An excerpt from the review by E. K. Nilova, a senior researcher at the SSTI “Nuclear and Radiation Safety Center”:

“The largest nuclear disaster occurred in the last century. The accident at the Chernobyl nuclear power plant has happened in 1986. It has the highest level on the international nuclear events scale (the 7th level).

The consequences of the accident effected many countries in Europe to varying degrees. Ukraine, Belarus and Russia suffered the most. Moreover, the relative accident consequences severity for the Republic of Belarus turned out to be significantly higher than for neighboring countries. This is why overcoming the consequences of Chernobyl has become a task of national importance for the Republic of Belarus.

Although the first half-life of the main “Chernobyl” radionuclides (Cs-137 and Sr-90) has already ended, public education on the current radiation situation in the contaminated territories remains relevant due to the current situation with radiation exposure in the post-Chernobyl period.

The informational and journalistic essay is written in an extremely simple style that is understandable to users whose professional activity is not related to nuclear and radiation safety, as well as for children and seniors.”

34 Years After Chernobyl. Radiation, Are You Still Here?

You can read on the Internet that the half-life of the cesium-137 the Chernobyl NPP released has already ended and the danger has passed. However, it seems to be more prudent to try to understand whether the risk continues today — and if so, to learn how to avoid it.

Chernobyl NPP, 1986

Let's briefly recall the history

The accident at the Chernobyl nuclear power plant on April 26, 1986 is for good reason considered one of the largest man-made disasters. Two explosions and the ensuing fire resulted in the release of at least 200 different types of radionuclides into the atmosphere. Pollution was on a planetary scale. Cesium-137 alone contaminated more than twenty European countries.

Radioisotope Composition of the Chernobyl NPP Release

Nuclide	Half life			Half life x 10
	hours	days	years	
Neptunium-239	58			24 days
Molybdenum-99	67			28 days
Tellurium-132	78			32 days
Xenon-133	126			53 days
Iodine-131		8		80 days
Barium-140		12.8		128 days
Cerium-141		32.5		325 days
Ruthenium-103		39.6		396 days
Strontium-89		50.5		505 days
Zirconium-95		64		1.8 years
Curium-242		163		4.5 years
Cerium-144		284		7.8 years
Ruthenium-106			1	10 years
Caesium-134			2.1	21 years
Krypton-85			10.7	107 years
Plutonium-241			14.4	144 years
Strontium-90			29.1	291 years
Caesium-137			30	300 years
Plutonium-238			87.7	877 years
Plutonium-240			6537	65370 years
Plutonium-239			24390	243900 years

Fig. 1 — radioisotope composition of the Chernobyl NPP release

Today we'll start from talking about cesium-137. This nuclide of cesium along with strontium-90 and americium-241 is still one of the most dangerous radionuclides for humans.

About 35% of all released cesium-137 was fell in Belarus. As a result, 3,678 settlements were detected in contaminated territories; 479 of them ceased to exist. About 200 thousand people left the effected territories or were resettled.

Gomel, Brest and Mogilev regions of Belarus suffered the most.

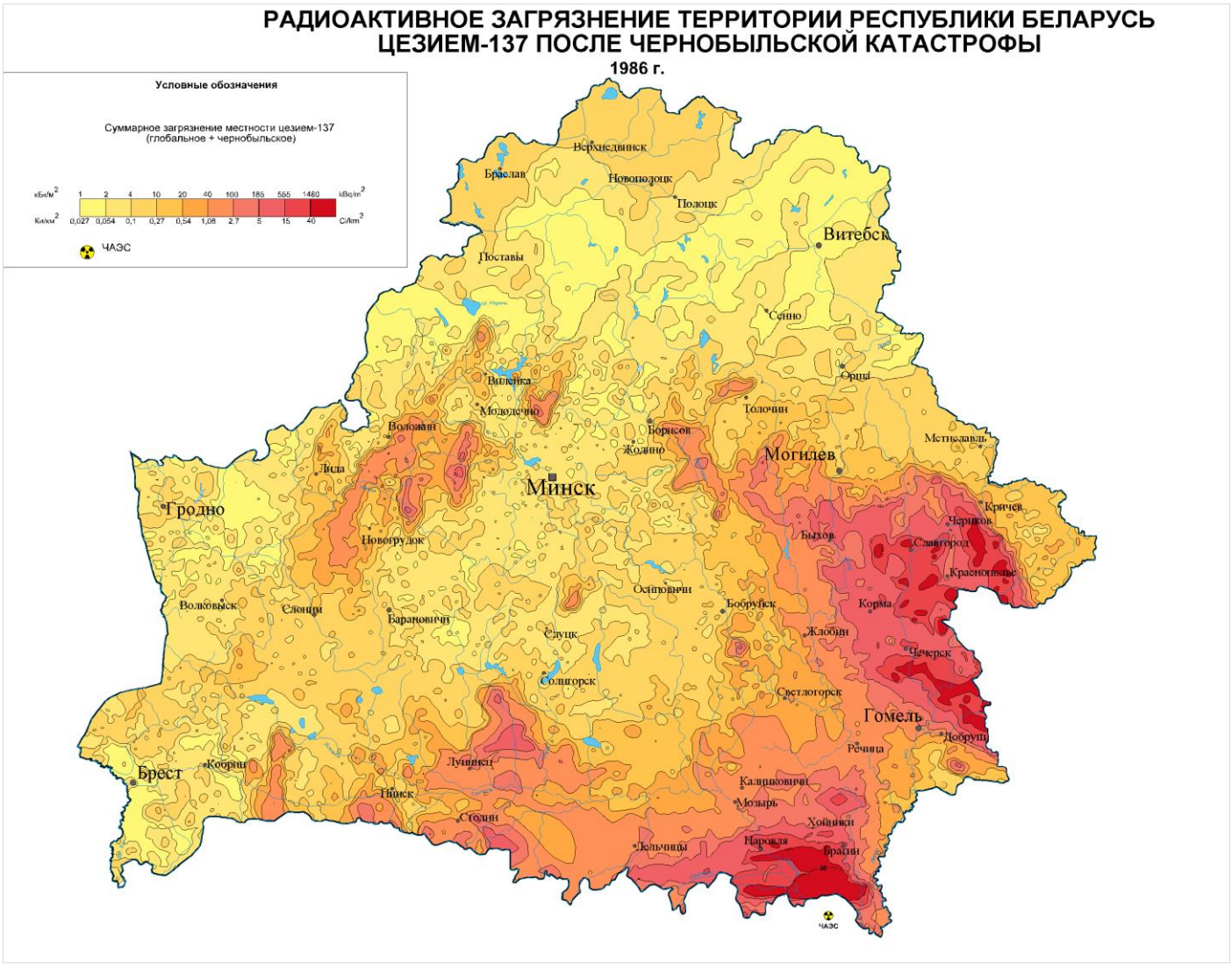


Fig. 2 — map of the Republic of Belarus territory radioactive contamination with caesium-137 after the Chernobyl disaster

How does cesium-137 enter our body?

Cesium-137 (radio-cesium) is one of cesium radioactive isotopes, that is, a type of cesium characterized by nuclear instability and tending to decay, while emitting dangerous beta and gamma radiation.

$$
\begin{aligned}
{}^{1\,37}_{55}\mathrm{Cs} &\rightarrow {}^{1\,37\mathrm{m}1}_{56}\mathrm{Ba} + e^{-} + \bar{\nu}_{e}; \\
{}^{1\,37\mathrm{m}1}_{56}\mathrm{Ba} &\rightarrow {}^{1\,37}_{56}\mathrm{Ba} + \gamma.
\end{aligned}
$$

Fig. 3 — formula for the cesium-137 radioactive decay

All cesium-137 on Earth appeared as a result of human activity. Cesium-137 that was released by the Chernobyl nuclear power plant, now lies in the soil at a depth sufficient for its absorption by plants and mushrooms (including the ones we eat).

There are more complex ways for cesium-137 to enter the human body. Wild animals, whose meat we eat, or cows, whose milk we drink, may turn out to be intermediaries between contaminated plants and humans.

Why is that bad?

Cesium-137, entering the human body, replaces potassium, which is necessary for the cardiovascular system, and accumulates in the soft tissues (mainly in the muscles and liver). Meanwhile, radioactive decay continues, resulting in internal exposure of the body.

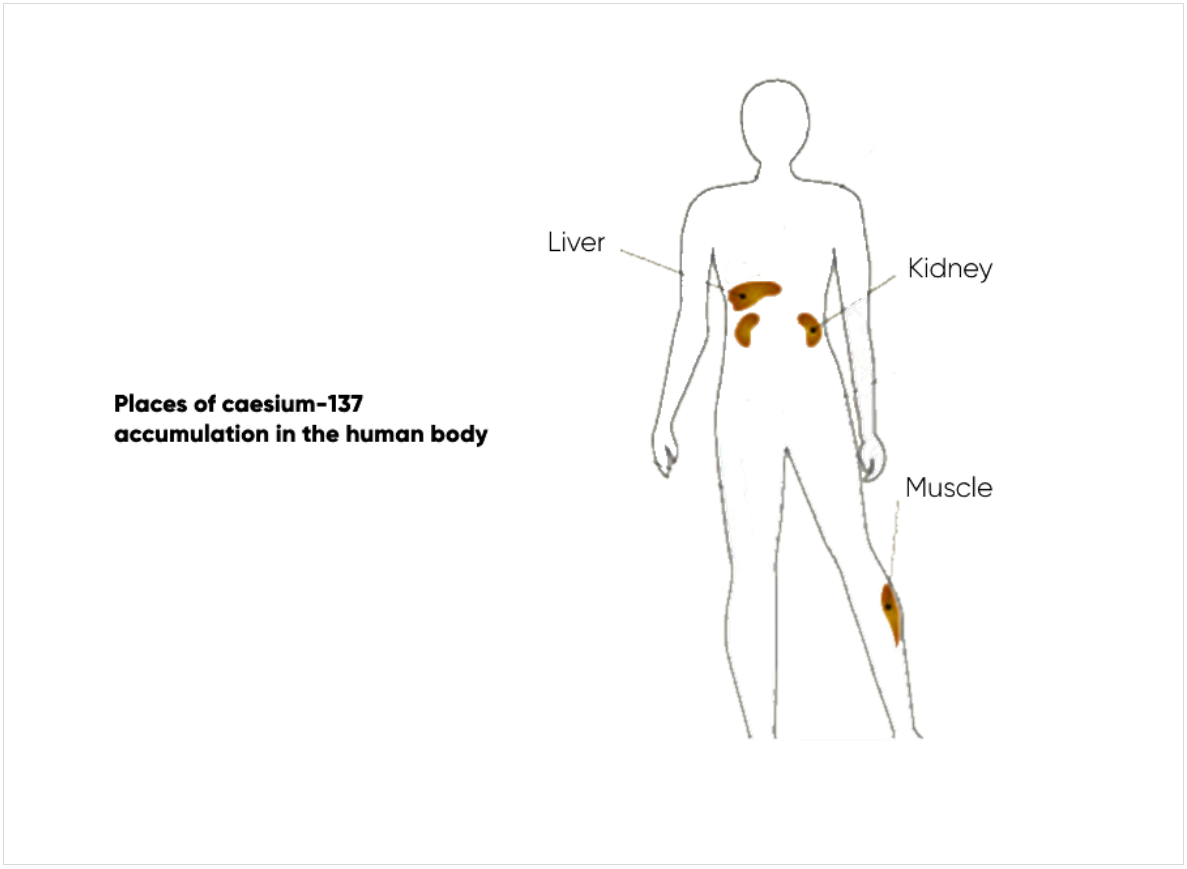


Fig. 4 — places of cesium-137 accumulation in the human body

The most common effects of cesium-137 on human health are heart diseases (vegetative-vascular dystonia, tachycardia, arrhythmia, which are known as harbingers of heart attack and stroke), as well as liver and digestive system diseases.

Also worth mentioning is a general decrease in immunity.

All of the above is compounded by the fact that the cesium-137's biological half-life is about 70 days (*biological half-life* is the time it takes from its maximum concentration to half maximum concentration in human body). Thus, with regular consumption of contaminated products, cesium radionuclide is almost constantly present in the human body.

The half-life of cesium-137 has passed. Is everything all right now?

Probably many of us breathed a sigh of relief when we heard in 2016 that the half-life of cesium had already ended (it's a bit over 30 years). But what does this really mean?

In simple terms, the amount of cesium-137 from Chernobyl has decreased by half Does this mean that radionuclide contamination has reached a safe level? Looking ahead, we can say that the data accumulated by the Belrad Institute directly indicates that it is still dangerous to consume foodstuffs collected in contaminated areas.

