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RESEARCH PROGRAM OF THE DEPARTMENT OF RADIATION AND RADIOBIOLOGICAL RESEARCH: ITS PERFORMANCE IN 1996 AND THE PLAN FOR 1997

Report to the 81st Session
of the Scientific Council of JINR
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Contents:

The Department of Radiation and Radiobiological Research (RRRD) was established in April 1995 on the basis of two JINR Divisions: Division of Radiation Protection - Radiation Research and Division of Radiobiological Research. This report contains the main results obtained in 1996 as well as the DRRR's proposals to the plan of scientific research and international cooperation for 1997.

1. Plan of scientific research in 1996

The availability of various nuclear-physical facilities at JINR provides a unique possibility to generate different types of radiation fields with wide energy range, linear energy transfer (LET) and complex component composition. This situation on one hand creates difficulties for adequate radiation monitoring and personnel dosimetry, but on the other hand it gives great opportunities for health physics researches in the field of radiation protection, radiation biology and for improvement of techniques and instruments of radiation monitoring. The actuality and necessity of such investigations are now due to change the conceptual approach to consequences of human being irradiation by different types of ionizing radiation.

The regulation of personnel irradiation are deeply connected with the problem of the stochastic radiation-induced effects in organism, which are caused by some change in the genetic structures. These ones are point and chromosomal mutations, cancer diseases. That is why the investigations of ionizing radiation-induced mutation mechanisms and regularities are very crucial problem, i.e. it is known that several

mutations induce cell's malignant transformations. Nuclear-physical facilities which generate the radiation with different LET are a very important tool for radiation mutagenesis and, in general, for stochastic radiation induced effects as a whole, problems decision. This situation allows to take JINR into consideration as a unique scientific center for such researches. It needs to remark that the information about mechanisms and regularities of appearance of cell's mutations (in mammalian and human cells most of all) by the heavy ion irradiation is very confined.

The detailed information on energy distribution of radiation with different physical characteristics in genetic structures is the necessary condition to conduct such radiobiological researches. In connection with this one it becomes necessary to carry out new techniques for charged particle beams precision dosimetry and mixed scattered radiation fields spectrometry, methods for measuring some microdosimetry radiation quantities (LET-metry) and to perfect the methods for calculation of the radiation interactions in matter and radiation transport through shielding.

Major objectives of the program in 1996 were connected with:
- development of the experimental equipment and measuring techniques;
- realization of the radiation shielding and dosimetric experiments by the basic nuclear facilities of the JINR;
- improvement of the calculation methods of radiation interaction with matter and radiation transport through the shielding;
- response radiation detector study;
- study of the peculiarities and mechanisms of mutations induction in mammalian cells, stable chromosomal aberrations in human lymphocytes using the FISH technique, induction of point mutations in haploid and diploid yeast, deletion mutation in bacteria under the radiation with different LET;
- investigation of biological effect of low doses of ionizing radiation on humans peripheral blood lymphocytes and plant cells;
- improvement of biosensoric registration methods of biological action of radiation for ecological monitoring.

2. Execution of the 1996 plan

2.1 Radiation researches

Radiation researches were connected with radiological safety aspects of heavy ion accelerators, neutron detector study, neutron spectrometry and development of mathematical models of radiation induced effects.

Overview of the radiological safety aspects of heavy ion accelerators was prepared and published in cooperation with scientists from GSI (Germany) and BNL (USA) on the request of *the International Radiation Protection Association (IRPA).*

Critical analysis of existing project for the *shield design of "Tesla"* accelerator installation was made. It was concluded that thickness of the side walls of accelerator room is not enough to perform safe radiation environment outside the shield. *New calculation, design and optimization* of the shield was carried out together with collaborators from *VINCA* Institute of Nuclear Sciences (Yugoslavia). Results of the work was presented at 1996 International Congress on Radiation Protection (IRPA9).

The systematic study of many parameters influencing the choice and application of the *neutron detector* has been completed in the main. These investigations were carried out on the IAEA request and needed for the nuclear material safeguards unattended radiation monitoring. The main problem of this monitoring is the assessment of the low neutron fluxes in presence of the very high γ-radiation background (up to several kR/h). Overcoming of these difficulties depends on the various factors and detection conditions. The experimental optimisation of the polyethylene moderator around a thermal neutron detector has been carried out in the field of fast neutrons. The comparative investigations of gases counters using as a neutron detector are shown the significant advantage of corona gases counter as compared with proportional gases counters. The result was obtained in mixed n - γ (Pu-Be source and ^{60}Co medicine installation) radiation fields with dose rate up to 2 kR/h. The optimisation of electronic parameters and shielding of the detector has been made as well. The prolongation of this work to design the prototype of the neutron detector on base of corona counter for the IAEA is drawing up now.

