

RADIATION SITUATION IN THE CONTAMINATED TERRITORIES OF UKRAINE IN THE POST-CHORNOBYL PERIOD FROM 2013 TO 2022

Z. Malimon* (ORCID ID 0000-0002-8616-3198), **H. Kochetova** (ORCID ID 0000-0003-3234-1355), **L. Gusak** (ORCID ID 0000-0001-7570-2574), and **S. Shuliak** (ORCID ID 0000-0001-8501-1750)

State Research Institute for Laboratory Diagnostics and Veterinary-Sanitary Expertise, Kyiv (Ukraine); e-mail: z_malimon@ukr.net*

Abstract. *Radiological tests analysis aimed to determine important issues regarding the safety of food products, feeds, medicinal herbs, etc., obtained from radioactively contaminated territories as a result of the accident at the Chornobyl nuclear power plant. The material for analysis was current documentation of the Regional State Laboratories of State Service of Ukraine on Food Safety and Consumers Protection in Zhytomyr, Volyn, Rivne, Chernihiv regions, Central Testing State Laboratory of State Service of Ukraine on Food Safety and Consumers Protection in Kyiv region and Kyiv city from 2013 to 2022. The analysis is conducted regarding contamination of food products, feeds, medicinal herbs, etc., with radionuclides ^{137}Cs and ^{90}Sr . The specialists of regional State Laboratories of State Service of Ukraine on Food Safety and Consumers Protection conducted 12 797 892 radiological tests, that showed 3 372 samples with higher than the permissible level content of ^{137}Cs and 10 samples with higher than permissible level content of ^{90}Sr . ^{137}Cs is a main dose-forming radionuclide that has considerable influence on getting internal irradiation by population. There have been rare cases of contamination of food, feeds, and medicinal herbs with ^{90}Sr . It was found that forest-based food (mushrooms, berries) – 62.1, milk – 22.7, meat of wild animals – 8.3, feeds – 1.8, and medicinal herbs – 0.8 had been mostly contaminated with ^{137}Cs from the total number of samples with positive results for the specified period. Thus, analyzing the results of radiological tests over the past decade, it should be noted that even today, further radiological control of food products, feeds, etc. in radioactively contaminated territories is expedient and requires further implementation of anti-radiation protection actions established by current national legislation.*

Keywords: radionuclides ^{137}Cs and ^{90}Sr , zones with radioactive contamination, forest-based food, feeds, medicinal herbs.

The quality and safety of food products and the provision of the population of Ukraine with environment-friendly products in the post-Chornobyl period are particularly important. (Kotelevich, 2019). Providing quality and safe products to the population residing in the areas with radioactive contamination as a result of the Chornobyl nuclear power plant accident is a pressing issue today that is essential for the health and well-being of future generations. (Supreme Council of Ukraine, 1991; Likhtarev, 1996; IAEA. 2011; Fesenko, 2013).

In 1986 Ukraine experienced one of the major radiation accidents in the history of nuclear energy development. As a result of the Chornobyl nuclear power plant accident, a large number of long-lived radionuclides, such as ^{90}Sr (with a half-life of 29 years) and ^{137}Cs (30 years), were released into the environment. This posed a particular and lasting threat to all living beings, making this accident a global disaster.

The natural conditions of the regions contaminated with the radiation, approximately 3.5 million hectares of forests, contributed to the mass migration of artificially exposed radiation elements to the environment. Therefore, one of the most important tasks of the overall research system on the radionuclides migration in the biosphere is to study processes in trophic chains involving agricultural, forest plants, and productive animals. The consumption of plant and animal products contaminated with radioactive substances is the main factor in forming the radiation dose rate in humans. Radioactivity can enter the body through the consumption of forest-based products, such as mushrooms, berries, and game, as well as through the consumption of products grown in household plots directly by the population. The public awareness of the radiological state of the environment after the Chornobyl

disaster and the getting radionuclides through the soil → plant → animal → human chain, as well as people's knowledge of effective means of individual protection, remain important today (Romanchuk, 2015).

