Ivan I. Kovalev

Evaluation of the effectiveness of sorbents for eliminating radionuclides in animals

03.01.01 - Radiobiology

Author's abstract

of Candidate's thesis

Moscow – 2017

The work was carried out at the Federal State Budget Educational Institution of Higher Education Moscow State Academy of Veterinary Medicine and Biotechnology named after K.I. Skryabin

Scientific supervisor
Doctor of Biological Sciences, Laureate of the RF Government Prize, Professor, Head of the Department of Radiobiology and Virology named after Acad. A.D. Belov and V.N. Syurin the Federal State Budget Educational Institution of Higher Education Moscow State Academy of Veterinary Medicine and Biotechnology named after K.I. Skryabin, Nikolay P. Lysenko

Official opponents:
Robert G. Ilyazov Corresponding Member of the Academy of Sciences of the Republic of Tatarstan, Honoured Doctor of Biological Sciences, Professor, Director of the Center of Ecological standardization and certification.
Lyubov L. Zakharova Doctor of Biological Sciences, leading scientific employee of the Laboratory of Radiobiology of the Federal Budget scientific institution of the All-Russian scientific Research Institute of Veterinary Sanitation, Hygiene

External reviewer:
Federal State Budget Scientific Institution "Federal Center for Toxicological and Radiation Safety of Animals" (Federal state budgetary institution"FTSTRB-VNIVI) Kazan Defense will be held on June 14, 2017 at 12:30 at the meeting of the Dissertation Council D 220.042.04 at the Federal State Budget Educational Institution of Higher Education Moscow State Academy of Veterinary Medicine and Biotechnology named after K.I. Skryabin at the address: 109472, Moscow, Akademika Skryabin St., 23, phone: (495) 377-93-83

The thesis can be found in the library of the Federal State Budget Educational Institution of Higher Education Moscow State Academy of Veterinary Medicine and Biotechnology named after K.I. Skryabin (Moscow) The electronic version of the abstract and the text of the announcement of defense is posted on the official website http://vak3.ed.gov.ru/ the text of the thesis, the author's abstract, the opinion of the supervisor on the official site of the Federal State Budget Educational Institution of Higher Education Moscow State Academy of Veterinary Medicine and Biotechnology named after K.I. Skryabin http: / /www.mgavm.ru/science/dissertation/220.042.04/events/detail.php?ID=34650

The author's abstract is available on the site «» _____ 2017.
The author's abstract was sent " " 2017.
Scientific Secretary of the Dissertation Council
Candidate of veterinary sciences V.D. Fomina

GENERAL DESCRIPTION OF WORK

Relevance of the topic As a result of catastrophes at nuclear facilities, significant areas of agricultural land in the territory of Belarus, Ukraine and Russia were subjected to radioactive contamination of various levels. After the nuclear disaster at the Chernobyl nuclear power plant, the contamination with cesium-137 was the most extensive. Therefore, the data on the content of cesium-137 is used as the basis for mapping contaminated areas or determining the level of pollution.

Despite the fact that more than 30 years have passed after the catastrophe, ^{137}Cs continues to be identified in livestock production as a result of migration of radioisotope with groundwater from deep to root-soil layers of soil.

High content of radionuclides in mushrooms, fish, berries and game, as well as radioactive contamination of fodder and livestock products are the main causes of radionuclide infiltration into food products today. Contamination of meat and milk can be reduced using clean feed (hay) and feed additives (sorbents), and also limiting the grazing time on contaminated pastures.

The catastrophe at the Chernobyl nuclear power plant dramatically highlighted the main problem of the 20th century: the progress of science and technology is increasingly associated with negative "side effects" of extensive and intensive exploitation of natural resources - damage by radionuclides, heavy metals salts entering the soil, pollution of water and the atmosphere.

One of the most urgent problems of modern medicine and veterinary medicine is the search for effective methods of prevention and pathogenetic therapy of radiation damage to the human body and animals. To reduce the radioactive contamination of the body with radionuclides, it is desirable to use low-cost sorbents, for example radionite, and highly effective, practical and versatile, in particular polymethylsyloxane polyhydrate.

Problem elaboration extent. The problem of radionuclides elimination from the organism of agricultural animals has acquired special significance in connection with the consequences of the Chernobyl disaster that caused the contamination of the territory intensively engaged in agricultural production. At present, the radiation situation on the territory contaminated with radionuclides has practically stabilized. However, it takes a long time to fully restore the affected areas, so it is necessary to adapt to life in the conditions of radioactive contamination of the terrain and try to make living conditions as safe as possible for health. (R.M. Aleksakhin, G.V. Konyukhov, N.N. Izamov, R.G. Ilyazov).

