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EXPERIMENTAL FACILITY "RADIOBIOLOGICAL TEST SETUP ON ACCELERATOR U-70" AS CENTERS FOR COLLECTIVE USE (CCU)

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Abstract

The experimental facility "Radiobiological test setup on accelerator U-70" was created on NRC "Kurchatov Institute" - IHEP, Protvino to carry out radiobiological and physical experiments on the extracted beam of carbon nuclei with an energy up to 450 MeV / nucleon. This test setup is designed as a center for collective use. Specialists from 5 Russian institutes participate in radiobiological research of the cell structures and laboratory animals, and in experiments on nuclear physics and dosimetry. The study of the biological effectiveness of carbon nuclei for the purposes of hadron therapy, as well as to evaluate the effect of high-energy ion irradiation on human cognitive functions are the main goals of these radiobiological experiments. The experiments performed on the radiobiological test setup at U-70 was briefly reported.

INTRODUCTION

The experimental facility "Radiobiological test setup on accelerator U-70" was created on NRC "Kurchatov Institute" - IHEP. The facility is designed to carry out radiobiological and physical experiments on a deduced beam of carbon nuclei. Radiobiological test setup has all the necessary equipment for conducting experiments. On the basis of the facility in 2017, the Center for Collective Use "Radiobiological Test Setup on Accelerator U-70".

The parameters of the carbon beam on the facility RBS:

- energy 450 MeV / nucleon;
- period 8 s;
- intensity - 1.5 - $2.0 \cdot 10^9$ nucleons per cycle;
- • Output mode - slow output - 0.6 sec.;
- the size of the uniform radiation field (± 2.5%) - Ø 60mm [1].

Equipment for carrying out radiobiological experiments:

- a water phantom;
- 3D moving system;
- ionization chambers for monitoring of radiation;
- TLD radiation dosimeters;
- radiochromic films Gafchromic EBT3.

Specialists from 3 institutes conduct radiobiological experiments at the "Radiobiological Test Setup on Accelerator U-70"

- Tsyb Medical Radiological Research Center – branch of the National Medical Research Radiological Center of the Ministry of Health of the Russian Federation (A. Tsyb MRRC).
- Institute of Theoretical and Experimental Biohpysics of Russian Academy of Sciences (ITEB RAS).
- State Scientific Center of Russian Federatiot - Institute of Biomedical Problems (SSC RF – IMBP RAS).

The experiments performed on the radiobiological test setup was briefly reported.

A. TSYB MRRC

Comparison of the biological efficiency of accelerated carbon ions and heavy recoil nuclei on chinese hamster cells [2].

Studies were carried out to determine the biological effectiveness of accelerated carbon ions upon irradiation of cell cultures on the plateau and at the peak of the Bragg curve, as well as heavy recoil nuclei (C, N, O) induced by 14.1 MeV neutrons in the monolayer of cells upon irradiation in the absence balance of secondary charged particles. The studies were performed on normal (V-79 and CHO-K1 lines) and tumor (B14-150) chinese hamster cells.

The experiments used transplant cultures of chinese hamster cells of three lines: CHO-K1 (ovarian cells, clone of CHO line), V-79 (lung fibroblasts), B14-150 (fibrosarcoma) obtained from the Cell Culture Bank at the Cell Culture Department of the Institute of Cytology RAS officially for laboratory experiments.

The results for the V-79 line are shown in Figs. 1 and 2.

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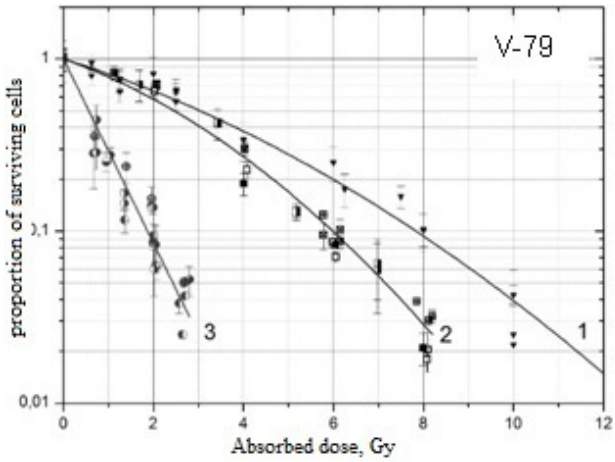

Figure 1: The curves of the survival of the chinese hamster cells of the V-79 line under the action of the ^{12}C ion beam in the plateau region (curve 2), unmodified Bragg peak (curve 3) and ^{60}Co γ-radiation (curve 1).

