Content of Radionuclides of Chernobyl Origin in Food Products for the Belarusian Population

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Abstract

Recent data on radionuclide contents of Chernobyl origin in food products and drinking water for the Belarusian population are reviewed. Strontium-90 and Cesium-137 are main radionuclides contributing to internal irradiation to the population. Contamination levels in food products from the social sector of agriculture (collective farms, agricultural co-operatives) are found to be generally below the current legal admissible level of RAL-99 that are defined to make internal dose of the population less than 1 mSv/yr. On the other hand, exceedings of RAL-99 are often found in food products from the private sector, especially in settlements of Gomel region where the contamination is the most serious in Belarus. Special attention should be paid to the non-farm products in the contaminated areas: mushrooms, berries, fish and meat of wild animals. For example, about 37,000 Bq/kg of ^{137}Cs in fresh mushroom was registered in a settlement of Gomel region, which corresponds to 100 times of RAL-99 values. Concerning drinking water, the situation is quite good and no exceedings have been registered for the last 10 years.

Introduction

The Chernobyl APS accident led to heavy socio-economic consequences and worsening of the environment in a large number of territories in Republic of Belarus as a result of their pollution with radioactive components including ^{90}Sr and ^{137}Cs. Presently, these two radionuclides are the principal dose-forming factors of radiation on man and the most typical radioactive contaminants of food products. As the majority of radioactive substances enter into human organisms together with food, there is a permanent necessity to develop the measures on radiation protection of population from incorporated radioisotopes ^{90}Sr and ^{137}Cs.

In order to decrease radionuclide incorporation with food, legal measures are taken in Belarus by setting admissible levels for ^{90}Sr and radiocesiums (^{137}Cs and ^{134}Cs) in food products. Current regulation of radionuclide contents in food products is carried out in correspondence with Republican Admissible Levels (RAL) adopted in 1999 (Table 1). The RAL values are defined so that annual internal dose of the population does not exceed the dose limit of 1 mSv/yr as far as the structure of their food consumption is typical in Belarus. Within the structure of food consumption by the Belarusian population, the share of potato, milk and bread constitutes more than 50%. This allows to consider them as the group of principal products.

In this paper the recent situation of radionuclide contents in food products in Belarus is overviewed.

Food products from the social sector

The majority of food products in Belarus are produced by the social sector of agriculture (collective farms, agricultural co-operatives).

^{90}Sr in principal products:

Strontium-90 activity in milk, potato, rye bread and wheat bread from the social sector in Brest, Minsk,

Table 1. Admissible levels of radionuclide content in food products and drinking water of Belarus population (RAL-99).

Product	RAL-99	
	Cesium radionuclides, Bq/kg, Bq/l	Strontium-90 Bq/kg, Bq/l
Drinking water	10	0.37
Milk and dairy products	100	3.7
Meat and meat products		
- beef, mutton products	500	-
- pork, poultry products	180	
Potato	80	3.7
Root crops	80	-
Bread, bakery products	40	3.7
Flour, groats, sugar	60	-
Vegetable and animal fats, margarine	40	-
Vegetables	100	-
Fruits and berries	70	-
Canned vegetables, fruits and berries	74	-
Forest berries	185	-
Fresh mushrooms	370	-
Dried mushrooms	2,500	-
All species of children food ready for consumption	37	1.85
Other food products	370	-

-; RAL is not defiend.

Vitebsk, Grodno and Mogilev regions registered in 2000 is shown in Table 2 [1]. The ^{90}Sr activity in milk, potato, rye and wheat bread generally does not exceed 0.25, 0.33, 0.34 and 0.33 Bq/kg, respectively.

In Gomel region where the radionuclide contamination is the most serious, some higher levels of ^{90}Sr – as compared with the mentioned – in rye and wheat bread and milk were registered (Table 3). Their averages in Gomel region were 0.89, 1.05 and 0.54 Bq/kg, respectively, and higher than on the whole in the country. The observed difference in ^{90}Sr pollution of the mentioned products in compared regions is a result of radioactive pollution of Gomel region which is higher than that of other Belarus areas.