Since the accident, accumulation of radionuclides in tissues and organs could occur, so it is important not only to limit intake of radionuclides with food, but also to take appropriate measures to remove radionuclides from the body.

The use of feed additives in the rations that selectively bind radionuclides in the gastrointestinal tract of animals is an effective way to reduce contamination of livestock products with radiocaesium and radiostrontium. Such additives include various substances capable of binding radionuclides in the gastrointestinal tract and thus preventing their absorption. These substances are usually called sorbents.

Many scientific groups including such prominent scientists as R.M. Aleksakhin, V.A. Budarkov, A.P. Sirotkin, R.G. Ilyazov, N.N. Isamov, G.V. Konyukhov et al. worked on the problem of eliminating radionuclides from the organism of agricultural animals, as well as decreasing the dose load during the internal irradiation of the animal organism after the disaster at the Chernobyl nuclear power plant in 1986.

Sorbents are subdivided by their origin (natural and artificial sorbents) and by the spectrum of action (selective, capable of selectively binding certain radionuclides and a broad spectrum of actions, linking several radionuclides at once). Natural sorbents include ordinary clay, zeolites,

bentonite, humolite, vermiculite and others. Artificial ones include ferrocyanide-containing preparations. (V.A. Budarkov, N.A. Korneev, A.P. Sirotkin, B.S. Pristor, etc.).

In this regard, the purpose of the work was to study the effectiveness of sorbents of various origin in removing radionuclides from the animal organism and decontaminating the contaminated surfaces of structural materials.

To achieve this goal, the following **objectives were set:**

1. To study the effectiveness of the use of sorbents for deactivation of structural materials;
2. To study the properties of sorbents in vitro;
3. To determine the effective half-life of cesium-137 in the body of mice when using sorbents;
4. To determine the effective half-life of strontium-90 in the body of mice when using sorbents;
5. To determine the percentage removal of cesium-137 and strontium-90 from the body of animals using different sorbents;
6. To determine the dose load from cesium-137 on the critical organs and the body of rats as a whole when using sorbents.

Scientific novelty. Thanks to modern radio spectrometric methods of research, it was possible to study more thoroughly the dynamics of accumulation and excretion of radiocaesium and radiostrontium from the animal organism.

Detailed localization and accumulation of radionuclides in the body are shown upon the excretion of the latter with and without sorbents. Due to the developed technique for determining the dose load of gamma-emitting radionuclides with the help of the EXL software, N.P. Lysenko, I.N. Lysenko, I.I. Kovalyov calculated the radiation dose from internal radiation by Cesium-137 on critical organs and the organism as a whole when using sorbents at the Department of Radiobiology and Virology of the Federal State Budget Educational Institution of Higher Education Moscow State Academy of Veterinary Medicine and Biotechnology named after K.I. Skryabin

.

Main points for defense:

1. The expediency of using a natural radionite sorbent is determined by its effectiveness in removing cesium-137 from the body, as well as its availability and harmlessness.
2. Of all the studied sorbents, polymethylsyloxane polyhydrate has shown the maximum efficiency in removal of strontium-90 from the organism of animals.
3. The tested compounds are non-toxic and safe to use. All the studied drugs reduce twice the dose load with internal irradiation of cesium-137.

Practical significance of the work. The results of the work have been implemented in the scientific research and the educational process of the Department of Radiobiology, Virology of the Federal State Budget Educational Institution of Higher Education Moscow State Academy of Veterinary Medicine and Biotechnology named after K.I. Skryabin.

Methodology and methods of study

The study was methodologically based on the traditional approaches, theoretical and experimental developments to the study of the effectiveness of using radio-sorption preparations for the removal of radionuclides from the animal organism and the system analysis of the obtained results.

The methodology of the study determined the feasibility of using a complex approach, including dosimetric, radio-spectrometric, biological and mathematical methods of investigation.

Work reliability degree. The reliability of the results is due to a multitude of series of different study experiments using a large number of biological test systems (5000 nonlinear male mice weighing 20 ± 1.7 g, 500 non-linear male rats weighing 220 ± 17.8 g). Experimental data was statistically processed using modern computer software.

Approbation of work.