Then will it be enough to wait another thirty years to finally populate empty areas and walk through the Polesie Forests without a care? Unfortunately, the answer is “no” again. The fact is that the radioactive decay is exponential, not linear, that is, in each subsequent thirty years only half of the cesium amount remaining after the previous thirty-year period will decay.

The graph shows it best (fig. 5):

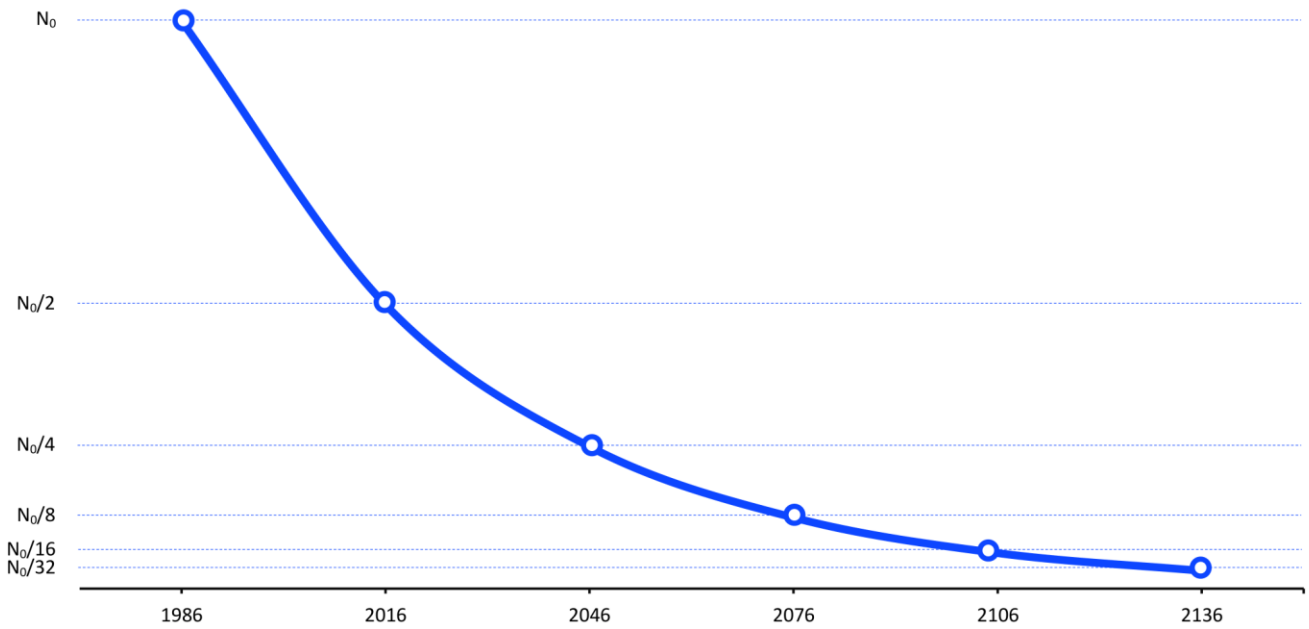


Fig. 5 — graph of the change in the number of un-decayed radionuclide atoms in accordance with the law of radioactive decay

Here, the horizontal axis shows time periods equal to thirty years, and the vertical axis — the number of cesium-137 nuclei that have not yet decayed. These nuclei continue to emit dangerous radiation and are ready to enter our body with food.

Therefore, a truly safe level of cesium contamination will only be reached after at least 10 half-lives, that is, by 2286.

What levels are safe?

Speaking about the foodstuffs contamination with cesium radionuclides, we rely on the MAC as a criterion — the Maximum Acceptable Concentration due to the republic guide standard (rus. *Республиканские допустимые уровни, РДУ*) developed by the Institute of Soil Science and Agro-chemistry, BelNII Animal Husbandry and Research Institute of Radiology of the Ministry of Emergencies (the latest edition was released in 1999).

Different foods have different acceptable levels, since the calculations took into account the average diet of Belorussian residents and the proportion of each type of food in it.

#	Product name	Bq/kg, Bq/l
1.	Drinking water	10
2.	Milk and dairy products	100
3.	Condensed and concentrated milk	200
4.	Cottage cheese and curd products	50
S.	Rennet and processed cheeses	50
6.	Cow butter	100
7.	Meat and meat products, including:	
7.1	beef, lamb and puffed ones	500
7.2	pork, poultry and products thereof	180
8.	Potatoes	80
9.	Bread and Bakery	40
10.	Flour, Grains, Sugar	60
11.	Vegetable fats	40
12.	Animal fats and margarine	100
13.	Vegetables and root vegetables	100
14.	Fruits	40
15.	Garden berries	70
16.	Canned vegetables, fruits, and garden berries	74
17.	Wild berries and canned products thereof	185
18.	Fresh mushrooms	370
19.	Dried mushrooms	2500
20.	Specialized baby foods ready to eat	37
21.	Other food	370

Fig. 6 — extract from the Maximum Acceptable Concentration of caesium-137 and strontium-90 in foodstuffs and drinking water (MAC-99, rus. *РДУ-99*)

There are some nuances, right?

It is important to understand that the actual diet of an individual person or family can seriously deviate from the average one, and in many cases, the use of products not even over limiting the MAC can lead to a significant accumulation of radionuclides in the body.

For example, the acceptable level of cesium-137 activity in cow's milk is 100 Bq/l (Becquerels per litre, which essentially means “100 radioactive decays per second in one litre of milk”). For game meat, this figure is 500 Bq/kg, as it is estimated that the average rural family consumes milk more often than game.

But let's assume that in the hunter's family, meat is consumed as often as milk. Also let’s assume that a specific meat sample has an activity of 480 Bq/kg. This sample doesn’t over limit the MAC, however, milk of similar activity would be considered unsafe to consume and over limiting the establisher norm several times.

Remembering the property of cesium-137 to accumulate in the body, we understand that the constant consumption of such meat can lead to a noticeable increase in internal radiation exposure.

Fig. 7 — wild boar meat

Often, children of hunters who have their measurements taken on a human radiation spectrometer (WBC) show results that are significantly higher than safe levels, and this repeats year after year. There’s another category of measured people: children whose

parents claim that they did not consume contaminated products, but it later turns out that they drank milk regularly. However, there are fewer and fewer of them, because young people leave villages for cities, while the elderly have no means and strength to keep a cow.

What is the situation in the “dirty” territories today?

The Belrad Institute has a radiation monitoring laboratory whose main function is to measure food samples for cesium-137 content. The LRC consists of *the basic laboratory* performing measurements in the Institute’s premises and *the mobile laboratory* based on a minivan and measuring foodstuffs during regular visits of laboratory specialists to contaminated areas.

In addition, the LRC has deployed a small but very informative network of the so-called “Centers for Practical Radiation Culture” (CPRC). In 2020, 11 such centers operate: 7 in the Gomel region, 2 in the Brest region, 1 in the Mogilev region and one more in Minsk. All of them are located in settlements with unfavorable radiation conditions.

In total, more than 352 thousand food samples were measured by the CPRCs and the basic and mobile laboratories over the years of the Institute's work.

Fig. 8 — location of the CPRCs on the Republic of Belarus territory

The radiometrists of the centers send the institute monthly reports on the measurement results of about three dozen foodstuffs samples received from the locals for the content of cesium-137 in them. As a result, it becomes possible to trace the dynamics of any product over the entire measurement period. The most problematic ones were chosen as indicative products. These are mushrooms, wild berries, game meat and milk.

Such dynamics is graphically illustrated (the following is a fragment of a diagram with the milk samples measurements results in Polesye village, Chechersky district, Gomel region from 2010 to 2013, fig. 9).

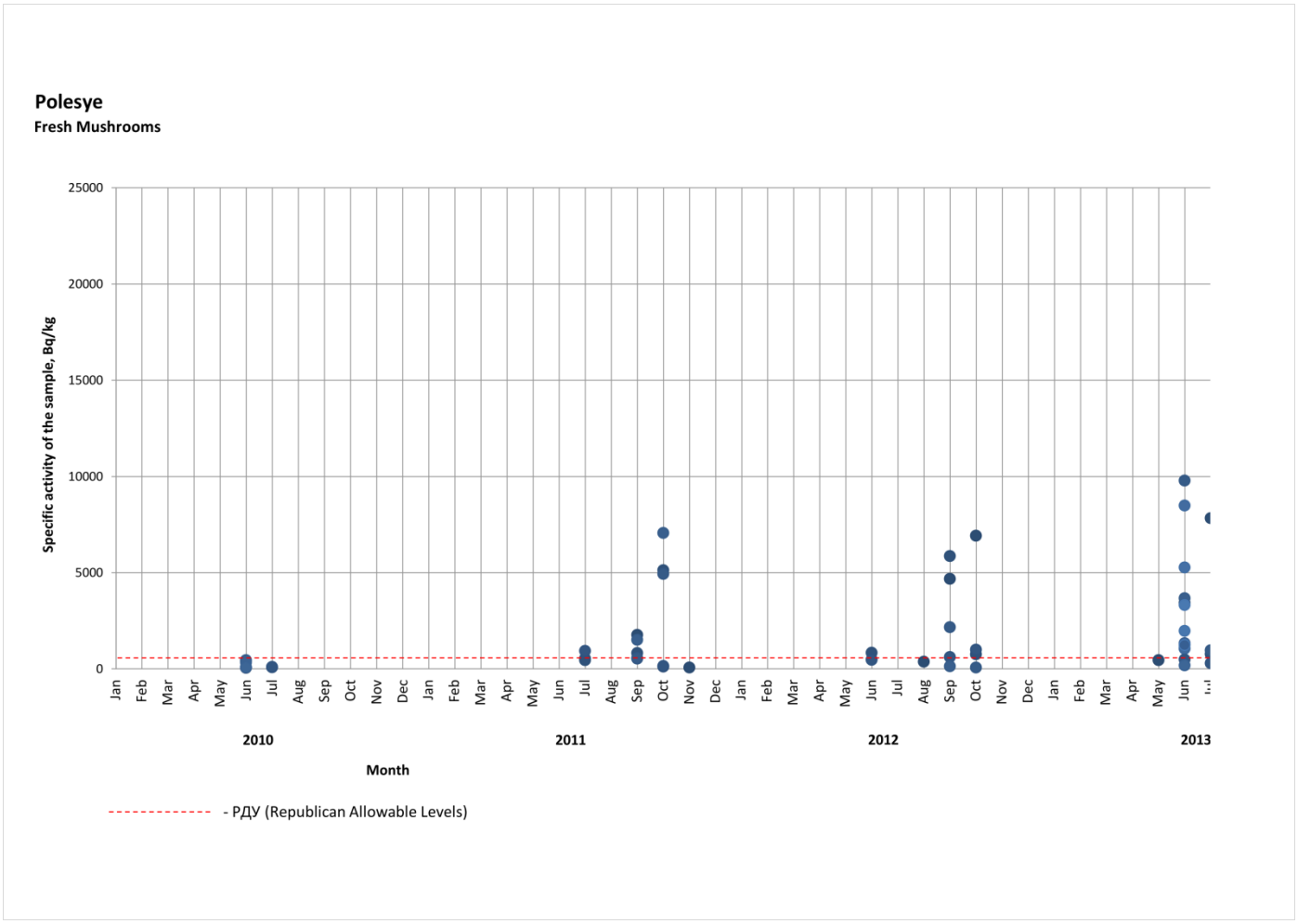
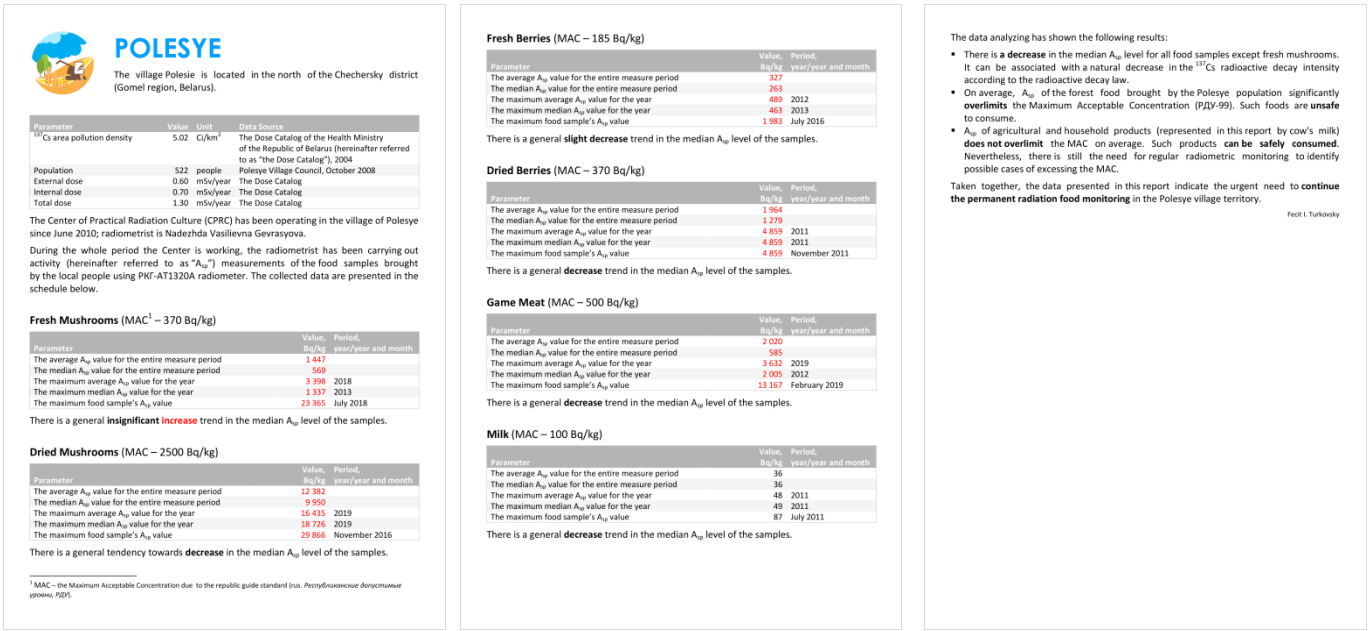


