). The researchers have developed models of migration of this radionuclide in the system "surface of the above-ground phytomass of plants – surface soil" of forest biogeocoenosis (Almahaayni & Houska, 2020).

The researchers determined the contents of some chemical elements and technogenic radionuclides (^{137}Cs) in the cranberries on the sphagnum bogs of Northern Canada (Shotyk *et al.,* 2019), as well as southern Poland (Mroz *et al.,* 2017). The authors of the latest publication presented materials indicating a significant accumulation of radionuclide in the sphagnum mosses, the average concentrations of this radionuclide in these plants are almost 2 times higher than in other plants studied. These data are well correlated with materials that show the contents of potassium in the same plants. It has been found that this chemical element is contained in the sphagnum mosses in significant quantities (Krasnov & Orlov, 2004). It is known that ^{137}Cs is a chemical analogue of potassium and it probably explains its concentration in mosses.

In Poland, studies were carried out on the migration of ^{137}Cs in peat soils of oligotrophic swamp ecosystems, the intensity of the inflow of this radionuclide to plants (Boron *et al.,* 2001). Scientists have established that the observed radioactive element on the sphagnum bogs concentrated in the mosses and surface layers of the tirr (Gaca *et al.,* 2006). At the same time, plants that grow under these conditions, including the cranberry, contain a significant amount of radionuclide (Bunzk & Kracke, 1989). At present, periodic research on levels of radioactive contamination of plants of grass-shrub cover in the forests of the automorphic and hydromorphic landscapes (Malostan *et al.,* 2019) is continuing, but at a much smaller scale and do not to deal with the cranberries.

In Ukraine at the beginning of 90-ies of the last century in the forest areas of Polissia of Ukraine were organized monitoring of migration of ^{137}Cs in forest biogeocoenosis and accumulation of this radioactive element of various species of berry plants. Studies on levels of radioactive contamination of the cranberry were carried out on mesotrophic sphagnum bogs. Scientists have studied biological and ecological peculiarities of this species (Orlov & Krasnov, 1998) quite fully, which allowed them to understand the mechanisms of radiation coming to vegetative mass of plants and berries. It is known that the shoots of the cranberry, on which the berries are located, placed on the surface of the sphagnum and can reach 1 m long. The annual rise of sphagnums in height leads to the deepening of a part of the shoot of cranberry in their thickness and formation on it additional roots. They are also responsible for the nutrition of the plant with the bog (surface) water. Since the root system of the cranberry is concentrated at a depth of 15-20 cm from the surface of the sphagnums, it becomes clear that the radiation coming to it will depend on its content in the water solution of the bog (Krasnov & Orlov, 2004). The researchers also found that the mineral nutrition of the cranberry is also due to the trophic connection with other components of this phytocenosis, first of all, with sphagnum mosses. The repartition of the cells is carried out by endophytic and mycorhizic micromycetes, which combine marsh plants into a single biogeochemical cycle (Kurchenko *et al.,* 2013). The researchers studied the dynamics of ^{137}Cs in the shoots and the berries of the cranberries by the years, as well as its connection with the specific activity of the given radionuclide in various parts of the sphagnum cover (living soil cover, litter and tirr). In general, it is established that there is a gradual reduction of radioactive contamination of generative and vegetative organs of the cranberry with time (Krasnov & Orlov, 2004). In the last 10-15 years, only single publications on the results of the distribution of radionuclides in forest and marsh biogeocoenosis (Malostan *et al.,* 2019; Holiaka *et al.,* 2020) and fragmented data on radioactive contamination of the cranberry (Buzynnyi *et al.,* 2019) have been published.

The review of literature sources allows to make some generalizations and conclusions about the degree of study of intensity of ^{137}Cs migration in bogs of different type, distribution of ^{137}Cs in thickness of sphagnum mosses on oligotrophic and mesotrophic bogs and content of this radionuclide in the cranberry. Since the accident at the Chernobyl Nuclear Power Plant, a small number of studies have been conducted on the sphagnum bogs, due to the technical difficulty of sample selection, determination of the specific and total activity of radionuclide in living and died parts of the sphagnum mosses. The largest values of ^{137}Cs specific activity are marked in different, by depth, parts of the tirr (depending on the type of bog). Significant content of radionuclide in the berries of the cranberry at low levels of radioactive contamination of territories is also marked. It can be noted that in the last 10-15 years such research is not conducted.