Among the examined food products from Gomel region, the highest level of ^{90}Sr (not higher, however, than the admissible level) in rye bread was registered from Vetka, and the highests in wheat bread and milk were from Mozyr (Table 3). The content of ^{90}Sr and ^{137}Cs in home-made cottage cheese constituted, respectively, 1.12 and 16.7 Bq/kg (Tables 3, 4). Such level of radioactive pollution of cottage cheese also does not exceed the admissible level even for children food (the requirements concerning the children food are the toughest).

According to the data by [2], in 2000 the mean level in Belarus of ^{90}Sr content in milk of dairy plants and children milk kitchens constituted 0.2 Bq/l.

The data of other authors [3, 4] testify that the levels of ^{90}Sr content in the principal food products from the mostly polluted areas of Gomel region are considerably higher than adduced in [1]. In 1999, the Sanitary-Epidemiological Service of Gomel region examined 448 samples of milk, dairy products, bread and bakery products, and in 2000 - 365 samples. There were found no cases of exceeding RAL-99 (3.7 Bq/l, kg) . Nevertheless, it is necessary to note that the boundary levels of ^{90}Sr content were registered in samples, being close to the limit of 3.7 Bq/l:

in 1999, milk – 3.52 Bq/l (Zhlobin cheese dairy plant),
dairy products – 3.44 Bq/l (Kalinkovichi dairy plant),
rye bread – 3.12 Bq/kg (Bragin bread factory);
in 2000, dairy products – 3.29 Bq/l (Rogachev dairy plant),
rye bread – 3.00 Bq/kg (Korma bread factory),
wheat bread – 3.0 Bq/kg (Narovlya bread factory).

Table 2. Levels of ^{90}Sr activity in food products from the social sector in Mogilev, Vitebsk, Brest, Minsk and Grodno regions.

Food product	Settlement	Region	Level of ^{90}Sr activity, Bq/kg
Milk	Bobrujsk	Mogilev	<0.15
	Mogilev	Mogilev	0.19±0.01
	Lepel	Vitebsk	<0.15
	Brest	Brest	<0.15
	B. Maleshevo	Brest	0.25±0.02
	Volozhin	Minsk	<0.15
	Vilejka	Minsk	<0.15
	Zhdanovichi	Minsk	<0.15
	Grodno	Grodno	<0.15
	Volkovysk	Grodno	<0.15
Potato	Bobrujsk	Mogilev	<0.15
	Slavgorod	Mogilev	0.21±0.01
	Polotsk	Vitebsk	0.33±0.03
	Novopolotsk	Vitebsk	0.33±0.04
	Logojsk	Minsk	0.26±0.03
	Volkovysk	Grodno	0.18±0.02
Rye bread	Bobrujsk	Mogilev	0.34±0.02
	Mogilev	Mogilev	<0.15
	Bykhov	Mogilev	0.18±0.02
	Novopolotsk	Vitebsk	<0.15
	Brest	Brest	0.27±0.02
	Baranovichi	Brest	<0.15
	Vilejka	Minsk	0.23±0.02
Wheat bread	Bobrujsk	Mogilev	<0.15
	Mogilev	Mogilev	<0.15
	Slavgorod	Mogilev	0.33±0.03
	Novopolotsk	Vitebsk	0.33±0.03

Table 3. The density of radioactive pollution of territory in places of sampling and the levels of ^{90}Sr activity in food products from the social sector in Gomel region.

Density of pollution with ^{90}Sr, Ci/km^2	Food product	Level of ^{90}Sr activity, Bq/kg
	Svetlogorsk	
<1	Milk	0.28±0.02
<1	Wheat bread	0.70±0.04
<1	Rye bread	0.96±0.04
	Gomel	
<1	Milk	0.59±0.05
<1	Wheat bread	0.50±0.04
<1	Rye bread	0.20±0.01
	Mozyr	
<1	Milk	0.76±0.04
<1	Wheat bread	1.96±0.16
<1	Rye bread	0.90±0.06
<1	Cottage cheese*	1.12±0.11
	Vetka	
1-2	Rye bread	1.49±0.13
In the region on the average	Milk	0.54
	Wheat bread	1.05
	Rye bread	0.89

*; Cottage cheese is not from the social sector.

