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Influence of ^{232}Th and ^{90}Sr radionuclides on the state of natural animals resistance in radioactively contaminated territories of Ukraine.

Abstract

The influence of ^{137}Cs and ^{90}Sr at different concentrations in rations on the functional state of natural resistance of cattle in radioactively contaminated territories of Ukraine was investigated. It was found that radioactive cesium and thorium had a negative effect on the functional state of the natural resistance of cattle. Against the background of the influence of small doses of ionizing radiation, changes were observed in the leukopoietic system, phagocytic activity of neutrophils, the bactericidal activity of blood serum, and T- and B-lymphocytes.

Keywords: resistance, ionizing radiation, cesium-137, strontium-90, radiation pollution.

Introduction

The overall feature of the current ecological state of Ukraine is that ecologically acute local moments are aggravated by the regional crisis. The Chernobyl disaster with its long-term biological impact has created a situation in the country that over the years is approaching the level of a global environmental catastrophe. More than 2 million people live in the territories classified as zones of radioactive contamination in 12 regions of Ukraine, agriculture and animal husbandry are actively developed [3].

A significant increase in the radioactivity of the natural environment becomes threatening due to the negative impact of radioactive radiation from radioisotopes in soil, water, and feed. This leads to genome instability, loss of the ability of cells to adequately respond to stimuli, regulate ontogenetic development, etc. [7].

The natural background radiation is determined by the presence of a large number of chemical elements scattered in the environment of radionuclides, as well as by cosmic radiation. For many years, this background radiation remained almost unchanged, and the radiation doses conditioned by it (about 1 mSv / year) did not cause a pronounced effect of radiation damage. However, in recent decades, the levels of ionizing radiation have increased due to the entry of additional sources of radiation into the biosphere: waste from nuclear power plants and nuclear industry enterprises, and most of all from radioactive releases after tests of atomic weapons and accidents at nuclear power plants, among which the most important is the accident at the Chernobyl nuclear power plant [5].

Long-term studies of scientists show that the radioecological factor (the general effect of an increased background of natural radiation by one to two orders of magnitude compared to background values and geochemical, climatic, and other natural and man-made conditions) can negatively affect the body and animal populations even at very low levels of ionizing radiation. On the example of the population of root voles, a high level of morphophysiological, histomorphological, cytogenetic variability of some organs and systems under the influence of an increased level of natural radiation in biogeocenoses was demonstrated [8].

In the study of cattle, in animals that have been under the influence of low-intensity ionizing radiation for a long time, blood counts are at the lower limit of the norm; over the course of a number of experiments, a "shift" of neutrophils to the left was observed. Animals brought to the zone of radioactive contamination being already adults are more stress-resistant than local animals, but over the years this difference almost disappears, and those raised in the “contaminated” zone are more painful. They were sick more often and longer with various forms of endometritis and mastitis [9]. At the same time, far from all the possible consequences of irradiation (under conditions simulating a nuclear reactor accident) have been studied so thoroughly as to become classical, that is, to be unambiguously perceived in the scientific environment. This is especially true of long-term exposure to radiation in the range of so-called "small doses", the boundaries of which are still not clearly delineated and do not have a generally accepted scientifically substantiated definition. Based on the realities prevailing in radiation-contaminated populated areas, the most unexplored range of doses is from near-background values to several tens of mSv / year, which will be conventionally called the range of low doses. It is concerning it that radiobiologists have no consensus in assessing the biological consequences of irradiation of mammals, on the contrary, sometimes diametrically opposite statements are made - from the statement of increased radiosensitivity [1] to the existence of a threshold below which negative radiobiological effects are not manifested and even biological stimulation occurs, i.e. hormesis effects [4].

One of the main components of radioactive contamination of the biosphere is cesium-137 (radiocesium, 137Cs) – contained in radioactive fallout, radioactive waste, emissions from plants that process waste from nuclear power plants, is intensively sorbed by the soil and deposited in water [1]. Strontium-90, also known as radiostrontium, a radioactive nuclide, is produced primarily by the separation of nuclei in nuclear reactors and nuclear weapons. 90 Sr gets into the environment mainly during nuclear explosions and emissions at nuclear power plants. Considering this and the fact that strontium-90 has a relatively long half-life, it is preferably used as a marker in determining the boundaries and levels of anthropogenic radioactive contamination. At the same time, the total level of ionizing radiation, including γ- and α- and the total content of all polluting radionuclides, in particular short-lived ones, in a given area may be higher than those for strontium -90 or β-radiation [2].