1. International conference dedicated to the 95th anniversary of the Federal State Budget Educational Institution of Higher Education Moscow State Academy of Veterinary Medicine and Biotechnology named after K.I. Skryabin. Participation with the report "Evaluation of the effectiveness of radiocaesium elimination from the body by adsorbing preparations of natural origin". November 2014

2. Participation in R&D and writing of the Grant Report from the Ministry of Education and Science in accordance with the Agreement No. 14.616.21.0034 for the grant work of the Ministry of Education and Science of the Russian Federation on the topic "Monitoring of animal infectious diseases in the regions of the world, ways to prevent their spread and elimination in environmental conditions" in the framework of cooperation with research organizations and universities of the EU member states ".

3. International Russian-German Forum "Bioeconomics and Biomedicine" Russian-German Forum "BIOECONOMY AND BIOMEDICINE" November 17, 2015. Pushchino. Participation with the report "The use of sorbents to reduce the dose load in cattle with internal exposure to cesium-137 and strontium-90 in conditions of radiation pollution of the environment."

Publications. Based on the materials of the thesis, 1 research report, 6 printed works, were published in publications recommended by the Higher Attestation Commission of the Russian Federation.

Author's personal contribution. All experimental and theoretical investigations on the topic of the thesis were carried out by the candidate.

Structure and scope of the thesis. The thesis is presented on 134 pages, contains 30 tables, 65 figures, a bibliography of 117 titles, including 31 foreign ones. The thesis consists of an introduction, three chapters, discussion of results, conclusions, information on the practical use of the obtained results, recommendations on the use of scientific conclusions, references, applications.

MAIN CONTENT OF WORK

In the Introduction, the relevance of the thesis theme is substantiated and the main goals of the studies, scientific novelty and practical significance of the obtained results are formulated.

Chapter 1 (Analytical review of literature) consists of two sections that contain an analysis of literary data on the topic of the thesis. In this chapter, based on the study of literature, the following issues were summarized and discussed: the use of sorption preparations for eliminating radionuclides from the organism of animals; the peculiarities of cattle breeding in the zones of resettlement and alienation.

Chapter 2 (Materials and methods of study). The work was carried out on the basis of the department of radiobiology and virology named after academicians A.D. Belov and V.N. Syurin of the Federal State Budget Educational Institution of Higher Education Moscow State Academy of Veterinary Medicine and Biotechnology named after K.I. Skryabin.

Investigated drugs were provided by clients.

Radionite, suspension (Technopark LLC), series 00006, production date 04.2013, expiration date 04.2016.

Polymethylsiloxane polyhydrate, paste for oral administration (TNK SILMA, LLC), series 730313, production date 03.2013, expiration date 03.2016.

In the course of studying radio-sorbents intended for elimination of radionuclides from the organism of animals and humans, a number of experiments were carried out. Evaluation of the effectiveness of radio-sorbents was carried out in four stages.

The first stage - the study of sorbents in vitro. Sorbents were divided into 8 groups, 50 columns with sorbents in each group. Through the columns, a radio tag with cesium or strontium was actively passed under pressure, and then the sorption properties of these preparations were evaluated by radio spectrometric analysis.

The second stage included the study of structural materials deactivation. To study the deactivating properties of the substances under consideration, 12 groups were formed. Each group consisted of 20 plates of certain structural materials (aluminum, bottle plastic, household linoleum). The size of the plates was 10x10 cm. Each plate was labeled with a cesium-137 radionuclide or strontium-90, after which a sorbent was immediately used. By conducting a radio spectrometric analysis, the sorption properties of these preparations were assessed.

The third stage was performed on laboratory animals. Animals were kept in a vivarium of the Radiobiology Department of the Federal State Budget Educational Institution of Higher Education Moscow State Academy of Veterinary Medicine and Biotechnology named after K.I. Skryabin at a temperature 20-22^{o}C, humidity not more than 50%, in standard plastic cells with fine wood chips. The keeping and feeding were carried out according to the "Rules for work using experimental animals" (Order of the Ministry of Health of the USSR No. 755 of 12.08.1977).

After admission and a two-week medical check-up, they were included in the experiment. During the experiment, the animals were kept under standard conditions (vivarium, recommended ration, free access to drinking water, natural lighting). Manipulations with experimental animals were undertaken in accordance with the provisions of the Helsinki Declaration on Humane Treatment of Animals (Guiding principles for research, 2002).

For the experiment, 10 groups of 500 mice, identical in age and mass, were formed, one group being identified as a control group of mice.

All groups of animals were fed with dried bread impregnated with work solutions of 137CsCl with activity 500 Bq or 90SrCl2 with activity 500 Bq.