Table 4. Density of radioactive pollution of territory and levels of ^{137}Cs activity in dairy products from the social sector in Gomel region.

Settlement	Density of pollution of territory with ^{137}Cs, Ci/km^2	Food product	Specific ^{137}Cs activity, Bq/kg
Svetlogorsk	<1	Milk	<3.75
Gomel	1-5	Milk	16.0±3.4
		Sour cream	13.3±2.8
Mozyr	1-5	Milk	17.0±3.5
		Cottage cheese	16.7±3.6

^{137}Cs in principal products:

The levels of ^{137}Cs activity in milk, bread and potato from the social sector of Brest, Grodno, Vitebsk, Minsk and Mogilev regions were considerably lower than the existing normative values and in the majority of cases they did not depend on the place of sampling. The results of Gomel region became exception, where the correlation was found between the level of ^{137}Cs activity in milk of local production and the density of radiocontamination of territory (Table 4). Whereas, the ^{137}Cs levels in milk and other food products from social sector in Gomel region were considerably lower than the values of admissible levels.

The Sanitary-Epidemiological Service of Gomel region examines annually potato from economies situated within the zones of radioactive pollution. In 1999–2000, exceedings of RAL-99 were found in 2 economies of Bragin district. That potato was not consumed as food product. In 2000-2001, there were no exceedings of RAL-99 found in other foods produced in the social sector, such as meat products, fish, vegetables, berries, fruits, eggs, children food [5].

On the whole, the agricultural protective measures in the social sector allowed to observe the normative values of ^{137}Cs content in milk which were valid in that period: up to 370 Bq/l in 1987, up to 185 Bq/l in 1990, up to 111 Bq/l in 1992, up to 100 Bq/l in 1999. Nearly 99% of milk samples from the social sector had specific activity of ^{137}Cs less than 20 Bq/l, whereas the normative value of RAL-99 is 100 Bq/l. However, in 1999 there were registered 1,962 tons of milk with ^{137}Cs content over 100 Bq/l. That milk was processed in dairy plants for butter.

Food products from the private sector

^{137}Cs in milk and potato:

Much more anxiety is caused by the quality of food produced in the private sector of agriculture. This may be explained by the limited possibilities in taking full-value protective measures. According to the data of Sanitary-Epidemiological Service, there were registered multiple cases of producing milk with high ^{137}Cs content in the private economies (Table 5).

While in the social sector the milk with exceeding radionuclide contents may be used as raw material for re-processing, in the private economies it is mainly used for personal consumption, being thus dangerous for the health of man, especially for children.

Table 5. Number of settlements in each region of Belarus where exceedings of RAL-96, RAL-99 were registered for ^{137}Cs content in milk from the private sector.

Region	Over 111 Bq/l (RAL-96)		Over 100 Bq/l (RAL-99)	
	1997	1998	1999	2000
Brest	97	90	73	54
Gomel	380	351	143	225
Grodno	7	2	4	4
Minsk	7	7	3	1
Mogilev	89	66	56	43
Belarus	580	516	379	327

The ^{137}Cs content in randomly selected milk samples reached the following values [6];

in Gomel region: Lelchitsy district – 979 Bq/l,
Bragin district – 637 Bq/l,
Korma district – 394 Bq/l,
in Mogilev region: Chausy district – 851 Bq/l,
Slavgorod district – 776 Bq/l,
Krasnopol'e district – 913 Bq/l,
Bykhov district – 625 Bq/l.

In 2000, the organs of state sanitary control of Gomel region examined 39,261 milk samples from the personal subsidiary economies (PSE). Exceedings were found in 4.8% of samples (1,873 samples). The maximum share of milk with RAL exceedings was registered in Lelchitsy (19.6%), Narovlya (14.9%), Vetka (13.1%), El'sk (9.0%) and Chechersk (8.3%) districts.

The maximum specific activity of radiocesium in milk samples was registered as follows:

- Khojniki district - 894 Bq/l,
- El'sk district - 889 Bq/l,
- Narovlya district - 872 Bq/l,
- Lelchitsy district - 803 Bq/l.

