Biological effects of factors associated with explosions of titanium foil in condensed media

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High-current explosions of titanium foil in condenced media are accompanied by distorsion of the natural titanium isotope ratio [[15]]. Initially, the foil was characterized by natural isotope distribution (^{46}Ti-8%, ^{47}Ti-7,3%, ^{48}Ti-73,8%, ^{49}Ti-5,5%, ^{50}Ti-5,4%), and following an electric explosion, the percentage of ^{48}Ti declined to 68 ± 0.4%. The composition of the remainder titanium isotopes (46, 47, 49, 50) retained its natural character, i.e. it was within the range of measurement errors. The results of the independent testing measurements of the titanium isotope distribution obtained by V. Kuznetsov's group using γ-analyses [[2]] matched those obtained by mass-spectrometry.

The phenomenological model constructed in [[13]] has shown that the ^{48}Ti atom transformation observed after electic explosion is not inhibited by the energy conservation law, and laws of conservation of baryonic, electric and leptonic charges. The measurements of such known types of radiation as neutron and γ-radiation associated with electric explosions have not demonstrated any significant excess elevation of the natural background [[15], [2]]. Using the Moessbauer's effect, it was possible to register a change in the magnetic field on the ^{57}Fe nuclei of the irradiated foil. [[15], [7]]. At a distance of 1 m from the epicenter of the shot, a magnetic field with inductance of 0.28 mTl per impulse was identified. A number of hypotheses were considered with the aim to account for the phenomenology of the changes observed. In particular, 15 years before these experiments were performed, the French theoretician J. Loshak had shown in a series of his works [[9], [10], [11], [3]] that leptonic magnetic monopoles representing magnetically-excited state of neutrinos can occur naturally. It

can be expected that this type of monopole would appear at relatively low energies but at high electromagnetic fields. Thus, the changes observed can be explained taking into account the existence of particles carrying a magnetic charge [[3], [10], [11], [9]]. The vector magnetic potential can be regarded as another hypothesis accounting for the results of the experiments [[5], [14], [8], [6]].

Thus, the following question arises: assuming the results of the studies performed [[7], [13], [15], [2]] are not erroneous, what is the mechanism through which the factors involved in highcurrent explosions of foil in condensed media can interact with biological systems? The present study represents an attempt to find an answer to the question posed above.

The dependencies governing the reactions of the hemopoietic system to different types of radiation have been studied fairly well, moreover, it is well known that this sytem is among the first to react to factors of various nature, and it is notable for its high radiosensitivity [[1]]. For these reasons, we have used the hemopoietic system for the purpose of investigating the biological effect of factors associated with highcurrent explosions of titanium foil in condensed media. In order to detect a non-damaging biological effect exerted by a factor of interest, we used the adaptive response model [[4]].

The study tasks:

1. Evaluate the key parameters in mice exposed to factors associated with highcurrent explosion of titanium foil in 40% aqueous solution of glycerol.
2. Evaluate the genotoxic effect produced by factors involved in highcurrent electric explosions of foil.
3. Identify the reaction of bone marrow cells to acute external gamma-radiation in animals exposed as a result of electric explosions.
4. Evaluate the biological effects of exposure to highcurrent electric explosions of titanium foil in 40% aqueous solution of glycerol in animals under the conditions of shielding using different materials (polyethylene, Al, Fe).

1 Material and methods

The studies were conducted at the laboratory of the RECOM Company “Kurchatov Institute”.

C57B16 line female mice aged 80 days, weighing 16-18 g were used in the experiment (Stolbovaya vivarium).

Conditions of experimental irradiation. The animals were irradiated during highcurrent explosions of titanium foil in 40% aqueous solution of glycerol.

The experimental setup is presented in detail in [[15]]. Brief characterization of the setup: two capacitor banks each with stored energy of about 50 kJ, charging voltage of 4.8 kV, current width of 120 ms at amplitude of 100 kA. In this experiment both batteries responded synchronously, each to its own foil load. Titanium foil weighing 180 mg that served as a load was placed in the blasting chamber filled with 40% aqueous solution of glycerol (Fig. 1).

