Ukrainian Journal of Ecology

Ukrainian Journal of Ecology, 2021, 11(2), 13-16, doi: 10.15421/2021_70

ORIGINAL ARTICLE *UDC: 504.064(477):635/1.8*

Migration of ^{137}Cs and ^{90}Sr radionuclides in the rural area of the Central Forest Steppe of Ukraine after the Chernobyl accident

V.Yu. Herasymenko, O.I.Rozputnyi, I.V. Pertsovyi, V.V. Skyba, O.M. Tytariova, M. E. Saveko, Yu.V. Kunovskyi, V.P. Oleshko

Bila Tserkva National Agrarian University
**Corresponding author E-mail: viktor.herasymenko@btsau.edu.ua, vgu160183@gmail.com*

Received: 09.02.2021. Accepted: 09.03.2021.

The territories of Bila Tserkva district, located in the north-eastern part of the right-bank Forest-Steppe of Ukraine, have been studied. This area is dominated by chernozems that are typically low-humus. In vegetable crops grown in Yosypivka and Tarasivka of Bila Tserkva district, which was exposed to radioactive contamination and is located in the southern part of Kyiv region, Central Forest-Steppe Ukraine, contamination of ^{137}Cs and ^{90}Sr were determined. The content of 137Cs and 90Sr in soils was studied, and the density of pollution of privately-owned vegetable plots in these villages was calculated. The transition coefficients of 137Cs and 90Sr radionuclides from the soil of typical chernozem into plants, in particular cucumbers, potatoes, onions, beets, carrots, tomatoes, and white cabbage, have been calculated and established, which makes it possible to calculate the transfer coefficients to vegetable crops to be grown in radioactively contaminated areas of the Central Forest-Steppe of Ukraine. Reducing 137Cs and 90Sr radionuclides from soil to vegetable crops is one of the leading agricultural production tasks on lands contaminated with radionuclides. These studies make it possible to elucidate the current state of migration of these radionuclides in the "soil-plant" link of agroecosystems of the Central Forest-Steppe of Ukraine for further forecasting.
Keywords: ^{137}Cs and ^{90}Sr radionuclides, pollution density, transition coefficients.

Introduction

Regardless of the time elapsed since the Chernobyl disaster, the problem of radioactive contamination continues to be quite relevant. At present, 6.7 million hectares of our country's territory remain contaminated, including 1.2 million hectares contaminated with 137Cs with a density of 42 to 589 kBq/m^2 (1–15 Ki/km^2). There are 2,161 population centers in radioactively contaminated areas with a population of about 3 million (20 years of the Chernobyl disaster. Looking to the future: National Report of Ukraine).
The primary food source for rural residents of these population centers is from products grown in privately owned home plots, which is why the determination of contamination of crop products with artificial radionuclides ^{137}Cs and ^{90}Sr on land affected by radioactive contamination from the Chernobyl accident is relevant. Since the internal radiation dose is formed by the consumed products grown mostly on privately owned plots (Chobot'ko, 2015; Beresford, 2016; Yakymenko, 2013; Kashparov, 2011; Hudkov, 2012) reducing the transition of ^{137}Cs and ^{90}Sr radionuclides from soil to vegetable crops is one of the main tasks of agricultural production on lands contaminated with radionuclides (Gudkov, 2003; Feshchenko, 2016; Skuterud, 2014; Zubets, 2011; Umans'kij, 2016)
The implementation of these findings will make a more detailed analysis of the current state of migration of these radionuclides in the "soil-plant" links of the Central Forest-Steppe of Ukraine's agroecosystems. Since the Chernobyl accident, leading scientists (Furdychko, 2011; Grodzinsky, 2011; Gudkov, 2009; Likhtarev, 2012, et al.) have conducted a significant amount of research in studying the migration of ^{137}Cs and ^{90}Sr in agricultural production facilities, their accumulation in food products, and estimates of human radiation doses.
The main focus of scientific research was concentrated in the Polissya region. There has also been slightly more focus on ^{137}Cs, the main dose-forming radionuclide (Schuller, 1988; Chobot'ko, 2014; Kimura Y, 2015; Jelin,2016, et al.) Besides, in areas of the Forest-Steppe that are radioactively contaminated, a significant share of contamination is accounted for by ^{90}Sr; the intensity of migration, according to scientists, will gradually increase (Prister, 2011; Herasimenko, 2017; Pertsovyi, 2017; Uematsu, 2016; Tsubokura, 2016). All these data necessitated a detailed study of the state of migration of ^{137}Cs and 90Sr, in the soil-plant chain of agroecosystems of agricultural enterprises and privately-owned home plots of the central forest-steppe, which are affected by radioactive contamination from the Chornobyl accident for the long term.
The content of radionuclide contamination of vegetable crops 33 years after the Chernobyl disaster indicates that the challenge of monitoring, studying, and forecasting products remains quite relevant. These studies aimed to investigate the migration of ^{137}Cs and ^{90}Sr in the soil - plant link in Yosypivka and Tarasivka, Kyiv region, in the central forest-steppe of Ukraine; and to establish 1^{37}Cs and ^{90}Sr transition coefficients from typical chernozem to vegetable crops for further forecasting.

