Legislation and Research Activity in Russia about the Radiological Consequences of the Chernobyl Accident

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I INTRODUCTION

One of the principal problems in liquidating the after-effects of the Chernobyl APS accident in the first weeks and months after it occurred was to protect people from external irradiation and internal intake of radioactive products through the consumption of local food stuffs. To solve this problem, evacuation of the population and livestock from a 30-km zone around the APS was carried out in the first days after the catastrophe. In the following period, assessment of the pollution of agricultural products in areas adjacent to the Chernobyl APS became one of the primary tasks, as was a general assessment and forecast of the ecological consequences of the environmental pollution both in natural and agricultural ecosystems.

The approach to solve these problems assumed:

1. Detailed study of the radiation characteristics of surface contamination, i.e. spatial distribution, composition and density of pollution by released radionuclides, dose of external γ-radiation in different landscape-ecological conditions, including surface waters.
2. Study of migration and penetration of the most dangerous (long-lived) radionuclides into the soil, their solubility and potential for root intake in different soil-geographical conditions.
3. Study of the initial aerial pollution of wild and agricultural vegetation. Later, assessment of accumulation coefficients of dangerous radionuclides by the biomass of wild and agricultural plants at the root intake to address the problem of how to use the yield economically.
4. Study of the accumulation of dangerous radionuclides in milk and organs of agricultural animals to solve the problem of animal products' use.
5. Assessment of direct effects and prognosis of long-term (genetic) effects of radioactive contamination on functional parameters of natural ecosystems, animals and human beings.

Many of these research directions had been developed during the study of environmental pollution by radioactive products formed during nuclear weapons tests, as well as accidents at nuclear power installations. However, the simple application of previous radioecological and radiobiological knowledge to the Chernobyl catastrophe could lead and did actually result in a number of significant errors due to the specificity of this case. Among the specific features of the Chernobyl accident, it is necessary to note the following:

1. The complex composition of radionuclides polluting the environment, which changes in a variety of ways depending on the direction and distance from the source.
2. Physico-chemical properties (dispersibility, solubility etc.) of radioactive precipitation, which also change over a wide range.
3. The diversity of natural and meteorological conditions which influence redistribution and migration of radionuclides in ecosystems.
4. The vast territory of radioactive pollution and the sheer number of people living under conditions of chronic ionizing radiation of small doses.

Owing to the above-mentioned circumstances, large-scale and systematic studies of the ecological and radiobiological effects of radioactive contamination in areas adjacent to the Chernobyl APS were started in the first weeks after the accident.

II LEGISLATION AND REGULATION IN THE USSR AND RUSSIA CONCERNING CHERNOBYL

2.a. Legislation and regulation pertaining to radiation dose limit

In April and May of 1986, the Governmental Commission of the Council of Ministers of the USSR and the Ministry of Health of the USSR directed implementation of protective activities and the liquidation of the consequences of the Chernobyl APS catastrophe. The first decision concerning limiting the irradiation dose of the population was to evacuate the population from a zone where the exposure dose rate exceeded 25 mR/h (a level observed approximately at a radial distance of 10 km from the Chernobyl APS). Then a decision was made to lower this limit to 5 mR/h corresponding to a zone with a 30 km radius.

Among other decisions made on the level of ministries and institutions of the USSR, it is necessary to mention the following:

- On May 12, 1986, the National Committee on Radiation Protection of the USSR (NCRP) determined to limit the irradiation dose for the population to 500 mSv/year, and for children under 14, pregnant women and nurses to 100 mSv/year.

- On May 22, 1986, a dose limit of 100 mSv/year was determined for the entire population.
- In 1987, NCRP approved norms of radiation safety (NRS-76/87). These norms gave the Ministry of Health the right to establish dose limits for the population irradiated as a result of the accident. A limit of 30 mSv was established for 1987, with a level of 25 mSv established for 1988 and 1989.

According to decree No. 1452-1 of the Supreme Soviet of the USSR made April 25, 1990, “About the Unique Program for Liquidating the Consequences of the Chernobyl APS Accident and the Situation Related to this Accident” and decree No. 645 of the Council of Ministers of the USSR made June 30, 1990, about this problem, a concept was developed concerning living in the areas affected by the Chernobyl APS accident. The objective of this concept was to formulate principles and criteria to justify the practical measures aimed at maximizing the mitigation of possible negative after-effects of the Chernobyl APS accident relating to human health and compensation of losses.