Animals were irradiated using the GUT 200 M installation with 64 ^{60}Co sources at a dose rate of 0.77 cGy/sec.

Design of the experiment. Two series of experiments were performed. The first series involved placing the animals in polyethylene cages at a distance of 1 m north of the epicenter of the blast. Each of the four experimental groups comprised 10-20 animals. The first group served as biological control. Animals composing groups 2-4 were exposed to experimental irradiation on days 1, 2 and 3, respectively (Table 1). The total number of shots per experimental group was 3, 7, and 10, respectively. Animals included in group 5 were exposed to gamma-radiation at a dose of 2 Gy. Animals composing group 6 were for 3 running days exposed to electric explosions, on day 4 they were irradiated at a dose of 2 Gy and exposed to 4 explosions, in addition.

The second series of experiments involved sampling 8 experimental groups, each composed of 12-15 mice (Table 1). The first group served as a biological control. Animals comprising groups 2-4 were, respectively, irradiated during the 3 days of the experiment under different shielding conditions: in polyethylene cages, in polyethylene cages placed in aluminium boxes (wall thickness: 2mm), in polyethylene cages placed in iron boxes (wall thickness: 2mm). Aluminium and iron shielding was used with the aim to prevent exposure to electromagnetic field impulse during electric explosions of titanium foil. Animals included in group 5 were exposed to gamma-radiation at a dose of 2 Gy. Animals of groups 6-8 were exposed to the factors of interest using the same approach as was applied to experimental groups 2-4, however , on day 4 they were exposed to gamma-radiation, and, additionally, to 4 blasts.

Hematological studies. The animals were examined on the day following cessation of experimental exposures. Blood samples taken from the tip of the tail were used for leukocyte counts and preparation of blood smears. Next, after the animals were victimized by dislocation of cervical vertebrae, their bone marrow was removed from femoral bones to be used for counting nucleated cells (NC) in the bone marrow, and for preparation of smears. Blood and bone marrow smears were fixed using methanol, and stained after

Romanovsky-Giemsa. Peripheral blood leukocyte and bone marrow nucleated cell counts were made using a hematocytometer.

Cytogenetic studies. Frequency of micronuclei in the animals' bone-marrow erythrocytes was estimated with the aim to evaluate the genotoxic effect of the exposure studied [[12]]. Cytogenetic studies also involved assessment of the ratio of polychromatophilic and normal chromatophilic erythrocytes in the bone marrow.

To evaluate the effect of the factors of interest on the hematological and cytogenetic parameters, single-factor analyses of variance and regression analyses were performed. Some parameters were compared using Student's t-criterion ($P \leq 0.05$).

2 Results

The number of nucleated cells identified in the bone marrow of the control C57B16 mice used in the 1-st series of experiments was 38.6 ± 1.6 mln/femur (Table 2). Although exposures of animals in polyethylene cages was followed by a certain impact of factors associated with highcurrent electric explosions of titanium foils in 40% aqueous solution of glycerol during day 1-2 which caused an increase in the values up to 42.3 ± 1.9 and 42.4 ± 2.1 mln/femur, respectively, these changes did not reach statistical significance. Exposures for 3 days resulted in a further increase in the values up to 45.1 ± 1.7 mln/femur which was significantly higher, by 17%, than the value obtained for the control group. Also, the difference between the mean number of NC in the bone marrow of all exposed animals and that obtained in controls was statistically significant.

The second series of experiments using the same shielding conditions as the first series (3-day exposure in polyethylene cages) produced results similar to those obtained earlier. In this case the number of NC in the bone marrow from control mice was 31.8 ± 1.8 mln/femur (Table 2). The exposure to the factors of interest resulted in a statistically significant increase (by 25%) in the number of nucleated bone marrow cells as compared to that shown by the controls.