Each group was given a certain sorbent. Mice kept in the same conditions but not administered sorbent served as control.

The mice were killed on days 1, 4, 7, 10, 14, 20, 30 after administration of the radioactive isotope. Muscle, liver, kidney, GIT, thigh bone of mice were taken for radiospectrometric studies.

The fourth stage consisted in evaluating the effectiveness of sorbents in rats upon the introduction of a cesium-137 radio-activity marker of high activity.

In this section, the biological effect of the investigated drugs intended for eliminating radionuclides from the animal organism was studied. The toxic effect of sorbents on the rats was investigated. Blood was studied in rats from the control group and groups in which sorbents were used. The dose load on the animal organism from incorporated cesium-137 was calculated.

For the experiment, 5 groups of 10 mice identical in age and mass were formed, one group being identified as a control group of mice.

All groups of animals were fed with dried bread, impregnated with work solutions of 137CsCl with activity 8 Bq.

Each group was given a certain sorbent. Mice kept in the same conditions but not administered sorbent served as control.

The mice were killed on days 3 and 7 after administration of the radioactive isotope. Muscles and kidneys were taken from rats for radiospectrometric studies.

Hematological blood tests by clinical analysis were studied.

Chapter 3. Results of the study.

In vitro testing of sorbents. Adsorption of cesium and strontium is due to the content of calcium and potassium exchange ions in the composition of natural sorbents, which can be replaced by radioactive analogues.

Thus, cesium-137 was adsorbed in the range of 80-96% with the maximum radionite effect (96%).

Strontium-90 was maximally adsorbed by Polymethylsiloxane polyhydrate (90%) and minimally by radionite (35%) (Table 1).

Table 1. Adrorption percent

Sorbent	Cs-137 adsorption %	Sr-90 adsorption %
Sapropel	80 ± 0.2	70 ± 0.2
Polymethylsiloxane polyhydrate	90 ± 0.2	90 ± 0.2
Radionite	96 ± 0.2	35 ± 0.2
Ferrocene	85 ± 0.2	70 ± 0.2

The results of structural materials deactivation. All investigated substances almost completely remove cesium-137 from surfaces of structural materials (aluminum, plastic, linoleum), due to their two main properties. They mechanically remove impurity from the surface, and also due to exchangeable potassium in composition, which can be replaced by cesium-137. Strontium-90 cannot be replaced by the exchangeable potassium of the sorbents under investigation. Therefore, its removal from the surfaces of the same structural materials occurs only due to the mechanical action of a material on the surface. Therefore, the wash effect is considerably weaker in comparison with that of cesium-137. Polymethylsiloxane polyhydrate is an exception.

From the obtained data, it can be seen that the sorption of cesium-137 ranges from 94 to 98% of the studied materials. Most of all, cesium is sorbed from plastic - 98%, less from linoleum - 94%. Linoleum is a porous material and therefore the process of removing radiocesium from the surface is challenging, while plastic has a relatively smooth surface. (Table 2).

Sorption of strontium-90 follows the same pattern. But the percentage ratio is much lower than for cesium-137 sorption.

Table 2. The percentage of cesium-137 and strontium-90 washout from the surface of structural materials before and after wash

Percentage of radioactive isotope washout from structural materials						
Radionite						
Aluminum		Bottle plastic		Linoleum		
Cesium-137	Strontium-90	Cesium-137	Strontium-90	Cesium-137	Strontium-90	
96%± 0.2	60%± 0.2	98%± 0.2	80%± 0.2	94%± 0.2	33%± 0.2	
Sapropel						
Aluminum		Bottle plastic		Linoleum		
95%± 0.2	53%± 0.2	99%± 0.2	80%± 0.2	93%± 0.2	20%± 0.2	
Ferrocene						
Aluminum		Bottle plastic		Linoleum		
95%± 0.2	53%± 0.2	99%± 0.2	80%± 0.2	93%± 0.2	20%± 0.2	
Polymethylsiloxane polyhydrate						
Aluminum		Bottle plastic		Linoleum		
96%± 0.2	93%± 0.2	99%± 0.2	93%± 0.2	94%± 0.2	47%± 0.2	

The effective half-life of cesium-137 in the organism of mice with the use of sorbents. If we compare the values of the biological half-life of cesium-137 in the organism of mice in all groups, then in groups where the adsorbents were radionitol, polymethylsyloxane polyhydrate, ferrocene, the biological half-life was 1.45-fold less than that of the control group.