Among the three main ways of radionuclides entering the human body (inhalation, alimentary, cutaneous), the alimentary way is of paramount importance. Since 1989, 95-98% of the internal radiation dose of people living in the contaminated area were formed due to cesium-134 and 76 cesium-137, 3-4% - due to strontium - 90, all other radionuclides were not more than 1 -2%; some of them further decreased due to disintegration [7]. Fortunately, the density of plutonium contamination of agricultural land outside the 30-kilometer zone is negligible (no more than 8.7 kBq / l). In addition, in the soil-plant system, plutonium compounds are inactive, absorption into the digestive tract is not more than 0.01-0.003%. Therefore, plutonium radionuclides do not pose a significant hazard as food contaminants. Thus, 30 years after the accident, the main dose-forming nuclides supplied with food are cesium-137 and strontium-90 [9]. At the same time, a number of authors investigated that radioactive cesium has a negative effect on the functional state of the natural resistance of cattle [6].

According to the Ministry of Ukraine for Emergencies and Protection of the Population from the Consequences of the Chernobyl Catastrophe in 2018, the content of ^{137}Cs and ^{90}Sr is the highest in the soils and water of Ukraine [10]. That is why the purpose of our research was to reveal the effect of low doses of ionizing radiation^{137}Cs and ^{90}Sr on the functional state of cattle resistance in Podillia region.

Research results.

To achieve this goal, the following tasks were set: to determine the contamination of the territory, pastures, and rations with radionuclides in the farms of Podillia region, to study the

features of the functional state of the natural resistance of cattle in farms with different intensity of radioactive contamination.

Radiological, hematological, biochemical, immunological research methods were used in the research.

Clinical and experimental studies were carried out on cattle aged 4-8 years, live weight 350-450 kg, on the premises of family farms in Kamianets-Podilskyi and Chemerovtsi districts of Khmelnitskyi region. Three experimental groups of cattle were formed. The first group included livestock from settlements with a soil contamination level of ^{137}Cs and ^{90}Sr to 40 кБк/м^2, the second – animals from settlements with a pollution level from 40 to 100 kBq / m2, and the third - with a level of m2 contamination. The conditions for feeding, caring for, and keeping animals in all three farms were the same.

Laboratory radiological studies were carried out in the research laboratory of the Department of Normal and Pathological Physiology and Morphology of the Higher Education Institution "Podillia State University". The material for laboratory research was the soil, feed, and blood of cattle.

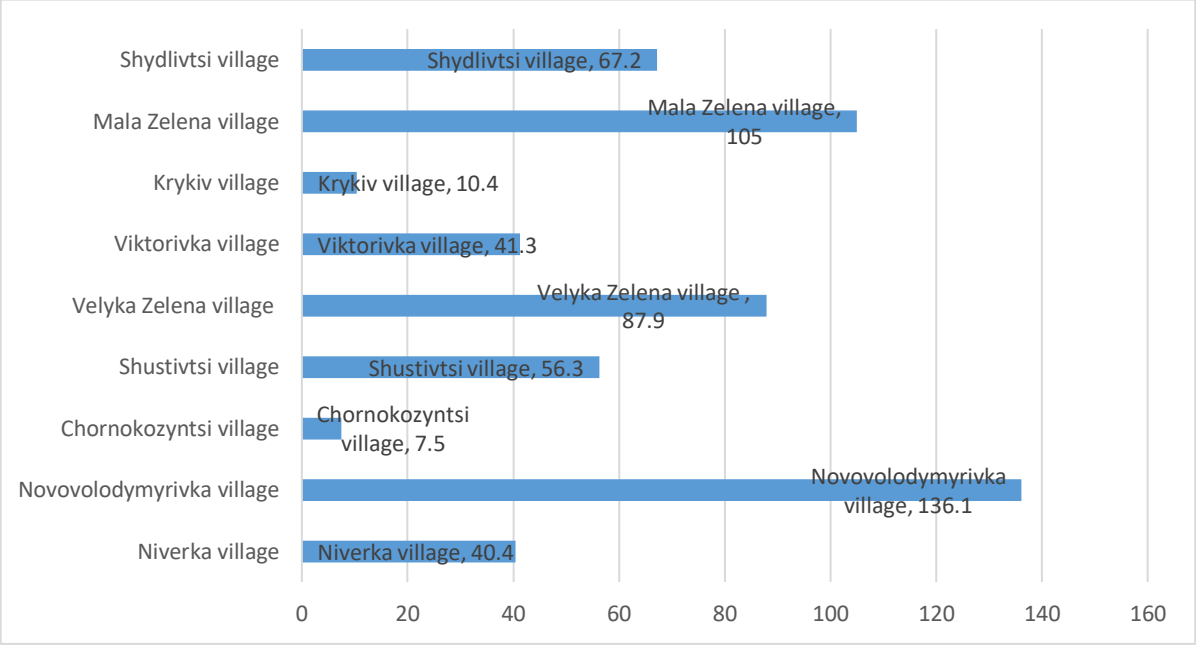
Blood for morphological, biochemical, immunological studies was taken from the jugular vein in experimental cows before feeding in accordance with the rules of asepsis and antiseptics.