Materials and Methods

The Bila Tserkva district's studied territories are located in the north-eastern part of the right-bank Forest-Steppe of Ukraine, represented mainly by typical low-humus chernozems in forests located in river plains. According to generally accepted methods, samples of crop production and soil were taken on private plots of residents of the villages of Yosypivka and Tarasivka, Bila Tserkva district, Kyiv region, according to generally accepted methods .
The territory of these villages was in the zone of the "southern trace of radioactive contamination." Samples were prepared, then analyzed for the activity of 137Cs and 90Sr, at the Department of Life Safety of Bila Tserkva National Agrarian University at the spectrometric complex "USC Gamma Plus," according to the method for this device . To determine 90Sr, selective radiochemical isolation by oxalate precipitation was performed. Determination of 90Sr was performed on the beta spectrometric tract of USC "Gamma Plus" . Research data were processed statistically using Microsoft Excel.

Results and Discussion

The main vegetable crops grown in the home plots were carrots, cucumbers, potatoes, cabbage, tomatoes, zucchini, beets, onions, peppers, and radishes. The research data were collected during 2015-2018. The activities of 137Cs and 90Sr in vegetable crops were studied, and the coefficients of their transition in home plots were calculated. According to the data shown in Fig. 1, it is seen that the lowest activity of ^{137}Cs was in potatoes, onions, and cucumbers. It was twice as high in zucchini and sweet peppers, carrots and tomatoes almost four times, beets and radishes almost eight times, and in beans, it was 11 times higher. Thus, the average activity of 137Cs in potatoes was 2.83 Bq/kg, cabbage 5.67, beets 13.93, carrots 8.45, onions 2.84, tomatoes 8.36, cucumbers 2.85, zucchini 5.65, sweet peppers 5.65, radishes 16.75, and beans 26.54 Bq/kg.