The period of effective half-life of cesium-137 when using sapropel was 1.6 days longer than the effective half-life of cesium-137 without its use (4.86 in the control group) - 6.5 days. The value of the effective half-life of cesium-137 in the muscles of animals was 2.2-fold less (1.8 days) in relation to the control group (4.29 days). The value of the effective half-life in the liver was 3.8-fold higher (10.45 days) compared with the control group (2.73 days) (Table 3).

Table 3. The biological half-life period (day), the effective half-life period (day) according to the results of the experiment

Preparation	Biological half-life period, day						Effective half-life period, day					
	Muscles	GIT	Heart	Kidneys	Liver	Organism	Muscles	GIT	Heart	Kidneys	Liver	Organism
Control	5	14	4	3	3	5.8	4.2	9.5	3.5	2.7	2.7	4.8
Sapropel	2	10	7	7	16	8.4	1.8	7.5	5.6	5.6	10.4	6.5
Polymethylsiloxane polyhydrate	2	4	4	3	7	4	1.8	3.5	3.5	2.7	5.6	3.5
Radionite	1	2	4	7	7	4.2	0.9	1.8	3.3	5.6	5.6	3.6
Ferrocene	2	8	4	3	7	4.8	1.8	6.3	3.5	2.7	5.6	4.1

The percentage of cesium-137 elimination from the organism using radionite was 77.7%, 37.8% more than in the control group.

The percentage of cesium-137 elimination from the organism using sapropel was 76.6%, 36.5% more than in the control group.

The percentage of cesium-137 elimination from the organism using polymethylsiloxane polyhydrate was 78.85%, 38.9% more than in the control group.

The percentage of cesium-137 elimination from the organism using ferrocin was 70.9%, 31% more than in the control group. (Table 4).

Table 4. ^{137}Cs elimination from the organism of mice (%)

Preparation препарата	Group number	^{137}Cs elimination from the organism of mice (%)					
		Muscles	GIT	Heart	Kidneys	Liver	Organism
Control	1	75	85.2	0	39.4	0	39.4
Sapropel	2	98.5	98.7	93.3	91.8	0	76.4
Polymethylsiloxane polyhydrate	3	99.5	98.3	97.9	0	98.4	78.8
Radionite	4	99.7	90.7	98.8	0	98.4	77.7
Ferrocin	5	96.2	98.3	0	82.7	77.5	70.9

The effective half-life of strontium-90 in the organism of mice with the use of sorbents. The periods of biological and effective half-life of strontium-90 in the organism of animals in the control group and in groups where the sorbents were ferrocene, sapropel and radionite were in the range from 11.5 to 12.6 days and from 8.15 to 8.32 days. Period of biological half-life of strontium-90 while using polymethylsiloxane polyhydrate stands at 7 days, while the effective period of strontium-90 half-life is 5.6 days, which is 1.5-fold less compared with other groups. (Table 5).

Table 5. The biological half-life period (day), the effective half-life period (day) according to the results of the experiment

Preparation препарата	Tb, days							TEff, days						
	Muscles	GIT	Heart	Kidneys	Liver	Bones	Organism	Muscles	GIT	Heart	Kidneys	Liver	Bones	Organism
Control	7	14	7	7	14	20	11.5	5.6	9.3	5.6	5.6	9.3	11.6	8.1
Sapropel	7	14	8	8	14	20	11.8	5.6	9.3	6.2	6.2	9.3	11.6	8.3
Polymethylsiloxane polyhydrate	1	0.01	1	16	14	10	7	0.9	0.01	0.9	10.1	0.9	7.3	5.6

Radionite	7	14	7	8	14	20	11.6	5.6	9.3	5.6	6.2	9.3	11.6	8.2
Ferrocin	7	14	7	14	14	20	12.6	5.6	9.3	5.6	6.2	9.3	11.6	8.2

Elimination of strontium-90 with the use of radionite, sapropel, ferrocene, and also without their use accounts for 46%. This indicates the inefficiency of using the above sorbents to remove strontium-90 from the organism of animals.

The percentage of cesium-137 elimination from the organism using polymethylsiloxane polyhydrate was 86.7%, 40.7% more than in the control group (Table 6).

Table 6. ^{90}Sr elimination from the organism of mice (%)

Preparation	Group number	^{90}Sr elimination from the organism of mice (%)
Control	6	46
Sapropel	7	46
Polymethylsiloxane polyhydrate	8	86.7
Radionite	9	46
Ferrocene	10	46

Evaluation of the effect of sorbents on the physiological and hematological parameters of rats. The maximum content of radiocaesium in rat muscles in the control group was recorded on day 7 of the experiment (400 Bq/g). On day 7, in the muscles of rats an intensive decrease in radiocesium specific activity indices was observed. In the group where radionite was used as a sorbent, the specific activity in muscles was reduced 10-fold (40Bq/g) compared to day 1.