In 2000, in 326 settlements of Gomel region were registered cases of exceeding RAL-99 of radiocesium contents in single samples of meat, meat products, potato, beet. In 1999, the RAL exceedings were found in 259 settlements. The number of settlements with RAL exceedings was registered as follows: in Bragin (in 2000 – 30 settlements, in 1999 – 11), Vetka (26 and 30, respectively), El'sk (25 and 21), Lelchitsy (41 and 36), Narovlya (23 and 22), Chechersk (40 and 33) and Khojniki (19 and 17) districts.

In 2000, the RAL exceeding in potato was registered only in one sample from v. Dzerzhinsk of Narovlya district of Gomel region [3].

In Minsk region which was polluted much less than Gomel region, there were almost no cases of exceeding the RAL of ^{137}Cs in principal food products from the private sector (Table 5). However, the radioactive pollution of agricultural products in relatively "clean" Minsk region is tens of times as high as the pre-accidental levels [7].

^{90}Sr in milk, potato and vegetables:

The precipitations of ^{90}Sr of Chernobyl origin are registered mainly in Gomel region. In 2000, the Sanitary-Epidemiological Service of Gomel region examined the products of PSE in 282 settlements: milk was examined in 264 settlements. On the whole in 2000, 1,613 samples of food products from PSE were examined. Out of 605 milk samples examined, exceedings of strontium were found in 45 samples (7.4%), and out of 331 potato samples the exceedings were found in 5 (1.5%).

In 2000, the RAL exceedings of ^{90}Sr in milk were registered in 35 settlements, in potato – in 3 settlements. The maximum levels of ^{90}Sr content in milk were registered as follows:

- Bragin district - 13.6 Bq/l,
- Khojniki district - 8.4 Bq/l,
- Narovlya district - 7.89 Bq/l,
- Dobrush district - 4.8 Bq/l.

Taking into consideration the results of observations for 4 years (1997-2000), the RAL exceedings of ^{90}Sr in milk and potato from PSE were registered in 93 settlements of Gomel region. Constant RAL exceedings of ^{90}Sr during four and more years of observation were registered in the samples of PSE products in 14 settlements of Gomel region, including 9 settlements in Bragin, 4 in Khojniki and 1 in Narovlya districts.

The Sanitary-Epidemiological Service of Gomel region carries out the monitoring of widely consumed

Table 6. The share (%) of samples of food products from the personal subsidiary economies which do not meet the requirements of RAL-99.

Food product	2000		2001	
	Cesium-137	Strontium-90	Cesium-137	Strontium-90
Milk	5.0	5.3	4.2	8.5
Dairy products	3.0	-	2.0	-
Meat and meat products	1.2	-	0.4	-
Potato	0.03	0.7	-	-
Vegetables	0.02	-	0.02	-

PSE products for which ^{90}Sr limitations are not defined in RAL-99: root crops and vegetables. Attracts attention the fact that quite high ^{90}Sr contents are registered in the samples of beet, carrot, cabbage in the region. In 2000, the maximum levels of ^{90}Sr content in these products were as follows:

- Beet in Bragin district - 18.6-34.3 Bq/kg,
- Carrot in Khojniki district – 43.3 Bq/kg,
- Cabbage in Khojniki district – 35.8 Bq/kg, in Narovlya district – 29.3 Bq/kg.

Quite high levels of ^{90}Sr content are also registered in samples from PSE of more "well-being" districts of region [3, 4]:

- Cabbage – 11.4 Bq/kg (El'sk district),
- Carrot – 7.9 Bq/kg (Kalinkovichi district), 12.7 Bq/kg (Vetka district), 15.6 Bq/kg (Dobrush district),
- Beet – 12.7 Bq/kg (Kalinkovichi district).

In Belarus as a whole, the RAL-99 exceedings of ^{137}Cs were registered in milk and dairy produce as well as in single samples of meat and vegetables from PSE. About ^{90}Sr contents, the RAL-99 exceedings were registered only in milk from settlements of Gomel region (Table 6) [5].