The basic principles and criteria are as follows:

1. Each person living on the territory polluted with radionuclides or having lived there for at least the established minimum period has a right to compensation for losses in the form of legal privileges, and guaranties of social and medical protection.
2. The irradiation dose resulting from radioactivity due to the Chernobyl APS accident is the principal criterion for making decisions about the necessity of protective measures, their content and scale, and the compensation for losses.
3. Overexposure (above the level of the natural and technogenic background for a given locality) of the average annual effective equivalent dose not higher than 1 mSv (0.1 rem) from the radioactive precipitation as a result of the Chernobyl APS accident is considered acceptable and does not require any intervention.
4. It is mandatory to carry out resettlement of people from the populated areas registered on the official list, by taking into consideration the established intervention levels and socio-economic conditions.
5. Besides radiation protection, the following countermeasures must be taken:

- improved medical service, including special medical observation of groups at increased risk, treatment in sanatoria and sanitation in resorts;
- provision of nutrition at full value including additional microelements, vitamins;
- measures to lower socio-psychological tension;

6. Each person living on the territory polluted with radionuclides has the right to make the decision independently about whether to continue living on a given territory or choosing resettlement to another place, on the basis of the objective information presented to him (her) about the radiation situation, irradiation dose and possible health effects.

Based on the above concept, a law of the USSR, "On Social Protection of Citizens Affected by the Irradiation as a Result of the Chernobyl APS Catastrophe" was written up and approved in May of 1991. This law established the rights of citizens who took part in the liquidation of the catastrophe, those resettled to new places, and those who still live in the given territories.

After the collapse of the USSR, the Russian Federation succeeded to addressing the tasks of coping with the consequences of the Chernobyl catastrophe. At present, there is an elaborated concept of radiation, medical and social protection and rehabilitation of the Russian Federation population who were irradiated due to the accident. It contains a concrete list of recommended measures for radiation protection of people who still live in situations vulnerable to the accident consequences. Those territories where people have a possibility to receive the annual effective dose exceeding 1 mSv are recognized now as being polluted. They are categorized in the following manner:

- zone of obligatory resettlement: areas where soil densities of Caesium-137, Strontium-90 and Plutonium are 1480, 111 and 3.7 kBq/m^2 or higher, respectively.
- zone of limited inhabitancy: areas where the annual dose of the people may exceed 5 mSv (Caesium-137 density from 555 to 1480 kBq/m^2).
- zone with the right to resettlement: areas where the annual dose is higher than 1 mSv (Caesium-137 density from 185 to 555 kBq/m^2).
- zone of living under periodical control: areas where the annual dose should not exceed 1 mSv (Caesium-137 density from 37 to 185 kBq/m^2).

Within this concept, those who have received a dosage of more than 50 mSv of acute and 70 mSv of chronic irradiation are recognized as ‘irradiated’, and as ‘affected’ are those who have developed a disease whose occurrence has been proven to be as a result of irradiation from the accidents. All of the people referred to are being included in the national radiation-epidemiological register.

A program of medical assistance and rehabilitation has been developed for all those ‘irradiated’ and ‘affected’. Special attention is being paid to the ‘affected’ people and groups at increased risk among the ‘irradiated’. In the system of medical protection and rehabilitation of the population, activities are foreseen to raise the resistance to and protect irradiated people from cancer, as well as for limiting the influence of injurious factors of a non-radiation nature. Psychological support and rehabilitation of the population are aimed to limit and prevent the development of stress among people living in the polluted territories. In order to do so, efforts are

Table 1 Temporary acceptable level of Caesium and Strontium contents in food products (TAL-94)

Name of food	Concentration (Bq/kg, l)	
	Caesium-134, 137	Strontium-90
1. Milk and milk products, bread and bread products, grains, flour, sugar, vegetable and animal fats, margarine	370	37
2. All types of infant foods (ready to be consumed)	185	3.7
3. Other food products	600	100

expected to raise the level of people's knowledge about irradiation effects, to provide convincing information about the radiation situation, and to create psychological support services in polluted areas.

In accordance with this concept, certain amendments and changes were introduced into the law of the Russian Federation, "On Social Protection of Citizens Affected by Radiation as a Result of the Chernobyl APS Catastrophe," which was approved by the State Duma of the Russian Federation on July 12, 1995.