An increase in the specific activity of cesium-137 was observed in the kidneys of rats in all groups, attesting to a renal pathway for the removal of this radionuclide. The maximum specific activity in the kidneys of rats was observed in the groups where radionite (306 Bq/g) and polymethylsiloxane polyhydrate (225 Bq/g) were used (Table 7).

Table 7 Dynamics of accumulation and excretion of cesium-137 from the organs and organism of rats (Bq/g)

Group	Time of killing (day)			
	Muscles		Kidneys	
	3	7	3	7
№ 1 control	400±100	800±200	26.6±1.2	182±32
№ 2 sapropel	400±100	117±23	26.6±1.2	114±22
№ 3 polymethylsiloxane polyhydrate	400±100	121±34	26.6±1.2	225±45
№ 4 radionite	400±100	40±12	26.6±1.2	306±60
№ 5 ferrocene	400±100	111±26	26.6±1.2	94.1±21

Calculation of the effective equivalent dose of gamma irradiation of incorporated cesium-137 affecting the organism of rats showed that its maximum was observed in the animals of the control group (1.4 mSv). In animals of experimental groups, its value was twice smaller amounting to 0.7 mSv (Table 8).

Table 8. Dose load on the body of rats from gamma-irradiation with incorporated cesium-137 (mSv).

Group	Muscles	Kidneys	Organism
Control	1.3±0.02	0.14±0.02	1.44±0.02
Sapropel	0.5±0.02	0.14±0.02	0.64±0.02
Polymethylsiloxane polyhydrate	0.5±0.02	0.26±0.02	0.76±0.02
Radionite	0.4±0.02	0.35±0.02	0.75±0.02
Ferrocene	0.5±0.02	0.12±0.02	0.62±0.02

The hematological studies of blood from control and experimental groups showed that all blood values were within the physiological norm, but the level of red blood cells was on the lower border (Table 9).

Table 9. Hematologic parameters of rats

Group	RBC (erythrocytes), 10^12 C/l		WBC (leukocytes), 10^9 C/l		LYM (lymphocytes), 10^9 C/l	
	Day 3	Day 7	Day 3	Day 7	Day 3	Day 7
Cs137	8.85 ±0.2	7.47 ±0.2	6.1 ±0.2	7.4 ±0.2	2.9 ±0.2	4.2 ±0.2
Cs137+Radionite	8.52 ±0.2	8.36 ±0.2	8.8 ±0.2	10.2 ±0.2	4.4 ±0.2	5 ±0.2
Cs137+Sapropel	8,4 ±0.2	8.33 ±0.2	6.9 ±0.2	10.2 ±0.2	4.5 ±0.2	5.3 ±0.2
Cs137+Ferrocene	8,48 ±0.2	8.35 ±0.2	7 ±0.2	9.3 ±0.2	4.3 ±0.2	5.2 ±0.2
Cs137+Polymethylsiloxane polyhydrate	8.53 ±0.2	8.38 ±0.2	6.8 ±0.2	8.8 ±0.2	4.2 ±0.2	5 ±0.2
Control	9 ±0.2		11 ±0.2		6.3 ±0.2	

CONCLUSION

Based on the conducted studies, the effectiveness of preparations of natural and synthetic origin intended for the removal of cesium and strontium radionuclides from the animals' organism was studied, as well as for a reduction of the dose load during internal irradiation with incorporated radionuclides.

Based on a thorough schematic analysis of the study results, the following conclusions can be drawn:

- The binding of cesium-137 with the studied sorbents from the surface of structural materials ranges from 94 to 98%. Most cesium is sorbed from plastic - 98%, less from linoleum - 94%. Sorption of strontium-90 follows the same pattern. But the percentage ratio is much lower than for cesium-137 sorption.

- Cesium-137 is adsorbed from the solution by the investigated sorbents in the range of 80-96% with the maximum radionite effect (96%). Strontium-90 is maximally adsorbed by polymethylsiloxane polyhydrate (90%) and minimally by radionite (35%).

- The effective half-life of cesium-137 in the body of mice with the use of sorbents: sapropel -6.5 days; polymethylsiloxane polyhydrate - 3.53 days; radionite - 3.68 days; ferrocene - 4.14 days; control - 4.8 days.