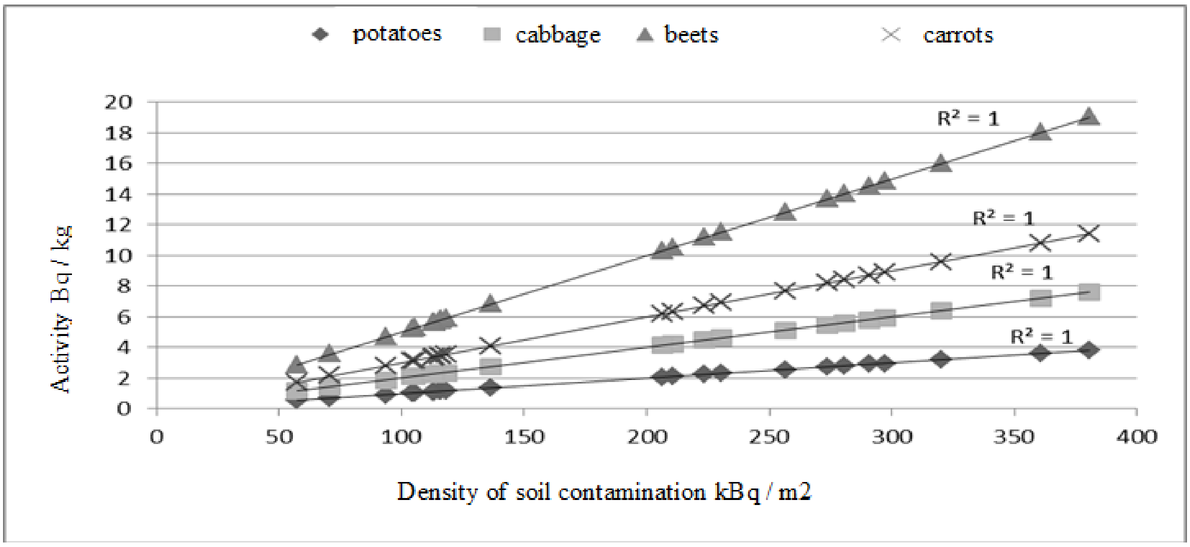

Fig. 1. The relationship between 137Cs activity and soil contamination density.

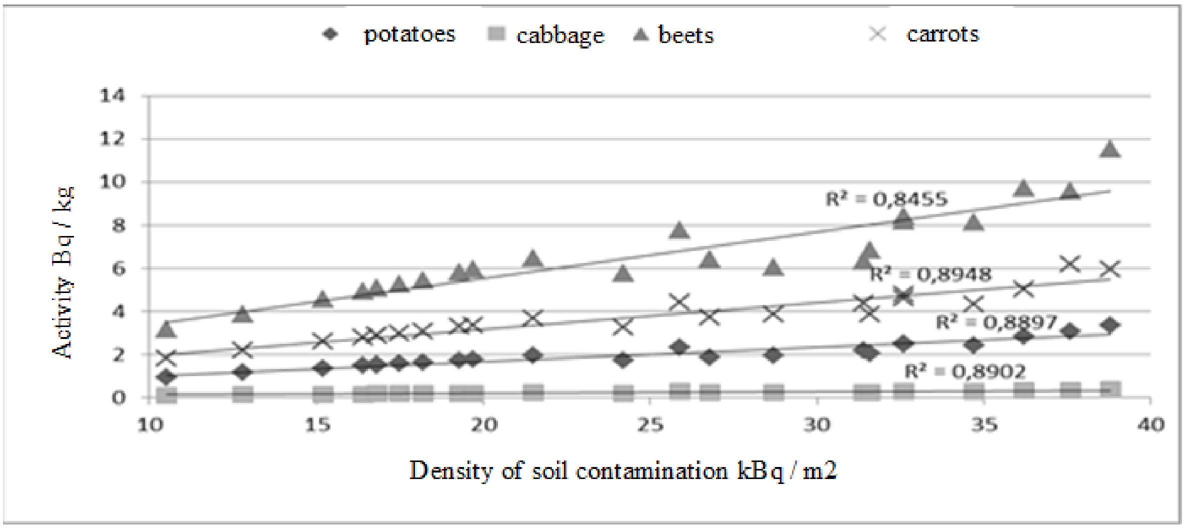

Fig. 2. The relationship between the activity of 90Sr and the density of soil contamination.