Fig. 9 — fragment of a diagram showing the results of milk samples measurements in the Polesye village (Chechersky district, Gomel region) from 2010 to 2013

Similar diagrams are built for individual farmsteads that produce milk. The overall CPRC results for the entire measurement period are summarized in a neat final report, where you can see trends, peak years and maximum values:



POLESYE

The village Polesie is located in the north of the Chechersky district (Gomel region, Belarus).

Parameter	Value	Unit	Data Source
^{137}Cs area pollution density	5.02	Ci/km^2	The Dose Catalog of the Health Ministry of the Republic of Belarus (hereinafter referred to as "the Dose Catalog"), 2004
Population	522	people	Polesye Village Council, October 2008
External dose	0.60	mSv/year	The Dose Catalog
Internal dose	0.70	mSv/year	The Dose Catalog
Total dose	1.30	mSv/year	The Dose Catalog

The Center of Practical Radiation Culture (CPRC) has been operating in the village of Polesye since June 2010; radiometrist is Nadezhda Vasilievna Gevrasyova.

During the whole period the Center is working, the radiometrist has been carrying out activity (hereinafter referred to as "A_{sp}") measurements of the food samples brought by the local people using PKГ-AT1320A radiometer. The collected data are presented in the schedule below.

Fresh Mushrooms (MAC[1] – 370 Bq/kg)

Parameter	Value, Bq/kg	Period, year/year and month
The average A_{sp} value for the entire measure period	1 447	
The median A_{sp} value for the entire measure period	569	
The maximum average A_{sp} value for the year	3 398	2018
The maximum median A_{sp} value for the year	1 337	2013
The maximum food sample's A_{sp} value	23 365	July 2018

There is a general **insignificant increase** trend in the median A_{sp} level of the samples.

Dried Mushrooms (MAC – 2500 Bq/kg)

Parameter	Value, Bq/kg	Period, year/year and month
The average A_{sp} value for the entire measure period	12 382	
The median A_{sp} value for the entire measure period	9 950	
The maximum average A_{sp} value for the year	16 435	2019
The maximum median A_{sp} value for the year	18 726	2019
The maximum food sample's A_{sp} value	29 866	November 2016

There is a general tendency towards **decrease** in the median A_{sp} level of the samples.

[1] MAC – the Maximum Acceptable Concentration due to the republic guide standard (rus. *Республиканские допустимые уровни, РДУ*).

Fresh Berries (MAC – 185 Bq/kg)

Parameter	Value, Bq/kg	Period, year/year and month
The average A_{sp} value for the entire measure period	327	
The median A_{sp} value for the entire measure period	263	
The maximum average A_{sp} value for the year	489	2012
The maximum median A_{sp} value for the year	463	2013
The maximum food sample's A_{sp} value	1 983	July 2016

There is a general **slight decrease** trend in the median A_{sp} level of the samples.

Dried Berries (MAC – 370 Bq/kg)

Parameter	Value, Bq/kg	Period, year/year and month
The average A_{sp} value for the entire measure period	1 964	
The median A_{sp} value for the entire measure period	1 279	
The maximum average A_{sp} value for the year	4 859	2011
The maximum median A_{sp} value for the year	4 859	2011
The maximum food sample's A_{sp} value	4 859	November 2011

There is a general **decrease** trend in the median A_{sp} level of the samples.

Game Meat (MAC – 500 Bq/kg)

Parameter	Value, Bq/kg	Period, year/year and month
The average A_{sp} value for the entire measure period	2 020	
The median A_{sp} value for the entire measure period	585	
The maximum average A_{sp} value for the year	3 632	2019
The maximum median A_{sp} value for the year	2 005	2012
The maximum food sample's A_{sp} value	13 167	February 2019

There is a general **decrease** trend in the median A_{sp} level of the samples.

Milk (MAC – 100 Bq/kg)

Parameter	Value, Bq/kg	Period, year/year and month
The average A_{sp} value for the entire measure period	36	
The median A_{sp} value for the entire measure period	36	
The maximum average A_{sp} value for the year	48	2011
The maximum median A_{sp} value for the year	49	2011
The maximum food sample's A_{sp} value	87	July 2011

There is a general **decrease** trend in the median A_{sp} level of the samples.

The data analyzing has shown the following results:

- There is **a decrease** in the median A_{sp} level for all food samples except fresh mushrooms. It can be associated with a natural decrease in the ^{137}Cs radioactive decay intensity according to the radioactive decay law.
- On average, A_{sp} of the forest food brought by the Polesye population significantly **overlimits** the Maximum Acceptable Concentration (РДУ-99). Such foods are **unsafe** to consume.
- A_{sp} of agricultural and household products (represented in this report by cow's milk) **does not overlimit** the MAC on average. Such products **can be safely consumed**. Nevertheless, there is still the need for regular radiometric monitoring to identify possible cases of excessing the MAC.

Taken together, the data presented in this report indicate the urgent need to **continue the permanent radiation food monitoring** in the Polesye village territory.

Fecit I. Turkovsky

Fig. 10 — final reports on the work of the CPRCs in Polesie village

All currently prepared reports are available here: https://drive.google.com/open?id=1sfCUzSYLnU5rY0tWNG6w2XRAWR0KXhqW

For clarity, we have shown some important parameters in two tables. The first one (fig. 11) illustrates the median value of the products specific activity in all the CPRC for the entire period of work, and the second one (fig. 12) reflects the increase or decrease trends in specific activity for each product and each settlement.

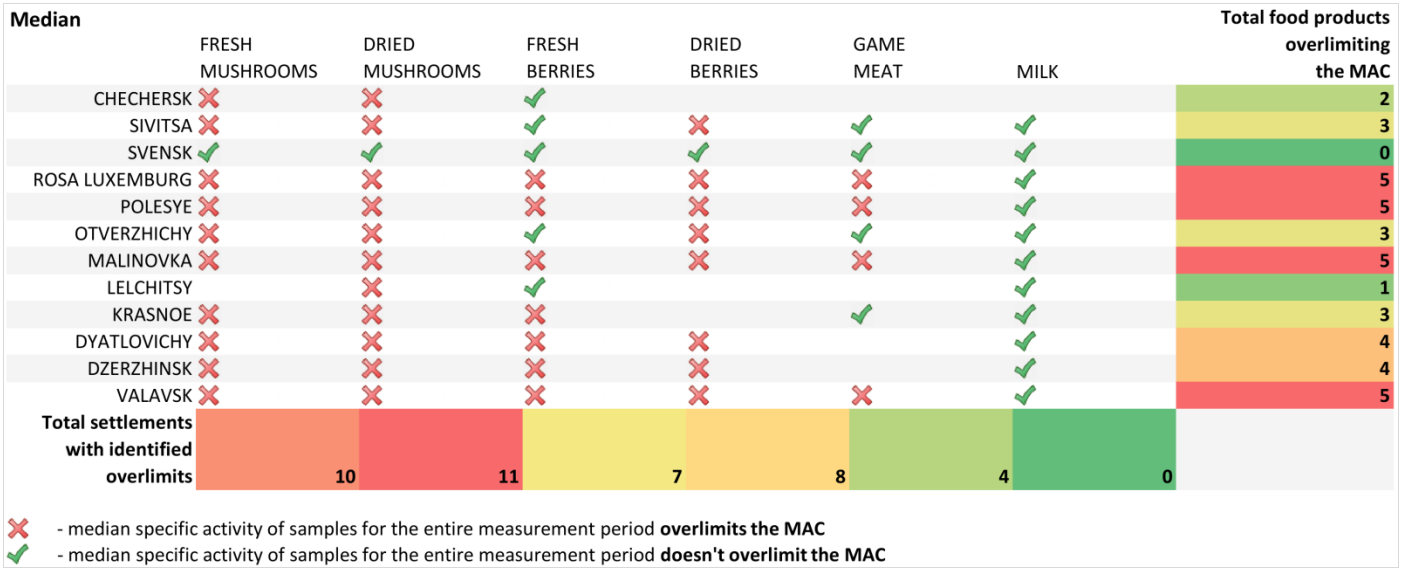


Fig. 11 — table illustrating the foodstuffs specific activity median value in all CPRCs for the entire period of their work

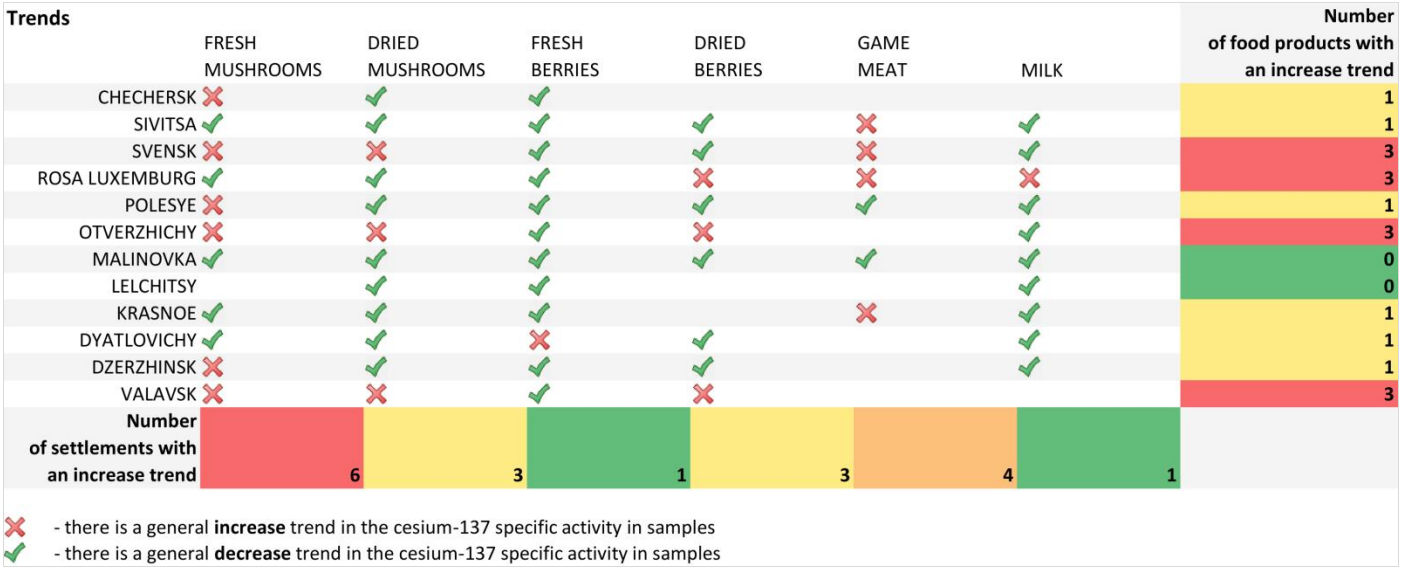


Fig. 12 — table illustrating increasing or decreasing trends in specific activity for each foodstuff and each settlement

For reference: in statistics, *the median* is the value separating the higher half from the lower half of a data sample. Compared with the average value, the median is less sensitive to the

so-called “outliers” (that is, atypical, too large or too small values). Therefore, it reflects the tendency for most values in the studied sample more correctly.