MATEDIALS AND METHODS

Research on ^{137}Cs accumulation in vegetative part and berries of the ranberry were carried out on stationary experimental plots (SEP) in Zhytomyr Polissia on the territories of SOE "Slovechne Forest Management" and SOE "Bilokorovych Forest Management". They lasted from 1991 (the first year of observation) for 8 years annually, and in the next period till 2020 – in 5-7 years. SEP size of 100×100 m is laid in quite close ecological and phytocenosis conditions – on mesoligotrophic and oligotrophic bogs, but at different amounts of exposure dose of gamma-radiation. In 1991, it was fluctuating on SEP within 10-120 $mcR \cdot h^{-1}$ at a height of 1 m from the surface of the bog, and in 2020 – it fluctuates within 5-40 $mcR \cdot h^{-1}$.

Characteristics of forest range, as well as floristic composition and coenotic structure on SEP are close and differed only by the quantitative presence of certain types. On all SEP there was a cenosis – a pinewood cranberry-cotton grass-sphagnum. The stand composition is 10Sp, age – 60-80 years, completeness – 0.4, average height – 4 m, average diameter – 16 cm, type of forest conditions – wet pine forest. In the undergrowth there are single copies of pine of usual age from 3 to 8 years. The plant cover of the grass-shrub tier was 50-55%. There are cranberry (*Vaccinium oxycokcos* L.) – 15-20%, tussock cottongrass *(Eriophorum vaginatum* L.) – 20-25%, wild rosemary (*Ledum palstre* L.) – 5-8%, roundleaf sundew (*Drosera rotundifolia* L.) – 3-5%, bog bilberry (*Vaccinium uliginosum* L.) – 3-5%, bog-rosemary (*Andromeda polifolia* L.) – 1-3%. In the moss layer, which was solid and even with a design cover of up to 98%, dominated the flat-topped bogmoss (*Sphagnum fallax* Klinggr.– 40%; Magellanic bogmoss (*Sphagnum magellanicum* Brid.) – 45%, met to a smaller extent the hair moss (*Polytrictum strictum* L.) – 5-10%.

At the end of August on each SEP were laid 3 accounting areas of size 1×1 m, on which samples of berries and shoots of the cranberry, as well as the living

part of the sphagnum, its tirr and the litter. The samples were dried (except the berries of cranberry) in the thermostats at temperature 105°C, chopped on the cutter of PRG-01T and PRP-01 and analyzed in the first 10 years on the spectrum analyzer LP-4900B "AFORA" with the semiconductor detector DGDK-100V3 and in the next years with the multichannel gamma-pulse-spectrum analyzer SEG-005-AKP with the scintillation counter BDEG-20-R1 and BDEG-20-R2. The relative error in measuring ^{137}Cs specific activity of did not exceed 15%. Mathematical processing was carried out by commonly accepted methods of variant statistics using the software MS Excel and Statistica.

RESULTS AND DISCUSSION

The results of the studies conducted in 2020 (34 years after the Chernobyl accident) show that the low rates of ^{137}Cs specific activity in the berries of the cranberry on all stationary experimental plots (Table 1). This value ranged from 286±16.9 Bq/kg to 871±82.6 (at an acceptable level of ^{137}Cs – 500 Bq/kg). It is also necessary to indicate a small variation of this indicator within each stationary experimental plots: the variation coefficient within the SEP ranged from 7.6% (SEP 12) to 16.4% (SEP 11). Perhaps this is explained by the fairly uniform dispersion of radio radiation in the area of the bogs due to the low degree of density during the period of its arrival in the environment during the Chernobyl accident in comparison with forest ecosystems). This in part, is explained by the fact that in previous years of research the values of the variation coefficient were small: in 2002 – 7.1-18.1%, in 1991 – 5.7-8.5%.

The ^{137}Cs specific activity in air dry shoots of the cranberry in 2020 ranged from 1492 (SEP 15) to 6197 Bq/kg (SEP 12) (Table 2).

