Referee report of the project “Radiation-biophysical and astrobiological research”

The current project is aimed at solving a number of fundamental problems of radiobiology and astrobiology, as well as practical tasks related to the development of radiation medicine. Only the world's leading scientific centers can afford to carry out this type of large-scale work. The presence at JINR of a wide range of sources of ionizing radiation and, in particular, beams of heavy ions with different energies makes it possible to carry out such a complex research plan.

Experimental reproduction of the energy and spectral composition of cosmic and other types of ionizing radiation is envisaged, providing methods for non-destructive analysis of unique samples of radiobiological and astrobiological studies. An important problem is also the provision of automated data processing of biological experiments, due to the high complexity and resource-intensiveness of computer modeling of processes in living systems.

During the implementation of the project, it is supposed to develop new irradiation facilities and dosimetry systems, implement methods for non-destructive analysis of unique samples, formulate new mathematical models and computational approaches for radiobiology, bioinformatics and radiation medicine, clarify the mechanisms and the pathways of catalytic synthesis of prebiotic compounds under the influence of radiation.

In the "radiation-biophysical studies" section, the study of the mechanisms of impact of ionizing radiations with various physical characteristics at the molecular, cellular, tissue and organismal levels of biological organization is envisaged, based on the specific mechanisms of impact of ionizing radiations of a photon and corpuscular nature , which fundamentally differ from the biological action on living organisms of other electromagnetic types of ionizing radiation.

The value of the set tasks is particularly significant due to the development of new approaches to increase the biological effectiveness of the radiations used in radiation therapy of tumors, and also to account for side effects occurring in radiation therapy of malignant neoplasms.

Of separate and independent importance is the disclosure of the mechanisms of functional disorders in the work of the brain under the influence of radiation, in order to assess the risk of radiation exposure to the body of astronauts during interplanetary flights.

An important part of the program is the automation of the processing of the results of the experiments, which will allow obtaining qualitatively more accurate data on the changes after the effects of ionizing radiations with different characteristics, the discovery of new regularities reflecting their nature, which will allow to be reduced the likelihood of misclassification and the timelines for obtaining meaningful scientific results. One of the most promising directions for solving these tasks is the development and implementation of machine learning methods for creating solutions based on neural network approaches.

The development of an information system for working with experimental data in the form of two-dimensional images, data from computer tomography and video recordings will ensure the development of protocols for automated data processing.

Based on the primary fast-flowing physico-chemical processes, when the particles pass through biological environments, the spectrum of emerging molecular damage will be determined, primarily of the genetic apparatus in normal and tumor cells of mammals and humans. The basic task set in the modeling of radiobiological effects is the study of the interaction of ionizing radiation with the substance of the cell. Remote and radionuclide radiation therapy scenarios will be modeled using different sources of ionizing radiation.

In contrast to traditional approaches used to plan therapies, a detailed distribution of not only absorbed dose but also DNA damage in tumors will be obtained. This also implies a more detailed assessment of damage not only in the tumor cells, but also in the adjacent normal tissues. Detailed models of tumor sizes and study of their dynamics after irradiation will be formulated. It is planned to generalize the mentioned approach in the cases of several promising mechanisms to increase the effectiveness of the therapies.

Astrobiological studies

One of the promising directions in modern astrobiology is the search for traces of extraterrestrial life in the form of organic compounds or microbial fossils due to the assumption that meteors can be carriers of organic molecules that are formed in cosmic conditions.

Planned research will focus on modeling the sequence of processes that can lead to the formation of a complete, chemically active prebiotic environment in a complex with meteorites or ancient terrestrial rocks.

Experiments on irradiation of formamide + catalyst systems with radiations of different physical characteristics are planned to be continued in order to determine the optimal conditions and synthesis pathways of prebiotic compounds, as well as the conditions under which oligo- and polymeric biomolecules can be formed . The methods of gas chromatography and mass spectrometry will be used to identify the organic substances in the resulting complex mixtures.

Development of research infrastructure

For the implementation of the international program for radiobiological and astrobiological research, the project envisages a phased renewal of the equipment and the creation of new installations. The development of the research infrastructure envisages the design, creation and commissioning of the Genome-3 installation, modernization of SARRP installations, design and commissioning of equipment for multimodal tomography of animals.

I will be designed, built and licensed radiochemical units for cell culture and laboratory animal studies and a simulator for modeling complex radiation fields, which will significantly increase the experimental capabilities of JINR.

The proposed project is at a high scientific level and has significant prospective scientific and applied capacity.

Achieving the set goals, which I assess as high but realistic, will contribute new knowledge in the field of radiation biology and astrobiology, but will also provide new opportunities for the improvement of radiobiological and medical technologies.

I believe that the project is realistic in financial and organizational terms, as well as in terms of inter-institutional and international cooperation.

On the basis of the above considerations, I recommend that the presented project of ZRB " Radiation-biophysical and astrobiological research" to be approved and included in the problem-thematic plan of JINR research for 2024-2028.

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