The investigation of polymer diethyleneglykol *nuclear track detector* (CR-39 NTD) and *bubble damage detector responses* in the neutron reference fields were done in collaboration with the NIP (Rgeg, Czech Republic) . NTD response investigations are needed for their application as a dosimeters of fast and high-energy neutrons. To study their responses to protons, the irradiation of foils was conducted on the phasotron beams with energy 85 and 200 MeV. The development of the neutron spectrometry method that is based on a set of bubble damage detectors with different thresholds from 10 keV to 10 MeV was continued. It was found out that the neutron spectra estimation following from the bubble spectrometer correlates well with the spectra obtained by a multisphere neutron spectrometer.

The main scientific results on a broad spectrum of radiation reset problems have been presented at the IPRA 9 International Congress on Radiation Protection (April 14-19, 1996, Vienna, Austria) in 6 presentation and at the 5 -th European Particle Accelerator Conference (June 10-14, 1996, Barcelona, Spain).

2.2. Radiobiological research

Radiobiological investigations were performed on mammalian cells in culture, human lymphocytes, haploid and diploid yeast and bacteria.

The main objective of investigations on *mammalian cells* was connected with the study of mutagenic action of ionizing radiation with different quality. As well known, ionizing radiation induces chromosomal damages in mammalian and human cells of two types: stable and unstable. The stable aberrations (for example, translocations) are connected with an exchange of parts of different chromosomes. The normal cell division is occurred in this case because the genetic material doesn't lose. Such type of aberrations are preserved for a long time in post-radiation period in populations of irradiated cells. It was shown that these cells could lead to the development of cancer diseases. The unstable aberrations lead to the disturbance of the cell division. As a result, the cells with such type of aberrations are lost. Unstable chromosome aberrations could be revealed by cytological methods at usual microscoping.

The new method, so called FISH-technique (fluorescent in situ hybridization), for detection of stable aberrations was used in our experiments. This method is based on

the property of separate chromosomes to connect with DNA probes which are constructed for specific chromosomes. This probes are associated with fluorescent stains. Therefore, these chromosomes and their parts (translocations) are revealed easy in fluorescent microscope. This method is perspective for the tasks of biological dosimetry, because it allows to reveal stable chromosome aberrations, for example translocations, which are preserved for a long time in postirradiation period even at relatively low doses.

Investigations of stable and unstable aberrations in lymphocytes from human blood by FISH-method were started in collaboration with Institute of Biophysics AS CR. The first data were obtained in experiments with study of chromosome-1 aberrations induction in human blood lymphocytes after irradiation with γ-rays and accelerated ^{14}N ions with LET ~84 keV/μm generated by U-400M. Chromosome-1 is the biggest one in chromosome set and its damages may occur with higher probability during irradiation. . It has shown that the percent of cells with chromosome-1 aberrations and frequency of stable translocations increase rapidly with the dose, especially after radiation with heavy ions. It was shown a high efficiency of ^{14}N ions on the yield of stable chromosome aberrations. Coefficients of relative biological efficiency of ^{14}N ions with LET ~84 keV/μm are ~3 and higher on these criteria.

On the base of the accelerators of heavy ions in GSI (Darmstadt, Germany) the set of experiments was finished for the investigation of cytogenetic effects of sparsely and densely ionizing radiation in repairproficient CHO-K1 Chinese hamster ovary cells and their radiosensitive mutant strain XRS-5 which shows a defect in the rejoining of DNA double-strand breaks. Both cell lines were synchronized by mitotic shake off, irradiated in G1-phase of the cell cycle with either 250 kV X-rays or 780 MeV/u Au ions (LET ~1150 keV/μm) and chromosome aberrations were analyzed at several sampling times from 12 up to 30 hours after irradiation in first postirradiation metaphases which were distinguished from subsequent mitoses by using the Fluorescence-plus-Giemsa technique.