Table 1. *Variation series statistics of definition ^{137}Cs specific activity (Bq/kg) in fresh berries of the cranberry in different years of research*

Year of research	No. SEP	Statistics						
		M	± m	± σ	V, %	P, %	min	max
1991	11	13320	654.1	1131.6	8.5	4.9	12650	13990
	12	3626	120.4	208.3	5.7	3.3	3140	4112
	15	2072	99.8	172.7	8.3	4.8	1844	2300
	18	2320	95.3	164.9	7.1	4.1	2227	2413
2002	11	1334	72.5	125.5	9.4	5.4	1234	1433
	12	2150	151.1	261.4	12.2	7.0	1736	2564
	15	588	61.4	106.2	18.1	10.4	452	723
	18	491	20.2	34.9	7.1	4.1	461	520
2020	11	871	82.6	142,9	16.4	9.5	541	1201
	12	755	33.2	57.4	7.6	4.4	608	902
	15	286	16.9	29.2	10.2	5.9	187	385
	18	303	18.5	32.0	10.6	6.1	224	382

Note: *M is the arithmetic mean value; m is the error of the arithmetic mean value; σ is the mean square deviation V is the coefficient of variation; P is the coefficient of value; min is the minimum value; max is the maximum value*

Table 2. *Variation series statistics of definition 137Cs specific activity (Bq/kg) in dry berries of the cranberry in different years of research*

Year of research	No. SEP	Statistics						
		M	± m	± σ	V, %	P, %	min	max
1991	11	94590	4236.2	7328.626	7.75	4.48	88287	100893
	12	31800	2325.1	4022.423	12.65	7.31	31037	32563
	15	12120	897.6	1552.848	12.81	7.41	11254	12986
	18	14732	1125.6	1947.288	13.22	7.64	11484	17980
2002	11	8847	414.7	717.4	8.10	4.70	7014	10680
	12	8647	672.4	1163,2	13.50	7.80	7745	9550
	15	2247	215.1	372,0	16.60	9.60	1923	2572
	18	2618	241.8	418.3	16.00	9.20	2179	3057
2020	11	6099	365.9	633	10.38	6.00	4798	7400
	12	6197	241.7	418	6.75	3.90	5034	7360
	15	1492	112.3	194	13.02	7.53	1364	1620
	18	1854	98.7	171	9.21	5.32	1352	2356

The materials obtained during the long period after the Chernobyl accident allow to compare the values of ^{137}Cs specific activity in berries and shoots and to draw conclusions about the rate of their reduction in different periods at each of the SEP.

For the first period of observation during 1991-1996 there is a significant decrease in ^{137}Cs specific activity in berries: from 3.8 times per SEP 11 to 2.2 times per SEP 12. In the next period (1996-2002) this decrease was within 2.9-1.4 times, less than in the previous one. In the next periods of decline in the value of the ^{137}Cs specific activity in berries was much smaller. Perhaps in the first 15 years since the arrival of radionuclide in the swamp ecosystems, there was a more intensive redistribution of ^{137}Cs between their components, which provided more flow of it to the cranberry. In general, during the observation period, the decrease in ^{137}Cs specific activity in berries reached: on SEP 11 – 15.3 times (from 13320±654 to 871±83 Bq/kg), on SEP 12 – 4.8 times (from 3626±120 to 755±33 Bq/kg), on SEP 15 – 7.2 times (2072±100 to 286±17 Bq/kg), for SEP 18 to 7.7 times (2320±95 to 303±19 Bq/kg). On each of the SEP, this reduction is specific, which can be related to the peculiarities of the cenotic and hydrologic conditions of each experimental plots, the degree of development and the condition of the cranberry, etc.

The observed decrease in the index is most closely approximated by the exponential equation of the form $Y=e^x$, where Y is ^{137}Cs specific activity, Bq/kg; X is the number of years after the Chernobyl accident (Fig. 1 and 2):

On SEP 11: $Y=11123e^{-0,485x}$, $R^2=0.84$, r=0.92;
On SEP 12: $Y=3496,8e^{-0,288x}$, $R^2=0.85$, r=0.92;
On SEP 15: $Y=2218,9e^{-0,382x}$, $R^2=0.87$, r=0.93;
On SEP 18: $Y=1833,8e^{-0,352x}$, $R^2=0.82$, r=0.91.