Forest products

Belarus population consume also non-farm products that are not principal but – being more polluted – make sometimes very significant contribution into the dose commitments. During a number of years, in Mogilev region and especially in Gomel region the RAL exceedings are registered in 30-40 % of samples of wild berries and mushrooms (fresh and processed), and more than in 50 % of dried mushrooms prepared for personal consumption. The RAL exceedings in these foods are registered in all districts of Gomel region. In separate districts the exceedings are 70 % or more (Vetka, El'sk, Bragin, Narovlya, Korma and other districts).

Table 7 shows the ^{137}Cs contents of forest products that were randomly selected in 1994-1995 in Mogilev and Gomel regions and measured by sanitary-epidemiological services of Mogilev and Gomel regions [6]. The data in Table 7 considerably exceed the existing norms.

The maximum levels of radiocesium content in mushrooms exceed RAL up to 100 times. For example, in 1999, in a sample of fresh mushroom from El'sk district the specific activity of radiocesium constituted 36,896.5 Bq/kg, while the RAL value is 370 Bq/kg [2, 3, 8].

In 2000, the following maximum levels of ^{137}Cs content were registered in Gomel region:

- Fresh mushroom from Korma district – 25,470 Bq/kg (75 times as high as RAL of 370 Bq/g),
- Wild berries from Narovlya district – 4,742 Bq/kg (26 times as high as RAL of 185 Bq/kg),
- Dried mushrooms from Rogachev district – 99,910 Bq/kg (40 times as high as RAL of 2,500 Bq/kg),
- Dried mushrooms from Khojniki district – 90,950 Bq/kg (36 times as high as the norm).

The consumption of wild berries and mushrooms with exceedings of RAL leads to high doses of

Table 7. ^{137}Cs contents in separate samples of meat of wild animals, mushrooms and forest berries from Mogilev and Gomel regions.

Region	District	^{137}Cs content in "dirty" food products, Bq/kg (random sampling)
Meat of wild animals (boars, elks, hares and others)		
Mogilev region:	Slavgorod district	1,974
	Cherikov d.	9,620
	Bykhov d.	15,910
	Klichev d.	7,445
Gomel region:	Korma d.	18,000
	Lelchitsy d.	17,659
	Vetka d.	9,768
	Bragin d.	11,407
Mushrooms (fresh)		
Mogilev region:	Krasnopol'e d.	875
	Cherikov d.	1,079
	Bykhov d.	2,512
	Slavgorod d.	966
Gomel region:	Korma d.	793
	Lelchitsy d.	1,984
	Bragin d.	915
	Bykhov d.	769
Wild berries		
Mogilev region:	Slavgorod d.	758
	Cherikov d.	993
	Bykhov d.	1,134
Gomel region:	Korma d.	1,754
	Lelchitsy d.	1,017
	Bragin d.	795

Table 8. Share (%) of samples not meeting the requirements of RAL-99 for ^{137}Cs in 2000 and in 2001.

Region	Mushrooms		Forest berries		Meat of wild animals	
	2000	2001	2000	2001	2000	2001
Brest	15.6	25.3	40.2	23.6	-	-
Vitebsk	4	11.5	6.7	2.3	-	-
Gomel	46.9	47.8	36	32.7	54.8	66.2
Grodno	25	28.5	7.7	1.25	-	-
Minsk	19.1	19.2	9.04	4.8	1/1*	-
Mogilev	32.4	33.3	26.2	31.2	68.7	64.7
Minsk city	16.3	21.1	6.9	6.4	2/2*	-

*; (Number of dirty samples)/(Number of measured samples).

internal irradiation. In case of non-observation of existing limitations of consumption for mushrooms and wild berries, the contribution of forest products into the formation of internal irradiation dose reaches 70% in a number of settlements of the region (by the data of Gomel branch of Research Institute of Radiation Medicine and Endocrinology).

In Table 8 is adduced the share of samples of mushrooms, forest berries and meat of wild animals, which do not meet the requirements of RAL-99 in all regions of Belarus [5].

Fish

The fish of local catch makes its own contribution into the formation of internal irradiation dose of population of region. In 1999, the RAL-99 exceedings of ^{137}Cs in fish of local catch were registered in 9.7%

Table 9. Causes of exceedings of internal irradiation dose of population of Gomel region in 1998-2000.