Following X-ray exposure at the dose 1 Gy XRS-5 cells showed a five fold excess of aberrant cells and a twelve fold excess of aberrations/cell compared to CHO-K1 cells. After high LET radiation these differences were drastically diminished: it is estimated that for the comparable doses of Au ions at the dose 2,2 Gy the number of aberrant cells was only 1.5 times higher in the mutant than in the wild type parent and the aberration frequency is 2 to 3 times higher in XRS-5 cells than in CHO cells. The variations in the yield time profiles causing by the radiation-induced cell cycle delay which is more pronounced after particle exposure complicated the determination of accurate RBE values. Depending on sampling time, the RBE value of Au ions for the production of aberrations varied from 2 at 14 hours after irradiation to 3 at 22 h. Furthermore, the analysis of the aberration types induced by sparsely and densely ionizing radiation showed for both cell lines specific changes in the spectrum of aberration types as LET increases. Following X-irradiation the frequency of chromatid-type aberrations among the total number of aberrations amounted to 20% in CHO cells and 55% in XRS-5 cells. After Au exposure the values increased for CHO and XRS cells to 55% and 70% respectively despite of irradiation in G1-phase. When aberrations were subdivided into chromosomal breaks and exchanges the frequency of chromosomal breaks was found to rise in CHO cells from 35% after X-irradiation to 50% after particle exposure and in XRS-5 mutant from 60% to 80% respectively. All these changes in spectrum of aberration depended only on radiation

quality (LET) but not on delivered dose or sampling time. The observed alterations supported the assumption that the initial molecular damage from high LET was qualitatively different from low LET damage: the lesions produced by particle tracks seemed to be more complex and therefore less rejoinable.

Earlier we studied the regularity of the lethal effects and mutation induction on HGPRT-locus in Chinese hamster cells after radiation with different LET. For the cytological analysis of HGPRT-mutants 130 spontaneous and radiation-induced mutant clones were isolated from Chinese hamster cell culture line V-79. It was shown that the mutants revealed different properties. The high heterogeneity in respect to different cytogenetic criteria has been found in the mitotic activity, modal number of chromosomes in the cells, in the chromosomal spectrum, the frequencies of aberrant cells and different types of chromosomal damages. In the control it were found (8.7±0.8)% cells with chromosome aberrations and the frequency of chromosome damages was (9.9±0.8) per 100 cells. Some groups of mutants have been revealed on the frequency of chromosome damages: the group I did not different from intact control on the frequency of chromosomal aberrations, the group II had the higher their level in 1.5–2 times, and amongst spontaneous mutants the group III have been discovered with extremely high level of chromosomal aberrations (30–60 % of aberrant cells). For analyzing mutants' aneuploidy was characteristic. Moreover, about 20 % of tetraploid mutants have been discovered as separate group amongst spontaneous and radiation-induced by doses of 2–3 Gy mutants. The level of chromosome aberrations in all tetraploid mutants was higher as compared with diploid control and was especially higher for spontaneous tetraploids (40–50 % of aberrant cells).

The fraction of group I mutants decreased from 70 % to 30 %, when inducing dose increased from 2 to 7 Gy, but at the same time the fraction of group II mutants increased from 15 % to 50 % . Besides that approximately 8–10 % of group I mutants had lower level of chromosomal damages as compared with control (in 2–4 times). We suppose that the appearance of such mutants and the absence of radiation-induced mutants with the extreme high level of chromosome aberrations (group III) are the result of that in the cell culture there are cells with some defects viable under normal conditions but are lost in first turn after irradiation. At the same time mutants derived from cells with effective repair system could have a lower level of chromosome aberrations as compared with the control. Analysis of the frequency of different chromosomal aberration types in all mutants and in control samples has shown similar correlation between them independently from its total number. But the increase of the chromosomal aberration level was accompanied by the increase of the number of dicentrics.

Appearance of high number of chromosome aberrations in cells of many mutant clones may show that at mutagenesis of mammalian cells the probability of chromosome damages rises, perhaps, as a stage of the formation of the according genome reorganization adequate to changed conditions of its function. Also probably, that a long preservation of genetic instability of clones is a universal natural phenomenon of diploid and poliploid eukariot cells.