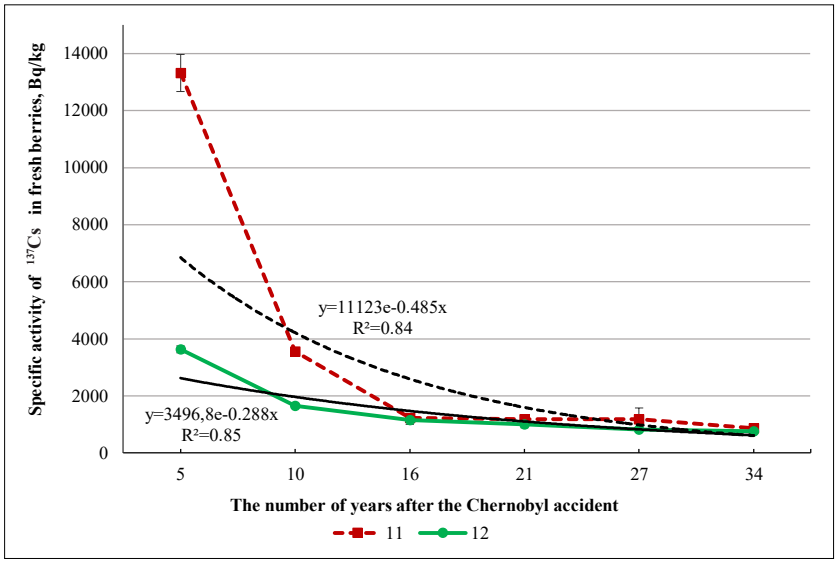

Figure 1. *Change of ^{137}Cs specific activity in fresh berries of the cranberry during 1991-2020 (5-34 years after the Chernobyl accident) on SEP (11, 12)*

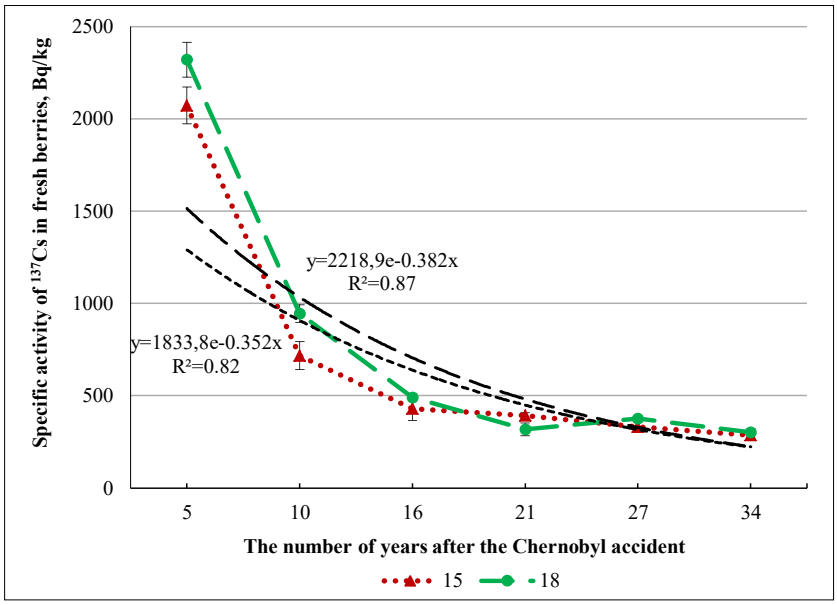

Figure 2. *Change of ^{137}Cs specific activity in fresh berries of the cranberry during 1991-2020 (5-34 years after the Chernobyl accident) on SEP (15, 18)*

Detected regularities in decreased ^{137}Cs specific activity in fresh berries of the cranberry during 1991-2020 are also confirmed by changes of the same indicator in the plant's shoots. Thus, the general decrease of ^{137}Cs specific activity in dry shoots of cranberry for the whole period of observation was: on SEP 11 – from 94590±4236 to 6099±366 Bq/kg (15.5 times), on SEP 12 – from 31800 ± 2325 to 6197±242 Bq/kg (5.1 times), on SEP 15 – from 12120±898 to 1492±112 Bq/kg (8.1 times), on SEP 18 – from 14732±1126 to 1854±112 Bq/kg (7.9 times). At the same time, a more intensive decrease in the content of radionuclide in the shoots also occurred in the first two periods of observation (1991-2002). The established decrease of ^{137}Cs specific activity in the shoots of cranberry are also most closely approximated by the exponential equation of the form $Y = e^x$, where Y is ^{137}Cs specific activity, Bq/kg; X is the number of years after the Chernobyl accident (Fig. 3 and 4):

On SEP 11: $Y=12775e^{-0,382x}$, $R^2=0.83$, r=0.91;
On SEP 12: $Y=10551e^{-0,38x}$, $R^2=0.82$, r=0.91;
On SEP 15: $Y=79358e^{-0,49x}$, $R^2=0.85$, r=0.92;
On SEP 18: $Y=29703e^{-0,306x}$, $R^2=0.84$, r=0.92.