All the data that we have collected as a result of the CPRC’s activities over the past decade, allow us to draw the following conclusions:

- The largest list of products in which the median specific activity for the entire measurement period over limits the MAC is shown by the CPRC in **Rosa Luxemburg** village (Elsk District), **Polesye** village (Chechersk District) and **Malinovka** village (Loev District). All of them are situated in Gomel region which is the most affected by Chernobyl region.

- The lowest values for this parameter were demonstrated by the CPRC at **Svensk village** (Slavgorod district, Mogilev region) and the **Lelchitsy District Gymnasium** CPRC (Lelchitsy district, Gomel region), and not the CPRC in the Minsk region, as one might suppose.

- Products that have over limited the MAC in their median specific activity over the entire measurement period are **dried and fresh mushrooms** and **fresh berries**.

- As expected, the peak months are the fall months, which are the most plenteous for forest products.

- **Fresh mushrooms** (absolute first place!) and **game meat** turned out to be the products most likely to increase the annual median specific activity over time.

- The most optimistic dynamics in the annual median specific activity can be seen in the CPRC at **Malinovka village** (Loev district, Gomel region) and the **Lelchitsy District Gymnasium** CPRC (Lelchitsy district, Gomel region).

Fig. 13 — forest products

On average, there is a decrease trend in the cesium-137 specific activity in food samples. This is probably due to a natural decrease in the radioactive decay intensity according to the previously mentioned exponential decay law.

Nevertheless, some settlements do not have positive dynamics. Moreover, they show an alarming increase trend in median specific activity for each subsequent year. These settlements are **Valavsk** and **Rosa Luxemburg villages** (Elsk district, Gomel region), **Svensk village** (Slavgorod district, Mogilev region), and **Otverzhichy village** (Stolin district, which is the most polluted area of the Brest region).

This may be due to a change in the “yield” of the forest in different years, as well as to a weakening of the population’s vigilance or to the expansion of mushroom and berry picking areas to territories that are completely unsafe for this.

Record values of specific activity of the samples are shown in the table below (fig. 14; there is no Lelchitsy District Gymnasium CPRC, because it worked for only three years):

The maximum specific activity values among all measured samples, Bq/kg

CPRC	Fresh Mushrooms	Dried Mushrooms	Fresh Berries	Dried Berries	Game Meat	Milk
РДУ	370	2500	185	370	500	100
Sivitsa Volozhin, since 2011	11 202 aug 2019 (12*)	15 842 sep 2014 (4)	1 204 jul 2013 (9)	914 feb 2014 (1)	12 933 feb 2016 (9)	3 438 may 2011 (8)
Svensk Slavgorod, since 2017	641 nov 2019 (3)	5 149 nov 2019 (3)	708 nov 2019 (3)	293 jan 2019 (2)	2 266 jan 2018 (1)	213 jan 2020 (3)
Polesye Chechersk, since 2010	23 365 jul 2018 (6)	29 866 nov 2016 (3)	1 983 jul 2016 (8)	4 859 nov 2011 (1)	13 167 feb 2019 (1)	87 jul 2011 (5)
Rosa Luxemburg Elsk, since 2011	12 800 oct 2014 (1)	17 600 feb 2016 (5)	5 637 jul 2014 (15)	5 366 jan 2017 (3)	24 899 jul 2014 (19)	104 aug 2017 (7)
Valavsk Elsk, since 2011	28 888 oct 2017 (2)	11 327 dec 2017 (1)	7 387 aug 2016 (22)	11 217 feb 2020 (2)	8 545 apr 2016 (1)	229 mar 2014 (23)
Dzerzhinsk Lelchitsy, since 2014	518 oct 2019 (16)	5 928 mar 2015 (2)	284 dec 2016 (1)	2 816 dec 2015 (1)	-	107 dec 2015 (2)
Malinovka Loev, since 2014	9 820 sep 2017 (14)	11 491 sep 2017 (6)	1 099 apr 2017 (2)	-	3 910 oct 2014 (4)	157 may 2016 (7)
Krasnoe Bragin, since 2013	20 108 nov 2019 (4)	17 376 oct 2013 (2)	797 may 2016 (2)	-	19 916 apr 2014 (12)	95 jun 2014 (11)
Dyatlovichi Luninets, since 2010	10 230 oct 2014 (17)	325 703 oct 2010 (5)	1 090 jul 2014 (5)	4 229 apr 2014 (1)	-	128 jul 2010 (18)
Otverzhichy Stolin, since 2014	427 sep 2017 (1)	260 000 dec 2019 (2)	331 nov 2017 (1)	15 567 mar 2016 (2)	60 mar 2018 (4)	54 may 2014 (1)
Chechersk, School #2, since 2018	3 717 nov 2019 (2)	29 988 dec 2018 (1)	676 nov 2018 (4)	-	-	-

* — the figures in parentheses indicate the number of the specified food product samples measurements in the specified CPRC, carried out during the specified month

Fig. 14 — table of samples with record measured specific activity

Let's summarize:

- Years with the largest number of "record" products in Gomel region are 2014, 2016 and 2017; in Brest and Minsk regions — 2014; in Mogilev region — 2019.
- Speaking about samples of fresh mushrooms, the maximum specific activity was recorded in **Valavsk** and **Polesie**; dried mushrooms — in **Dyatlovichy** and **Otverzhichy** (pay attention to these colossal numbers!); fresh berries — in **Valavsk** and **Rosa Luxemburg**; dried berries — **Valavsk** and **Otverzhichy** again; game meat — in **Rosa Luxemburg** and **Krasnoe**, and milk in **Sivitsa**.
- Thus, the largest number of record values is in Yelsk district centers (Gomel region); Stolin district (Brest region) is not far behind.

Here is another table: the so-called "peak" years with the maximum median specific activity value for a whole year of measurements are shown here (fig. 15):

Maximum annual median values of specific activity, Bq/kg

CPRC	Fresh Mushrooms	Dried Mushrooms	Fresh Berries	Dried Berries	Game Meat	Milk
РДУ	370	2500	185	370	500	100
Sivitsa Volozhin, since 2011	**600** 2014 (46*)	**2 245** 2016 (13)	**388** 2013 (21)	**914** 2014 (1)	**577** 2011 (51)	**32** 2011, 2012, 2013 (42, 53, 50)
Svensk Slavgorod, since 2017	**237** 2018 (64)	**2 274** 2018 (11)	**183** 2017 (40)	**223** 2018 (5)	**782** 2018 (16)	**27** 2017 (27)
Polesye Chechersk, since 2010	**1 337** 2013 (30)	**18 726** 2019 (4)	**463** 2013 (15)	**4 859** 2011 (1)	**2 005** 2012 (7)	**49** 2011 (64)
Rosa Luxemburg Elsk, since 2011	**3 700** 2011 (11)	**9 733** 2014 (27)	**2 822** 2014 (24)	**4 160** 2015 (1)	**2 930** 2014 (134)	**55** 2017 (105)
Valavsk Elsk, since 2011	**3 491** 2016 (2)	**4 833** 2020 (7)	**1 451** 2015 (3)	**8 941** 2020 (3)	**8 545** 2016 (1)	**72** 2011 (28)
Dzerzhinsk Lelchitsy, since 2014	**398** 2019 (27)	**4 413** 2015 (7)	**217** 2016 (2)	**2 224** 2015 (5)	-	**93** 2016 (12)
Malinovka Loev, since 2014	**1 188** 2014 (29)	**6 871** 2016 (23)	**616** 2018 (30)	-	**1 386** 2014 (29)	**7** 2014–2016 (76, 72, 66)
Krasnoe Bragin, since 2013	**1 313** 2017 (20)	**12 439** 2013 (4)	**318** 2014 (14)	-	**416** 2015 (29)	**27** 2014 (96)
Dyatlovichi Luninets, since 2010	**1 002** 2010 (25)	**7 012** 2011 (7)	**599** 2017 (14)	**4 002** 2014 (2)	-	**66** 2010 (26)
Otverzhichy Stolin, since 2014	**427** 2017 (1)	**55 811** 2020 (7)	**80** 2019 (7)	**2 114** 2019 (8)	**35** 2018 (4)	**44** 2014 (3)
Chechersk, School #2, since 2018	**1 865** 2019 (9)	**29 888** 2018 (1)	**34** 2018 (5)	-	-	-

* — the figures in parentheses indicate the number of the specified food product samples measurements in the specified CPRC, carried out during the specified year

Fig. 15 — table of years with the maximum median specific activity value for a whole year of measurements

This shows the following:

- The peak years in Gomel region are 2014, 2015 and 2016; in Mogilev region — 2018; in Minsk region — 2011–2014; in Brest region — 2010, 2014, 2017 and 2019.
- The maximum number of record annual median values belong to Yelsky District CPRCs (Valavsk and Rosa Luxemburg) again.

Thus, the record values and the MAC over limits were observed not only at the times when the CPRCs were created, but also in very recent years, including the current. It seems to be the most obvious answer whether it is possible to "calm down" and consider yourself safe only because the first radio-cesium half-life has ended.

At the same time, the general decrease trend is also quite expected and natural (once again we recall the exponential radioactive decay). This is confirmed by data obtained from radiometrists.

We also want to note that some settlements appeared in our “leaderboard” in several "nominations" at once, which requires at least, close attention to them, as well as

continuing radiometric monitoring on their territory. However, we'll say some words about how to deal with it later.

What about other sources?

Information about such measurements on the Internet is presented rather sparingly. More often everything is limited to a historical excursion and a reminder of the cesium-137 dangers. All this is undoubtedly useful, but it is equally certain that you should know where exactly this danger is hidden.

With a certain zeal, useful information is discovered. For example, here is the 2014 material of RUE "Scientific and Practical Center for Hygiene" (SPCH) (https://www.rspch.by/ru/node/137), from where we learn that due to continuous radiation monitoring it is practically impossible to find agricultural products over limiting the MAC in our republic.

On the other hand, the authors note the following: *«in 2014, the record holders for over limiting permissible levels ... were game meat (over limiting in 24.3% of samples), mushrooms (overlimiting in 22.9%) and wild berries (exceeding 15.5%).»*

Also: *«The main source of exposure in the affected areas is forest products (mushrooms, berries, game meat). They account for up to 40% of the radionuclides intake in the human body in recent years, the remaining 60% are other foods of the normal diet.»*

This information is consistent with the results obtained by the Belrad Institute.

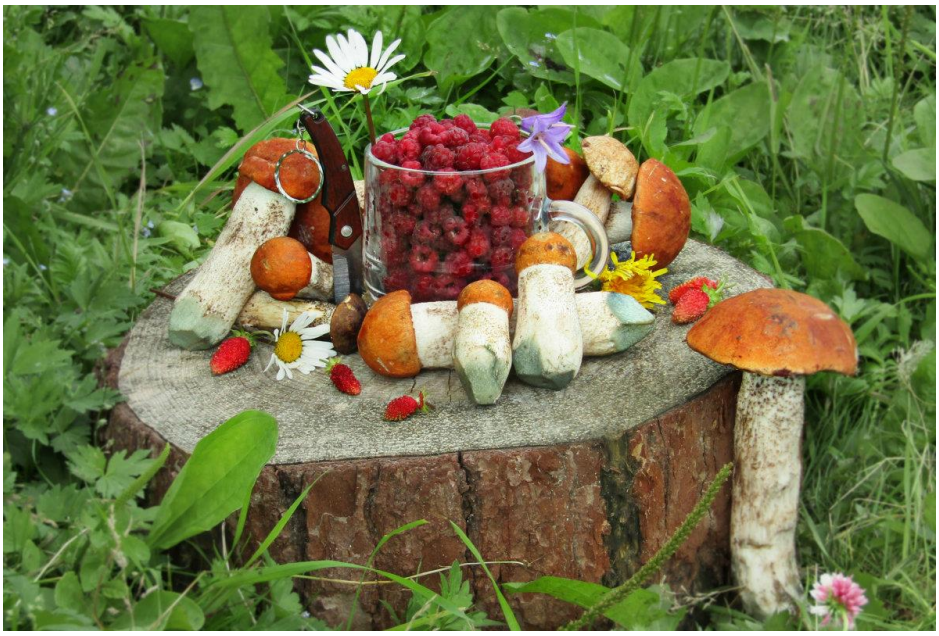


Fig. 16 — forest mushrooms and berries

We also found a very interesting work by the senior lecturer of the Life Safety Department and the candidates of agricultural and technical sciences of BSTU on the degree of forest foodstuffs radiation contamination and its contribution to the radiation dosage of the population. (https://cyberleninka.ru/article/n/issledovanie-stepeni-radiaktivnogo-zagryazneniya-pischevoy-produktsii-lesa-i-ee-vklad-v-dozovuyu-nagruzku-naseleniya, N. O. Azovskaya, V. V. Peretrukhin, G. A. Chernushevich, 2018).