According to data shown in Fig. 2 obtained for 90Sr activity in vegetable crops, we observe that based on its lowest activity in onions, it was twice as high in tomatoes and cucumbers, four times higher in sweet peppers, almost ten times higher in potatoes and cabbage, twenty times higher in zucchini, and 30 times higher in table beets, carrots, radishes, and beans. Thus, 90Sr activity

in onions was 0.34 Bq/kg, tomatoes 0.60, cucumbers 0.62, sweet pepper 1.10, potatoes 2.70, cabbage 2.53, zucchini 4.67, table beets 9.0, carrots 7.98, radishes 7.45, and beans 7.87 Bq/kg.
Coefficients of 137Cs transition from soil to vegetable crops grown in the third zone of radioactive contamination accumulate from 0.01 to 0.09, and 90Sr accumulates from 0.01 to 0.30 (Fig. 3). The lowest 137Cs transition coefficient is in potatoes, onions, and cucumbers (0.01). Cabbage, zucchini, and sweet pepper have a conversion rate twice as high (0.02), carrots and tomatoes three times as high (0.03), beets five times (0.05), radish six times (0.06), and beans nine times higher (0.09).
The lowest conversion factor of 90Sr is in onions (0.01), in tomatoes and cucumbers, it is two times higher (0.02), in peppers four times (0.04), in potatoes and cabbage nine times (0.09), in zucchini eighteen times (0.18), in radishes 26 times (0.26), and in table beets, radishes, carrots and beans 27-30 times (0.27-0.30) higher.
According to GN 6.6.1.1-130-2006, "Permissible levels of 137Cs and 90Sr radionuclides in food and drinking water," the content of 137Cs should not exceed 60 Bkg/kg in potatoes or 20 Bq/kg in fresh vegetables and legumes; while the content of 90Sr should not exceed 40 Bq/kg in potatoes or 20 Bq/kg in fresh vegetables and legumes. Therefore, these vegetable crops meet the criteria of radiation safety. The data indicates that, on average, the lowest activity of 137Cs and 90Sr in vegetable crops grown in the village of Tarasivka is twice lower when compared with crops from the village of Yosypivka. Thus, the average activity of 137Cs in potatoes was 1.10 Bq/kg, cabbage 3.10, beets 5.45, carrots 3.67, onions 1.23, tomatoes 3.45, cucumbers 1.33, zucchini 2.56, sweet peppers 2.32, radishes 6.44, and beans 9.58 Bq/kg. Activity of 90Sr in potatoes was 1.51 Bq/kg, cabbage 1.52, table beets 5.05, carrots 4.71, onions 0.17, tomatoes 0.35, cucumbers 0.34, zucchini 2.86, sweet peppers 0.67, radishes 4.37 and beans 5.04 Bq/kg. The lowest activity of ^{137}Cs was in cucumbers, potatoes, onions. In zucchinis and sweet peppers, it was twice as high, in carrots and tomatoes almost four times, in beets and radishes almost eight times, and in beans ten times higher. The lowest activity of 90Sr was in onions. Tomatoes and cucumbers were two times higher, sweet peppers four times, potatoes and cabbage almost ten times, zucchini 20 times, and in table beets, carrots, and beans, 30 times higher. As mentioned above, the accumulation of ^{137}Cs and ^{90}Sr in vegetable crops depends on their mineral nutrition properties. Thus, plants that contain lots of potassium accumulate more radioactive cesium, while crops that contain lots of calcium contain more radioactive strontium. According to the literature, the potassium content in white cabbage is 190 mg/100 g, beets 278, carrots 195, tomatoes 304, cucumbers 157, sweet peppers 145, radishes 265 mg/100 g, and calcium is contained in cabbage 53mg/100 gr., beets 42, carrots 49, tomatoes 15, cucumbers 24, sweet peppers 19, onions 27, and radishes 37 mg/100 gr.

