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***A.I. Smagin*[1, 2], *A.V. Dmitrieva*[2]**
([1]Urals Scientific Research Veterinarian Institute, [2]Southern Urals Biophysics Institute;
e-mail: biogeo@telecom.ozersk.ru)

ZOOGENIC TRANSFER OF RADIONUCLIDES AS A FACTOR OF HUMAN EXPOSURES

This given article presents the results of investigations of radionuclide accumulation in commercial fish and waterfowl inhabiting the water basins located in the vicinity of radionuclide abnormality in the Southern Urals. It was indicated that use in food these waterfowl and fish brings about annual irradiation 150-200 persons in dangerous dose.

Key words: radionuclide migration, zoogenic transfer, waste storage reservoirs, waterfowls, fish.

***А.И. Смагин*[1, 2], *А.В. Дмитриева*[2]**
([1]Уральский научно-исследовательский ветеринарный институт,
[2]Южно-Уральский институт биофизики; e-mail: biogeo@telecom.ozersk.ru)

ЗООГЕННЫЙ ВЫНОС РАДИОНУКЛИДОВ КАК ФАКТОР ОБЛУЧЕНИЯ ЧЕЛОВЕКА

Представлены результаты авторских исследований накопления радионуклидов рыбой и водоплавающими промысловыми птицами, обитающими на водоемах в зоне радионуклидной аномалии на Южном Урале. Установлено, что употребление в пищу этих птиц и рыбы приводит к ежегодному облучению 150-200 человек в дозе, превышающей безопасный уровень.

Ключевые слова: миграция радионуклидов, зоогенный вынос, водоемы-хранилища радиоактивных отходов, водоплавающие птицы, рыба.

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Introduction

Series of radiation incidents at Mayak Production Association (PA) specializing in weapon plutonium production resulted in contamination of vast territories of the north of Chelyabinsk Region to long-lived radionuclides. Radioactive contamination of the riverbed and inundable sites of the river head resulted from liquid radioactive wastes discharges to the river Techa held by Mayak PA in the early 1950s. Total activity entered the river amounted up to approximately $8{,}8 \cdot 10^{16}$ *Bq* (2,78 *MCi*). In 1957 about $7{,}4 \cdot 10^{17}$ *Bq* (20 *MCi*) of activity was injected into atmosphere due to chemical explosion of radioactive wastes storage tank. About 90 % of entered the atmosphere compounds was precipitated in the vicinity of the facility industrial site but approximately $7{,}4 \cdot 10^{16}$ *Bq* (2 *MCi*) of activity was brought away beyond the facility by wind and overstretched hundreds of kilometers north-eastward from the accident site known as East Urals Radioactive Trace (EURT). Due to wind transport of dry radioactive sediments from the bottom of radioactive wastes storage reservoir, the lake Karachai (R-9), radioactivity of about $2{,}2 \cdot 10^{14}$ *Bq* (6 *kCi*) was entered the environment in 1967 [1].

As a result of the above radiation incidents in the north of Chelyabinsk Region in the vicinity of the Mayak PA was formed technogenic radio-geochemical anomaly with long-lived ^{137}Cs and ^{90}Sr as the main dose contributors. Manifold landscapes were exposed to contamination including numerous water basins located in the area of the Mayak PA influence. Technologic waste storage reservoirs have the maximum levels of radioactive contamination. The effects of long-term (40-60 years) radioactive exposures of natural complexes as well as population are still insufficiently studied up to the present day [1, 2].

Nowadays an access to the territories exposed to radioactivity to a greater extent is limited for the population and the lands are taken out of practical use being guarded by forces of the Ministry of Internal Affairs. At the same time guard regime does not prevent the animal migration both to contaminated areas and outside their limits. Once entered into the environment the radionuclides go into food chains of biota and are rapidly accumulated by the organisms with concentrations exceeding the relative activity in soils and waters by 5 or more orders of magnitude [1-5 and others]. Consequently, the problem of zoogenic transfer of technogenic radionuclides from the radioactive hotspots is of significant importance during the process long-term estimating of effects on population from radioactive accidents.

The results of studies

Sources of accumulation of radionuclides in waterfowls and fish

The first data about the coefficients of radionuclide accumulation by waterfowls were obtained by W.C. Hanson and H.A. Kornberg [6]. They determined that coefficients of radionuclide accumulation calculated with regard to contaminated water for the waterfowls inhabiting storage reservoirs for Hanford Site waste changed in the range from 250 to 900 for ^{137}Cs that mostly deposited in soft tissue, and from 500 to 1500 for ^{90}Sr deposited in bones.