Determination of induced point mutations *in haploid and diploid yeast* and the study of influence of the nuclear srm mutations on mutagenesis in yeast induced by ionizing radiation has been started in 1996. The objective of the first research is the estimation of point mutation induction in eukaryotic cells. A new test system for

detection each of the six base-pair substitutions in Saccharomyces cerevisiae will be used in experiments. The strains are based on the critical requirement for cysteine at position 22 of iso-1-cytochrome c, encoded by the CYC1 gene. Six isogenic strains, each containing a unique, single base substitution in codon-22, were constructed. This tester system is valuable as a simple and reliable assay for specific mutations without DNA sequence analysis. Cell survival curves was obtained for diploid and haploid strains. Diploid strains were tested by monitoring reversion to Cys+ spontaneously and in response to γ-irradiation. These strains revert spontaneously at very low frequencies about 10^{-10} and 10^{-9}. Obtained data allow to say about specificity of point mutation induction (transition and transvertion) after g-irradiation. It has been shown that g-rays induce AT-TA transitions very efficiently. The shape of the dose-response curves are similar and may be fitted by a linear-quadratic function.

In experiments with *bacteria* the optimization of the X7026 (I8) lysogen for it stabilization was continued. The new lysogen which was received in this experiments enable to start the study of mutagenic effects of γ-irradiation on this test-system. In parallel of these experiments the other strains of E.coli cells are tested for the lysogenization of I8 phase. The main objective for the reporting period with lux-test experiments was the test of the different E.coli strains on their capacity to induce the SOS response higher then in wild type cells after low doses UV irradiation. In the previous study such measurements was carried out for the cells under 37^0 C incubation. The task of this investigation in reporting period was connected with comparison of the SOS response of different repair deficient mutants after low dose UV-irradiation which were incubated at 30^0 C.

A mathematical model for the development of the SOS signal in nucleotide-excision repair deficient *Escherichia coli* bacterial cells subjected to ultraviolet light irradiation is proposed, in which regions of single-stranded DNA (gaps) are created during replication of a damaged chromosome when the strand elongation stops at pyrimidine dimers. The length of the gaps as a function of time is obtained. The model for the interaction of the LexA and RecA proteins, the well-established key event in SOS regulation, is presented, resulting in a system of differential equations for the concentrations of LexA, RecA and activated RecA proteins. The simulated LexA concentration agrees with experimental data. It is shown that the model can be used to quantitatively describe the kinetics of SOS response through the amount of the SOS signal (length of the gaps) in a cell as a function of time.

3. Proposals for 1997-1999

The actuality and necessity of health physic and radiobiological researches are now due to change the conceptual approach to consequences of human being irradiation by different types of ionizing radiation. These new approaches are reflected in international recommendations and new Russian standard on radiation protection.

The regulation of personnel irradiation, as we emphasized, are deeply connected with the problem of the stochastic radiation-induced effects in organism, which are caused by some changes in the genetic structures. That is why the investigations of ionizing radiation-induced mutation mechanisms and regularities are a very crucial problem, i.e. it is known that several mutations induce cell's malignant

transformations. Nuclear-physical facilities which generate the radiation with different LET are a very important tool for studying radiation mutagenesis and, in general, for stochastic radiation-induced effects as a whole.

Radiation research in the frame of the program will be connected with the following directions:

a) *Neutron spectrometry.* It is proposed to design a modernized-type of a high energy neutron spectrometer with nearly spherical detector and with veto-counter for charged particles rejection in 4-π geometry. It is also suggested to complete the multisphere spectrometer by 18 inches diameter moderator to enhance the sensitivity up to a higher energy range. In our main attempts, it is proposed to concentrate on the investigations connected with the response functions. The base for these experiments are the neutron beams at the medical facility of the Laboratory Nuclear Problems.

b) *Test and Characterization of Neutron Detector Systems for Use in Unattended Radiation Monitors.* One of the most important problems for the aims of the nuclear material safeguards unattended radiation monitoring is the assessment of the low neutron fluxes in presence of very high gamma-radiation background. In this program it is suggested to make a systematic study of many parameters influencing the choice of the neutron detector and the design of the prototype of measurement system.

c) *Shielding Studies.* It is planned to carry out shielding experiments at the U-400M cyclotron. Investigation of mixed radiation fields behind the shield of proton and heavy ion accelerators at JINR will be done with application to verify shielding calculation methods. In the frame work of the program it is also intended to develop methods and calculate fields of neutrons generated by heavy ions in thick targets with application to radiation protection.

d) Physical Support of Radiobiological Experiments and Physical Modeling of Radiation Induced Damage. It is proposed to develop and design a system of monitoring instruments for physical support of the radiobiological investigations in the beams of particles with various LET. These systems will be created at JINR accelerators and will include the beam monitors (ionization chambers, scintillation counters, etc.), the instruments for beam compositions and lateral distributions study. It is suggested to design the LET-spectrometer in cooperation with IHEP (Russia) or use the spectrometer available now at VINCA Institute of Nuclear Sciences (Yugoslavia). It is also planned to carry out modeling of the radiobiological effects obtained in experiments (see section ``Radiobiological Research"). Methods of micro- and nanodosimetry
will be developed and used.