The number of NC in the bone marrow of animals shielded by aluminium and iron boxes during exposure to the blasts was higher than that in the control group, amounting to 36.3 ± 1.9 and 34.6 ± 1.7 mln/femur, respectively, however, these differences did not reach statistical significance. Nevertheless, the mean number of bone-marrow NC estimated for animals of all experimental groups exposed to the blasts was found to be significantly higher (by 16%) compared to that for controls.

Thus, the results of the two independent experiments allow us to conclude that exposure to electric explosions of titanium foil in 40% aqueous solution of glycerol bring about an increase in the number of NC in the bone marrow of mice after a 3-day exposure.

The evaluation of the reaction exhibited by the hematopoietic system to a combination of the factors of interest and acute external gamma-radiation at a dose of 2 Gy produced the following results. Exposures to gamma-radiation induced a 2-fold decrease in the number of bone-marrow NC as compared with that in the controls. The effects of combined exposures did not differ significantly from those induced by gamma-irradiation alone (Table 2).

The analyses of the bone marrow cell composition did not reveal any consistent changes which would occur with regularity in the course of the first- and second-series experiments, except for an increase in the proportion of lymphoid cells in the animal groups exposed to factors associated with electrical explosions of foil.

No statistically significant changes in the peripheral blood leucocyte counts were registered in mice exposed to electrical explosions of foil during the first series of experiments (Table 3).

The results of the second series of the experients were indicative of a statistically significant increase in the peripheral blood leucocyte counts in animals shielded with iron sheets at the time of exposures. Peripheral blood leucocyte counts obtained for this experimental group amounted to 15.39 ± 0.92 thou/ml compared to 12.41 ± 0.76 thou/ml found for the controls (Table 3).

Evaluation of the combined effect of the factors under study and the external whole-body exposures to gamma-radiation at a dose of 2 Gy allowed detection of the following changes in the peripheral blood of the experimental animals. Exposures to gamma-radiation caused a dramatic decrease in peripheral blood leucocyte count in control animals as compared to that manifested by non-irradiated mice following both the first- and the second-series experiments.

During the first- and second-series experiments involving 3-day exposures of animals placed in polyethylene cages to explosions followed by gamma-irradiation at a dose of 2 Gy, peripheral blood leucocyte counts did not differ significantly from those obtained for the comparison groups (gamma-irradiation of the control animals).

The shielding of mice exposed to explosions using iron sheets during the second-series experiments induced not only increased counts of peripheral blood leucocytes, but also changes in the blood system reactions to

additional ionizing exposure. Peripheral blood leucocyte counts determined for the group exposed to a combination of factors was 3.4 ± 0.2 as compared to 2.6 ± 0.2 thou/ml registered in the group of animals exposed to just gamma-radiation alone at a dose of 2 Gy (Table 3). The use of shielding with aluminium sheets did not entail any statistically significant changes in peripheral blood leucocyte counts.

Therefore, the use of shielding with iron sheets in exposures to the factors of interest results in increased peripheral blood leucocyte counts in cases of exposures to both electric explosions of foil alone and to combinations of explosions and gamma-radiation, by about 25-30% versus the respective values obtained for the comparison group. This repetition of one and the same effect in the two series of experiments gives us grounds to suggest with greater confidence that shielding plays a role in the occurrence of the consequences of the factors under study.

The frequency of peripheral blood neutrophils in animals in the first series of experiments was 17.1 ± 2.0%, of that number stab neutrophils made up 2.2 ± 0.5% and segmented neutrophils 14.9 ± 1.7% (Table 4). Experimental exposures resulted in a consistent increase of peripheral blood neutrophil counts. Thus, 24 hrs after exposure to 3 explosions peripheral blood neutrophil counts reached 17.8 ± 0.8%, 48 hours later they were 22.1 ± 2. 1%, and 72 hours later a statistically significant increase of this parameters was registered – up to 25.2 ± 1.8%. Regression analyses of the dependence of neutrophil counts on the duration of exposure revealed a statistically significant ($F=13.53$; $P = 0.0005$) effect of the factor on the parameter studied.

