Radioactivity in foodstuffs after the Chernobyl accident – 20 years research

N. K. Shandala, N. Ya. Novikova, M. P. Semenova, S. M. Kiselev, E. G. Metlyaev, A. A. Filonova & S. V. Akhromeev
Burnasyan Federal Medical Biophysical Centre, Russia

Abstract

Three republics of the former USSR – Belarus, Ukraine and Russia – became more contaminated following the Chernobyl accident. The subject of this paper is radioactivity assessment of the foodstuffs in Belarus and Russia, where more than 5000 food samples have been examined over more than the 20-year period after the Chernobyl accident. The methods used: beta– and gamma–spectrometry, radiochemical method. Over the whole surveillance period in Belarus, excluding 1986, when the surface contamination made a significant contribution to the product, ^{137}Cs and ^{90}Sr in agricultural foods, with few exceptions, was lower than the actual temporary permissible levels for that time. Real ^{90}Sr or ^{137}Cs content in the prime foodstuffs over the Russian territory are currently a small fraction of the established regulations, excepting areas of emergency contamination. Nevertheless, up to now, among the regions most contaminated due to the Chernobyl precipitations, there are ones, where permissible radionuclide contents are in excess for some foodstuffs.
Keywords: foodstuff, Chernobyl accident, Belarus and Russia.

1 Introduction

Radiation monitoring of radioactive substance content in foodstuffs is one of the important conditions of radiation safety assurance to the population of the state. This monitoring includes control radiation and hygienic examinations of different food samples within the state sanitary and epidemiological system [1, 2]. Findings of such kind of monitoring show that today there are some Russian regions (among those under the most contamination due to the Chernobyl precipitations), where the permissible radionuclide contents are in excess in

WIT Transactions on Biomedicine and Health, Vol 14, © 2009 WIT Press
www.witpress.com, ISSN 1743-3525 (on-line)
doi:10.2495/EHR090351

some foodstuffs. So, over 2007, of more than 180 thousand of food samples of those being examined to define radioactive substance content, 0,4% did not comply with hygienic requirements for ^{137}Cs and ^{90}Sr content. Exceeding permissible ^{137}Cs and ^{90}Sr content is registered mainly in foodstuffs produced in the private sector, in dairy and meat, as well as in mushrooms and berries collected in the settlements of some Bryansk and Kaluga areas of Russia [3].

2 Material and methods of research

The results of 20 years after the Chernobyl accident, gamma spectrometry and radiochemical investigations of ^{137}Cs and ^{90}Sr content in the main food patterns (bread, milk, meat, fish, potato, vegetables, wild berries and mushrooms) served as initial data to carry out this work. ^{137}Cs and ^{90}Sr content was being defined in foodstuffs ingested by the residents of territories affected by the Chernobyl accident (Bryansk, Orel, Tula and Kaluga Russian regions and some Belorussian regions), as well as by those living in the areas which are not considered to be contaminated (Moscow, Twer, Rostov, Voronezh regions of Russia). Areas uncontaminated due to the accident have been used for comparison.

To calculate internal doses due to food intake, the food patterns are necessary to be known as well as the amount of foodstuffs intake. It is recognized that the food intake quality and quantity is different for different residential areas, because of not only climatic features, but also social and economic conditions, national traditions and food habits. Therefore, we used data from the RF Goscomstat on the public food patterns in dynamics over recent years taking into account age and occupation information [4]. ^{137}Cs and ^{90}Sr intakes via the foods and effective internal doses were calculated using the real public food patterns.

The research was comprehensive and accumulative, so two databases have been developed: "^{137}Cs and ^{90}Sr content in foodstuffs over four Russian areas contaminated due to the Chernobyl accident" and "Food patterns of the population over four Russian regions". These databases were developed using the special Microsoft Office management systems. They include more than 9000 records and their volume is about 6 Mb. The database frame allows both data filtration by several indexes of user interest, and data statistical processing [5].

3 Findings of the food radioactivity study

3.1 The first years after the accident at the Chernobyl nuclear power plant (NPP) – 1986–1991

Over the significant area of the USSR, ^{137}Cs and ^{90}Sr content in all foodstuffs, over 1986 – 1987, was rather higher in comparison with pre-accidental values over 1985 due to the global fallout [6, 7]. So, ^{137}Cs content in dairy and meat intake of Muscovites increased from 2 to 400 times, on average, while ^{90}Sr content was from 1.5 to 4 times higher. In 10-12 years after the accident, the radionuclide content in foodstuffs returned again to the pre-accident levels.