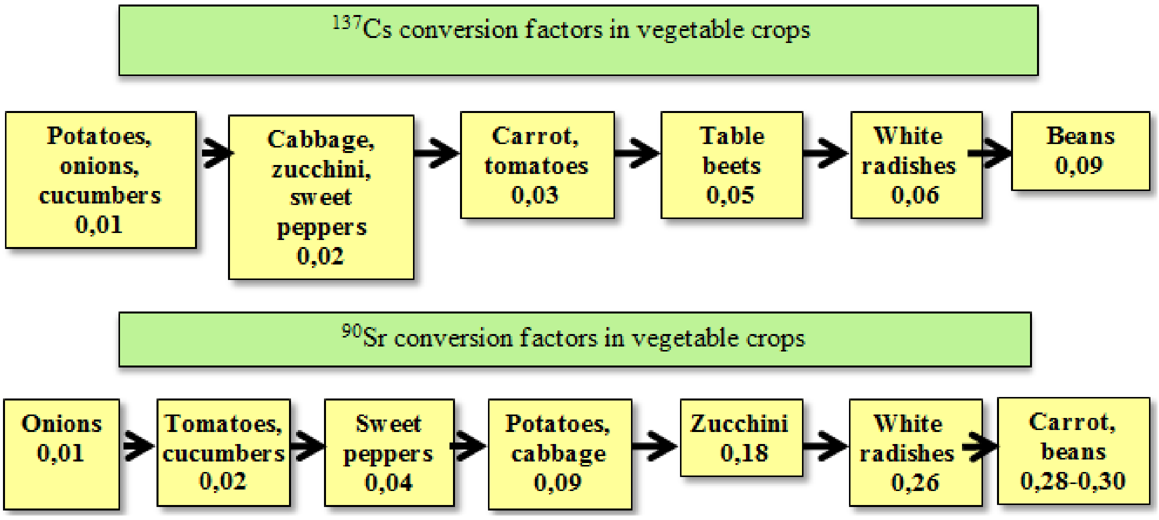

Fig. 3. Transfer factor 137Cs i 90Sr in vegetable crops.

This can be explained by the fact that the soils in home plots of these villages are typical light and medium loam chernozems with an average humus content (3.3 - 3.6%), with a neutral reaction of the water extract environment (6.80 - 7.72), soil density of 1.18 - 1.25 g/cm^3, and the average content of metabolic potassium (82 - 120 mg/kg) and calcium (15 - 20 mg-eq/100 g).
We found the lowest conversion rate of 137Cs in potatoes, onions, and cucumbers (0.01). In white cabbage, zucchini, and sweet peppers, the conversion rate is two times higher (0.02), in carrots and tomatoes three times higher (0.03), in beets five times, radishes six times, and in beans nine times higher. The lowest conversion factor of 90Sr is observed in onions (0.01). I in tomatoes and cucumbers, it is twice as high (0.02), in peppers four times (0.04), potatoes and cabbage nine times (0.09), and in table beets, carrots, white radish, and beans 28-30 times higher.
Our research data show a directly proportional relationship between ^{137}Cs and ^{90}Sr in vegetable crops and soil contamination density.
The research results make it possible to predict the contamination of plant products grown in the radioactively contaminated territories of the Central Forest-Steppe of Ukraine based on the clarified transition coefficients for 1^{37}Cs and ^{90}Sr.

Conclusions

Our research proves that the studied vegetable crops, which were obtained in the villages of Yosypivka and Tarasivka, do not exceed DR – 2006 and are therefore quite suitable for consumption. However, despite this, it should be noted that research data indicates the content of artificial radionuclides 137Cs and 90Sr, which previously did not exist in nature, indicating that constant monitoring of their content in the agroecosystems is justified.
The coefficients of the transition of ^{137}Cs and ^{90}Sr radionuclides from soil (in this case, typical chernozem) to vegetable crops grown on home plots have been determined and can be used to predict 137Cs and 90Sr contamination of vegetable crops in radioactively contaminated areas.