- The periods of biological and effective half-life of strontium-90 in the organism of animals in the control group and in groups where the sorbents were ferrocene, sapropel and radionite were in the range from 11.5 to 12.6 days. The period of effective elimination of strontium-90 from the body with the use of polymethylsyloxane polyhydrate - 8.24 days.

- The percentage of cesium-137 elimination from the body with the use of sorbents: radionite - 77.7%, sapropel - 76.6%; polymethylsiloxane polyhydrate - 78.85%; ferrocene - 70.9%.

- The percentage of strontium-90 elimination from the organism when using sorbents: sapropel, ferrocin, radionite, control - 46%; polymethylsiloxane polyhydrate - 86.7%.

- Calculation of the effective equivalent dose of gamma irradiation of incorporated cesium-137 affecting the organism of rats showed that its maximum was observed in the animals of the control group (1.4 mSv). In animals of experimental groups, its value is twice smaller amounting to 0.7 mSv. The hematological studies of blood in control and experimental groups showed that all blood values were within the physiological norm.

Practical use of obtained scientific results:

- The obtained results of the work show the possibility of using all investigated sorbents for deactivation of constructional materials surfacescontaminated with cesium-137. Strontium-90 is solidly deactivated by polymethylsiloxane polyhydrate.

- The obtained results of the work show the possibility of using all investigated sorbents to accelerate the elimination of cesium-137 from the animal organism. Decorporation of strontium-90 from the organism of animals is best achieved by using polymethylsiloxane polyhydrate.

- The obtained work results show the possibility of using all investigated sorbents to reduce the dose of internal irradiation from cesium-137 to individual organs and the whole organism as a whole.

RECOMMENDATIONS

A further study is recommended for investigating the effectiveness of sorbents in agricultural animals kept in conditions of radioactive contamination of the environment.

LIST OF ABBREVIATIONS, CONVENTIONAL SYMBOLS, SYMBOLS, UNITS

AFCF - ammonium-iron-hexocyanoferrate
AD converter - analog-to-digital converter
Bq/kg - Becquerel/kilogram
Bq / l - Becquerel/liter
GIT - gastrointestinal tract
KBq/kg - kilobecquerel/kilogram
KBq/day - kilobecquerel/day
LD50/30 - lethal dosage
μSv - microsivert
ICRP - International Commission on Radiological Protection
MeV - megaelectron-volt, output energy unit
RSS - Radiation Safety Standards
OSPORB - Principal Sanitary Radiation Safety Rules
RM - radioactive material
SanPiN - Sanitary Rules and Regulations
SDU - Scintillation Detection Unit
USSR - Union of Soviet Socialist Republics
Tb - biological half-life period
Teff - effective half-life period
PMT - photoelectric multiplier
AXION - selective ion-exchange materials
ES - enterosorption

LIST OF WORKS PUBLISHED ON THE THEME OF DISSERTATION

R&D reports

Report on the grant agreement No. 14.616.21.0034 for the grant work of the Ministry of Education and Science of the Russian Federation on the theme: "Monitoring of animal infectious diseases in the regions of the world, ways to prevent their spreading and liquidation in environmental conditions" in cooperation with research organizations and universities Member States of the EU "N.P. Lysenko, L.A. Gnezdilova, A.N. Sidorchuk, I.I. Kovalev, F.I. Vasilevich Report on research work No. 14.616.21.0034 of 27.11.2014 (Ministry of Education and Science of the Russian Federation).

Publications in journals recommended by State Commission for Academic Degrees and Titles

1. Оценка эффективности выведения радиоцезия из организма адсорбирующими препаратами природного происхождения Ковалев И.И. Ветеринарная патология. 2015. № 3 (53). С. 55-59. *[Estimation of the efficiency of eliminating radiocaesium from the body by adsorbing preparations of natural origin I.I. Kovalev Veterinary pathology. 2015. № 3 (53). P. 55-59. – in Russ.]*.
2. Выведение препаратом энтеросгель радиоактивного цезия из организма лабораторных животных Лысенко Н.П., Ковалев И.И., Волков М.Ю., Кусурова З.Г. Известия Международной академии аграрного образования. 2015. Т. 1. № 25. С. 39-44. *[Removal of radioactive cesium by Enterosgel from the organism of laboratory animals N.P. Lysenko, I.I. Kovalev, M.J. Volkov, Z.G. Kusurova News of the International Academy of Agricultural Education. 2015. T. 1. № 25. P. 39-44. – in Russ.]*.
3. Эффективность применения иммунных препаратов и сорбентов для крупного рогатого скота в зоне радиационного неблагополучия на фоне сочетанного применения