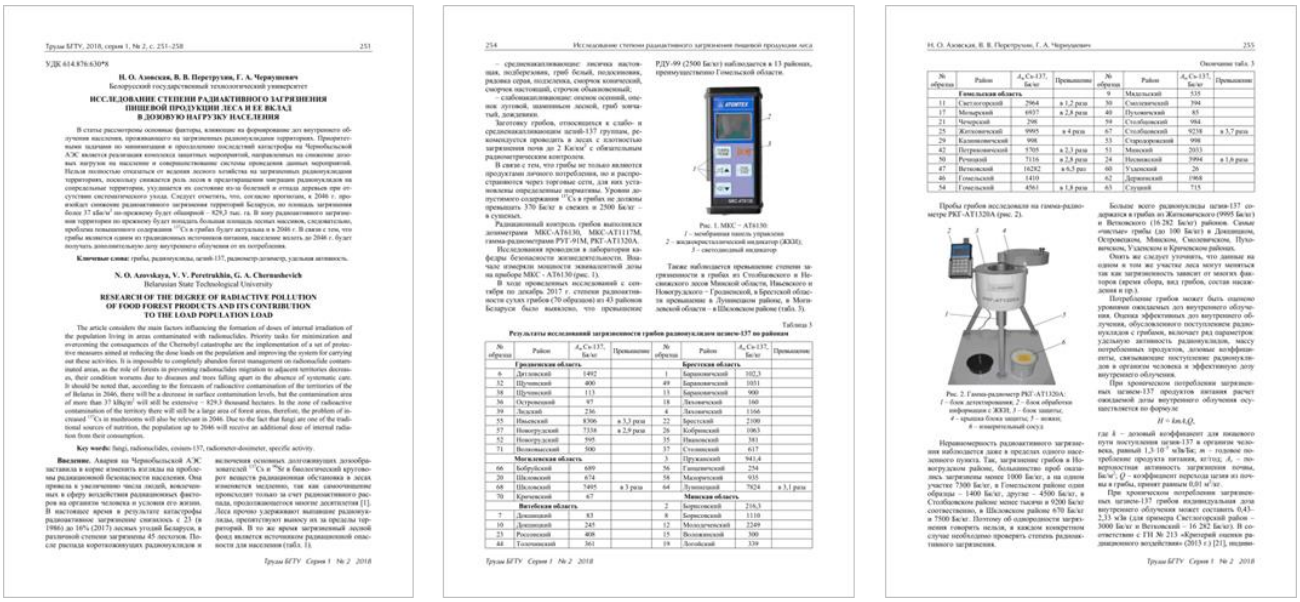


Fig. 17 — fragment of a scientific article «Research of the Degree of Radioactive Pollution», N. O. Azovskaya, V. V. Peretrukhin, G. A. Chernushevich, 2018

Here, the authors argue that the main contribution to the radiation dosage is made from mushrooms, and this situation will continue for several decades. In second place are wild berries.

To come to this conclusion, the authors conducted a very geographically extensive study. The biggest interest is the table of over limiting the MAC in mushrooms samples in 56 districts of the republic — we will show you the entire table (fig. 18):

The results of studies of contamination of mushrooms with radionuclide caesium-137 by district

Sample number	District	A_m Cs-137, Bq/kg	Overlimiting	Sample number	District	A_m Cs-137, Bq/kg	Overlimiting
Grodno region				**Brest region**			
6	Diatlovsky	1492		1	Baranovichsky	102,3	
32	Shchuchinsky	400		49	Baranovichsky	1031	
38	Shchuchinsky	113		13	Baranovichsky	900	
36	Ostrovetcky	97		18	Liahovichsky	160	
39	Leedsky	236		4	Liahovichsky	1166	
55	Ivievsky	8306	3.3 times	22	Brestsky	2100	
57	Novogrudsky	7338	2.9 times	26	Kobrinsky	1063	
52	Novogrudsky	595		35	Ivanovsky	381	
71	Volkovyssky	500		37	Stolinsky	617	
Mogilev region				3	Pruzhansky	941,4	
66	Bobruisky	689		56	Gantcevichsky	254	
20	Shclovsky	674		58	Maloritsky	935	
68	Shclovsky	7495	3 times	64	Luninetcky	7824	3.1 times
70	Krichevsky	67		**Minsk region**			
Vitebsk region				2	Borisovsky	216,3	
7	Dokshitcky	83		8	Borisovsky	1110	
10	Dokshitcky	245		12	Molodechensky	2249	
23	Rossonsky	408		15	Volozhinsky	300	
44	Tolochinsky	361		19	Logoisky	339	
Gomel region				9	Miadelsky	535	
11	Svetlogorsky	2964	1.2 times	30	Smolevichsky	394	
17	Mozyrsky	6937	2.8 times	40	Puhovichsky	85	
21	Chechersky	298		59	Stolbtcovsky	984	
25	Zhitkovichsky	9995	4 times	67	Stolbtcovsky	9238	3.7 times
29	Kalinkovichsky	998		53	Starodorozhsky	998	
42	Petrikovichsky	5705	2.3 times	51	Minsky	2033	
50	Rechitcky	7116	2.8 times	24	Nesvizhsky	3994	1.6 times
47	Vetkovsky	16282	6.5 times	60	Uzdensky	26	
46	Gomelsky	1410		62	Derzhinsky	1968	
54	Gomelsky	4561	1.8 times	63	Slutcky	715	

Fig. 18 — table of over limiting the MAC in the mushroom samples in the Republic of Belarus regions

We also present you a chart from one of the forestries of Lelchitsky district. It shows birch sap contamination levels with an interesting increase in the maximum level in 2019 (fig. 19):

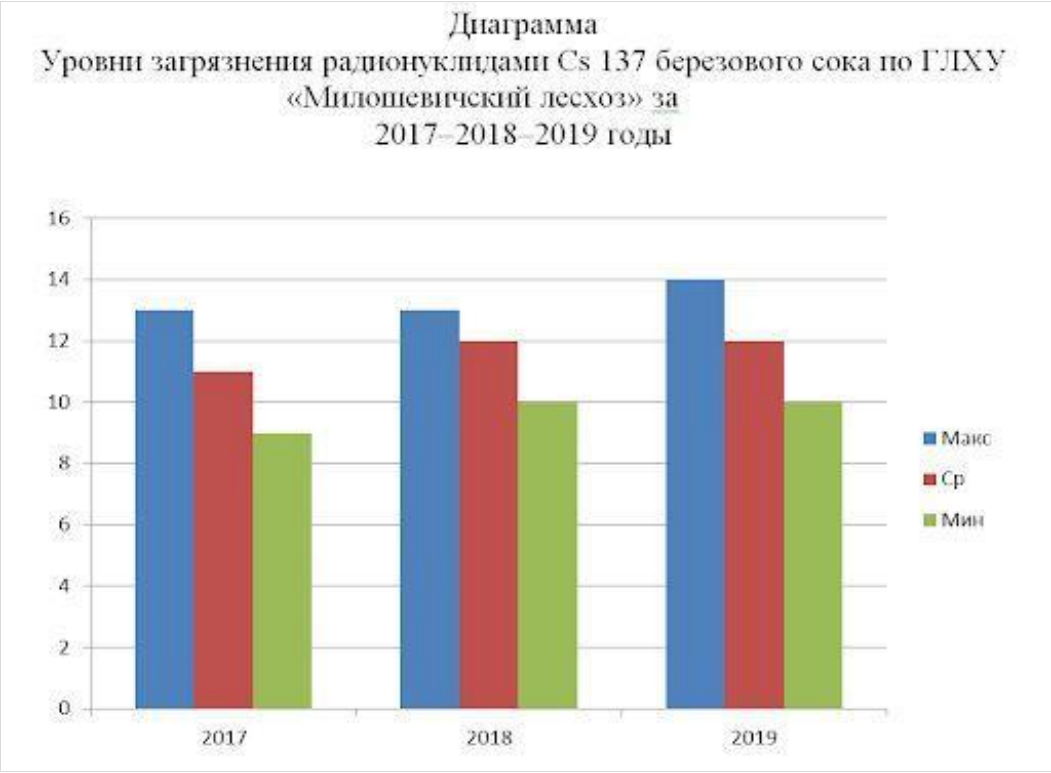


Fig. 19 — diagram of the birch sap contamination level with radionuclides of cesium-137 according at the Miloshevichy forestry in 2017–2019

Many forestries (though not all of them) more or less regularly update information on the results obtained from forest food measurements on the Internet.

How to protect yourself from radiation?

The most complete and affordable way to gain knowledge in this area without having a radiometrists nearby is reading the book "How to Protect Yourself and Your Child from Radiation: A Guide for Parents" by V. I. Babenko (fig. 20; published in 2003 and re-released in 2007; it was also translated into German, French and Japanese).

Fig. 20 — Book «How to Protect Yourself and Your Child from Radiation: Parents' Allowance», V. I. Babenko

We will now briefly highlight some key points. So, what can everyone do to eliminate the influence of harmful cesium on us and our families?

- **Radiometric control.** Any products from the forest, as well as homemade milk, should be checked on a radiometer before eating.

- **Exclusion from the diet.** It can be difficult to find a radiometrists with a radiometer in the nearest access — then potentially dangerous foods are simply better not to eat. Moreover, it is absolutely necessary to remove from the diet everything that, when measured, showed an over limit of the MAC.

- **Special food preparation.** Even food contaminated with radio-cesium can be cleaned to a certain level. Sometimes the financial situation of rural population simply does not allow

changing the diet and excluding dangerous products from it. In such cases, it is strongly recommended to process food in a certain way.

- **Mushrooms** should be soaked in a salted vinegar solution. Ionic exchange cleans them of radionuclides, provided that you repeat the procedure several times and often discharge the water.

- **Berries** are quite effective to soak in a citric acid solution.

- **Milk** needs processing for partial purification of radionuclides. As a result, about 90% of radionuclides will remain in serum.

- **The** meat can be soaked in a salt solution or boiled. Both slould be repeated several times. Also, salting meat in combination with soaking is effective.

- **WBC-measurements.** None of the above excludes radionuclides from entering the body. Comprehensive monitoring is most effective for identifying contaminated foods. It includes both radiometric food control and measuring the population with a WBC-spectrometer (the whole body spectrometer).

A special spectrometer chair is used for such measurements. It works in a manner similar to that of the photomultiplier. a gamma particle entering a detector called a scintillator causes a photon flash in it. Then these flashes are recorded and counted by the device.

Fig. 21 — measurement on a spectrometer of human radiation

Values up to 20 Bq/kg are considered a safe level of radionuclide activity in the human body. From 20 to 50 Bq/kg for a child and from 20 to 70 Bq/kg for an adult is a control level that does not carry great danger, but still requires measures to reduce and re-control. Values above may be harmful.

- **Excretion of cesium from the body.** If unsafe levels are detected as a result of WBC measurements, it is equally necessary to eliminate the pathways of the radionuclide entering the body and take measures to remove from the body those radionuclides that have already been accumulated. Pectin preparations and pectin-containing products (apples, apricots, marshmallows, and generally all fruits and vegetables that have a color from yellow to red) cope with this most effectively. Apples are especially remarkable in that they never accumulate radio-cesium.

At the end of such events, monitoring on the WBC should be repeated.

Food product	The content of pectin, %	Food product	The content of pectin, %
Sugar beet	18–30	Black currant	4.2–12.6
Carrot	6.4–20	Cranberry	6.6–11
Feed watermelon	6.4–23.6	Red currant	4.2–12.6
Pumpkin	2.6–17	Citrus	9–14
Apple	6.1–19.9	Persimmon	9–12
Rowan	9.3–10.6	Fig	5.5–15.8
Quince	5.3–9.6	Pear	3.3–8.0
Gooseberry	5.5–7.9	Grape	4.2–6.6

Fig. 22 — pectin content of certain foodstuffs

Where to get the WBC measurements?

The Belrad Institute has the laboratory of human radiation (WBC) since 1997. The laboratory focuses on measuring children as the most vulnerable part of the population, therefore, most often measurements are carried out in schools and kindergartens.

The WBC laboratory also takes measurements at its premises in Minsk. Regional hospitals, border troops and some scientific organizations conduct such activities in Belarus too.

The WBC laboratory made more than 600 thousand measurements in 322 settlements of the Gomel region, 43 in Mogilev region, and 105 in Brest region throughout its existence.