e) Response Detectors Study. It is planned: to study the response of individual dosimeters in reference neutron fields developed at JINR and in the high energy neutron beams of the medical facility of LNP at JINR; to take part in the IAEA Co-ordinated Research Program on Intercomparision for Individual Monitoring of External Exposure from Photon Radiation; to investigate responses of thermoluminescence detectors, nuclear track detectors and bubble damage neutron detectors by high energy charged particles and neutrons; to measure cross sections of selected activation reactions for high energy neutrons and charged particles.

Radiobiological research. The main objectives will be connected with:
- study of the peculiarities and mechanisms of mutation induction in mammalian cells, induced stable chromosomal aberrations in human lymphocytes using the FISH technique, point mutations in haploid and diploid yeast, deletion mutations in bacteria under the radiation with different LET;
- investigation of biological effect on humans peripheral blood lymphocytes and plant cells under low doses of ionizing radiation;
- improvement of biosensoric registration methods of biological action of radiation for ecological monitoring.

a) *Mutagenic Action on Mammalian Cells.* The goals of planned investigations are the study of peculiarities of mutation induction in mammalian cells exposed to radiation with broad region of LET, RBE assessment by the criteria of mutation induction, study of molecular nature of mutations in cells exposed to radiation with different LET. The objects of investigations are peripheral blood lymphocytes of human beings and V79 line, B11-d-ii-FaF28431 clone of Chinese hamster cell cultures. The research on human lymphocytes is connected with the analysis of stable chromosomal aberrations induction using FISH-method. The peculiarities of induced mutations in HGPRT locus of Chinese hamster cells are going to be studied.

b) *Mutagenic Action of Radiation on Yeast Cells.* The objective of this research is the estimation of point mutation induction in eukaryotic cells. A new test system for detecting each of the six base-pair substitutions in Saccharomyces cerevisiae will be used in experiments. The role of cdc28-srm mutation in Saccharomyces cerevisiae radiation mutagenesis will be studied.

c) *Determination of Deletion Mutations in E.coli Cells.* The objective of this work is connected with research of peculiarities of deletion mutant induction in bacteria by ionizing radiation with different LET. The program of the research includes the following directions: investigations of forward mutant induction in bacteria irradiated with gamma-rays and heavy ions; the study of deletion mutant induction in bacteria irradiated with gamma-rays and heavy ions; investigations of deletion mutant induction in repair deficient cells.

d) *Biological Effects of Low-Dose Exposure.* The investigation of genetic consequences under low doses irradiation on plant cells (Vicia faba), mammalian cells (Chinese hamster) and human cells (peripheral blood lymphocytes) will be performed. By the cytogenetic criteria the effectiveness of the influence of low doses will be taken into account.

e) *Improvement of Biosensor Methods.* The correlation between the level of the SOS expression and inducible mutagenesis in the wild type of E.coli cells makes these cells, in fact, a convenient test-system for the study of the mutagenic effects of radiation and chemical agents, which is an important problem of radiobiology, ecology and etc. As known, SOS response and mutagenic effect of radiation and chemical agents depend strongly on the strain re-pair genotype. Combinations of the different repair mutations may lead to an increase of the SOS-lux test sensitivity. Taking it into consideration, the different repair mutants will be constructed on the basis of the SOS-lux test.

f) In cooperation with UNESCO and different Institutes of Russia the ***International Symposium "Problems of biochemistry, radiation and space biology"*** on the 90-th anniversary of the Academician N.M.Sissakian will be held in Moscow and Dubna in January 1997.

Investigations in radiation biology and medicine at the LNP phasotron.

In this area the LNP scientists are intended in frame of the program 08-2-0980-92/97 to carry out medico-biological and clinical research on cancer treatment using the clinico- physical complex of JINR; to improve equipment and to devise new radiation treatment techniques with medical beams of the JINR phasotron.