Water basins in the area of radioactive abnormality nearby the Mayak PA are inhabited by 10 species of waterfowls of which Mallard Duck (*Anas platyrhynchos L.*) and Gadwall (*Anas strepera L.*) are the subjects of mass hunting. High metabolism rate is characteristic for the fowls of this area and therefore consumption of larger volumes of food per weight unit results in accumulation of higher radionuclide concentrations comparing to other animal groups. The results of investigations conducted by I.A. Ryabtsev in 1960 through 1970 indicated that average concentration of ^{90}Sr in the skeleton of ducks inhabited the water basins in the area of radioactive abnormality varied in a wide range from 370 to 0,37 *kBq/kg* of bone tissue. Female ducks, as a rule, accumulate higher radionuclide concentrations than male ducks. This difference is due to nesting conservatism which is more evidently marked in females. Female waterfowls in contrast with male make fewer passages for foraging. Male waterfowls often overfly the zone of radioactive abnormality for foraging hence accumulating smaller radionuclide concentrations. Besides, physiological differences between females and males have some sort of effect. Reproduction function associated with eggs laying determines body-nutrient needs of female ducks, thus resulting in higher

levels of radionuclide accumulation. It was determined that concentration of ^{90}Sr in bone tissue of female ducks that inhabited the zone of radioactive abnormality in the vicinity of Mayak PA amounted up to 100 ± 50 *kBq/kg* while for male ducks it amounted to 20 ± 5 *kBq/kg* [7, 8]. As for ^{137}Cs accumulation the overall picture is much more complicated due to relatively rapid accumulation and excretion of the given radionuclide. ^{137}Cs has wider limits for specific activity values in soft tissue of ducks in comparison with ^{90}Sr (Table 1).

Table 1

Distribution of waterfowls by body burden, % of total number of fowls caught at the territory of water basins contaminated due to radioactive releases from Mayak PA

Species	Number of birds caught	Average specific activity of ^{137}Cs in soft tissue			
		37 kBq/kg	3,7 kBq/kg	0,37 Bq/kg	0,037 Bq/kg
Mallard duck	23	22 %	17 %	26 %	35 %
Gadwall	30	20 %	43 %	27 %	10 %

Accumulating significant amount of radionuclides and migrating outside the contaminated area birds may become the sources of higher levels of human exposures to radionuclides. Seasonal migration of birds gives rise to transfer of radioactive substances to vast distances of hundreds and thousands kilometers. Therefore birds take an active part in world-wide distribution of radioactivity [8]. Data on banding of waterfowls nesting in the area of water basins located in zone of radioactive abnormality indicated that prevailing winter quarters are districts of the Caspian, Black and Mediterranean Seas. Ringed at the territory of research the birds were captured at the Volga river estuary, at the Caspian Sea, in Turkey, Iran and Italy [9]. During the migration season birds move long distance to their wintering grounds therefore being spreaders of radioactivity accumulated. Waterfowl hunting is a widespread occupation. Consequently, the potential of shooting and consumption of contaminated fowl by people at a long distance outside Russia is very likely (see the Figure 1).

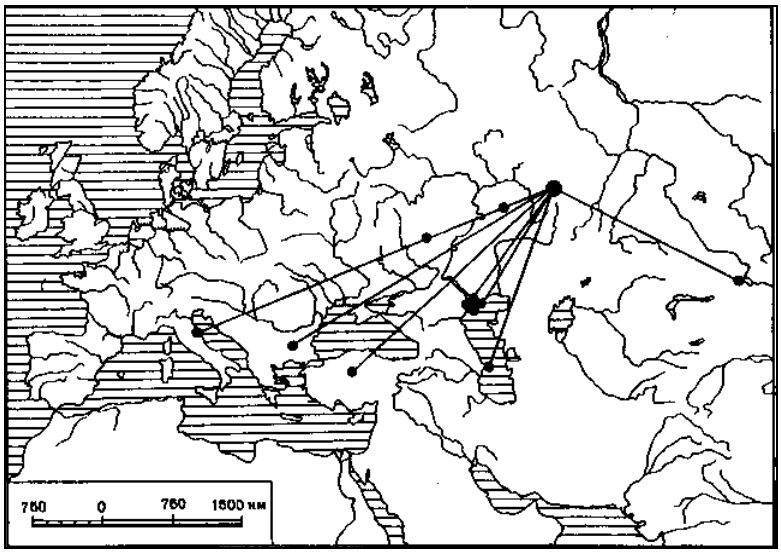

Figure. 1. Places of capturing of waterfowl ringed in the areas of EURT water basins and Techa River reservoirs system [9]