2.b. Legislation and regulation concerning radioactivity levels in foods, water and air

Before the Chernobyl APS accident, limits on radionuclide intake with food, water and inhaled air by humans, as well as permissible levels of radioactive contamination of different surfaces, were defined in the "Norms of Radiation Safety" (NRS-76) and the "Principal Sanitarian Rules of Working with Radioactive Substances and Other Ionizing Radiation Sources" (PSR-72/80). Complying with these documents was obligatory for all state and cooperative enterprises, institutions and organizations throughout the USSR. After the Chernobyl APS accident, however, they could not be complied with across a vast territory. Therefore, starting May 3, 1986, the USSR's NCRP established a temporary acceptable level of radioactive iodine of 3.7 kBq/l,kg for drinking water and food products. It was then revised on May 30, 1986, by the USSR Ministry of Health to add standards for Caesium-137 and -134. These standards were calculated to not exceed 50 mSv of the internal dose permissible for the first year after the accident.

Meanwhile, on May 7, 1986, the USSR Ministry of Health approved temporary permissible levels of surface contamination of land, vehicles, clothing, skin, etc., which were then reduced on October 26, 1986.

The temporary acceptable levels of pollution of food products and water with cesium isotopes were introduced in 1988 (TAL-88) in order to limit the internal irradiation dose. TAL-91 were then established in 1991, and TAL-94 (Table 1) in 1994. The acceptable levels of pollution of food products and drinking water decreased gradually, and in the last document the levels correspond to those in the majority of European countries and the USA.

Also, in 1987, the new "Norms of Radiation Safety" (NRS-76/87) and "Principal Sanitarian Rules of Work with Radioactive Substances and Other Ionizing Radiation Sources" (PSR-72/87) were approved. They defined more precisely some standards about the influence of ionizing radiation on human beings. The experience gained in radiation control and prophylactic activities in corresponding institutions and the environment was reflected in them, including the knowledge gained from the liquidation of the Chernobyl after-effects. PSR-72/87 was valid on the USSR territory and, after its collapse, on the territory of Russia until recently. At present, they have been revised, amended and corrected, and in the shortest time are to become obligatory to apply the entire Russian territory.

In addition to the principal laws and regulations mentioned above**,** a number of instructions, recommendations and rules were published. They were oriented to decreasing the dose commitment and radionuclide intake by people living on polluted territories and those working in various spheres of the economy. For example: "Instruction on Protection of Population from Accidents Which Release Radioactive Substances into the Environment," "Instruction on Radiation Safety for the 30-km Zone around the Chernobyl APS," "Provisional Instruction on Forestry Regulations and Radiation Safety under the Condition of Radioactive Pollution," "Recommendations on the Agro-industrial Complex Activities under the Condition of Radioactive Pollution of Territories," "Recommendations to the Population about Behavior on Territories Polluted with Radionuclides" and so on.

III GOVERNMENTAL ORGANIZATION CONCERNING CHERNOBYL

The principal policy of the government was made in two directions:

- to carry out restoration and decontamination activities aimed at decreasing radioactive pollution of the territories;
- to provide social guaranties to the sufferers, first of all, their resettlement away from polluted zones, supply of clean food products and organization of medical service.

Since the time of the accident, the following organizations have been in charge of handling the consequences of the accident in the former USSR and then in the Russian Federation:

- Since May 1986 - Governmental Commission of the Council of Ministers of the USSR,
- Since 1989 - State Commission on Emergencies of the USSR Council of Ministers,
- Since 1990 - State Committee of Russian Federation on the Liquidation of Consequences of the Chernobyl APS Accident.
- Since 1994 - Ministry of Russian Federation on Civil Defense, Emergencies and Liquidation of Consequences of Natural Disasters.

Besides the above, almost all of the union and republican ministries and institutions have been involved in the liquidation of the Chernobyl consequences and the activities to help the affected population right from the first years after the accident. Currently, the ministries below fulfill these functions in the Russian Federation:

- Ministry on Civil Defense, Emergencies and Liquidation of Consequences of Natural Disasters;
- Ministry of Health;
- Ministry of Social Protection;
- Ministry of Agriculture;
- Ministry of Forestry;
- Ministry of Atomic Energy and Industry;
- Ministry of Chemical Industry;

The Ministry of Health and the Ministry on Emergencies are responsible for medical assistance to the people affected by the Chernobyl APS accident. In the period after the accident, the material-technical base of health services was improved significantly in several areas. Necessary scientific methods were developed to examine and treat adults and children. Practical medical activities were undertaken; all of these activities acted to preserve the health and, sometimes, the lives of thousands of people.