One experimental group was formed on each farm with 20 cows. All cows were examined for clinical status according to generally accepted methods. To assess the radiation situation and determine the intake of radionuclides into the animal organism, in each of the experimental farms, the gamma background was measured using SRP-68-01 at various livestock facilities and the specific radioactivity of the feeding fodder.

In experimental groups of cows, in laboratory conditions, the following was studied: the number of leukocytes and erythrocytes - by counting in the Goryaev's chamber, leukocyte formula - by counting white blood cells in smears stained according to Romanovsky-Giemsa; the absolute content of lymphocytes in the peripheral blood - by the calculation method; the content of total protein in the blood serum - using a refractometric, hemoglobin - by the generally accepted method using a Sali hemometer; bactericidal activity of blood serum - by photonephelometric method according to D.A.Petrachev; lysozyme activity of blood serum - by the photoelectrocolometric method in the modification of the department of zoo hygiene of the UNIIEV; opsonophagocytic activity of blood leukocytes - by the method of absorption by leukocytes St. Aureus 209-P followed by counting on a stained smear according to Romanovsky-Giemsa; T-lymphocytes - by the method of spontaneous rosette formation with sheep erythrocytes (E-ROK); B-lymphocytes - by the method of detecting on their surface receptors up to the Fc fragment of immunoglobulins and C3 (EAK-ROK).

According to the research results (Fig. 1), most of the settlements had pollution from 40 to 100 kBq / m^2, but in two settlements the level of soil contamination with ^{137}Cs was significantly less than 40 kBq / m^2. It was found that animals in the summer period were grazed on pastures with contaminated grass stand with radionuclides, and in the winter stall period they were fed in the diet of feed also contaminated with radionuclides, the total contamination of the diet in the winter stall period was 3158, respectively.

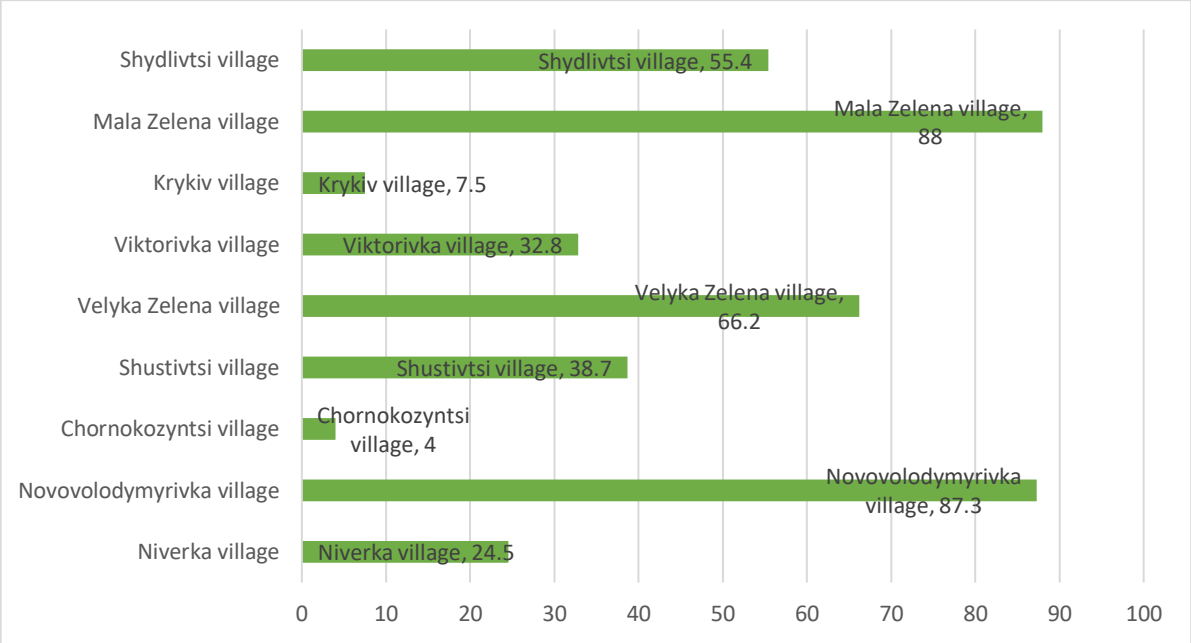
Figure 1. Level of soil pollution ^{137}Cs (kBq / m^2) in the settlements of Western Podillia referred to the fourth zone of radioactive contamination.
Source: https://www.dsns.gov.ua/UserFiles/File/2009/table_1.pdf