Ichthyofauna species composition of reservoirs located at the territory of Mayak PA influence presents species of fish typical for the lakes of the Ural Region. It was proved that radiation doses received by the ichthyofauna of industrial reservoirs did not impede preservation of fish populations over a period of tens of years and restrictions for fishing out created favorable conditions for abundance of fish resources [1, 10].

Radionuclide accumulation in fish is known to be not only due to concentrations of main dose contributing radionuclides ^{137}Cs и ^{90}Sr contained in water but due to other elements with similar features, fish biological peculiarities, size, food, hydrochemical and ecological characteristics of water reservoirs either [1]. Table 2 represents the results of experimental estimates of specific activity of water, fish and waterfowl inhabiting the water basins located in zone of radioactive abnormality. Due to the lack of information about specific activity of radionuclides in waterfowl tissues within recent years we used mean values of coefficients of radionuclide accumulation with regard to water of storage reservoirs for Hanford Site waste [6]: 500 for ^{137}Cs in soft tissue and 1000 for ^{90}Sr in bone tissue.

Table 2

Basic morphometrical and radioecological characteristics of water basins located in the zone of radioactive abnormality

Water basin	Surface area, *km*^{2}	Average depth, ~ *m*	Water capacity, *mln. m*^{3}	Reservoir bed pollution density, *kCi/Km*^{2}	Specific activity in					
					water, *Bq/l*		waterfowl, *kBq/kg*		fish, *kBq/kg**	
					^{90}Sr	^{137}Cs	^{90}Sr (bones)	^{137}Cs (muscles)	^{90}Sr (trunk)	^{137}Cs (trunk)
R-2 l. Kyzyl-Tash	18,6	4,0	85	1000	2000	150	2000	150	370	80
R-3**	0,8	2,0	0,8	19300	4100	1500	4100	1500	-***	-***
R-4**	1,3	2,5	3,8	3230	4400	380	4400	380	1500	200
R-10**	18,3	4,0	80	13600	3800	220	3800	220	200*	1000*
R-11**	47	4,5	255	800	2200	3	2200	3	100*	50*
R-6 (l. Tatysh)	3,6	2,5	16,1	-	5	0,5	5	0,5	10	1,0
l. Uruskul	4,4	2,0	8,62	270	46	2	46	2	1	0,1
l. Berdyanish	12	1,9	18	280	16	0,2	16	0,2	0,2	0,1
l. Kazhakul	8,5	4,0	39	0,78	0,5	0,01	0,5	0,01	0,05	0,001
l. Alabuga	8,6	4,0	34	0,46	0,5	0,01	0,5	0,01	0,03	0,001

Note: * specific activity of fish soft tissues is presented;
** R-3, R-4, R-10 and R-11 are combined into the Techa River reservoirs system;
*** the reservoir was not inhabited by fish.

Table 3 shows permissible levels of radionuclide contents in different foodstuffs.

Table 3

Sanitary safety requirements for foodstuffs (in accordance with SanPiN 2.3.2.1078-01) [11]

Foodstuff	Permissible levels, *kBq/kg*, no more than	
	^{90}Sr	^{137}Cs
Wild animals meat, fillet	0,1	0,32
Bones (all kinds)	0,2	0,16
Poultry meat	0,08	0,18
Fish alive, fresh, chilled, minced, fillet	0,1	0,13

From the given Tables 2 and 3 we can infer that from 65 to 90 % of waterfowls nesting in zone of radioactive abnormality have higher levels of radioactive contamination exceeding sanitary requirements established in Russia. Specific activity in fish of all industrial water reservoirs has also higher levels exceeding health standards.