The objective of our paper was to analyze the results of radiological studies of food products, feeds, medicinal herbs feedstock, etc., regarding the content of radionuclides ^{137}Cs and ^{90}Sr from 2013 to 2022 in areas contaminated with radiation. To identify critical dose-forming food products and trace their dynamics.

Methods and materials. During the analysis, the following methods and materials were applied: reports of radiology departments of state laboratories of the State Service of Ukraine for Food Safety and Consumer Protection, commonly accepted statistical and analytical methods for processing research results, as well as radiometric and gamma-beta spectrometric methods for identifying radionuclides.

Results Specialists from the state laboratories of the State Service of Ukraine for Food Safety and Consumer Protection (State Consumer Service of Ukraine) regularly conduct radiological tests of food products, feeds, etc., to ensure compliance with permissible levels of radionuclides according to current regulatory acts.

The analysis of the results of radiological tests of the contamination of food products, feeds, medicinal herbs feedstock, etc., with ^{137}Cs and ^{90}Sr radionuclides in the regions established as zones with radioactive contamination were conducted for the period from 2013 to 2022 in Zhytomyr, Volyn, Rivne, Chernihiv, and Kyiv regions. It was found that for the past ten years, specialists from the state laboratories of the State Service of Ukraine for Food Safety and Consumer Protection conducted 12,797,892 radiological tests of food products, feeds, etc., to identify the content of the mentioned radionuclides. Notably, there were 3 372 samples with content higher than the permissible level of ^{137}Cs and 10 samples with ^{90}Sr content higher than the permissible level.

The number of cases with the content of ^{137}Cs and ^{90}Sr radionuclides higher than permissible levels in food products, feed, etc., for the period from 2013 to 2022, in the regions established as zones with radioactive contamination is provided in Table 1.

According to the data in the Table, it is clear that from 2013 to 2022, there was a clear tendency of decline in the number of samples with higher ^{137}Cs content in all types of food products, feeds, etc. The year 2017 was an exception regarding the number of positive samples, which could be explained by the increased number of radiological tests in the Rivne and Kyiv regions that year, compared to all the mentioned years.

There were 615 samples with the content of ^{137}Cs higher than the permissible level, in 2013, the highest number, which constituted almost 0.1% of the total number of samples that year. In 2021, there were the least number of samples with content of ^{137}Cs higher than the permissible level – 0.01% of all cases (128 samples), if exclude the year 2022 when the number of samples with higher content was 0.006% (67 samples). However, these results can't be considered frontmost since the overall number of tests in 2022 was also the least throughout the entire research period, this was likely because of the hostilities in Ukraine.

A higher content of ^{90}Sr radionuclide than a permissible level was found in 3 samples of feeds (Kyiv region) in 2013, 2014 there were 4 samples in feeds (Kyiv region), one sample from medicinal herbs feedstock, and one sample from wild animals' bones (Chernihiv region) in 2016. – one sample from medicinal herbs feedstock (Chernihiv region).

Table 1

The number of samples with ^{137}Cs and ^{90}Sr radionuclides higher than permissible levels in food products, feeds, etc., (from 2013 to 2022)

Year	Overall number of tests for radionuclides $^{137}\text{Cs}/^{90}\text{Sr}$ in the regions	Number of samples with higher content of $^{137}\text{Cs}/^{90}\text{Sr}$ in the regions	Regions established as zones with radioactive contamination									
			Zhytomyr		Volyn		Rivne		Chernihiv		Kyiv	
			Number of samples taken	With higher content	Number of samples taken	With higher content	Number of samples taken	With higher content	Number of samples taken	With higher content	Number of samples taken	With higher content
2013	1285368	615/3	285562	292	61916	63	94326	201	192894	13	650670	46/3
2014	1261787	441/6	286773	267	60110	51	86383	101	185233	5/2	643288	17/4
2015	1221646	437	275645	287	64378	56	78031	68	182206	3	621386	23
2016	1152658	346/1	272412	242	45444	44	61392	49	192474	3/1	580936	8
2017	1684104	518	265571	232	43104	69	150581	77	183717	8	1041131	132
2018	1389189	343	252954	201	26268	45	100788	52	172934	10	836245	35
2019	1374729	293	266278	174	28347	44	104118	7	182258	3	793728	65
2020	1115215	184	210183	90	19686	24	106975	23	147112	6	631259	41
2021	1230318	128	217465	47	19369	22	63330	11	143305	3	786849	45
2022	1082878	67	183558	22	23640	15	124204	11	99655	1	651821	18
Total	12797892	3372/10	2516401	1854	392262	433	970128	600	1681788	55/3	7237313	430/7