As seen in Table 4, the increase in neutrophil counts was primarily accounted for mature segmented neutrophils while the stab neutrophil count did not differ significantly from the respective values for the controls.

Along with the changes in the proportion of peripheral blood neutrophil counts, a decrease in lymphocyte counts was also noted during the first-series experiments. The group of animals exposed for 3 days manifested a statistically significant decrease in this parameter to 70.4 ± 1.9%.

No statistically significant changes occurred in peripheral blood eosinophil and monocyte counts during the first-series experiment.

In principle, similar changes were observed during the second series of the experiments. In these experiments the relative numbers of neutrophils in the control group was 11.1 ± 0.6%: 0.24 ± 0.10% of them were juvenile cells, 2.8 ± 0.4% stab cells and 8.1 ± 0.4% segmented neutrophils (Table 4). Experimental exposures to electric explosions of titanium foil in 40% aqueous solution of glycerol resulted in an increase in the proportion of

neutrophils registered in all experimental groups vis-à-vis the controls. Such changes, similar to those seen in the first-series experiments, were mostly determined by an increase in the proportion of mature cells. Thus, the content of segmented neutrophils noted in the group of animals exposed in polyethylene cages was 11.8 ± 1.1% which exceeded the value obtained for the controls by 45% (Table 4). These changes were even more manifest for the group of animals shielded with aluminium boxes. The content of segmented neutrophils registered in this group was 13. ± 2.%, which was by 60% higher than the respective value for the controls. The use of iron boxes for shielding resulted in less manifest changes. The changes registered in this group did not reach statistical significance.

The analysis of effects from exposure to a combination of factors associated with electric explosions of titanium foil and external whole-body irradiation at a dose of 2 Gy during the first-series experiments did not reveal statistically significant differences from the effects of exposure to gamma-radiation alone.

The changes observed in all groups during the second-series experiments were manifested by an increased proportion of stab neutrophils as compared with the effects resulting from exposure to gamma-radiation alone (Table 4). Such changes were especially pronounced for groups of animals shielded with aluminium and iron. The proportions of stab neutriphils observed for these experimental groups exceeded the values obtained for animals exposed to gamma-radiation alone by 92% and 47%, respectively.

Thus, the results of two independent experiments allow us to draw a conclusion that the exposure associated to explosions of titanium foil in 40% aqueous solution of glycerol lead to an increased proportion of peripheral blood segmented neutrophils in mice.

To enable an evaluation of the genotoxic effect of factors involved in electric explosions of foil in 40% aqueous solution of glycerol, the frequency of micronuclei in bone marrow erythrocytes, as well as the correlation between erythrocytes at different stage of maturity, was assessed.

No significant changes in the ratio of polychromatic erythrocytes (PCE) to normochromatic erythrocytes (NCE) and frequency of micronuclei in bone marrow erythrocytes were revealed as a result of a 3-day exposure to electric explosions. during the first-series experiments (Table 5). However, the evaluation of the reaction to external whole-body gamma-irradiation at a dose of 2 Gy shown by the mice exposed to factors associated with electric explosions of foil revealed significant changes. Such changes were manifested by increased ratio of the PCE/NCE and by decreased frequency of radiation-induced micronuclei in bone marrow erythrocytes (Table 5).

The changes revealed during the second-series experiments were associated with the differences in the exposure conditions during the explosions of foil (Table 5).

The group of animals shielded during exposure in aluminium boxes exposed displayed no changes in the correlation between bone marrow erythrocytes at different stage of maturity, but a 2-fold increase in erythrocytes with micronuclei was registered as compared to the respective value seen in the controls.

The evaluation of the cellular reaction to acute gamma-irradiation observed in the group of animals shielded from explosions of foil with iron sheets showed a precise repetition of the results obtained in the course of the first-series experiments which involved exposures of animals placed in polyethylene cages. It is important to note that the animals comprising this group were placed in the same area (north of the epicenter of the explosion) in which the animals used in the first-series experiments were located. In the group of animals shielded from explosions of foil with iron sheets a statistically significant increase in the PCE/NCE factor by 60% as compared with the respective values estimated for the control group (gamma-exposure of intact animals), and almost a 3-fold decrease in the frequency of micronuclei induced by radiation exposure was registered (Table 5).