Exposures of population due to consumption of products, contaminated with radioactive substances

Sufficiently frequent excessive uptakes of ^{90}Sr and ^{137}Cs in humans living in the vicinity of Mayak PA is due to consumption of waterfowls or fish captured from the water basins contaminated to technogenic radionuclides. That sort of exposures of higher radioactive levels to Ozyorsk residents are regularly recorded by the SUBI dosimetrists and Sanitary & Epidemiological Station of healthcare system-71. Over a period of 2001 through 2006 some 10 cases of higher levels of ^{90}Sr and ^{137}Cs uptake via foodstuff (fish and waterfowls) were registered (see Table 4).

Table 4

The results of survey of 10 subjects underwent to entry of ^{137}Cs and ^{90}Sr with food (on evidence of Laboratory № 3 SUBI)

№	Age of a person, years	Date and source of radionuclide uptake	Intake, *kBq*		Relation of intake to *ALI* $^{food}_{population}$	
			^{90}Sr	^{137}Cs	^{90}Sr	^{137}Cs
1	56	November, 2001. Mayak PA. Foodstuff (duck)	-	71	-	0,9
2	36	December, 2001. Mayak PA. Foodstuff (duck)	2	250	3,3	0,15
3	27	May, 2002. Mayak PA. Foodstuff (fish)	0,18	26	0,01	0,33
4	36	May, 2002. Mayak PA. Foodstuff (fish)	30	160	2,3	2,0
5	34	May, 2002. Routine medical survey. Foodstuff (fish)	10	93	0,78	1,2
6	11	May, 2002. Routine medical survey. Foodstuff (fish)	0,19	45	0,01	0,58
7	64	May, 2004. Suspected radionuclide intake. Uptake via food (fish)	1,3	58	0,1	0,75
8	27	May, 2005. Mayak PA. Foodstuff (duck)	0,173	390	0,01	5,1
9	27	May, 2005. Mayak PA. Foodstuff (duck)	0,013	110	>0,01	1,4
10	47	November, 2006. Mayak PA. Foodstuff (duck)	0,28	26	0,02	0,34

In majority of cases the exposures with higher levels of radioactivity (see Table 4 № 1-4, 8-10) were detected due to alarm system of walkthrough radiation detector which is passed through by all the Mayak PA workers at the end of the shift, two cases – during the routine medical survey of the population and one case – during verification survey of suspected intake of radionuclides.

The highest dose from intake of higher concentrations of ^{90}Sr and ^{137}Cs was received by a workwoman in May, 2005 (see Table 4, № 8). Interviewing indicated that poultry bought from a private citizen, a resident of Kassargi settlement located at about 50 *km* distance from Mayak PA industrial area, was the source of radionuclide contamination. Biophysical and spectrometric analyses allowed to calculate committed effective dose from ^{137}Cs that amounted up to 5,1 *mSv*. The second subject who had also consumpted contaminated poultry meat was surveyed in similar way and the committed effective dose from ^{137}Cs amounted to 1,4 *mSv*. Total committed effective dose from both radionuclides (^{137}Cs and ^{90}Sr) for every subject exceeded the dose limits established by NRB-99 for the members of society (1 *mSv/year*) except for the case № 8 where the committed effective dose exceeded dose limits established by NRB for the group B personnel (5 *mSv/year*) [12].

The performed calculations showed that about 1000 workers of the Mayak PA passed through the dosimetric monitoring system (highly sensitive dosimeters). The population of Ozyorsk and neighboring settlements is approximately 150-200 thousand people. If we assume the same frequency of exposures due to contaminated fish or poultry consumption among the population as it occurs among 1000 of the Mayak PA personnel we can come to the conclusion that annually 150-200 persons are exposed to radiation levels exceeding the safety standards (1 *mSv* per year for the members of population). Therefore, this problem is serious enough to require elaborate study.

Conclusion

As a result of the study performed it was ascertained that in zone of radioactive abnormality nearby the Mayak PA specific activity of technogenic radionuclides ^{90}Sr and ^{137}Cs in meat of hunting subjects such as waterfowls and fish significantly exceeded maximum permissible levels provided by the current standards. The problem of transfer of radioactive substances at long distances by the migrating birds is of current interest. The consumption of contaminated poultry and fish by approximately 150-200 residents of Ozyorsk urban district results in annual exposure dose exceeding safe level of 1 *mSv* per year established by regulatory authorities. The problem of technogenic exposures to population due to consumption of hunting subjects namely wild fowl and fish as a foodstuff requires further elaborate study.

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