Table 1 indicates that the ^{137}Cs radionuclide forms the main part of the internal radiation dose for residents in radioactively contaminated areas. There have been registered a few cases of contamination with ^{90}Sr of food products, feeds, and medicinal herbs feedstock.

As scientists claim (Gudkov, 2012; Romanchuk, 2019), now and in the future ^{137}Cs will remain the main radionuclide influencing the health of people residing in these areas.

Analyzing the reports of the radiological departments of regional state laboratories of the State Service of Ukraine for Food Safety and Consumer Protection over the past ten years, the highest number of samples with content of ^{137}Cs higher than the permissible level has been observed in forest-based food products – 2094 samples, milk – 767 samples, wild game meat – 280 samples, feed – 62 samples, medicinal herbs – 26 samples. At the same time, higher content of ^{90}Sr was found in 7 samples of feeds, 2 samples of medicinal herbs, and 1 sample of bones from wild animals, respectively.

Therefore, the majority of samples with ^{137}Cs radionuclide content higher than permissible level have been detected in forest-based food products – 62.1% of the total number of positive results, which were detected in 3372 samples from 2013 to 2022, taken in regions established as zones with radioactive contamination because of the Chornobyl disaster. The number of samples with ^{137}Cs radionuclide content higher than the permissible level in milk, meat of wild animals, forest-based food products, medicinal herbs feedstock, and feed in the regions established as zones with radioactive contamination for the period of 2013–2022 is shown in Figure 1.

The Figure shows the period from 2013 to 2022, forest mushrooms and berries took the largest share of samples with ^{137}Cs radionuclide content higher than the permissible level. Thus, in 2014, 210 positive samples of these forest-based products were identified, they had – 47.6% of the total number of all samples with ^{137}Cs radionuclide content higher than permissible level (441 samples) for that year,

in 2021 the highest share of samples with higher content was found – 84.4% (108 samples) in forest mushrooms and berries, with a total number of samples with higher content – 128 registered that year.