IV ACTIVITY OF THE ACADEMY OF SCIENCES

Immediately after the Chernobyl APS catastrophe, scientists of the Academy of Sciences and the Academy of Medical Sciences simultaneously started functional and expeditionary investigation.

In 1986, the "Coordinative Council on Scientific Problems Related to the Ecological Aftermath of New Technologic Systems" was created at the Presidium of the Academy of Sciences of the USSR and headed by Academician ALEKSANDROV A. P. The "All-Union Science-Technical Program on the Liquidation of Chernobyl APS Accident Consequences for 1986-1990" was worked out under the support of this Council. The program consisted of major six foci:

1. Geophysical aspects of radioactive pollution.
2. Agro-industrial aspects of radioactive pollution.
3. Ecological aspects of radioactive pollution.
4. Biomedical aspects of radioactive pollution.
5. Decontamination bases.
6. Methodological and instrumental provision of control for the radiation situation.

Leading scientists of the USSR entered into the Coordinative Council, and scientists from various ministries, institutions and academies were charged with implementation of this program.

The "State Union-Republican Program on the Liquidation of the Consequences of the Chernobyl APS Accident for 1990-1995" was worked out later on, as were legislative acts regulating different aspects of activity in the post-accident period.

However, it must be pointed out that both research and socio-economical programs for 1992-1995 were not implemented. The principal reason for this is that only 16% of the scheduled funds were provided for this period. In this case of unsatisfactory financial provision, only selected activities were implemented, disregarding the integrated approach. Thus, the planned objectives were not met and the indices of people's lives did not improve. This period, moreover, coincided with a general socio-economical crisis in Russia, the rapid decline in industrial and agricultural production, the appearance of unemployment and impoverishment of the population. All of these processes exerted negative effects on the health and birth-rate of the country. The mortality rate increased, and the population in the Russian Federation began to decrease.

It is also necessary to note that the pre-Chernobyl radiobiological science in the USSR was oriented mainly to the study of the effects of high irradiation dose on cellular, tissue and organisms of living things. When the Chernobyl catastrophe took place, experts found themselves in a complicated situation. The classic texts of radiobiology asserted that effects of small-dose irradiation in people should not be that extensive. Therefore, such terms as 'radiophobia', 'acute psychological stress' and so on were often used by the officials to describe the situation.

Other than mentioned above, a very important biological concept of the non-proportionally strong effects of small doses of radiation on biological objects has been developed. It was formulated in the 1960's by Professor BURLAKOVA E. B. (and, independently, in the 1970's by Canadian researcher, PETKO A.). This concept requires to the revision of many commonly accepted theories concerning 'dose-effect' dependence, not only for ionizing radiation but for all physico-chemical influences on living organisms. Therefore, before making optimistic predictions, it is necessary to understand the regularities of the effects of small doses of radiation and carry out extensive investigation into this field.

The results of research concerning the effects of Chernobyl radioactive contamination on human health were reported at the World Health Organization's

conference in Geneva in November 1995. They can be formulated as follows:

1. Thyroid cancer incidence among children and adolescents is several tens of times as high as was prognosticated by medical officials. Obviously, the rate of other types of cancer has begun to increase in recent years.
2. (As compared with children in similar socio-economic conditions living on "clean" territories) more than half of the children born on the contaminated territories show a delay in mental development (psycho-linguistic and other forms).
3. Immunological and cytogenetic disturbances has been found in people living on territories polluted with radionuclides and those who worked at the Chernobyl APS after the explosion of the 4th block.
4. Incidence of cataract, cardiovascular diseases, diseases of the gastrointestinal tract, respiratory and urogenous systems are increasing.