Similar to the animals used in the first-series experiments, the group of animals kept in polyethylene cages during exposures to explosions of foil displayed a statistically significant increase in the ratio of poluchomatophilic to normal chromatophilic erythrocytes following gamma-irradiation, but no reduction in the genotoxic effect of ionizing radiation was observed.

The reaction of the bone marror cells to gamma-radiation in animals kept in aluminium boxes during the electric explosions did not differ from that observed in intact animals.

Thus, it has been revealed in our experiments that exposures to factors associated with electric explosions of titanium foil exert a genotoxic effect if aluminium shielding is used, and cause changes in the reaction of bone marrow cells to acute gamma-radiation if iron is used for shielding animals kept in polyethylene cages during exposures.

It was revealed based on the results of these studies that exposures of C57Bl6 female mice to 10 electric explosions of titanium foil in 40% aqueous solution of glycerol resulted in a statistically significant increase in the number of bone marrow cells, increase in the proportion of mature (segmented) peripheral blood neutrophils, and changes in the bone marrow cell reactivity to acute gamma-irradiation at a dose of 2 Gy.

The fundamentally different reaction of the bone marrow cells shown by experimental groups differing in the conditions of exposure to explosions of foil leads to the conclusion that factors, such as noise and gas-aerosol releases, do not influence significantly the biological parameters studied. Exposure to these factors was the same for animals of all the experimental groups, and, in case they exerted a determining influence, their influence should have led to the same effects in all groups.

The conditions of the exposures received by the animals in different experimental groups during explosions of foil differed in terms of two parameters: shielding material and position relative to the the epicenter of the explosion. In this connection, the biological effects observed, differing fundamentally in different experimental groups, allow the following assumptions:

1) the key biotropic factor observed during electric explosions of foil in aqueous solutions may represent a new type of radiation of magnetic nature [1, 5-9].
2) Shielding materials (polyethylene, aluminium, iron) modify the biological effects of factors inherent in highcurrent explosions of conductors in condensed media, and/or biological effects are determined by the position of the experimental animals relative to the explosion point and the terrestrial magnetic field. The latter does not rule out the existence of symmetry of the operating biotropic factors.

In our separate experiments we have shown that physical factors with adverse symmetry may interact differently with biological systems.

Electromagnetic fields of radio-frequency bandwidth (EMF RF) (925 MHz, average power density: 0.5–1.2 mWt/cm^2), in particular, produced different biological effects depending on polarization.

In our experiments, EMF RF with right-hand polarization were more effectively inducing biological reactions as compared to EMF RF with left-hand polarization. Typically, EMF RF with right-hand polarization produced a more manifest genotoxic effect at the subcellular level, while at exposures to EMF RF with left-hand polarization the frequency of micronuclei was either equal to that seen in the controls, or significantly lower. In terms of genotoxcic effects EMF RF with linear polarization occupied an intermediate position between EMF RF with right-hand polarization and that with left-hand polarization. At cellular level, EMF RF with right-hand polarization induced more pronounced adaptational reactions as compared to those cause by EMF RF with left-hand polarization. The use of EMF RF with right-hand polarization resulted, in particular, in a higher rate of hemopietic stem cell survival. At the level of the hemopoietic system level

exposure to EMF RF with right-hand polarization resulted in a more pronounced increase of the number of resting stem cells (Spleen colony forming units, exotest), and a reduced number of functionally active nucleated cells in the none marrow). The effects produced by of EMF RF with linear polarization were comparable to those produced by EMF RF with right-hand polarization, or even exceeded them, and the effects of EMF RF with left-hand polarization were always undistinguishable from those seen in the controls or were found to be considerably less pronounced than those observed in case of EMF RF with right-hand or linear polarization.