4. International cooperation

The work under the project will be done in close collaboration with specialists from Austria, Bulgaria, Czech, Germany, Poland, Romania, Slovakia, Yugoslavia, CIS countries and Russian scientific Institutes. DRRR maintains extensive contacts especially with Czech and Germany Institutes. The profitable collaboration between IAEA and JINR is important for international cooperation in the frame work of this project in order to optimize the IAEA systems for the technical support of nuclear material safeguards. The cooperation with IAEA also maintains for participation in a program of individual dosimeters intercomparision. DRRR takes part in shielding calculation and design of the "Tesla" accelerator installation (Yugoslavia) and the participation in shielding calculations and radiation protection system design of the Slovakian cyclotron is planed from 1997.

5. Workshops and educational activity

The International workshop on modern radiobiological problems has been conducted in Dubna from 25 to 27 June 1996 by the DRRR in cooperation with the Keln Institute of space biology and medicine (Germany) and Institute of biophysics (Brno, Czech).The scientific program of the workshop has been applied to theoretical and experimental investigations of ionizing radiation with matter interactions, investigations of regularities and mechanisms of the mutagenic action of ionizing radiation with different physical characteristics, development of biosensoric registration methods for ecological monitoring, mathematical modeling in radio-biology and radioecology.

The IAEA Regional post-graduate educational course on radiation protection in Russia was organized by IAEA in cooperation with the Government of Russia and JINR in 1996 and contained two parts: the first is covering a wide multidisciplinary field of fundamental background knowledge in radiation protection and health physics and the second is giving a special training in nuclear safety. The first main part was held in Dubna on August 19 - October 19 (9 weeks) on base of the DRRR and the JINR Training Center.

Educational courses based on the Standard Syllabus is designed to meet the educational and initial training requirements of junior staff of graduate level or the equivalent holding or earmarked for positions in radiation protection and health physics. It is expected that the target audience will include young professionals needing to acquire a sound basis in radiation protection and a knowledge of some related nuclear safety fundamentals in order to become- in the course of time- trainers in their home countries. The training course was opened to 21 participants from IAEA Member States in Europe and West Asia region. They were young staff in the early phase of their career (up to 5 years of work experience).

The course consisted of lectures (85), work sessions (10), laboratory exercises (13), scientific visits (10), discussions and examinations (9). It was designed to provide both the theoretical and practical training in the multidisciplinary scientific / technical bases of international recommendation, development of radiation protection / nuclear safety standards and their implementations in framework of a new conceptual approach elaborated the International Committee on Radiation Protection (ICRP). These standards were also took into consideration in the new Russian standard on radiation protection (НРБ-96). For lectures there were attracted 38 scientists and specialists from JINR (24 lecturers), IAEA (Germany, Austria, Poland, Czech Republic) and several scientific organization of Russia. Besides the scientific visits in Laboratories and nuclear, radiochemistry and medical facilities of the JINR listeners visited the Whole Body Counters Lab and Radiological Hospital of the Institute of Biophysics (Moscow) and the Waste Management Enterprises "Radon" (Sergiev Posad). As a result of the course the listeners were awarded the IAEA educational certificates. Than part of them were continued the education on the specialized course in Obninsk (2 weeks).

6. JINR Training Center

In 1996 year the process of student training in the Training Centre on the specialty "Radiobiology" (holder of the chair Prof. E.A.Krasavin) was successful. From the beginning of it's existence in 1991, as a subsidiary of physics dosimetry and protection faculty of the Moscow Engineering Physics Institute, in the early 1996 the faculty makes the forth graduate of students. Eight of them are already working at DRRR, which significantly assists to the rejuvenation of the Department staff.

7. Administrative activity

Personnel. As of 01.01.97 the total personnel of the DRRR is 92, including the direction staff 10. The number of personnel whose activity is financed by non-budget sources are 4 employees.

Finance. Funding of research in the field of radiation and radiobiological research in 1997 is shown in Table 1. The DRRR share in the JINR budget is 1.4%. The annual extra-budgetary resources will depend on grants (RFFR, ISTC, ISF, etc.) received by the research groups.

Table 1. Financing DRRR in 1996

Area (k$US)	Lab	Financing plan
08-9-1015-96/2000 (I-st priority)	DRRR	274.0
Infrastructure	DRRR	79.1
08-2-0980-92/98 (2-nd priority)	LNP	7.6
Infrastructure	LNP	2.4
Total		363.1

8. Conclusion

The realization of the program will enable JINR to reach the world level of radiation monitoring and in some fields of radiation protection even to surpass this level. It will also receive the basic experimental and theoretical data which can be used for the estimations of risk caused by ionizing radiation.

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