V ACTIVITY OF NON-GOVERNMENTAL ORGANIZATION ABOUT CHERNOBYL

The Union "Chernobyl" is the biggest and most ramified public organization uniting the participants in the liquidation of the Chernobyl APS accident. Its brief history follows:

1. August 1988 - an initiative group was created of those who worked in 1986 on the cleaning of the 3rd and 4th blocks of the Chernobyl APS and who were still working in the zone.
2. December 1988 - the first version of the union's Statutes was written up.
3. April 5-11, 1989 - the first four primary organizations of the future Union were created.
4. April 12, 1989 - the uniting session took place, thus making the date of birth of the Union.
5. May 13, 1989 - 1st Conference of Union "Chernobyl" took place at the Zeleny Mys settlement in the Kiev region. The Statutes were approved, the final name of the Union was approved, the Board was elected, and a declaration to all "liquidators" and to the public organizations and movements of the USSR was composed.
6. April 14- the broadcast from the all-Union radio station "Mayak" of a program about the organization, its aims, and the tasks of the "Chernobyl" union.

In different cities and regions of the USSR, organizations, societies and associations of "Chernobyl" people began to appear independently, and already in October 1989, the All-Union Conference of the "Chernobyl" Union was held in Kiev. 344 persons from 11 republics of the USSR participated in it.

The Union "Chernobyl" took the great tasks upon itself. Firstly, protection of the interests of the Union members, their families, and the people affected by the Chernobyl APS accident. Secondly, discovery of the truth relating to Chernobyl and an objective analysis of what took place and what has continued until the present time. Thirdly, organization of social-patriotic activity based on the experience having worked at Chernobyl.

At present in Russia, besides the Union "Chernobyl", there are many regional public organizations made up of Chernobyl invalids. Charitable funds (e.g. A. Yaroshinskaya Fund) also do what they can to help the people affected by Chernobyl.

VI LIST OF SCIENTIFIC ORGANIZATIONS WORKING ON CHERNOBYL

6.a. Physical processes and radioactivity release dynamics

The following organizations have been involved in investigating the physical processes and the dynamics of radioactivity release during the course of the Chernobyl accident:

- Russian Scientific Centre "Kurchatovskij Institut", Moscow
- All-union Scientific Research Institute for Nuclear Power Plant Operation (VNIIAES), Moscow
- Scientific Research and Design Institute for Power Technology, Moscow
- Institute of Problems of Safe Development of Atomic Energy of RAS (Russian Academy of Sciences), Moscow
- Science-Production Corporation "V. G. Khlyupin Radievyj Institut", St. Petersburg
- L. Ya. Karpov Research Institute of Physical Chemistry of RAS, Moscow
- Ministry of Defense of the USSR

6.b. Radioactivity contamination and radiation monitoring

- Institute of Experimental Meteorology of Science-Production Corporation "Tajfun", Obninsk
- State Committee of the Russian Federation on Sanitarian-Epidemiological Control, Moscow
- All-Russia Research Institute of Agricultural Radiology and Agroecology, Obninsk
- Radiation Hygiene Research Institute, St. Petersburg
- V. I. Vernadskij Institute of Geochemistry and Analytical Chemistry of RAS, Moscow
- Science-Production Corporation "V. G. Khlyupin Radievyj Institut", St. Petersburg
- Institute of Problems of Safe Development of Atomic Energy of RAS, Moscow
- Institute of Applied Geophysics, Moscow
- Moscow M. V. Lomonosov State University, Moscow
- A. N. Severtsov Institute of Evolution and Ecology of RAS, Moscow

CBGD: Since 1991, efforts to create a Central Bank of Generalized Data (CBGD) started at the Institute of Problems of Safe Development of Atomic

Energy of RAS. The information for CBGD was supplied by tens of organizations participating in the liquidation of the consequences of the Chernobyl APS accident, including those mentioned above. The total volume of accumulated data is over 1 Gbyte. At present, CBGD consists of more than 20 sub-banks which include the following:

- data bank on the radiation-hygienic situation in settlements (nearly 10 thousand settlements in Russia, up to 150 indices about every settlement);
- data bank on the radioactive pollution of agricultural and forest lands, and agricultural products;
- data bank on the demography (sex-age distribution and sex-age mortality due to different causes from 1982 to the present in the majority of Russian regions);
- data bank on the population's migration in the zones of radioactive contamination;
- data bank on the chemical pollution of atmosphere, surface waters, agricultural lands and agricultural products;
- data bank on socio-psychological status of population;
- data bank on legislative acts, directive documents, and reference information concerning the problem of liquidating the consequences of radiation accidents and catastrophes;
- data bank of electronic maps of Russian territories polluted with radionuclides with a scale of 1:500,000;
- data bank on the registration of persons affected by Chernobyl or other radiation catastrophes.