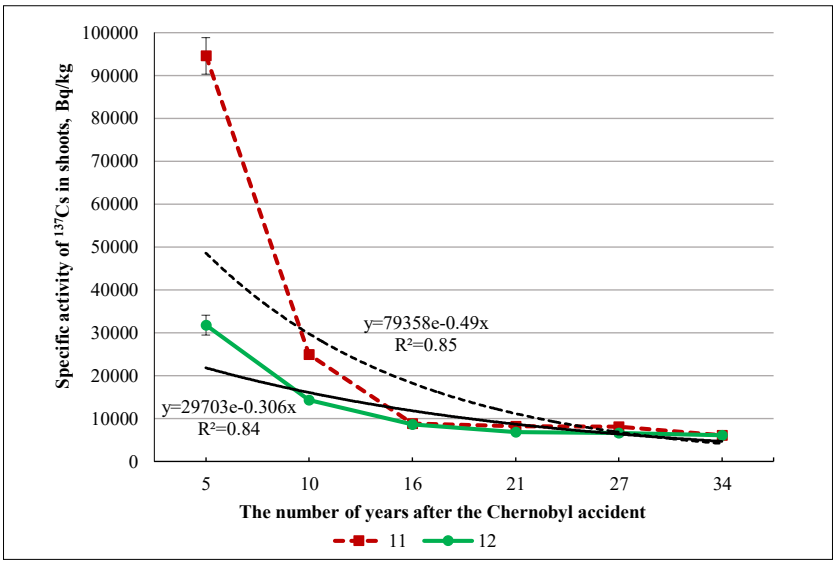

Figure 3. *Change of ^{137}Cs specific activity in dry shoots of cranberry during 1991-2020 (5-34 years after the Chernobyl accident) on SEP (11, 12)*

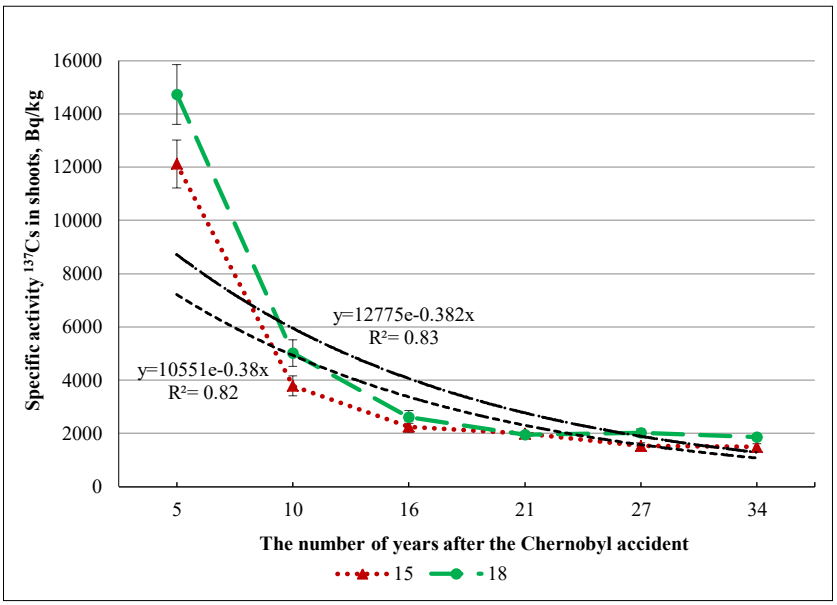

Figure 4. *Change of specific activity ^{137}Cs in dry shoots of cranberry during 1991-2020 (5-34 years after the Chernobyl accident) on SEP (15, 18)*

The materials received during such a long period of observation expand the idea of repartition of ^{137}Cs on oligotrophic and mesotrophic sphagnum bogs in time, which, on its part, will allow to work out the forecast methods of further migration of this radionuclide in the given ecological conditions and its inflow to various components. Given the importance of the bogs, which was noted in the literature analysis, this is very important, because there is a need in forecasting the possible arrival of radioactive elements to neighboring, with bogs, ecosystems and groundwater. The literature sources did not reveal materials on levels of radioactive contamination of certain or other components of the sphagnum bogs in 30 years since the arrival of radionuclides. Data

on ^{137}Cs in the shoots and berries of the cranberry were published by the authors of this publication in previous years (Krasnov & Orlov, 2004). This allows to identify received regularities as priority. At the same time, according to the authors, in the course of the further researches it is necessary to pay some attention to the following question: to develop the methodology of determination of density of radioactive contamination of substrate that will allow to find dependencies between content of radionuclide in plants and substrate on which they grow; to study migration of ^{137}Cs in deeper layers of soil.