вакцины Лысенко Н.П., Сидорчук А.А., Гнездилова Л.А., Ковалев И.И. Вестник АПК Ставрополья. 2015. № 4 (20). С. 106-109. *[Effectiveness of the use of immune preparations and sorbents for cattle in the zone of radiation malnutrition against the background of combined use of the vaccine N.P. Lysenko, A.A. Sidorchuk, L.A. Gnezdilova, I.I. Kovalev Herald of the agrarian and industrial complex of Stavropol. 2015. № 4 (20). P.106-109. – in Russ.]*.

4. Использование сорбентов для снижения дозовой нагрузки у крупнорогатого скота при внутреннем облучении цезием-137 и стронцием-90 в условиях радиационного загрязнения окружающей среды Лысенко Н.П., Ковалев И.И., Гнездилова Л.А., Сидорчук А.А., Щукин М.В., Волков М.Ю. Биоэкономика и экобиополитика. 2015. № 1 (1). С. 101-104. *[The use of sorbents to reduce the dose load in cattle during internal irradiation with cesium-137 and strontium-90 under conditions of radiation contamination of the environment N.P. Lysenko, I.I. Kovalev, L.A. Gnezdilova, A.A. Sidorchuk, M.V. Shchukin, M.J. Volkov Bioeconomics and eco-biopolitics. 2015. No. 1 (1). P. 101-104. – in Russ.]*.

5. Эффективность использования сорбентов для выведения радионуклидов из организма животных, выпасающихся на радиационно-загрязненных территориях И.И. Ковалев, Н.П. Лысенко, Л.А. Гнездилова Биоэкономика и экобиополитика. № 1 (2) 2016С. 170-175 *[Efficacy of using sorbents to remove radionuclides from the organism of animals grazing on radiation-contaminated territories I.I. Kovalev, N.P. Lysenko, L.A. Gnezdilova Bioeconomics and eco-biopolitics. No. 1 (2) 2016 P. 170-175 – in Russ.]*.

6. Радиоэкологический мониторинг территории Новозыбковского района брянской области Лысенко Н.П., Ковалев И.И., Кусурова З.Г., Хрусталева Н.А. Известия Международной академии аграрного образования. 2016. № 29. С. 74-76. *[Radioecological monitoring of the territory of Novozybkovsky district of the Bryansk region N.P. Lysenko, I.I. Kovalev, Z.G. Kusurova, N.A. Khrustaleva News of the International Academy of Agricultural Education. 2016. No. 29. P. 74-76. – in Russ.]*.

Publications in other sources, including in the collections of abstracts of scientific events

1. Оценка эффективности выведения радиоцезия адсорбирующими препаратами природного происхождения Лысенко Н.П., Волков М.Ю., Ковалев И.И. В сборнике: Актуальные проблемы ветеринарной медицины, зоотехнии и биотехнологии Сборник научных трудов, посвященный 95- летию Московской государственной академии ветеринарной медицины и биотехнологии имени К. И. Скрябина. 2014. С. 157-159. *[Estimation of the efficiency of eliminating radiocesium by adsorbing preparations of natural origin N.P. Lysenko, M.J. Volkov, I.I. Kovalev In the collection: Actual problems of veterinary medicine, zootechnics and biotechnology. Collection of scientific works dedicated to the 95th anniversary of the Moscow State Academy of Veterinary Medicine and Biotechnology named after K.I. Skryabin. 2014. P. 157-159. – in Russ.]*.

2. Снижение последствий дозовой нагрузки и повышение противорадиационной устойчивости организма в условиях радиоактивного загрязнения окружающей среды Лысенко Н.П. Поздеев А.В., Ковалев И.И., Щукин М.В. Сборник тезисов по материалам Международной практическо- научной конференции «Медицинские радиологические последствия Чернобыля: прогноз и фактические данные спустя 30 лет» 2016г. С 80-81. *[Mitigating consequences of dose loading and an increase in the body's anti-radiation resistance in conditions of radioactive contamination of the environment N.P. Lysenko, A.V. Pozdeev, I.I. Kovalev, M.V. Shchukin A collection of abstracts based on the International Practical Scientific Conference "Medical Radiological Consequences of Chernobyl: A Prediction and Actual Data After 30 Years" 2016 P. 80-81. – in Russ.]*.