

Contents of natural radium-226 and lead-210 in foods produced within the Russian territory

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Abstract

Dynamical examination of contents of the observed natural radionuclides in prime foodstuffs demonstrated their relative stability. Generally, ^{210}Pb and ^{226}Ra specific activities in foodstuffs depend upon the food type and options of agriculture management. Many-year researches show that average specific activities of ^{210}Pb and ^{226}Ra for different foodstuffs vary over the range 0.04-0.15 Bq/kg and 0.02-0.08 Bq/kg. Soil dependence of ^{210}Pb and ^{226}Ra contents in foodstuffs has not been revealed. Taking into account the food patterns of the Russian population, the highest intake of ^{210}Pb and ^{226}Ra is due to ingestion of bread, meat and drinking water. Annual effective internal doses are about 50 $\mu\text{Sv/a}$.

Keywords: natural radionuclides, foodstuffs, doses, ingestion, intake.

1 Introduction

Natural radionuclides are present in all environmental media to a certain degree. Radionuclides of ^{238}U and ^{232}Th series, half-lives of which is comparable with the Earth age, and their progenies in significant amounts present in the environment and in the human body.

External exposure to the human is mainly due to gamma radiation of ^{238}U and ^{232}Th series, and ^{40}K .

Among radioactive ^{238}U products, the most contribution into the natural background is due to ^{226}Ra , its fission product ^{222}Rn (radon) and long-lived products of ^{210}Pb and ^{210}Po decay, which precipitate on the surface of soil and make significant contribution into dose.



Behavior of radionuclides uranium and thorium series in the biological system is different. ^{226}Ra and its radioactive products (^{210}Pb , ^{210}Po) have the most migration abilities among natural radionuclides in the chain soil – vegetations, while ^{238}U and ^{232}Th – the least.

Accumulation of natural radionuclides in the productive parts of crop (kern (corn), edible roots) is less than that in vegetative organs and roots.

Some factors define accumulation of natural radionuclides by plants, the prime of which are their physical and chemical properties (5-38%), soil-climatic features of regions (22-47%) and biological special features of plants (38-48%) [6].

Cultivation of soil reduces significantly dependence of radionuclide intakes upon soil-climatic conditions and physical and chemical properties of radionuclides in the chain “soil – plants” and, hence, in foodstuffs.

So, ^{210}Po , ^{210}Pb and ^{226}Ra are practically important for the purposes of radiation hygiene, because they are contained in vegetation, water, foods of animal and vegetable origin and, respectively, transferred into the human organism via foods [1–3].

Therefore, these radionuclides are the most informative (indicative, reference) in the course of the observation of the natural radionuclide contents in foods and internal dose assessment in the human organism. Nevertheless, monitoring is reasonable to be performed of long-lived ^{226}Ra and ^{210}Pb .

2 Contents of natural radionuclides in foodstuffs

Analysis of ^{210}Pb and ^{226}Ra contents in foodstuffs in Russia showed that there was no statistically valid difference in annual radionuclide contents.

Therefore, to assess ^{210}Pb and ^{226}Ra contents in the prime foodstuffs we use the mean value for Russia, table 1.

The findings show that contents of natural radionuclides in foodstuffs depend upon the type of product and the spread of ^{210}Pb and ^{226}Ra specific activities is rather wide and reaches an order of a magnitude.

To clarify dependence of natural radionuclide contents in foodstuffs on the soil type, data on natural radionuclide contents in foodstuffs were being joined into some groups according to the prevailing types of soil, typical for the Russian areas and regions under monitoring. Regardless identification of regions with soddy-podzolic and chernozem-chestnut soils, levels of ^{210}Pb and ^{226}Ra contents in foodstuffs at which is higher a bit, than at boggy and podzolic soils, no statistically valid dependence of natural radionuclide contents in foods upon the soil type has been revealed.

Table 2 includes calculation results of ratio between ^{210}Pb and ^{226}Ra specific activities in foodstuffs obtained using results of the Russian mean specific activities for these radionuclides in each of four Russian regions with different types of soil: soddy-podzolic, podzolic, boggy, and chernozem. On average, the ratio values by the soil types show satisfactory compliance with the mean Russian values, table 2.



Table 1: Mean ^{210}Pb and ^{226}Ra contents in foodstuffs in Russia, Bq/kg [1].

Foods	^{210}Pb	^{226}Ra
Bread	0.10 0.01-0.67* (236)**	0.05 0.002-0.5 (229)
Milk	0.05 0.01-0.35 (342)	0.02 0.001- 0.15 (312)
Meat: beef	0.15 0.01-0.36 (5)	0.08 0.002-0.15 (6)
Fish	<0.01-0.44	0.03-0.25
Potato	0.07 0.01-0.35 (143)	0.03 0.001- 0.3 (159)
Cabbage	0.04 0.001-0.48 (96)	0.02 0.001-0.4 (120)
Beet + Carrot	0.10 0.002-0.34 (38)	0.03 0.001-0.2 (29)
Drinking water	0.04 0.001-0.2 (83)	0.02 0.001-0.36 (390)
Note: *range of values; **number of samples.		