An integrated computer system has been elaborated for analyzing and processing the CBGD data. It can be used in different analyses and in creating prognostication systems to support decision-making by officials at the time of radiation accidents. 'Model Bank' is a part of the integrated system and consists of:

- models of atmospheric transfer of radioactive admixture;
- models of migration of radionuclides in soil and in water systems;
- models of radionuclides transfer within food-chains;
- models for analysis and processing of spatially distributed radioecological data;
- models for calculating the radiation field and equivalent dose in human organs from sources with various geometrical forms.
- models for calculation of equivalent doses in 25 organs and tissues of persons of different ages in cases of radioactive substances intake through inhaled air, food, or direct injection into the blood;
- models of risk calculation.

The system presupposes a wide choice of sources, radionuclides and materials which are frequently used in calculation. The formation of the data bank, model bank, and development of methods of data processing and analysis, as well as the means to interpret them by computer, enable carrying out systematic analysis and predictions of radiation situation on polluted areas with an acceptable level of precision and validity. There is no analog of this set of models in terms of the scale and computer technology.

6.c. Dose estimation

Thyroid dose: The Medical Radiological Scientific Centre (MRSC, Obninsk) of RAMS (Russian Academy of Medical Sciences) and the Radiation Hygiene Research Institute (St. Petersburg) have been working from the first weeks after the accident to reconstruct thyroid doses received by the population of Russia as a result of the Chernobyl APS accident. In the first weeks after the accident, the personnel of these institutions measured the Iodine-131 content in the thyroid of approximately 31,000 persons. The results of these direct measurements were used to develop a dose reconstruction model which allowed the carrying out of a retrospective assessment of individual and average thyroid doses in settlements.

External dose: The State Scientific Centre of the Russian Federation - the Institute of Biophysics, Moscow, has been involved in reconstructing the dose of external β- and γ-irradiation received by those who worked in the zone of the Chernobyl accident. The lack of individual dosemeters in the months just after the accident and their virtual absence among the military servicemen and clean-up workers made such studies necessary. In order to improve the verifiability of the available information about γ-irradiation doses, all 'liquidators' were divided into 10 cohorts with different quantities: Chernobyl APS personnel, 'Sarcophagus' builders, military liquidators and so on. The distribution of individual doses of γ-irradiation was determined for all cohorts, as well as the statistical parameters including the average and maximum values for each cohort. Doses of β-irradiation of skin and crystalline lens received in the first months after the accident were assessed using the β/γ ratio, and, starting in July 1986, they were measured in a sample of the liquidators using the multilayer dosemeters developed at the Institute of Biophysics. The Medical Radiological Scientific Centre (Obninsk) is concerned with a retrospective assessment of individual accumulated doses among the population of the central part of Russia after the Chernobyl APS accident using the 'EPR' method (spectrometry of dental enamel). Dental clinics collected extracted decayed teeth. More than 2,000 samples of individual accumulated doses have been measured until now.

Internal dose: To reconstruct the internal irradiation dose, special methods were developed at the Institute of Biophysics of the Ministry of Health and the RSC "Kurchatovskij Institut." These methods are based on the results of measurements of Chernobyl

radionuclide content in organs and tissues of those who took part in the liquidation of the accident consequences. The Radiation Hygiene Research Institute (St. Petersburg, filial branch - Novozybkov) carried out individual surveys of the cesium radionuclides content in the organ of more than 90,000 people living on territories having a density of Caesium-137 pollution over 550 kBq/m^2. For the purpose of effectively using the information obtained, a data bank to reconstruct individual irradiation doses is being developed at the institute. It includes primary data of the radiometric surveys of the population, the data on the radiation situation and social factors determining irradiation conditions, as well as software for verifying data and processing information.

In addition to the above, efforts to reconstruct the equivalent irradiation dose are being held in the Laboratory of Radiation Genetics of the N. I. Vavilov Institute of General Genetics, Moscow, by means of the FISH method - fluorescence analysis of chromosomes after in-situ hybridization of DNA samples with specific reagents for certain chromosomes. It is noteworthy that the dose defined by this method does not always coincide with the official dosimetric data.

Institute of Problems of Safe Development of Atomic Energy of RAS are occupied with the long-term prospective assessment of dose.