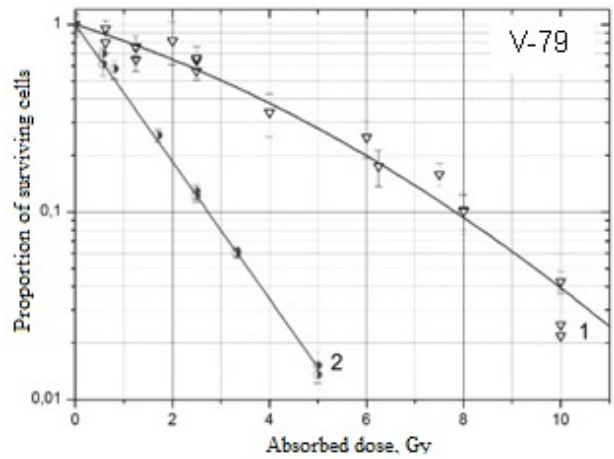

Figure 2: The survival curves of the chinese hamster cells of the V-79 line under the action of neutron radiation in the absence of proton balance (curve 2) and gamma radiation of ^{60}Co (curve 1).

The values of RBE coefficients (10% level of cell survival) of the effect of accelerated ions of carbon and neutrons in the absence of proton balance on chinese hamster cells of different lines are given in Table 1.

Table 1. The Values of RBE Coefficients (10% Level of cell Survival).

Chinese hamster cells lines	Accelerated ions ^{12}C		Neutrons 14.1 MeV
	Area of the Bragg curve plateau	Peak Bragg	
CHO-K1	1,4	4,2	2,8
V-79	1,3	4,2	2,8
B14-150	1,3	4,1	–

ITEB RAS

Study of the biological effect of accelerated carbon ions with an energy of 450 MeV / nucleon in IN VIVO mice [3].

Dose dependences of cytogenetic lesions in the bone marrow, thymus and spleen cellularity, production of active forms of oxygen (ROS) in whole blood were studied in a short time under irradiation of mice with ions of carbon with energy 450 MeV / nucleon in the modified Bragg peak in the dose range from 0.1 up to 1.5 Gy. The effect on the central nervous system of mice irradiating carbon ions with a dose of 0.7 Gy by means of standard behavior tests in the long term after irradiation was studied.

The results of experiments evaluating the biological effect of 450-MeV / nucleon carbon ions in the modified Bragg peak on mice at doses ranging from 0.1 to 1.5 Gy showed that a nonlinear dose dependence is observed in the cytogenetic test, and the RBE value varies with the dose from 1.3 to 2.4.

The indices of thymus and spleen mass were significantly reduced at lower doses compared to the same index in mice irradiated with X-rays.

In a study of the behavior of mice in the late term after irradiation with ions of carbon with an energy of 450 MeV / nucleon in the dose of 0.7 Gy it was revealed that after 2 months the mice display a modified behavior model characterized by anxiety and deficiency of long-term hippocampus-dependent memory, but without disturbances episodic memory.

The obtained data revealed significant differences in the effect of low and medium doses of carbon ions with energy 450 MeV / nucleon on the hematopoietic and immune systems, as well as the brain in comparison with X-ray radiation, and can serve as a basis for developing new schemes of ion therapy , risk assessment for long-term space flights, and search for remedies against functional violations of various organs.

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Experiments were conducted with irradiation of rats and monkeys (Fig. 3) with carbon ions, devoted to the study of neurobiological effects of galactic cosmic radiation simulated on accelerators. Galactic cosmic rays (GCR) pose the greatest danger to the cosmonaut's work in interplanetary flight, so experimental data on their neurobiological effects are necessary for assessing the risk of possible violations of it. Among the experiments carried out, a unique experiment on primates devoted to the effects of combined action of ionizing radiation and hypogravitation, simulated in terrestrial conditions.

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Figure 3: Preparing the monkey for irradiation.

Studies continue.

CONCLUSION

The experimental facility "Radiobiological test setup on accelerator U-70" as the center of collective use is in demand for carrying out radio-biological experiments on the deduced beam of carbon nuclei.

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