The territories of Minsk, Grodno and Vitebsk regions and Bryansk region (the most affected region in Russia) were visited by the laboratory too.

The WBC laboratory specialists visit many settlements annually or even several times a year to track the dynamics in the measurement results. Then the statistical processing of these results is published in the radio-ecological atlas “Human and Radiation”.

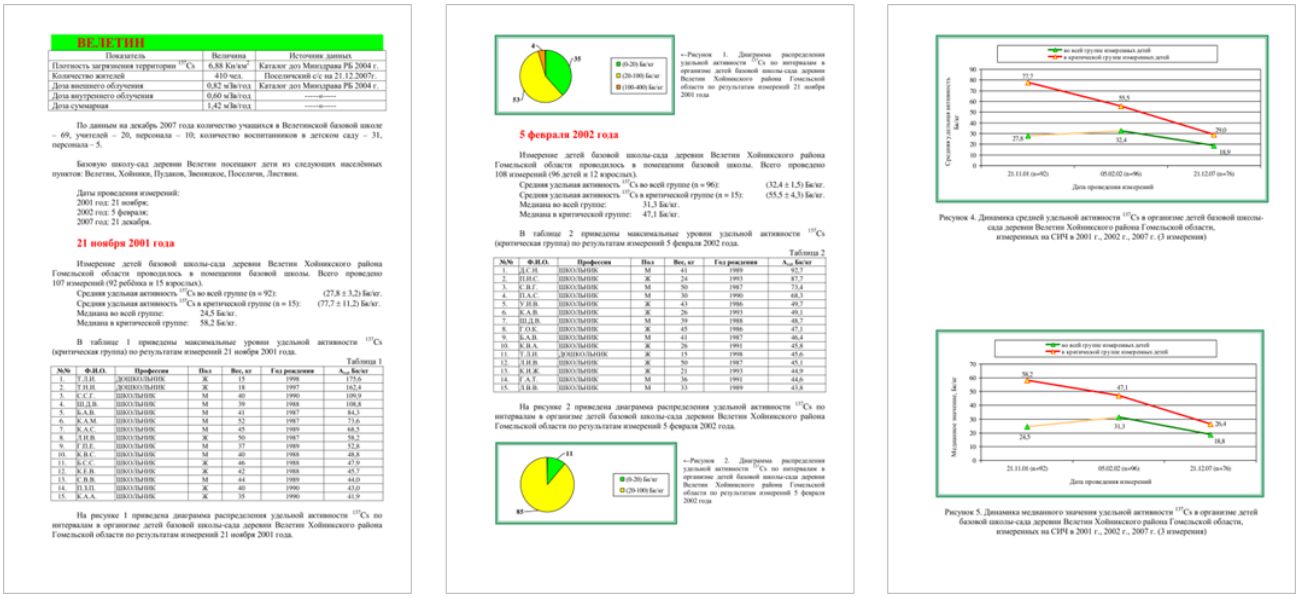


Fig. 23 — fragment of the radioecological atlas “Human and radiation”

Currently the 2011 edition of the atlas is available in in the National Library of Belarus catalog (https://e-catalog.nlb.by/Record/BY-NLB-br0001149725), and right now the staff of the institute is preparing a new edition that will show up both WBC measurements results up to 2019 and CPRC activity reports. The integration of the WBC statistics with data from CPRC will enable the relationship between these data to be identified. This in turn will help to formulate more effective recommendations on prevention and protective measures for inhabitants of affected areas.

The atlas “Human and Radiation” is a very informative and detailed work of our colleagues, and we advise all those who are interested in radiation safety to familiarize with it themselves.

In general, materials from the atlas show that:

- on the one hand, the decrease trend in specific activity (i.e., the amount of radionuclides in the body) in children in contaminated areas is observed quite clearly;
- on the other hand, looking at the measurement results of even the last three years, we admit with regret: it is too early to consider this decrease to be sufficient, children continue to accumulate cesium.

How do we help children in this situation?

We have already mentioned that pectin preparations are quite effective in the fight against radionuclides that have entered our body. The Belrad Institute has developed such a preparation too. Meet: already well known to many children from contaminated areas pectin-containing enterosorbent Vitapect-3. It binds and removes radionuclides and salts of heavy metals from the body, while having a pleasant apple taste, which is important for a children's audience.

Composition

	Daily intake			Percentage of recommended daily intake	
	Single dose content	children from 3 years old	adults	children from 3 years old	adults
Vitamin B_{12}, μg	0.46	0.93	1.39	62	46
Vitamin B_2, mg	0.155	0.31	0.46	26	31
Vitamin B_6, mg	0.54	1.08	1.62	77	85
Vitamin C, mg	15.5	31	46.5	62	66
Vitamin E, mg	2.32	4.64	6.96	58	77
β-carotene, mg	0.77	1.55	2.32	31	46
Folic acid, μg	31	62	93	31	47
Zn, mg	2.32	4.64	7.0	58	47
K, mg	96.75	193.5	290.3	14	
Citric acid, mg	44	264	396		

Nutritional value per 100 g: protein - 2.0 g, fat - 1.7 g, carbohydrates - 87.0 g
Energy value kcal / kJ - 371/1553

Fig. 24 — appearance of packaging and composition of enterosorbent «Vitapect-3»

To a large extent, the decrease in specific activity in children, which was recorded by the WBC laboratory, is due to pectin cures using Vitapect-3. To assess the effectiveness of cures, the measurement is carried out before and after the course of enterosorbent treatment, and then the results are compared — this is also demonstrated in the atlas “Human and Radiation”.

As a result, the most impressive decrease in specific activity in children’s bodies is observed when they receive Vitapect-3 during the recuperative holidays abroad (in some cases up to 90%) or in Belarusian sanatoriums (40–60%). This is due both to a healthy diet and clean foods during recovery, as well as to the fact that adults control the intake of enterosorbent by children.

For example, here is a diagram that shows the decrease in specific activity in different years by groups of children resting in the children's rehabilitation and health center "Nadezhda" (Vileyka district, Minsk region; Fig. 25).

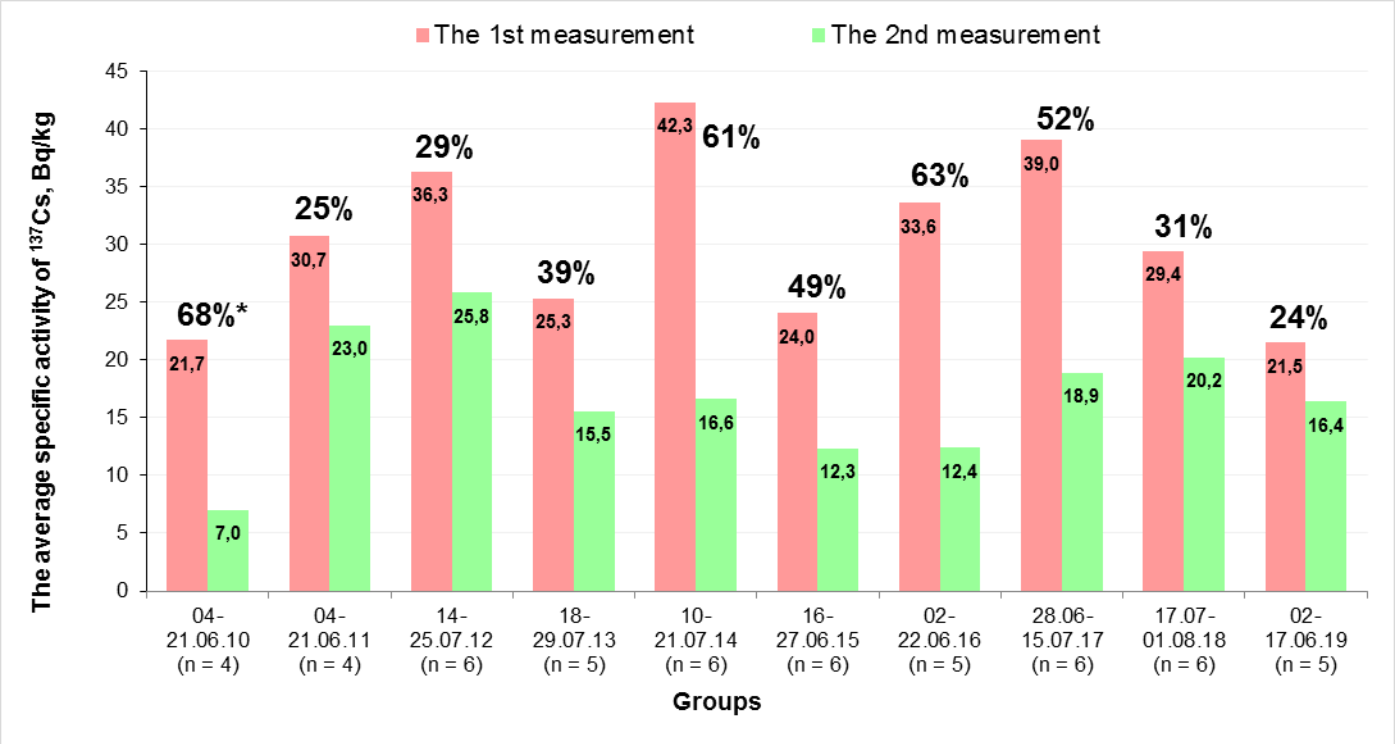


Fig. 25 — comparative diagram of the recovery effectiveness of children from Sokolovka and Otverzhichy villages in 2010–2019 (* — percentage of Cs-137 specific activity decrease)

And here is one of the best results achieved during a children's trip to Japan in 2010 (Fig. 26):

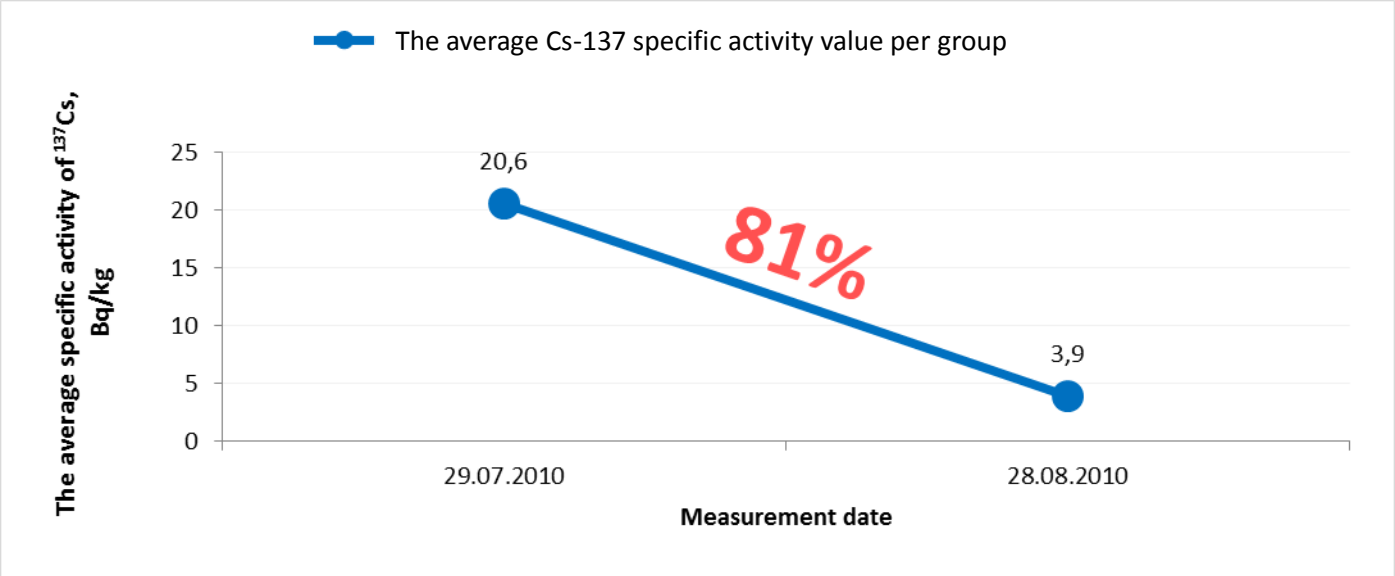


Fig. 26 — diagram showing the decrease trend in average activity in children's body as a result of pectin cures and recovery in Japan in 2010

In the areas with the worst radiation conditions, the WBC laboratory conducts pectin cures annually, sometimes even several times a year. The average reduction of radionuclides in the body reaches 30% here — but only if children do not eat forest foods. Unfortunately, not

all parents are responsible for radio-protective measures, and as a result, the level in some children remains the same or even increases.