6.d. Epidemiological study

In 1986, immediately after the Chernobyl APS accident, the USSR Ministry of Health approved a large-scaled program creating the All-Union Distributed Register of irradiated persons. All republics of the former Soviet Union were involved in the creation of this Register as were a significant number of scientific and other institutions.

Presently, the National Radiation-Epidemiological Register (NRER) exists in Russia. The Ministry on Emergencies of Russia is the general sponsor of the work carried out within the Register. The head organization is the Medical Radiological Scientific Centre of RAMS which collects primary medical and dosimetric data through 24 regional centers.

The Register includes three subsystems of principal medical-dosimetric information:

1. Registration list of the people affected by irradiation divided according to special dosimetric categories (Southern Urals, Altai, Chernobyl and other regions),
2. All-Russia State Medical-Dosimetric Register (RSMDR, so-called Chernobyl Register, created in 1986).
3. Registry of expert councils.

Presently, the creation of the Chernobyl register in Russia is practically over. At the end of 1994, the data base of RSMDR contained information on 370,120 persons including 159,027 liquidators (43.0%), 8,091 evacuees (2.2%), 185,912 inhabitants of Russian contaminated territories (50.2%), 16,226 children of liquidators of 1986-1987 (4.4%), 864 resettled people (0.2%). In 1993, there were registered 8,006 invalids among the liquidators (2.2% - 1st class, 58.6% - 2nd class, 32.9% - 3rd class). Incidentally, malignant neoplasms constitute 3.61% within the structure of disablement, while diseases of the nervous system and sensory organs - 26.39%, mental disorders - 15.12%.

Therefore, one of the most real and complicated problems in determining the socio-medical after-effects of the Chernobyl catastrophe is to conduct a complex (integral) evaluation of the damage to liquidators' health, including both direct radiation effects and other factors relating to participation in the liquidating work of Chernobyl.

6.e. Other scientific organizations related to Chernobyl

Besides the above-mentioned, the following Russian institutes have also played a role in solving various problems related to the Chernobyl APS accident:

- Hematological Scientific Centre of RAMS.
- Endocrine Scientific Centre of RAMS.
- Medico-Genetic Scientific Centre of RAMS.
- Oncological Scientific Centre of RAMS.
- Moscow P. A. Gertsen Research Oncological Institute.
- Research Institute of Neurology of RAMS.
- V. P. Serbskij State Scientific Centre of Social and Juridical Psychiatry.
- Institute of Psychology of RAS.
- Moscow Research Institute of Psychiatry.
- Department of Psychology of Moscow State University.
- All-Russia Centre of Ecological Medicine.
- Research Institute of Experimental Veterinary.
- Republican Science-Production Veterinary Radiological Laboratory
- Institute of Biology of Komi Scientific Centre of Ural Section of RAS.
- All-Russia Research Institute of Chemical Production of Forestry.
- State Research Institute of Lake and River Fishery.
- Institute of Ecology of the International Engineering Academy.
- Institute of Chemical Physics of RAS.
- Science-Production Corporation "Radon".
- State Scientific Centre VNII NM of Academician A. A. Bochvar.
- Kaluga Institute of Sociology.
- Institute of Economics of RAS.
- Institute of Physical Chemistry of RAS.
- Institute of Parasitology of RAS.
- Laboratory of Forest Science of RAS.
- Institute of Epidemiology of the Ministry of Health.

This list is far from complete.

VII DESCRIPTION OF SOME LEADING ORGANIZATIONS

a) Medical Radiological Scientific Centre (MRSC) of RAMS was established based on the Research Institute of Medical Radiology created in 1962 in Obninsk. An academician, TSYB A. F., the chairman of Russia Scientific Commission on Radiation Protection, is the director of MRSC.

MRSC is a research and medical institution concerned with fundamental and clinical radiobiology, experimental radiology, radiopharmaceutics, radiation diagnostics, radiation epidemiology, and radiooncology.

MRSC consists of 10 departments uniting 32 laboratories and sections as well as 11 independent scientific units. The Center's clinic has 400 beds.

The Center's staff numbers over 1900 including 350 scientists (25 professors, 51 Drs. and 174 candidates of Dr.).