References

Ivan, P., Oleksandr, R., Viktor, H. (2018). Assessment of the radiation safety of the rural population of the Central forest-steppe of Ukraine in the remote period after the Chernobyl catastrophe. Proceedings of the 2nd Annual Conference, Technology transfer: fundamental principles and innovative technical solutions. Tallinn, Estonia, DKLex Academy OÜ and Scientific Route OÜ, November 23, 30-33.
Beresford, N. A., Fesenko, S., Konoplev, A., Skuterud, L., Smith, J. T., et al. (2016). Thirty years after the Chernobyl accident: What lessons have we learnt. Journal of Environmental Radioactivity, 157, 77–89.
Chobot'ko, G.M., Landin, V.P., Rajchuk, L.A., Shvidenko, I.K., Umans'kij, M.S. (2015). Ocinjuvannja formuvannja dozi vnutrishn'ogo oprominennja naselennja na viddalenomu etapi podolannja naslidkiv avariï na ChAES/G. M. Chobot'ko, Visnik agrarnoï nauki, 7, 54-58.
Chobotko, G., Raychuk, L., Shvidenko, I., McDonald, I. (2016). The issue of radioactive contamination in context of ecosystem services development. Agricultural science and practice, 3, 48–53.
Chobot'ko, G.M., Landin, V.P., Rajchuk, L.A. (2014). Osnovni chinniki formuvannja doz vnutrishn'ogo oprominennja naselennja radioaktivno zabrudnenih regioniv u viddalenij period pislja avariï na Chornobil's'kij AES, Radioekologija, 355–358.
Feshchenko, V.P., Hurelia, V.V. (2016). Prohnostychnyi analiz ekolohichnoi bezpeky silskohospodarskoho vyrobnytstva na radioaktyvno zabrudnenykh ahrolandshaftakh Polissia. Zbalansovane pryrodokorystuvannia, 3, P. 25–30.
Gudkov, I.M., Lazarev, M.M. (2003). Osoblyvosti vedennja sil's'kogospodars'kogo vyrobnyctva na zabrudnenyh radionuklidamy terytorijah Lisostepu. Naukove zabezpechennja stalogo rozvytku sil's'kogo gospodarstva v Lisostepu Ukrai'ny, 1, 747–775.
Herasimenko, V., Rozputny, O., Pertsovyi, I., Skyba, V., Saveko, M. (2017). Migration and prognosis of radionuclides 137Cs and 90Sr in vegetable produce: the case of villages of the Central Forest-Steppe of Ukraine in the remote period after Chernobyl Disaster. Ukrainian Journal of Ecology, 7(3), 246 – 250.
Hudkov, I.M., Kashparov, V.O. (2012). Aktualni zavdannia i problemy silskohospodarskoi radioekolohii cherez chvert stolittia pislia avariyi na Chornobylskiyi AES. Visnyk ZhNAEU, 1(1), 27–36.
Instruktivno-metodicheskie ukazaniya: Rekonstrukciya i prognoz doz oblucheniya naseleniya, prozhivayushchego na territoriyah Ukrainy, podvergshihsya radioaktivnomu zagryazneniyu v rezul'tate avarii ChAES: Metodika-97/ MZ Ukrainy, AMN Ukrainy, MNS Ukrainy, NCRM AMN Ukrainy, NII RZ ATN Ukrainy, Kyiv.
Jelin, B.A., Sun, W., Kravets, A., Naboka, M., Stepanova, E.I, et.al. (2016). Quantifying annual internal effective 137Cesium dose utilizing direct body burden measurement and ecological dose modeling. J of Exp Sci and Environ. Epidemiol, 26(6), 546-553.
Kashparov, V. (2016). Report Chernobyl: 30 Years of Radioactive Contamination Legacy. Kyiv.
Kashparov, V.A., Polishchuk, S.V., Otreshko, L.M. (2011). Radiolohichni problemy vedennia silskohospodarskoho vyrobnytstva na zabrudneniy v rezultati Chornobylskoi katastrofy terytoriyi Ukrainy. Chornobylskyi naukovyi visnyk. Biuleten ekolohichnoho stanu zony vidchuzhennia ta zony bezumovnoho (oboviazkovoho) vidselennia, 2 (38), 13–30.