Table 2: Ration between ^{210}Pb and ^{226}Ra specific activities in foodstuffs in Russia, $^{210}\text{Pb}/^{226}\text{Ra}$ (quotas).

Foodstuff	$^{210}\text{Pb}/^{226}\text{Ra}$ on average over Russia	$^{210}\text{Pb}/^{226}\text{Ra}$, mean value by the soil types
Bread	1.9	1.9
Milk	2.3	2.7
Potato	2.3	1.9
Vegetables	3.0	2.1
Fish	2.2	-
Meat	1.8	5.0

Generally, ^{210}Pb content is higher in all products (the ratio $^{210}\text{Pb}/^{226}\text{Ra}$ values vary over the range from 1.0 to 9.0).

Study of materials on ^{210}Pb and ^{226}Ra contents in foodstuffs over different years and at the areas with different types of soil allows further use the mean Russian data in calculation of intake and effective internal doses.



3 Consumption and intake of natural radionuclides via foodstuffs by the population of Russia

Analysis of food ingestion in the home economics (all households), according to data of the Federal state statistic service over the period 2003-2006 showed that the food ration of the Russian population remained stable in terms of mass of its component (particular foodstuffs) [4].

Data on per capita food intake by the Russian population [5] are used in assessment of internal doses due to radionuclide intakes via the food ration. In the course of analysis, the frame of food ration on the prime 7 food groups has been developed indicating their ingestion in kg/day units.

Table 3 deals with ingestion of the particular foodstuffs by the population of the Russian Federation (RF), both per capita intake and intake by urban and farm adults separately.

Table 3: Ingestion of particular foodstuffs by the RF population, kg/a.

Foods	On average per capita	Urban citizen	Farm citizen
Bread and bread products	146.5	134.6	179.3
Milk and dairy	144.4	138.9	156.7
Potato	86.3	78.7	107.0
Vegetables and melons	83.9	83.3	85.6
Meat and meat products	60.7	62.8	55.0
Fish and fish products	14.2	14.3	13.9
Fruits and berries	35.3	37.8	29.3
Mushrooms	1.0	1.0	1.0
Drinking water	511.0	511.0	511.0

Table 4: ^{210}Pb and ^{226}Ra intake by the population of Russia, Bq/a.

Foods	Per capita		Urban citizens		Farm citizens	
	^{210}Pb	^{226}Ra	^{210}Pb	^{226}Ra	^{210}Pb	^{226}Ra
Bread	13.2	7.0	12.1	6.5	16.2	8.60
Milk	6.5	2.8	6.3	2.8	7.0	3.13
Potato	6.0	2.6	5.5	2.4	7.49	3.21
Vegetables and melons	5.3	2.1	5.2	2.1	5.39	2.14
Meat	9.1	4.9	9.4	5.2	8.25	4.51
Fish	2.1	1.0	2.2	1.0	2.1	1.0
Drinking water	17.9	8.7	17.9	8.7	17.9	8.7
Gross intake	60.2	29.2	58.6	28.5	64.3	31.2



As drinking water is important for uranium and radium series intake, it is included into intake assessment via the full ration, and the intake value of 1.4 l/day is accepted for all groups of population.

Data on natural radionuclide contents in foodstuffs (table 1) and on ingestion of the particular foods by the population of Russia (table 3) were used to calculate ^{210}Pb and ^{226}Ra intake via foods per capita and for farm and urban population. Table 4 includes the calculated results. Here, ^{210}Pb and ^{226}Ra contents in water are 0.035 and 0.017 Bq/l, respectively (table 1).

Table 4 shows that bread and drinking water have the highest ^{210}Pb and ^{226}Ra intakes.

4 Doses induced by natural radionuclides

Table 5 show effective internal doses to the population of Russia due to ^{210}Pb and ^{226}Ra intake via the food ration.

With the purpose of comparison, tables 6 and 7 include intakes and doses induced by ^{137}Cs and ^{90}Sr . Mean ^{90}Sr and ^{137}Cs values for foods in Russia were used in calculations, table 8.

Table 5: Effective internal doses induced by ^{210}Pb and ^{226}Ra intaking by the RF population via foods, $\mu\text{Sv/a}$.

Dose induced by	On average to a person	To urban citizen	To farm citizen
^{210}Pb	41.5	40.5	44.4
^{226}Ra	8.2	8.0	8.7
Total	49.7	48.5	53.1

Table 6: ^{137}Cs and ^{90}Sr intake by the population of Russia, Bq/a.