In 1986, at the area of the Belorussian Republic, ^{137}Cs content in milk was 300-540 times higher than the pre-accident levels, while in meat – about 300-600

times. Since 1987, ^{137}Cs levels have been reduced slowly and up to 1989, milk contamination was 10 times lower; meat, mainly, beef –15 times. ^{137}Cs highest concentrations in bread were observed in 1987, because corn of the previous, 1986, has been used in its production. In 1989, the level of bread contamination was 4 times lower. Of other food patterns, black and green tea, fresh water fish and mushrooms were the most contaminated over those years. In addition to ^{137}Cs, ^{134}Cs was also present in samples: in 1986 ~50 %, and by 1989 – ~20 % of ^{137}Cs activity.

In 1986, ^{90}Sr content also increased in comparison with the pre-accident values, but this increasing was not so significant, as for ^{137}Cs: in rye-bread – 6 times, in milk – up to 12, in meat – 4 and in potato – 2 times.

Over 1986–1991, experts from the Institute of Biophysics (today – Burnasyan Federal Medical Biophysical Centre) made 14 expedition journeys to more than 120 settlements affected by the Chernobyl NPP accident, situated in the areas of the three Belorussian regions. 7000 soil, vegetation and food samples were collected and analyzed there.

Figures 1 and 2 show the dynamics of ^{137}Cs and ^{90}Sr content in milk and potato, produced in the area of one of the affected Belorussian regions.

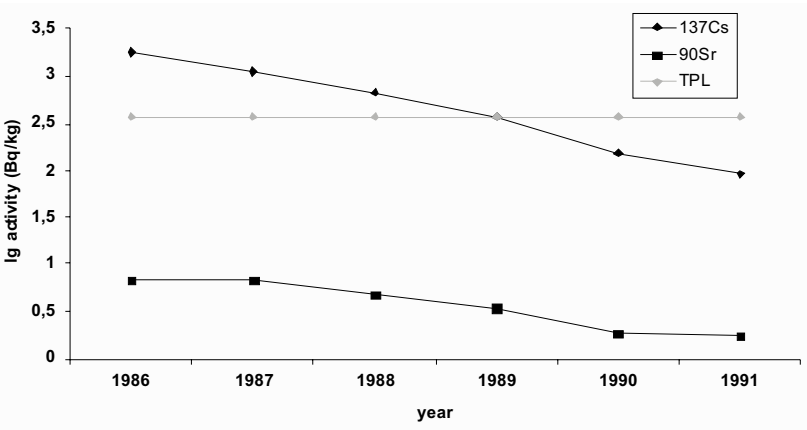

Figure 1: Dynamics of milk contamination with ^{137}Cs and ^{90}Sr over the first years after the Chernobyl NPP accident in comparison with the Temporary Permissible Level (TPL).

Slow decreasing of ^{137}Cs and ^{90}Sr content in foods is due to the process of radionuclide fixation by the soil, as well as the whole number of agricultural and chemical measures performed at the contaminated area. Contamination of vegetables and fruit was under laws typical for potato. Over the first years after the accident, the most contamination was registered in wild berries and mushrooms, ^{137}Cs content in which in some areas is higher than the established regulations so far.

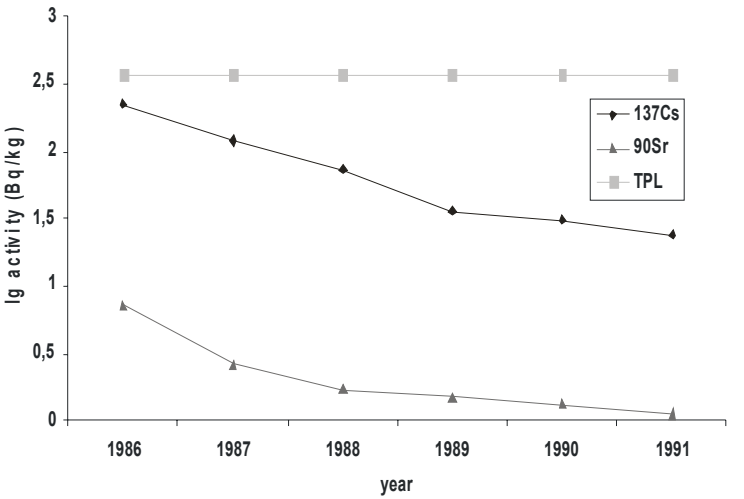

Figure 2: Dynamics of potato contamination with ^{137}Cs and ^{90}Sr over the first years after the Chernobyl NPP accident in comparison with the Temporary Permissible Level (TPL).