From the point of view of radiophysics, when EMF RF polarization is used, a high-quality radio-signal recept is possible on the condition that the construction of the pickup antenna corresponds with the polarization of the emitted signal. From this point of view, exposures of biological systems to EMR with different polarization may bring about bilological effects that are more pronounced in case the spatial structure of the antenna (of molecular biological targets) matches the polarized radiation used. Thus, the specific features of biological effects produced by EMF RF with different polarization allows us to suggest that in mice the targets capable of inducing non-specific adaptational cell reactions have a spatial structure corresponding to EMF RF with right-hand polarization.

Turning back to biological effects of factors associated with explosions of titanium foil in condesed media it is possible to formulate the following: if the biotropic factors of such exposure have a symmetry, it should suppose the existence of differences in interactions with a matter of different “charges”, or existence of a new type of biological systems dissymmetry.

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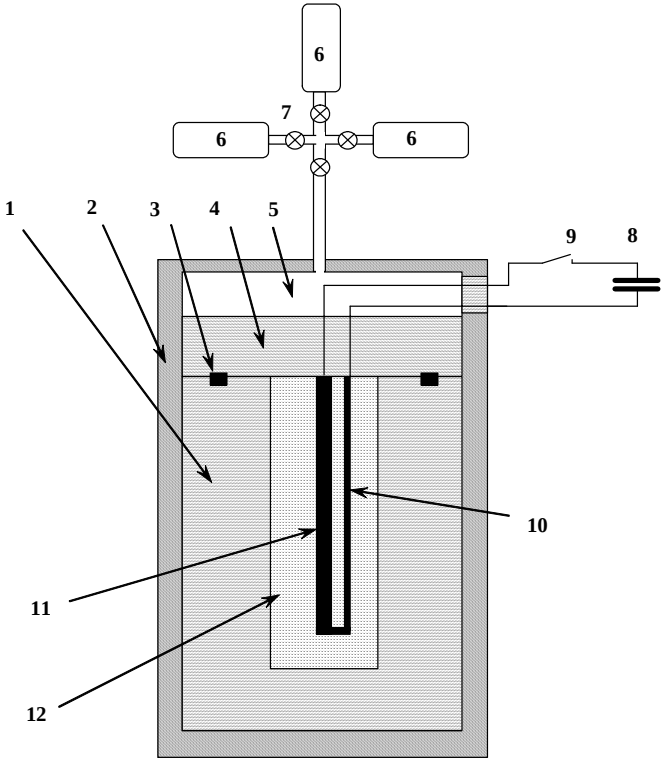

Fig. 1. The scheme of experimental plant. 1- blasting chamber, 2 - stainless steel body, 3 - consolidation, 4 - polyethylene cover, 5 - prechamber, 6 - cylinders, 7 - valves, 8 - capacitor bank, 9 - discharger, 10 - foil, 11 - electrode, 12 - solution

Table 1 - Design of the experiment

Conditions of exposure to explosions of foil	Duration of exposure, day	Gamma-irradiation	Total explosions	Number of animals per group
1st series				
Control	-	-	-	20
Polyethylene cages	1	-	3	20
Polyethylene cages	2	-	7	17
Polyethylene cages	3	-	10	19
Control	-	2 Gy	-	10
Polyethylene cages	4	2 Gy	14	10
2nd series				
Control	-	-	-	15
Polyethylene cages	3	-	12	15
Polyethylene cages	3	-	12	15
Polyethylene cages in an iron box	3	-	12	15
Control	-	2 Gy	-	12
Polyethylene cages	4	2 Gy	16	12
Polyethylene cages in an aluminium box	4	2 Gy	16	12
Polyethylene cages in an iron box	4	2 Gy	16	12

Table 2 - Number of nucleated cells (NC) in the bone marrow of mice compring different experimental groups