Foods	On average to a person		To urban citizen		To farm citizen	
	^{137}Cs	^{90}Sr	^{137}Cs	^{90}Sr	^{137}Cs	^{90}Sr
Bread	205.2	19.0	188.4	17.5	251.0	23.3
Milk	101.0	17.3	97.2	16.2	109.7	18.8
Potato	60.4	6.9	55.1	6.3	74.9	8.6
Vegetables and melons	2.5	7.6	2.5	7.5	2.6	7.7
Meat	18.2	3.6	18.8	3.8	16.5	3.3
Fish	2.6	10.9	2.8	11.0	2.5	10.7
Fruits and berries	1.4	4.2	1.5	4.5	1.8	3.5
Mushrooms	39.0	3.7	39.0	3.7	39.0	3.7
Drinking water	0.5	1.0	0.5	1.0	0.5	1.0
Gross intake	430.8	74.3	405.3	71.5	497.9	80.6



Table 7: Doses induced by ^{137}Cs and ^{90}Sr intaking by the RF population via foods on average to a person, $\mu\text{Sv/a}$.

Dose induced by	On average to a person	To urban citizen	To farm citizen
^{90}Sr	2.1	2.0	2.3
^{137}Cs	5.6	5.3	6.5
Total	7.7	7.3	8.8

Table 8: Average ^{137}Cs and ^{90}Sr contents in foods in Russia, Bq/ kg, [1].

Foods	^{137}Cs	^{90}Sr
Bread	1.4 ± 0.03	0.13 ± 0.03
Milk	0.7 ± 0.04	0.12 ± 0.01
Potato	0.7 ± 0.03	0.08 ± 0.01
Vegetables and melons	0.03 ± 0.01	0.09 ± 0.01
Meat	0.3 ± 0.03	0.06 ± 0.02
Fish	0.18 ± 0.03	0.77 ± 0.01
Fruits and garden berries	$0.04 (0.10)^*$	$0.12 (0.19)$
Wild berries	18.0 (40.0)	0.33 (0.80)
Mushrooms	39.0 (270.0)	3.7 (36.0)
Drinking water	0.001	0.002
Note: * - in parentheses – maximum value		

Table 9: Percentage contribution of the main dose-forming radionuclides into internal dose to the population of Russia, %.

Dose induced by	On average to a person	To urban citizen	To farm citizen
^{210}Pb	72.0	73.0	72.0
^{226}Ra	14.0	14.0	14.0
^{90}Sr	4.0	4.0	4.0
^{137}Cs	10.0	9.0	11.0
Total	100	100	100

Calculations show that internal doses due to intake of natural radionuclides via foods by the population of Russia can be assessed at the level of about $50 \mu\text{Sv/a}$. Here, effective internal dose induced by ^{210}Pb intake is 5 times higher than dose induced by ^{226}Ra . The mentioned values are about 6 times higher than effective doses due to ^{90}Sr and ^{137}Cs intakes via the food ration.

Total dose induced by ^{90}Sr and ^{137}Cs varies from $7.3 \mu\text{Sv/a}$ (to the ran citizen) to $8.8 \mu\text{Sv/a}$ (to the farm citizen).



Table 9 shows the percentage contribution of the main dose-forming radionuclides (natural and man-made) into internal dose to the population of Russia due to ingestion of foods.

Table 9 shows that quota of natural radionuclides in comparison with man-made radionuclide is much higher: the percentage contribution into gross ^{210}Pb and ^{226}Ra dose is 72% and 14%, respectively.

External exposure to the public [7] due to natural radionuclides containing in soil being calculated taking into account time of staying outdoors and in dwellings, is 350 $\mu\text{Sv/a}$, which is 87,5% of gross internal and external dose (table 10).

Table 10: Effective internal and external ^{210}Pb and ^{226}Ra induced doses to the population of Russia, $\mu\text{Sv/a}$.

Dose induced by	On average to a person	To urban citizen	To farm citizen
^{210}Pb	41.5	40.5	44.4
^{226}Ra	8.2	8.0	8.7
Total	49.7 (12.5%)	48.5 (14.5%)	53.1 (11.4%)
External due to natural radionuclides	350.0 (87.5%)	286.0 (85.5%)	414.0 (88.6%)
Internal + external	399.7	334.5	467.1

The mentioned data confirm that contribution of internal exposure due to natural radionuclides into total dose to the public of Russia is only 11-14% of gross internal and external dose, so, regulation of natural radionuclides in foods is unreasonable.

5 Conclusion

The majority of arguments found in the course of this work do not confirm the necessity of development of the particular numerical values of permissible specific activities of natural radionuclides for the prime types of foods. Doses due to internal exposure of natural radionuclides obtained in this work are about twice lower than average over-world data (50 $\mu\text{Sv/a}$ in comparison with 120 $\mu\text{Sv/a}$).

Nevertheless, having in mind that doses due to internal exposure due to ^{210}Pb and ^{226}Ra intakes are much high than those of man-made radionuclides (^{90}Sr and ^{137}Cs): percentage contribution into gross dose of ^{210}Pb and ^{226}Ra is 72% and 14%, respectively, now, monitoring of natural radionuclide contents should be performed prime foods. Such kind of monitoring must be carried out within social hygienic monitoring, which is the prime mechanism regulating sanitary and epidemiological prosperity of the public, as well as within radiation hygienic certification of regions.



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