^{137}Cs content in milk was significantly higher than this radionuclide content in the vegetable products, in contrast with ^{90}Sr behavior. Increasing of ^{90}Sr penetration in the vegetation with time resulted in its increased content in potato and edible roots.

Wide contamination of foods with ^{137}Cs and ^{90}Sr over the first years after the accident is due to the different density of the area contamination, different physical and chemical states of radionuclides in emergency discharges and geo-chemical features of the soil covering.

3.2 Food radioactivity after 1992

^{137}Cs and ^{90}Sr content in agricultural foods in the Russian and Belorussian areas contaminated following the Chernobyl NPP accident over a twenty-year period became tens time lower. So, ^{137}Cs content in milk became 3–13 times lower, while in potato – 2–3 times, in mushrooms depending upon the origin and type – 1.1–2.5 in total. In the contaminated areas, ^{137}Cs and ^{90}Sr content in local foods depends upon the contamination density, type of soil, its physical and chemical properties, as well as on the manner of farming (use of natural or cultivated land for meat and dairy husbandry).

Table 1 illustrates the dynamics of ^{137}Cs and ^{90}Sr content in the main types of foods in the Gomel region of Belarus (the same region, as in figs. 1 and 2).

Table 2 shows the comparison of average content of man-made radionuclides ^{137}Cs and ^{90}Sr in foods cultivated after 20 years after the Chernobyl accident, the areas affected by the accident (the Bryansk region of Russia) and other Russian

territories, which are not included in the category of contaminated due to radiation accidents and incidents.

As Table 2 shows, the average specific activities of man-made radionuclides in foods from the "pure" regions vary from 0.12 to 33.20 Bq/kg by ^{137}Cs, and from 0.07 to 0.48 Bq/kg by ^{90}Sr. In foods cultivated in the areas contaminated due to the accident, ^{137}Cs and ^{90}Sr content is 270 times higher in comparison with those for the "pure" regions. ^{137}Cs content in mushrooms collected in the Bryansk forests is 100 times higher, in comparison with mushrooms collected in other places not affected by the accident.

The food radioactivity after the Chernobyl accident is interesting to be analyzed in terms of different soil characteristics of the regions. With these purposes, two Russian regions with ultra different types of soil characterized by

Table 1: Average ^{137}Cs and ^{90}Sr content in the prime foods of the Gomel region of Belarus, Bq/kg.

Foods	Year							
	2000		2001		2002		2003	
	^{137}Cs	^{90}Sr	^{137}Cs	^{90}Sr	^{137}Cs	^{90}Sr	^{137}Cs	^{90}Sr
Milk	16.95	0.85	19	0.9	14.55	0.8	14.05	0.85
Meat	81.9		46.45		36.9		22.8	1.05
Fish	129.8		57.1		35.2		33.3	0.6
Bread	5.3	1.2	5.3	1.3	4.7	1.4	4.1	0.9
Potato	7.3	1.1	6.3	0.9	5.8	0.9	5.3	0.8
Vegetables	8.4	3.4	7.9	4.0	7.5	7.0	8.5	5.3
Wild berries	330.2		241.6		278.2		196.3	
Mushrooms	1970		2460		4624		1082	
Game	4068		3572		869		1041	

Table 2: ^{137}Cs and ^{90}Sr content in foods cultivated in the areas contaminated following the Chernobyl accident and in the "pure" regions over 2006. Bq/kg.

Foods	Affected (Bryansk) Russian region		Pure regions (Moscow. Twer. Voronezh. Rostov region of Russia)	
	^{137}Cs	^{90}Sr	^{137}Cs	^{90}Sr
Milk	49.0	1.5	0.12	0.09
Meat	36.5	2.3	0.24	0.10
Fish	84.6	2.3	0.31	0.48
Bread	4.5	1.8	0.20	0.07
Potato	8.4	1.7	0.19	0.12
Wild berries	614.4	2.3	8.79	0.37
Mushrooms	3376.0	2.2	33.20	0.19

maximum and minimum ^{137}Cs and ^{90}Sr migration have been selected. These are the Bryansk region. where soddy-podzolic sandy loam soils are dominant. and Orel region with chernozem soils. Coefficients of radionuclide conversion within the "soil–foods" system for soddy-podzolic soils are 1-2 orders of a magnitude higher than those for chernozems. Table 3 includes ^{137}Cs and ^{90}Sr content in foods of the Bryansk and Orel regions.