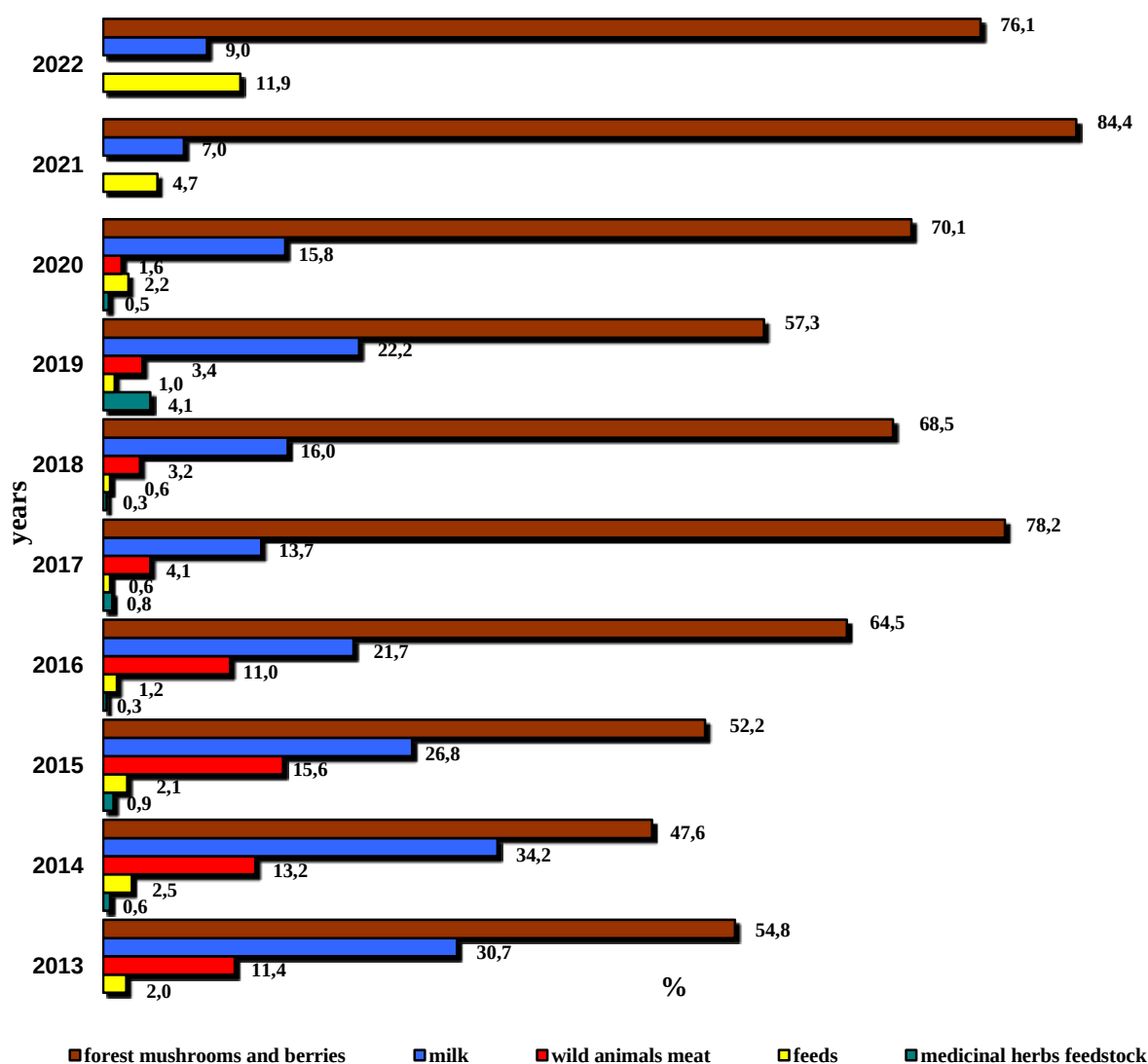


Figure 1. The shares of samples with ^{137}Cs radionuclide content higher than the permissible level in the regions established as zones with radioactive contamination from 2013 to 2022.

Thus, in 2014, there were 47.6% of samples with ^{137}Cs content higher than the permissible level in forest mushrooms and berries, 32% were taken in Zhytomyr, 9.0% in Volyn, 4.1% in Rivne, 1.4% in Kyiv, and 1.1% in Chernihiv regions. Thus, in 2021, there were 84.4% of samples with ^{137}Cs radionuclide content higher than the permissible level in forest mushrooms and berries, 35.2% were taken in Kyiv, 33.6% in Zhytomyr, 14.8% in Volyn, and 0.8% in Chernihiv regions. The change in sample number with ^{137}Cs radionuclide content higher than the permissible level in forest mushrooms and berries over the years depends on natural conditions that influence the mass migration of artificial radionuclides in the regions established as zones with radioactive contamination. However, the share of forest mushrooms and berries in the aggregate of food products, medicinal herbs feedstock, and feed contaminated with radionuclides over the past decade (2013–2022), remains significant.

This period showed no samples with a content of ^{90}Sr higher than PL in forest mushrooms and berries during the specified period.