Conditions of exposure to explosions of foil	Duration of exposure, day	Gamma-irradiation	Number of NC in bone marrow, mln/femur
1st series			
Control	-	-	38,6 ± 1,6
Polyethylene cages	1	-	42,3 ± 1,9
Polyethylene cages	2	-	42,4 ± 2,1
Polyethylene cages	3	-	* 45,1 ± 1,7
Explosions, all groups		-	* 43,3 ± 1,1
Control	-	2 Гр	* 17,9 ± 1,6
Polyethylene cages	4	2 Гр	* 17,6 ± 0,8
2nd series			
Control	-	-	31,8 ± 1,8
Polyethylene cages	3	-	* 39,7 ± 1,8
Polyethylene cages in an aluminium box	3	-	36,3 ± 1,9
Polyethylene cages in an iron box	3	-	34,6 ± 1,7
Explosions, all groups	3	-	* 36,9 ± 1,1
Control	-	2 Гр	* 15,4 ± 1,4
Polyethylene cages	4	2 Гр	* 16,4 ± 1,8
Polyethylene cages in an aluminium box	4	2 Гр	* 14,1 ± 0,8
Polyethylene cages in an iron box	4	2 Гр	* 16,4 ± 0,7
Explosions, all groups	4	2 Гр	* 15,7 ± 0,7

Note: * statistically significant differences from the control ($P \leq 0.05$)

Table 3 - Peripheral blood leukocyte counts in different groups of mice

Conditions of exposure to explosions of foil	Duration of exposure, day	Gamma irradia-tion	Peripheral blood leukocyte counts, thou/ml
1st series			
Control	-	-	18,1 ± 1,5
Polyethylene cages	1	-	16,8 ± 1,1
Polyethylene cages	2	-	17,5 ± 1,5
Polyethylene cages	3	-	17,4 ± 0,8
Explosions, all groups		-	17,2 ± 0,7
Control	-	2 Гр	* 6,8 ± 0,5
Polyethylene cages	4	2 Гр	* 7,4 ± 0,5
2nd series			
Control	-	-	12,4 ± 0,8
Polyethylene cages	3	-	11,2 ± 1,7
Polyethylene cages in an aluminium box	3	-	12,7 ± 1,1
Polyethylene cages in an iron box	3	-	* 15,4 ± 0,9
Explosions, all groups	3	-	13,1 ± 0,8
Control	-	2 Гр	* 2,6 ± 0,2
Polyethylene cages	4	2 Гр	* 2,7 ± 0,2
Polyethylene cages in an aluminium box	4	2 Гр	* 2,8 ± 0,2
Polyethylene cages in an iron box	4	2 Гр	* 3,4 ± 0,2 †
Explosions, all groups	4	2 Гр	* 3,0 ± 0,1

Note: * - statistically significant differences from the control, † - statistically significant differences from the group exposed to gamma-radiation (2 Gy), $P \leq 0.05$