Table 3: ^{137}Cs and ^{90}Sr content in foods of the Bryansk and Orel regions of Russia over 2005. Bq/kg.

Foods	Bryansk region		Orel region	
	^{137}Cs	^{90}Sr	^{137}Cs	^{90}Sr
Milk	45.5	1.7	1.69	1.07
Meat	34.5	2.25	2.67	1.64
Fish	68.6	1.85	3	2.7
Bread	4.4	1.6	1.72	1.61
Potato	7.9	1.8	2.3	1.85
Wild berries	514.4	2.25	17.5	3.5
Mushrooms	2329.5	2	21.4	1.15

The comparative level of radionuclide migration in vegetable foods under conditions of the same contamination of the soil covering can be described by ratio of their specific activities. Table 4 includes ratios of radionuclide specific activities in wild berries and mushrooms to the appropriate specific activity for milk from private subsidiary plants. which reflects the area contamination more exactly. These data demonstrate that ^{137}Cs and ^{90}Sr content in wild berries and mushrooms are higher than in milk because of higher values of the accumulation coefficients. The ratios mushrooms/milk and berries/milk for ^{90}Sr in the Bryansk region are exclusions (0.9 and 0.8. respectively). because ^{90}Sr content in the forest products is lower than the associated value for milk. and this complies with the relevant literature data.

Table 4: Ratio of ^{137}Cs and ^{90}Sr content in mushrooms and berries to that in milk. (Bq/kg)/(Bq/l).

Region	Mushrooms/Milk		Berries/Milk	
	^{137}Cs	^{90}Sr	^{137}Cs	^{90}Sr
Bryansk	33 – 100	0.9	14	0.8
Orel	11 – 17	4 – 8	4	4

High levels of soil radioactive contamination in the regions inspected induced contamination of the food potential of wild animals and their organisms. The average content of ^{137}Cs in game (boar. elk. duck) in the areas. soil contamination density with ^{137}Cs of which varies over the range 37 kBq/m^2 to 555 kBq/m^2. varies from 500 to 3500 Bq/kg at maximum value 10000 Bq/kg [8].

4 Regulation of man-made radioactivity of foods in Russia

Now. radiation safety of the whole food patterns is defined by compliance with the established radiation and hygienic regulations for indexes of the foodstuffs included. With the purpose of operative monitoring of internal exposure. the permissible levels of ^{137}Cs and ^{90}Sr activities have been developed for the particular types of foods. These permissible levels are obligatory within Russia both for the local and for import foodstuffs. Table 5 [1].

Table 5: Permissible specific activity (PSA) of ^{137}Cs and ^{90}Sr in some types of foodstuffs. (Bq/l (kg)).

Foods	Permissible specific activity	
	^{137}Cs	^{90}Sr
Milk	100	25
Meat	160	50
Fish	130	100
Bread	40	20
Potato	120	40
Fruits and berries	40	30
Mushrooms	500	50

Permissible content of ^{137}Cs in foods have been exceeded mainly in two regions – Bryansk ad Kaluga. At the Russian areas affected by the accident. in 2008. the hygienic regulations for ^{137}Cs have been exceeded for milk produced in the individual husbandries (37.6 – 697 Bq/kg). as well as in the forest products (mushrooms – from 4937 to 49380 Bq/kg. berries – from 683 to 23090 Bq/kg) [3]. Data on ^{137}Cs content in bread over 2007 are absent. while data for potato vary over the range from 6.1 to 114 Bq/kg.

5 Effective internal doses

Taking into account the food patterns of the farm and urban population (Table 6) and averaged data on the specific activity of foods. ^{137}Cs and ^{90}Sr intakes have been calculated via the prime food components. Using dose factors for ^{137}Cs ($K = 1.3 \cdot 10^{-8}$ Sv/Bq) and ^{90}Sr ($K = 2.8 \cdot 10^{-8}$ Sv/Bq) for adults. gross effective internal doses to urban and farm adult residents of the Bryansk region have been calculated over 2004 and was 0.2 and 0.3 mSv/a.