Milk holds second place, with 22.7% of the total number of positive samples with ^{137}Cs radionuclide content higher than the permissible level for the past decade. According to the analysis, the least share of samples with ^{137}Cs radionuclide content higher than the permissible level was in milk in 2021. – 7 % (9 samples) of the total number of samples with higher content (128) for the year in the Rivne region. 34.2% (151 samples) was the highest number of samples with ^{137}Cs radionuclide content higher than permissible level in

milk, in 2014, out of the total number of positive samples (441), with 17.2% taken in Zhytomyr, 16.1% in Rivne, and 0.9% in Volyn regions.

The Polesie region, one of the most affected areas because of the Chernobyl disaster, had 80% of samples with ^{137}Cs radionuclide content higher than permissible level due to animal products consumed by people (Kotelevich, 2017; Malimon, 2020).

Samples with ^{137}Cs radionuclide higher than the permissible level in wild animals' meat over the mentioned period took 8.3% of all positive samples. However, no samples with higher content than PL of ^{137}Cs were found in 2021 and 2022. The lowest share of samples with higher content of the mentioned radionuclide in wild game meat was found in 2020–0.9% (3 samples) in the Zhytomyr region out of a total of 184 positive samples that year. In 2015, the highest share of samples with a higher content of ^{137}Cs was recorded – 15.6% (68 samples) out of the total 437 positive samples. So, out of the 15.6% of samples with higher content of ^{137}Cs , 11.9% were taken in Zhytomyr, 3.2% in Kyiv, and 0.5% in Rivne regions, respectively. In 2014, according to the test, one sample with ^{90}Sr content higher than PL was found in the bones of wild animals in the Chernihiv region.

Based on the analyzed data and the conclusions of other scientists (Gupta et al., 2018), the study of the dynamics of radionuclide content in meat should be conducted regularly. This will allow for the continuous updating of existing scientific databases and the implementation of actions to reduce the content of hazardous radionuclides in meat.

Feeds play a significant role in the chain of plants → animals → humans. According to the analysis of test results, the share of samples with ^{137}Cs radionuclide content higher than permissible levels in feeds from 2013 to 2022 was 1.8% of all positive samples. In 2017, there were only 518 positive samples for the year, with 3 cases of ^{137}Cs content higher than permissible levels in feeds. Similarly, in 2018, there were 2 samples out of a total of 343 with higher permissible levels that gave the same share of samples with higher content – 0.6% for these two years, it was the least value for the last decade, and all positive samples were taken in Volyn region. The greatest number of samples with ^{137}Cs higher content than permissible levels in feeds was found in 2022, there were 11.9% (8 samples) of all positive samples (67) for that year, with 7.4% taken in Rivne and 4.5% in Volyn regions. It should be mentioned that there were 3 samples with ^{90}Sr higher content than PL in feeds in 2013 and 4 samples in 2014 in the Kyiv region.

The higher-than-permissible level content of the radionuclide ^{137}Cs was found in medicinal herbs feedstock (substances) used for the production of medicinal products and it took 0.8% of the total number of samples with higher content. During the period from 2013 to 2022, the samples with higher than permissible level content of the radionuclide ^{137}Cs in medicinal herbs feedstock were absent in 2013, 2021, and 2022. The least number of samples with higher content of ^{137}Cs was found in 2016 with one positive case (Chernihiv region) and in 2018 with one positive case (Zhytomyr region), it took 0.3% of the total number of samples with higher content for each year out of 346 and 343 samples respectively. The greatest number of samples with a higher content of ^{137}Cs in medicinal herbs feedstock was found in 2019. – 4.1% (12 samples) out of a total number of all samples with higher content – 293. The higher content of ^{90}Sr was detected in medicinal herbs feedstock in one sample each in 2014 and 2016 year in the Chernihiv region.

The system of monitoring radiological tests still ensures the safety of food products, feeds, medicinal herbs feedstock, etc., in Ukraine in the post-Chernobyl period (Chechet et al., 2023).

Conclusions

The analysis of the results of radiological tests of food products, feeds, medicinal herbs feedstock, etc., was conducted for the period from 2013 to 2022. It has been found that there is a trend for the decline in the number of samples with a higher content of ^{137}Cs than permissible levels in all types of food products and feeds.