CONCLUSIONS

Reduction of ^{137}Cs specific activity in berries and shoots of cranberry after the Chornobyl accident has been established. During 1991-2020 this indicator decreased: in the berries of plants in 15.3 (SEP 11) – 4.8 (SEP 12) times, in the shoots – in 15.5 (SEP 11) – 5.1 (SEP 12) times. The rate of reduction of radionuclide content in vegetative and generative organs of cranberry was more intensive in the first 12 years of observation (1991-2002) and significantly slowed down in the next period until 2020 inclusive. The decrease of ^{137}Cs specific activity in the cranberry (dry shoots and fresh berries) over the years is described by the exponential equation of the form $Y=e^x$. The revealed regularities of the dynamics of the studied indicators allow to create the forecast models of radioactive contamination of the cranberry.

At present, ^{137}Cs continue to be supplied to the berries and shoots of cranberry, but the intensity of this process has considerably decreased compared to the initial period. These circumstances require a review of the existing regulation of the berrying of this plant taking into account the current radiation situation on specific areas of the sphagnum bogs.

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Динаміка накопичення 137Cs журавлиною болотною на сфагнових болотах Полісся України

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Анотація. Оліготрофні і мезотрофні болота є поширеними екосистемами у Поліссі України. Після аварії на Чорнобильській АЕС дані екосистеми були забруднені радіонуклідами. Поширеною ягідною рослиною на цих болотах є журавлина болотна, що широко використовується у харчовій промисловості. Метою досліджень є встановлення динаміки питомої активності ^{137}Cs у журавлині болотній впродовж останніх 30 років. Отримані результати моніторингових досліджень є необхідним для прогнозування радіоактивного забруднення журавлини. Дослідження проводились на постійних пробних площах (ППП) у Житомирському Поліссі. Питому активність ^{137}Cs вимірювали за допомогою спектроаналізаторів, з використанням сцинтиляційних і напівпровідникових детекторів. Отримані результати свідчать, що спостерігається інтенсивна міграція ^{137}Cs у сфагнових болотах Полісся України. Результати досліджень, проведених через 34 роки після аварії на ЧАЕС, демонструють, що нині відмічаються невисокі величини питомої активності ^{137}Cs у журавлині болотній (*Vaccinium oxycoccus* L.) на всіх пробних площах. Даний показник у 2020 р у свіжих ягодах коливався від 871±82,6 до 286±16,9 Бк/кг (при допустимих рівнях вмісту ^{137}Cs – 500 Бк/кг), а у сухих пагонах – від 1492 (ППП 15) до 6197 Бк/кг (ППП 12). Виявлено, що за перший період досліджень протягом 1991–1996 рр. спостерігається досить значне зниження питомої активності ^{137}Cs в ягодах: від 3,8 разів на ППП 11 до 2,2 разів на ППП 12. У наступний період спостережень (1996–2002 рр.) це зниження було у межах 2,9–1,4 разів, що менше ніж у попередній. У подальший період зниження величини питомої активності ^{137}Cs в ягодах було значно меншим. Виявлені закономірності у знижені питомої активності ^{137}Cs в ягодах журавлини болотної протягом 1991–2020 рр. підтверджуються змінами цього показника у її пагонах. Загальне зниження цього показника у пагонах за період спостережень склало: на ППП 11 – від 94590±4236 до 6099±366 Бк/кг (15,5 разів), на ППП 12 – від 31800±2325 до 6197±242 Бк/кг (5,1 рази), на ППП 15 – від 12120±898 до 1492±112 Бк/кг (8,1 рази), на ППП 18 – від 14732±1126 до 1854±112 Бк/кг (7,9 разів). Продовження моніторингу на постійних пробних площах дозволить прогнозувати рівні радіоактивного забруднення журавлини на основі математичного моделювання

Ключові слова: питома активність, радіонуклід, *Vaccinium oxycoccus* L., сфагн, сухі пагони, свіжі ягоди