Cause of exceeding the dose	Years					
	1998		1999		2000	
	number of cases		number of cases		number of cases	
	Total	Share (%)	Total	Share (%)	Total	Share (%)
Wild berries and mushrooms	732	57.6	308	30.4	458	53.4
Milk from PSE	232	18.3	140	13.4	72	8.4
Fish from rivers	47	3.7	303	28.8	-	-
Meat of wild animals	99	7.8	56	5.4	141	16.4
Unknown	160	12.6	240	22.0	187	21.8

(13 samples out of 134), in 2000 – in 17.4% (21 samples out of 121). The samples of fish with RAL-99 exceedings were registered in the private sector of eight districts of Gomel region: Vetka, Dobrush, Kalinkovichi, Petrikov, Narovlya, Rechitsa, Khojniki and Mozyr town. They reached 36% (Narovlya district), 50% (Rechitsa district) and 82% (Khojniki district). The maximum levels of radiocesium content in fish from reservoirs and rivers of the region were 11 times as high as RAL-99 in 1999 and 25 times – in 2000 (Vetka district, maximum level – 9,310 Bq/kg).

Drinking water

When we speak about the radiation state of food products of Belarus population, we must mention drinking water. In 2000, there were more than 3,000 samples of water from water pipes, wells, artesian wells and open reservoirs in which ^{137}Cs was measured, and near 100 samples in which ^{90}Sr was measured. There were found no water samples with exceedings of RAL-99. The samples of drinking water with exceedings of norms were not registered in Belarus during the last ten years, testifying thus to quite good situation [2].

Formation of radiation dose

Internal dose:

In case of observing RAL-99 of radionuclide contents in food products, dose values of internal irradiation are not higher than 1 mSv/year [9]. In the real situation, however, there are being registered many people whose internal dose exceeds the normative value due to the radionuclide intake through food products.

Taking into account the results of laboratory studies of food products, the contribution of various foods to the exceedings of annual internal dose limit was analyzed [3]. As seen in Table 9, the consumption of wild berries and mushrooms by population comes to the first place. In Gomel region, the exceeding of internal dose in 1498 persons (47.2% of registered number of persons) is connected with that cause. The second component of exceeding the irradiation norm is the consumption of milk from the private subsidiary economies: 444 persons (14%). 296 cases (9.3%) are connected with consumption of meat of wild animals, 350 cases (11%) – with consumption of fish from local reservoirs, in 587 persons (18.5%) the cause was not revealed.

Table 10. Annual external dose registered among the critical groups working on polluted territories in Gomel region.

Group	Annual external dose (mSv/yr)		
	1998	1999	2000
Agricultural mechanics	1.5 – 1.9	1.5 – 1.8	1.6 – 2.0
Animal breeders	1.6 – 2.9	1.5 – 1.9	1.8 – 2.2
Field workers	1.5 – 1.9	1.5 – 1.7	1.9 – 2.0
Foresters	2.0 – 2.5	2.0 – 2.4	1.8

External dose:

In the last three years, a tendency of decrease is observed in the average annual doses of external irradiation of the population living on polluted territories. Whereas, during a number of years, the cases of high indices of dosimeters have been registered in separate critical groups (field workers, animal breeders, foresters). Annual external dose of these groups is summarized in Table 10, which testifies to the exceedings of dose limit of 1 mSv/year. The analysis of seasonal trend of external dose shows that maximum values of irradiation (2 times and higher) as compared with the average annual indices in critical groups are registered in period of spring-autumn, when field works are carried out and the population is picking mushrooms and forest berries [3].

Conclusion

The content of radionuclides in food products of population of the Republic of Belarus, which have been produced in social sector of agriculture, as a rule, does not exceed the norms of Republican Admissible Levels of 1999. The products from personal economies are of worse quality, from the point of view of radiation hygiene. Considerable contribution into the dose of internal irradiation can be made by so-called "non-traditional" food products: meat of wild animals, fish from open reservoirs, wild berries and mushrooms.

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