Specialists of the Scientific Center of Radiation Medicine in Ukraine obtained similar values as a result of measurements in the villages of Polessky district of Kiev region (it's one of the most contamination regions of Ukraine) in 2006 and 2008: the specific activity after applying Vitapect in powder form decreased by 26–33%.

Another uninvited guest

In addition to cesium, it is necessary to mention another radionuclide, which largely determines the dose load on a modern resident of the affected areas. This is strontium-90, a radioactive isotope of strontium. Like cesium-137, strontium-90 is produced during nuclear decay in nuclear reactors (natural strontium-90 does not exist on Earth), it undergoes beta decay too, and even the half-life of strontium-90 is 29 years, i.e. almost like cesium.

$$^{90}_{38}\mathrm{Sr} \rightarrow {}^{90}_{39}\mathrm{Y} + e^{-} + \bar{\nu}_e$$

Fig. 27 — formula for the strontium-90 radioactive decay

The map of strontium-90 contamination in Belarus also correlates well with a similar map for cesium-137, however, the strontium spot has a much smaller area:

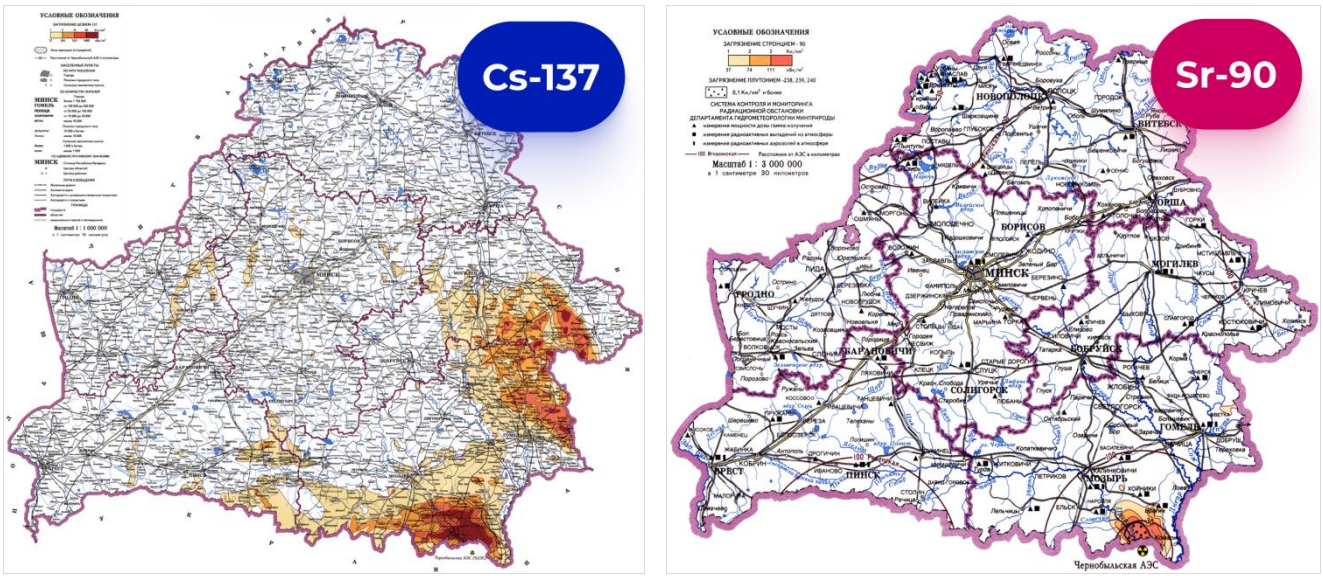


Fig. 28 — maps of the contamination density the Republic of Belarus territory with caesium-137 (left) and strontium-90 (right)

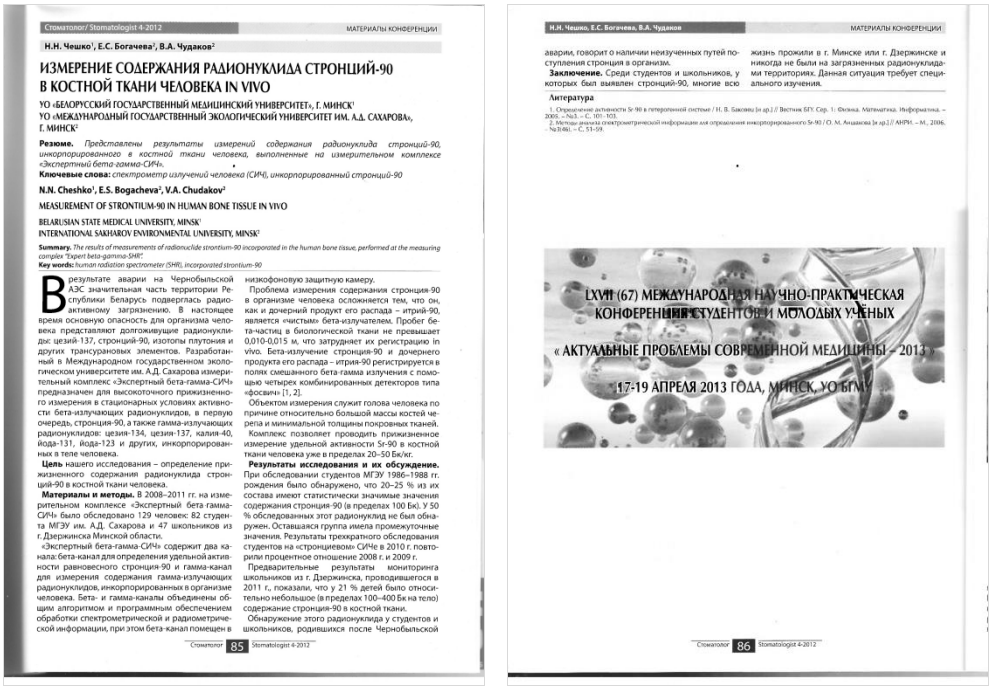
But this is not a reason to consider strontium harmless, because the similarities end here. Entering our body with food (mainly milk and dairy products), strontium-90 accumulates in bones, replacing natural calcium. Strontium is most difficult to remove from the body, since metabolic processes are slower in bone tissue than in soft tissues.

The biological half-life of strontium-90 in bone tissue is about 8-10 years. Strontium-90 accumulates in the bones and therefore irradiates the bone marrow, affecting the hematopoietic system and resulting anemia.

Measures to prevent strontium-90 from entering the body are mostly the same as measures for cesium-137. At the same time, we can say that strontium-90 is virtually impossible to remove from the body, if we assume its almost constant presence in the diet.

Who measures strontium-90 activity and how?

Measuring the internal radiation of strontium-90 in the human body is technically quite difficult. However, such studies are conducted at the International Sakharov Environmental Institute of Belarusian State University. Some results of such studies can be found in this material: https://www.bsmu.by/files/4e266e599cbdb779ab59ba1b1d49bb13/ (N. N. Cheshko, E. S. Bogacheva and V. A. Chudakov; materials of the "Dentist 4-2012" conference).



Стоматолог/ Stomatologist 4-2012 МАТЕРИАЛЫ КОНФЕРЕНЦИИ

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ИЗМЕРЕНИЕ СОДЕРЖАНИЯ РАДИОНУКЛИДА СТРОНЦИЙ-90 В КОСТНОЙ ТКАНИ ЧЕЛОВЕКА IN VIVO

УО «БЕЛОРУССКИЙ ГОСУДАРСТВЕННЫЙ МЕДИЦИНСКИЙ УНИВЕРСИТЕТ», Г. МИНСК[1]
УО «МЕЖДУНАРОДНЫЙ ГОСУДАРСТВЕННЫЙ ЭКОЛОГИЧЕСКИЙ УНИВЕРСИТЕТ ИМ. А.Д. САХАРОВА», Г. МИНСК[2]

Резюме. *Представлены результаты измерений содержания радионуклида стронций-90, инкорпорированного в костной ткани человека, выполненные на измерительном комплексе «Экспертный бета-гамма-СИЧ».*

Ключевые слова: *спектрометр излучений человека (СИЧ), инкорпорированный стронций-90*

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MEASUREMENT OF STRONTIUM-90 IN HUMAN BONE TISSUE IN VIVO

BELARUSIAN STATE MEDICAL UNIVERSITY, MINSK[1]
INTERNATIONAL SAKHAROV ENVIRONMENTAL UNIVERSITY, MINSK[2]

Summary. *The results of measurements of radionuclide strontium-90 incorporated in the human bone tissue, performed at the measuring complex "Expert beta-gamma-SHR".*

Key words: *human radiation spectrometer (SHR), incorporated strontium-90*

В результате аварии на Чернобыльской АЭС значительная часть территории Республики Беларусь подверглась радиоактивному загрязнению. В настоящее время основную опасность для организма человека представляют долгоживущие радионуклиды: цезий-137, стронций-90, изотопы плутония и других трансурановых элементов. Разработанный в Международном государственном экологическом университете им. А.Д. Сахарова измерительный комплекс «Экспертный бета-гамма-СИЧ» предназначен для высокоточного прижизненного измерения в стационарных условиях активности бета-излучающих радионуклидов, в первую очередь, стронция-90, а также гамма-излучающих радионуклидов: цезия-134, цезия-137, калия-40, йода-131, йода-123 и других, инкорпорированных в теле человека.

Цель нашего исследования – определение прижизненного содержания радионуклида стронций-90 в костной ткани человека.

Материалы и методы. В 2008–2011 гг. на измерительном комплексе «Экспертный бета-гамма-СИЧ» было обследовано 129 человек: 82 студента МГЭУ им. А.Д. Сахарова и 47 школьников из г. Дзержинска Минской области.

«Экспертный бета-гамма-СИЧ» содержит два канала: бета-канал для определения удельной активности равновесного стронция-90 и гамма-канал для измерения содержания гамма-излучающих радионуклидов, инкорпорированных в организме человека. Бета- и гамма-каналы объединены общим алгоритмом и программным обеспечением обработки спектрометрической и радиометрической информации, при этом бета-канал помещен в низкофоновую защитную камеру.

Проблема измерения содержания стронция-90 в организме человека осложняется тем, что он, как и дочерний продукт его распада – иттрий-90, является «чистым» бета-излучателем. Пробег бета-частиц в биологической ткани не превышает 0,010-0,015 м, что затрудняет их регистрацию in vivo. Бета-излучение стронция-90 и дочернего продукта его распада – иттрия-90 регистрируется в полях смешанного бета-гамма излучения с помощью четырех комбинированных детекторов типа «фосвич» [1, 2].

Объектом измерения служит голова человека по причине относительно большой массы костей черепа и минимальной толщины покровных тканей.

Комплекс позволяет проводить прижизненное измерение удельной активности Sr-90 в костной ткани человека уже в пределах 20–50 Бк/кг.

Результаты исследования и их обсуждение. При обследовании студентов МГЭУ 1986–1988 гг. рождения было обнаружено, что 20–25 % из их состава имеют статистически значимые значения содержания стронция-90 (в пределах 100 Бк). У 50 % обследованных этот радионуклид не был обнаружен. Оставшаяся группа имела промежуточные значения. Результаты трехкратного обследования студентов на «стронциевом» СИЧе в 2010 г. повторили процентное отношение 2008 г. и 2009 г.

Предварительные результаты мониторинга школьников из г. Дзержинска, проводившегося в 2011 г., показали, что у 21 % детей было относительно небольшое (в пределах 100–400 Бк на тело) содержание стронция-90 в костной ткани.

Обнаружение этого радионуклида у студентов и школьников, родившихся после Чернобыльской

Стоматолог 85 Stomatologist 4-2012

Н.Н. Чешко, Е.С. Богачева, В.А. Чудаков МАТЕРИАЛЫ КОНФЕРЕНЦИИ

аварии, говорит о наличии неизученных путей поступления стронция в организм.

Заключение. Среди студентов и школьников, у которых был выявлен стронций-90, многие всю жизнь прожили в г. Минске или г. Дзержинске и никогда не были на загрязненных радионуклидами территориях. Данная ситуация требует специального изучения.

Литература

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LXVII (67) МЕЖДУНАРОДНАЯ НАУЧНО-ПРАКТИЧЕСКАЯ КОНФЕРЕНЦИЯ СТУДЕНТОВ И МОЛОДЫХ УЧЕНЫХ

«АКТУАЛЬНЫЕ ПРОБЛЕМЫ СОВРЕМЕННОЙ МЕДИЦИНЫ – 2013»

17-19 АПРЕЛЯ 2013 ГОДА, МИНСК, УО БГМУ

Стоматолог 86 Stomatologist 4-2012

Fig. 29 — materials of the “Dentist 4-2012” conference “Measurement of the content of strontium-90 radionuclide in human bone tissue in vivo” (N. N. Cheshko, E. S. Bogacheva and V. A. Chudakov, 2012)

The authors draw our attention to the discovery of *"statistically significant (within 100 Bq)"* values of strontium-90 content in *"20–25%"* of the Institute students measured (results with this percentage were obtained in 2008, 2009 and 2010). In addition, strontium was also found in the bone tissue of school-age children in Dzerzhinsk town (not to be confused with the previously mentioned *Dzerzhinsk village*). Considering that the measured students and schoolchildren live in a relatively clean area, the authors talk about the possibility of unexplored ways of strontium entering the body.