Table 4 - Peripheral blood cell composition for different experimental groups, %

Conditions of exposure to explosions of foil	Duration of exposure, day	Gamma-irradiation	Juvenile neutrophils	Stab neutrophils	Segmented neutrophils	Monocytes	Lymphocytes	Eosinophils
1st series								
Control	-	-	0,00 ± 0,00	2,23 ± 0,37	14,2 ± 1,6	2,86 ± 0,48	78,6 ± 1,9	2,05 ± 0,37
Polyethylene cages	1	-	0,00 ± 0,00	2,65 ± 0,25	15,2 ± 0,9	2,58 ± 0,41	77,2 ± 0,8	2,45 ± 0,31
Polyethylene cages	2	-	0,00 ± 0,00	1,97 ± 0,39	20,2 ± 1,8	2,06 ± 0,27	74,3 ± 2,5	1,74 ± 0,43
Polyethylene cages	3	-	0,00 ± 0,00	2,83 ± 0,38	* 22,4 ± 1,6	2,16 ± 0,30	*70,4 ± 2.0	2,24 ± 0,36
Control	-	2 Gy	0,00 ± 0,00	4,00 ± 0,54	46,9 ± 3,0	2,30 ± 0,65	43,3 ± 2,9	3,50 ± 0,83
Polyethylene cages	4	2 Gy	0,00 ± 0,00	2,70 ± 0,51	51,5 ± 2,3	2,55 ± 0,34	38,3 ± 2,2	4,85 ± 0,49
2nd series								
Control	-	-	0,24 ± 0,10	2,78 ± 0,35	8,1 ± 0,4	6,12 ± 0,71	79,9 ± 0,9	2,87 ± 0,30
Polyethylene cages	3	-	0,04 ± 0,04	* 1,75 ± 0,28	* 11,8 ± 1,1	*3,7 ± 0,28	81,3 ± 1,2	1,43 ± 0,34
Polyethylene cages in an aluminium box	3	-	0,00 ± 0,00	3,30 ± 0,68	* 13.0 ± 2,0	5,37 ± 0,71	75,4 ± 2,6	2,87 ± 0,53
Polyethylene cages in an iron box	3	-	0,10 ± 0,05	2,13 ± 0,27	9,3 ± 0,9	4,37 ± 0,50	80,7 ± 1,4	3,07 ± 0,64
Explosions, all groups	3	-	0,05 ± 0,02	2,41 ± 0,28	* 11,4 ± 0,8	* 4,5 ± 0,3	79,1 ± 1,1	2,48 ± 0,32
Control	-	2 Gy	0,11 ± 0,11	2,78 ± 0,36	* 31,4 ± 1,5	4,33 ± 0,55	* 56,4 ± 1,7	4,89 ± 0,73
Polyethylene cages	4	2 Gy	0,00 ± 0,00	3,92 ± 0,54	* 32,7 ± 2,1	5,00 ± 0,55	* 54,4 ± 2,4	4,42 ± 1,13
Polyethylene cages in an aluminium box	4	2 Gy	0,00 ± 0,00	* 5,33 ± 0,72 †	* 32,3 ± 2,8	4,92 ± 0,67	* 52,8 ± 2,9	4,71 ± 0,70
Polyethylene cages in an iron box	4	2 Gy	0,00 ± 0,00	4,08 ± 0,45 †	* 33,7 ± 2,4	5,50 ± 0,29	* 50,7 ± 2,2	* 5,83 ± 0,81
Explosions, all groups	4	2 Gy	0,00 ± 0,00	* 4,44 ± 0,34 †	* 32,9 ± 1,4	5,14 ± 0,30	* 52,6 ± 1,4	4,99 ± 0,51

Table 5 - Results of the micronuclear test

Conditions of exposure to explosions of foil	Duration of exposure, day	Gamma-irradiation	PCE/NCE ratio	Frequency of micronuclei In PCE, ‰
Control	-	-	1,31 ± 0,11	1,16 ± 0,26
Polyethylene cages	1	-	1,19 ± 0,06	1,39 ± 0,27
Polyethylene cages	2	-	1,44 ± 0,09	1,11 ± 0,22
Polyethylene cages	3	-	1,65 ± 0,14	0,95 ± 0,19
Control	-	2 Gy	* 0,51 ± 0,02	* 14,47 ± 0,92
Polyethylene cages	4	2 Gy	* 0,72 ± 0,03 †	* 9,57 ± 0,95 †
2^{nd} series				
Control	3	-	1,28 ± 0,05	3,29 ± 0,45
Polyethylene cages	3	-	* 1,06 ± 0,05	2,33 ± 0,37
Polyethylene cages in an aluminium box	3	-	1,37 ± 0,05	* 6,13 ± 0,50
Polyethylene cages in an iron box	3	-	* 0,86 ± 0,04	3,93 ± 0,42
Control	-	2 Gy	* 0,43 ± 0,04	* 21,30 ± 1,70
Polyethylene cages	4	2 Gy	* 0,73 ± 0,03 †	* 18,55 ± 1,95
Polyethylene cages in an aluminium box	4	2 Gy	* 0,43 ± 0,02	* 23,42 ± 3,38
Polyethylene cages in an iron box	4	2 Gy	* 0,69 ± 0,02 †	* 7,58 ± 0,96 †

Note: * - statistically significant differences from the control, † - statistically significant differences from the group exposed to gamma-radiation (2 Gy), $P \leq 0.05$