According to the results of studies of soil contamination with ^{90}Sr (Fig. 2), most settlements had pollution from 40 to 100 kBq / m2, however, in two settlements, the level of soil contamination with Sr was also significantly less than 40 kBq / m2. At the same time, the lowest level of soil contamination ^{90}Sr was observed in the villages of Krykiv and Chornokozyntsi, and the highest level is in the villages of Novovolodymyrivka and Mala Zelena. The obtained data can be explained by the fact that in the immediate vicinity of these settlements is the Khmelnytsky nuclear power plant, which makes adjustments to the overall analysis of its emissions.

The total contamination of the diet during the winter stall period was 2954 and 2036 Bq, respectively.

Figure 2. Level of soil pollution ^{90}Sr (kBq / m^2) in the settlements of Western Podillia referred to as the fourth zone of radioactive contamination.
Source: https://www.dsns.gov.ua/UserFiles/File/2009/table_1.pdf



In the experimental animals, the morphological parameters of the blood (Table 1) were within the physiological norm, but in the animals of the third group they were significantly lower compared to the animals of the first group, which were kept in farms with ^{137}Cs and ^{90}Sr contamination below 40 kBq / m^2. The leukogram showed significant changes in the blood of animals from farms with the high radioactive background.

Concerning erythrocytes, it should be noted that their content in the blood decreased depending on the contamination of ^{137}Cs and ^{90}Sr diets, but this difference is unlikely. Analyzing the leukoformula, it should be concluded that with increasing concentration of ^{137}Cs and ^{90}Sr in the diets of animals of the third group there is a decrease in the content of segmental neutrophils and monocytes ($p > 0.95$), with a probable increase in the content of rod neutrophils and lymphocytes in both indicators.

There was a decrease in the number of basophils, segmented neutrophils, lymphocytes, and monocytes in the blood of animals from the contaminated area in relation to their counterparts from the conditionally clean area, and there were fewer stab neutrophils only in animals, although these changes were not sufficiently pronounced. The content of ^{90}Sr influenced the leukoformula to a lesser extent. At the same time, the number of eosinophils, on the contrary, was probably higher in animals from the zone of radioactive control.

Table 1. Morphological parameters of cattle blood.

Source: Own survey based on conducted research

Radionuclide		^{137}Cs	^{90}Sr	^{137}Cs	^{90}Sr	^{137}Cs	^{90}Sr
Indexes		I group	I group	II group	II group	III group	III group
Erythrocytes, T / l		5,20±0,2	4,10±0,10	5,03±0,21	4,00±0,1	4,47±0,31	3,89±0,38
Leukocytes, G / l		9,17±0,3	8,10±0,24	7,67±0,4	5,22±0,3	6,70±0,46*	5,62±0,33*
Leukoformula, %:							
Basophils		0,1±0,04	0,2±0,01	0,03±0,02	0,01±0,01	0	0
Eosinophils		6,00±0,41	4,00±0,32	5,00±0,41	3,00±0,12	4,33±0,47	3,83±0,24
Neutrophils	Juvenile	0,2±0,08	0,1±0,04	0,33±0,06	0,33±0,06	0,7±0,08	0,74±0,01
	Band	3,3±0,62	2,3±0,48	4,00±0,41	3,00±0,31	5,67±0,24*	4,35±0,07*
	Segmented	23,00±0,8	19,00±0,2	20,67±0,4	10,20±0,2	18,00±0,1*	16,00±0,1*
Lymphocytes		61,70±0,8	54,70±0,4	65,9±0,6*	58,9±0,5*	68,97±0,6*	55,57±0,1*

Note. Here and beyond * – p>0,95.