"This situation requires special study," the experts conclude. Unfortunately, we haven't yet found any information about conducting such a study.

Products are also measured for strontium-90 content. For this purpose, a gamma-beta spectrometer operates in the laboratory of radiation monitoring of the Belrad Institute. Here is a table of measurements taken since 2016 to demonstrate (fig. 30):

Date	Foodstuff	Locality	The specific activity measurement result, Bq/kg	MAC
05.05.2016	Grain	Mikulichy, Braginsky, Gomel region	12.3±3.55	11
20.01.2017	Grain (rye)	Yelsk, Yelsky, Gomel region	8.80±3.96	11
06.02.2017	Grain (oats)	Yelsk, Yelsky, Gomel region	3.60±1.88	11
22.03.2017	Grain (barley)	Yelsk, Yelsky, Gomel region	5.20±4.52	11
20.10.2017	Grain	Kozeluzhye, Khoiniki district, Gomel region	23.9±4.3	11
31.10.2017	Milk	Mikulichy, Braginsky, Gomel region	0.40±0.30	3.7
13.11.2017	Grain	Mikulichy, Braginsky, Gomel region	1.50±1.36	11
26.12.2017	Grain (rye)	Stodolichy, Lelchitsky district, Gomel region	< 1.40	11
18.06.2018	Milk	Minsk	< 0.30	3.7
22.06.2018	Milk	Minsk	< 0.20	3.7
12.07.2018	Milk	Minsk	< 0.20	3.7
12.09.2018	Milk	Minsk	< 0.30	3.7
27.09.2018	Grain	Dzerzhinsk, Lelchitsky, Gomel region	< 1.90	11
10.10.2018	Milk	Minsk	< 0.30	3.7
16.11.2018	Milk	Minsk	< 0.30	3.7
20.11.2018	Grain (oats)	Sivitsa, Volozhinsky, Minsk region	10.1±2.60	11
29.11.2018	Grain (barley)	Sivitsa, Volozhinsky, Minsk region	< 2.80	11
18.12.2018	Milk	Minsk	< 0.30	3.7
03.01.2019	Grain (wheat)	Otverzhichy, Stolin, Brest region.	< 2.00	11
18.02.2019	Grain (oats)	Dyatlovichy, Luninets, Brest region	< 1.70	11
26.02.2019	Grain (oats)	Dyatlovichy, Luninets, Brest region	< 2.50	11
07.03.2019	Grain (wheat)	Malinovka, Loevsky, Gomel region	< 2.90	11
22.03.2019	Grain (oats)	Valavsk, Yelsky district, Gomel region	2.10±0.70	11
08.04.2019	Grain (oats)	Krasnoye, Braginsky, Gomel region	11.3±2.80	11
12.04.2019	Grain (oats)	Krasnoye, Braginsky, Gomel region	4.30±1.66	11
26.04.2019	Grain (oats)	Kirov, Narovlyansky, Gomel region	< 1.60	11
13.05.2019	Grain (wheat)	Valavsk, Yelsky district, Gomel region	< 1.60	11
22.05.2019	Grain (wheat)	Dzerzhinsk, Lelchitsky, Gomel region	< 1.90	11
03.06.2019	Grain (wheat)	Otverzhichy, Stolin, Brest region.	< 1.90	11
26.11.2019	Grain (wheat)	Krasnoye, Braginsky, Gomel region	19.1±3.49	11

05.12.2019	Grain (oats)	Krasnoye, Braginsky, Gomel region	< 3.60	11
17.12.2019	Grain (barley)	Krasnoye, Braginsky, Gomel region	3.90±1.77	11

Fig. 30 — table of strontium-90 specific activity in samples measured at the Belrad Institute Laboratory of Radiation Monitoring from 2016 to 2019

The table shows that the most contaminated samples were brought from areas that are geographically close to the Chernobyl nuclear power plant.

It is sad, but it was practically impossible to find openly published information on the similar measurements results by any other institutions of Belarus or neighboring countries. A query in Google only displays guidelines and standards. The only publication more or less relevant was the study of the strontium-90 concentration dynamics in some rivers of Gomel region (published on the Main Information and Analytical Center of the National Environmental Monitoring System website https://www.google.com/url?sa=t&source=web&rct=j&url=http://www.nsmos.by/uploads/archive/Sborniki/10%2520RADIOACTIVE%2520Monitoring%25202018.pdf&ved=2ahUKEwjpsI2rsojqAhXL_CoKHSUfAKUQFjAAegQIBhAC&usg=AOvVaw092N5KGLQEvvdkSArvjykH).

Analyzing the data, the authors conclude that there is a decrease trend in the average annual concentrations of strontium-90 in surface waters with some surges in certain years. These surges are associated with a change in a so-called water discharges of the year (that is, the amount of water that the river carries from its basin for a given year).

The content of strontium-90 in food supplied to stores is regulated by the MAC and controlled. But the "purity" of homemade milk can hardly always be guaranteed. As in the case of caesium, this suggests the need for continuing ongoing monitoring.

Delayed danger

In the coming decades, another radionuclide with a whole set of unpleasant features will remind us of itself. Meet americium-241, the isotope of americium — another radionuclide that we inherited as a disastrous Chernobyl legacy.

Firstly, the amount of americium in Belarus only increases over time. This is due to the fact that americium-241 is the decay product of plutonium-241. Half of plutonium-241 turns to americium-241 in 14 years, which means that approximately 2056 should be considered the peak of the formation of americium, and only after that its activity will decrease.

$$^{2\,41}_{95}\mathrm{Am} \rightarrow {}^{2\,37}_{93}\mathrm{Np} + {}^{4}_{2}\alpha.$$

Fig. 31 — formula for the americium-241 radioactive decay

Secondly, americium-241 itself has a half-life of 433 years. As we remember, it takes about 10 half-lives to assume that the territory has cleared of the radionuclide, so for americium this will happen to the distant year 6316.

Thirdly, americium-241 nuclei are subject to alpha decay, which means its high toxicity to living organisms.

According to contamination maps, most of americium-241 has fallen out on the territory of today's Polesie State Radio-ecological Reserve (PSRR). This means that the most probable way of its entry into the human body is the meat of wild animals that freely migrate through the territory of Belarus and other states, carrying with them the radionuclides consumed along with the contaminated plants they eat.

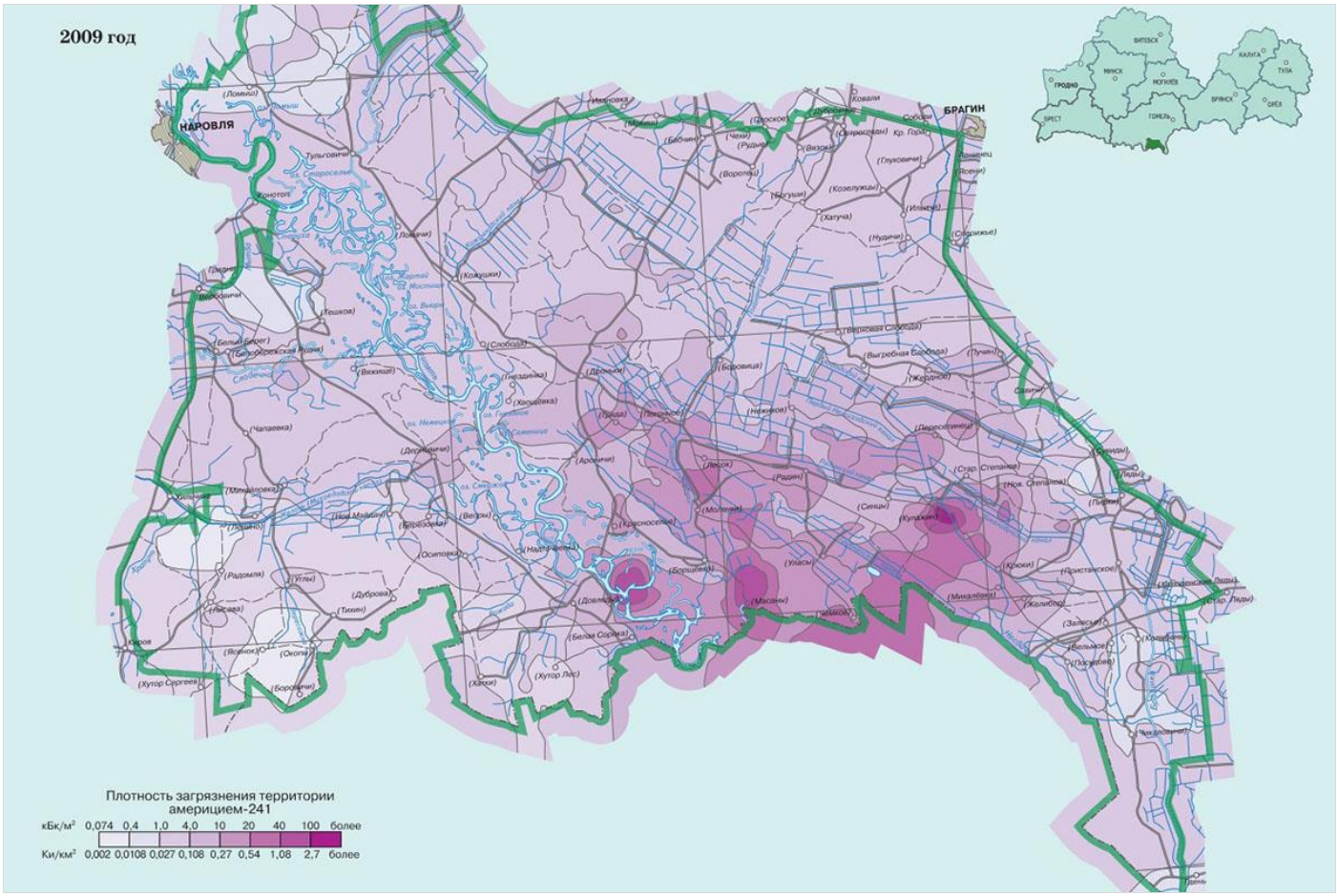

Fig. 32 — map of the contamination density of the Narovliansky district territory (Gomel region) by americium-241

Unfortunately, at the moment, Belarusian regulations do not take into account contamination with americium-241.

Disaster like a habit

CPRC radiometrists are specially trained for both measurements and the theoretical part of the problem to conduct educational work among the population and answer any questions related to radiation and protection from it.

Fig. 33 — radiometrist at Valavsk village school

It would seem that residents of Chernobyl-affected areas have been living with the disaster for more than thirty years and they can tell you more about radiation than anyone else, so do they really need reminders of danger?

They do. Because a human gets used to anything. Getting used to danger, we tend to ignore it. The absence of a momentary, immediately visible radiation effect also contributes to this.

Even residents of the most polluted areas often completely neglect radiation safety — or rather, they remember, but disregard it. every year the same children in the Dzerzhinsk village have a cesium-137 level of at least 300 Bq/kg, but this information does not cause

any emotional response or any changes in the way of eating. And this is just one of many examples.

We want to believe that at least solid and accumulated over many years data can be convincing. Therefore we undertook to write this article.

Afterword

In sum, all the above information suggests that the problem of forest food and some home foods products radiation pollution remains urgent today, decades after a terrible technological accident, and indicates the insistent demand to continue constant food radiation monitoring, to take all available measures to protect against the effects of radionuclides in the body, as well as conduct educational work in contaminated areas.

And finally, we want to express one more thought. Norm is a conditional term by its own definition. It is not very reasonable to consider, for example, that milk with an activity of 99 Bq/kg is completely safe, and just stepping over the 100 Bq/kg line, it immediately becomes deadly. It's much more practical to follow the "the cleaner, the better" approach, regardless of the norms that people agreed on just because of the need to bring at least some clarity to this difficult issue.

Knowing that until the recent appearance of cesium-137 artificially created by humans, nature and our bodies were not familiar with it at all, it seems appropriate to consider *the complete absence* of radionuclides in the human body and food as a norm. This goal is almost unattainable. But the main task of our institute and those who are not indifferent to themselves and their descendants is to advance to this goal as far as possible.

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