According to the observations over the specified period, the most critical and consistent dose-forming food products were forest mushrooms and berries, which took the most – 62.1% of samples from the total number of all samples with higher content, milk contaminated with the ^{137}Cs radionuclide had 22.7%, and feeds – 1.8%. The dynamics of samples of food products, feeds, and medicinal herbs feedstock with the content of the ^{137}Cs radionuclide higher than PL indicate that there is a continuous hazard of radioactive contamination of the local population on radiation-contaminated territories with long-lived radionuclides.

It has been proven that during the analyzed period, the ^{90}Sr was found in food products, feeds, etc., rarely.

Therefore, the content of radionuclides in forest mushrooms, berries, milk, game, feeds, and medicinal herbs, in regions contaminated because of the Chernobyl accident, in most cases significantly higher than permissible levels, it forms high dose of radiation and has a negative impact on the health of the population. Hence, conducting further radiological monitoring remains relevant today.

Further research perspective. The question of monitoring radiological tests of food products, feeds, etc., as well as timely informing the population, requires constant focus, therefore, our future tests will be devoted to implementing radiological control of products and feedstock in contaminated regions because of the Chernobyl accident. This is considered one of the effective actions for radiation protection of the population.

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РАДІАЦІЙНА СИТУАЦІЯ НА ЗАБРУДНЕНИХ ТЕРИТОРІЯХ УКРАЇНИ В ПОСТЧОРНОБІЛЬСЬКИЙ ПЕРІОД З 2013 ПО 2022 РОКИ
Малімон З. В., Кочетова Г. С., Гусак Л. М., Шуляк С. В.

Державний науково-дослідний інститут з лабораторної діагностики та ветеринарно-санітарної експертизи, Київ (Україна); e-mail: z_malimon@ukr.net*

Резюме. Метою аналізу радіологічних досліджень було визначення актуальних проблем щодо безпечності харчових продуктів, кормів, рослинної лікарської сировини тощо, одержаних з радіоактивно забруднених територій внаслідок аварії на Чорнобильській атомній електростанції. Матеріалом для аналізу була звітна документація Регіональних державних лабораторій Державної служби з питань безпечності харчових продуктів та захисту споживачів Житомирської, Волинської, Рівненської, Чернігівської областей, Центральної випробувальної державної лабораторії Держпродспоживслужби в Київській області та м. Києві за період з 2013 по 2022 рр. Проведено аналіз щодо забрудненості харчових продуктів, кормів, рослинної лікарської сировини тощо радіонуклідами ^{137}Cs та ^{90}Sr . Фахівцями регіональних державних лабораторій Держпродспоживслужби було проведено 12 797 892 радіологічних досліджень, при цьому у 3 372 зразках виявлено перевищення допустимих рівнів ^{137}Cs та у 10 випадках перевищення ДР ^{90}Sr . Основним дозоутворюючим радіонуклідом, який має значний вплив у формуванні дози внутрішнього опромінення населення встановлено ^{137}Cs . Забруднення ^{90}Sr харчових продуктів, кормів, рослинної лікарської сировини має поодинокий характер. Виявлено, що найбільшу частку перевищень допустимих рівнів радіонукліду ^{137}Cs становлять харчові продукти лісового походження (гриби, ягоди) – 62,1 %, молоко – 22,7 %, м'ясо диких тварин складає 8,3 %, корма – 1,8 %, рослинна лікарська сировина – 0,8 % від загальної кількості позитивних зразків за вказаний період. Отже, проаналізувавши результати радіологічних досліджень за останні десять років, слід зазначити, що і на сьогодні подальше проведення радіологічного контролю харчових продуктів кормів тощо на радіоактивно забруднених територіях є доцільним та потребує подальшого здійснення заходів протирадіаційного захисту, встановлених чинним національним законодавством.

Ключові слова: радіонукліди ^{137}Cs і ^{90}Sr , радіоактивно забруднені зони, харчові продукти лісового походження, корми, рослинна лікарська сировина.

DOI: 10.31073/onehealthjournal2023-IV-07