Kimura, Y., Okubo, Y., Hayashida, N., Takahashi, J., Gutevich, A., et.al. (2015). Evaluation of the relationship between current internal 137Cs exposure in residents and soil contamination west of Chernobyl in Northern Ukraine. PLoS One.10(9), e0139007.
Metodika izmereniya aktivnosti beta-izluchayushchih radionuklidov v schetnyh obrazcah s ispol'zovaniem programmnogo obespecheniya "Progress" (1996). Moscow.
Metodika izmereniya aktivnosti radionuklidov v schetnyh obrazcah na scintillyacionnom gamma-spektrometre s ispol'zovaniem programmnogo obespecheniya. Moscow.
Metodychni, R., Vidboru, Z. (1997). Radioizotopnogo analizu pry obstezhenni sil'gospugid'. Dovidnyk dlja radiologichnyh sluzhb Minsil'gospprodu Ukrai'ny. Kiyv.
Beresford, N.A., Fesenko, S., Konoplev, A., Smith, J., Skuterud, T., (2016). Thirty years after the Chernobyl accident: What lessons have we learnt? J. Environ. Radioact, 157, 77-89.
Prister, B. S. (2011). Problemy radiatsiynoho zakhystu naselennia na terytoriyakh, zabrudnenykh u naslidok avariyi na Chornobylskiyi AES. Visnyk NAN Ukrainy, 4, 3–11.
Pro vvedennia v diu Derzhavnykh hihienichnykh normatyviv. Normy radiatsiynoi bezpeky Ukrainy (NRBU-97). Kyiv.
Pro zatverdzhennia Derzhavnykh hihienichnykh normatyviv. Dopustymi rivni vmistu radionuklidiv 137Cs ta 90Sr u produktakh kharchuvannia ta pytniy void. Kiyv.
Uematsu, S., Vandenhove, H., Sweeck, L., Van Hees, M., Wannijn, J. E. (2016). Smolders Variability of the soil-to-plant radiocaesium transfer factor for Japanese soils predicted with soil and plant properties. J Environ Radioact, 153, 51-60.
Schuller, P., Handl, I. (1988). Tramper R. Dependence of the 137Cs soil - to - plant transfer factor on soil parameters. Health Physics. 55, (3), 575-577.
Skuterud, H., Thorring, M.A., Ytre, E. (2014). Use of total 137Cs deposition to predict contamination in feed vegetation and reindeer 25 years after Chernobyl. ICRER 2014 – Third International Conference on Radioecology and Environmental Radioactivity, 7–12 September 2014. Kiyv.
Tsubokura, M., Nomura, S., Sakaihara, K., Kato, S., Leppold, C., et.al. (2011). Estimated association between dwelling soil contamination and internal radiation contamination levels after the 2011 Fukushima Daiichi nuclear accident in Japan. BMJ Open, 6(6), e0109070.
Umansky, M.S. (2016). On the issue of estimating the formation of the dose of internal exposure of the population at a remote stage of overcoming the consequences of the accident at Chornobil's NPP. Proceedings of the XXI scientific scientific conference of the Institute of Nuclear Research of the National Academy of Sciences of Ukraine, 4, 233-234.
Yakymenko, H. M., Shvydenko, I. K., Raichuk, L. A., Pankovska, H. P. (2013). Vyznachennia rivnia radiatsiinoho zabrudnennia bulb kartopli, vyroshchenoi v umovakh Ukrainskoho Polissia. Naukovyi visnyk NLTU Ukrainy, 23 (4), 105–110.
Zubets, M. V., Prister, B. S., Aleksakhin, R. M., Bohdevich, I. M., Kashparov, V. A. (2011). Aktualni problemy i zavdannia naukovoho suprovodu vyrobnytstva silskohospodarskoi produktsiyi v zoni radioaktyvnoho zabrudnennia Chornobylskoi AES. Ahroekolohichnyi zhurnal, 1, 3–20.

Citation:
Herasymenko V. Yu., Rozputnyi O.I., Pertsovyi I.V., Skyba V.V., Tytariova J.V., Saveko M.E., Kunovskyi Yu.V., Oleshko V.P. (2021). Migration of 137Cs and 90Sr radionuclides in the rural area of the Central Forest Steppe of Ukraine after the Chernobyl Accident. *Ukrainian Journal of Ecology, 11* (2), 13-16.