According to the indicators of the cellular defense factor of the organism, a probable decrease (P> 0.95) in the phagocytic activity of neutrophils was observed in cows with a zone contaminated with radionuclides and a pronounced decrease in the phagocytic intensity of neutrophils (P> 0.95) compared with analogs from the clean zone.

Table 2. Immunological parameters of cattle blood.

Source: Own survey based on conducted research

Радіонуклід	^{137}Cs	^{90}Sr	^{137}Cs	^{90}Sr	^{137}Cs	^{90}Sr
Indexes	I group	I group	II group	II group	III group	III group
BASK, %	55,00±2,04	54,00±1,0	51,67±2,49	50,12±3,19	48,00±1,67*	39,00±1,55*
LASK, %	27,33±1,25	22,53±1,13	30,33±1,63	24,38±1,22	36,67±2,05*	29,14±1,05*
Lymphocytes, G/l	6,47±0,37	5,49±0,55	4,30±0,45*	3,30±0,12*	3,77±0,42*	2,84±0,02*
T- lymphocytes, %	34,67±1,43	30,29±1,63	31,33±1,65	28,30±1,12	29,33±1,84*	28,40±1,19*
B-lymphocytes, %	16,33±1,70	14,50±1,90	13,67±1,03	10,22±1,0	12,50±1,14*	10,40±1,4*

After analyzing the changes in the immunological parameters of the blood of the experimental animals (Table 2), it should be concluded that in the third experimental group there was a probable decrease in the bactericidal and lysozyme activity of blood serum, the content of lymphocytes and T- and B-lymphocytes (p> 0.95). While in animals of the second

group, a decrease in these blood parameters was not likely, with the exception of the lymphocyte content.

According to the results of the study, it was found that radioactive cesium to a greater extent and thorium to a lesser extent caused a negative impact on the functional state of the natural resistance of cattle. The most sensitive were the leukopoietic system, phagocytic activity of neutrophils, bactericidal activity of serum and T- and B-lymphocytes. Blood indexes of cattle kept in the area of radioactive contamination were within the physiological norm.

However, a decrease in the number of leukocytes was observed, in the leukoformula the number of young and stab neutrophils and lymphocytes increased, the level of sigmentonuclear neutrophils and monocytes, bactericidal and lysozyme activity of blood serum, the content of B and T lymphocytes decreased.

Table 3. Biochemical parameters of cattle blood.

Source: Own survey based on conducted research

Radionuclide	**^{137}Cs**	**^{90}Sr**	**^{137}Cs**	**^{90}Sr**	**^{137}Cs**	**^{90}Sr**
Indexes	**I group**	**I group**	**II group**	**II group**	**III group**	**III group**
Hemoglobin, g / l	95,00±4,08	93,00±2,02	89,00±2,04	85,00±1,04	81,00±3,34*	78,00±3,08*
Total protein, g / l	69,00±1,87	68,00±0,81	65,00±2,04	62,08±1,08	62,00±2,16*	58,00±1,10*
Albumins, %	37,67±2,46	35,03±2,10	36,00±1,87	34,00±2,45	32,00±0,82	30,00±0,52
α-globulins, %	11,67±0,62	10,12±0,52	12,00±0,82	10,23±0,48	13,00±0,82	10,00±0,42
β-globulins, %	14,00±0,82	12,00±0,2	12,67±1,25	10,36±2,36	10,33±1,65	08,27±1,88
γ- globulins, %	36,67±2,62	34,27±2,30	39,33±1,84	36,75±1,00	44,67±3,47*	41,62±2,27*

Analyzing the changes in the biochemical parameters of the blood of experimental animals, it should be noted that the difference between the first and second experimental groups was not probable, although a decrease in the content of hemoglobin and total serum protein, albumin, and β-globulins was observed with an increase in the concentration of α- and γ-globulins.

Conclusions.

1. Blood indicators of cattle kept in the zone of radioactive contamination were within the physiological norm.
2. Against the background of the influence of small doses of ionizing radiation, a decrease in the number of leukocytes was observed, in the leukoformula the number of young and stab

neutrophils and lymphocytes increased, the level of sigmentonuclear neutrophils and monocytes decreased.

3. With an increase in the concentration of α- and γ-globulins, a decrease in the content of hemoglobin and total protein of blood serum, albumins and β-globulins, a decrease in the bactericidal and lysozyme activity of blood serum, lymphocytes, and T- and B-lymphocytes were also observed.

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