Calculation of food contribution into internal doses of urban and farm population of the Bryansk region due to ^{137}Cs intake showed that milk serves as the prime source – 43 and 47 %. respectively. for urban and farm residents. Contribution of the wild component is the second item significant for internal exposure – total contribution of intake of wild berries and mushrooms is responsible for 22% ^{137}Cs intake per capita. Contribution of meat into internal dose to urban and farm residents of the Bryansk region due to ^{137}Cs intake is 16 and 9%. respectively. and is the third “critical foodstuff”.

Table 6: Intake of the prime food groups by the residents of the Bryansk region older than 17 years old. kg/days.

Foods	City	Farm
Bread and cereal products	0.47	0.55
Milk and dairy	0.44	0.37
Potato	0.28	0.46
Vegetables and melon crops	0.23	0.30
Meat and meat food	0.21	0.15
Fish and fish products	0.05	0.05
Fruits and berries	0.08	0.09
Mushrooms	0.004	0.009
Total (mass):	1.76	1.98

Eventually. re-distribution of contributions of different radionuclide intakes via different foods into internal dose to the public takes place. The contribution of the prime agricultural products decreases due to the natural behavior of radionuclides in the "soil – foodstuffs" system.

6 Conclusion

In the Russian areas not considered as contaminated due to accidents. incidents and industrial activity. ^{137}Cs and ^{90}Sr specific activities in foods due to the global fallout are currently the same. from units to hundredths Bq/kg. depending upon the type of product. soil and climatic conditions. Wild foods (forest berries and mushrooms) are exclusions: ^{137}Cs and ^{90}Sr content there are about 100 times higher than in foodstuffs from the same regions.

The findings of inspections performed in some Russian and Belarusian areas contaminated following the Chernobyl NPP accident demonstrate that the coefficient of ^{137}Cs conversion from soil into the prime local foodstuffs following significant reducing at the first years after the accident. since 1992 up to now remain practically the same. Since 1992 till 2005. statistically significant change of ^{90}Sr coefficient of conversion has not been registered either. At the same time. the radionuclide coefficients of conversion into mushrooms and wild berries are practically the same since the first years after the accident. The prognosis assessments demonstrate that this trend will remain in future. i.e.. radioactivity of the foodstuffs produced in the contaminated areas and that of wild berries and mushrooms and game will decrease according to their half-lives. Nevertheless. intake of wild products and game by residents of the regions affected by the Chernobyl NPP accident is trivial (in the weight amounts of the food patterns). therefore. statistically significant increasing of ^{137}Cs and ^{90}Sr intakes via the foods is unlikely.

References

[1] Hygienic safety requirements and food cost of foodstuffs //Sanitary and epidemiological rules and regulations. *SanPiN* 2.3.2.1078-01. M.: FGUP "InterSEN". 2002. – pp. 168.
[2] Radiation monitoring. Strontium-90 and Cesium-137. Foodstuffs. Sampling. analysis and hygienic assessment. //*Guidelines for control*. MUK 2.6.1.717-98. M.: Minzdrav of Russia. 1998. – 59 pp.
[3] Findings of radiation and hygienic certification in the subjects of the Russian Federation over 2008 (Radiation hygienic passport of Moscow Territory over 2008. GUP MosNPO "Radon": Moscow 2009)
[4] Food intake in domestic husbandries (according to results of selective inspection of the domestic economy budgets). Statistic bulletins of the RF State committee on statistics over 1990-2007.
[5] Shandala N K. Savkin M N. Novikova N Ya. ea. Radioactivity of foodstuffs after the Chernobyl NPP accident // *Medicine of emergencies*. 2007. – No 4 (22) – p. 70-86.
[6] Knizhnikov V A. Petukhova E V. Barkhoudarov R M. Shandala N K. Radiation hygienic situation in Russia induced by global fallout of nuclear explosion products //*Hygiene and sanitary*. 2000. – No 4. – p.10-15.
[7] Korenkov I P. Shandala N K. Filatov N N ea. Findings of radiation monitoring in Moscow region over the period 1957-2005. //*Medicine of labor and industrial ecology*. 2006. – No 2. – p. 11-17.
[8] Shutov V N. Brook G Ya. Kadouka M V ea. Dynamics of radioactive contamination of natural foods following the Chernobyl NPP accident //*Public health and life environment. Information bulletin*. ZNiSO. M.: Federal Centre of the Gossanepidnadzor MZ RF – 2003. – No 4 (121) – p. 9-11.