From the first days after the Chernobyl APS catastrophe in 1986, scientists and specialists of MRSC have been engaged actively in efforts concerning the estimation of possible medical consequences of the accident and the elaboration of measures to mitigate their influence on human health. At present, MRSC conducts studies of the biological effects of small doses of radiation, reconstruction of irradiation doses using cytogenetic methods and EPR-spectrometry, epidemiological investigations of the Russian population. Regular investigations are carried out in Kaluga, Bryansk and other regions. As described before, the Chernobyl Registry (RSMDR) is maintained by MRSC.

In addressing the Chernobyl-related scientific and medical problems, MRSC collaborates fruitfully with WHO, IAEA, Commission of European Community, scientists from Japan, Germany, USA, Great Britain, Finland, France and other countries.

b) Russian Scientific Center "Kurchatovskij Institut" was organized in November of 1991 based on the Kurchatov Institute of Atomic Energy. The former Kurchatov Institute was established during World War II for special military purposes. After quick success in achieving its first task, the Kurchatov Institute began to work in a wide range of scientific fields not only for military, but for peaceful, practical and fundamental purposes. The scope of the Institute gradually widened to where it has contained practically every field of the natural sciences.

At present, the main activities of the Institute are related to the development of safe and clean nuclear energy (power reactor and fuel cycle), control of thermo-fusion and plasma processes, and research for nuclear physics of low and medium energy, solid physics and superconductivity.

The institute employs 8,500 staff in total: with the number of scientific staff at 3,048, technicians -2,562, workers - 2,198 and other specialists - 692. There are 13 Academicians of RAS, and 900 Drs. and Cds. of Dr. Academician VELIKHOV E.P. is the director of the Institute.

c) Institute of Biophysics was established in 1946 to investigate the effects of ionizing radiation on living organisms and the methods to ensure radiation safety of persons working in the nuclear industry. It belonged at first to the Academy of Medical Sciences of the USSR and then was moved under the Ministry of Health of the USSR. Since 1995, it has been called the State Scientific Center of Russian Federation - Institute of Biophysics.

The principal activities of the Institute are research in the fields of radiobiology in animals and man, medical cures for radiation syndrome and protection of individuals from various sources of radiation. Standards for radiation safety in the USSR have been developed based on the results of this research. Radiation dosemeters, various instruments and medicines have also been invented to protect the people from radiation.

There are 5 Academicians and one associate Academician in the Institute. There are now 64 Drs. and 215 Cds. of Dr. Since 1968, Academician IL'IN L.A. has been the director of the Institute

VIII INTERNATIONAL COOPERATION RELATED TO CHERNOBYL

8.a. Cooperation within the framework of the 4-side agreement among CEC, Russia, Ukraine and the Republic of Belarus

The long-term and structural help began after concluding an agreement on June 23, 1992, between the Commission of European Community, the Republic of Belarus, Russia and Ukraine on overcoming the consequences of the Chernobyl catastrophe. This agreement permitted the involvement of the leading scientific institutions in the fields of radioecology and radiation medicine of the different EC countries into direct cooperation with those institutes of the former USSR which since the first stage in 1986 had worked actively on the accident liquidation.

The first step within the framework of this CEC-CIS agreement was the organization of 7 experimental and research projects in 1992. In 1994, the number of projects was increased to 16. Presently, specialists of 30 Russia institutes participate in them. The EC partners are represented by nearly all leading institutes of CEC countries.

Implementation of these projects is not humanitarian aid, but rather presupposes the equivalent participation of the 4 sides. From the side

of CEC, financial support is given according to items of the agreement: equipment, exchange of scientists and local support. Thus, from 1992 to 1995, within the framework of agreement the CEC side provided nearly 2 million ECU. This is quite a significant contribution to support the intellectual part of the program - to provide help to Russian scientists. It was a considerable help in purchasing up-to-date scientific equipment. The sum used to procure equipment for the years of the collaboration reached more than 0.5 million US dollars.

In 1993, the Coordinative Council decided to create national secretariats in each participating republic in order to support cooperation and to solve practical problems. It was worthy to note that high-ranking officials of Ministries on Emergencies of Russia, Belarus, of Minchernobyl of Ukraine and the XII Directorate of EC entered into the Coordinative Council. In 1994, the structure of project coordination was perfected, and the Directive Group was created. The mission of the Directive Group was to guarantee the implementation of projects according to the policy of the Coordinative Council, as well as to prepare reports on project implementation for the Coordinative Council.

Russians had close contacts not only with the representatives of western laboratories, but also with Ukrainian and Belarussian scientists. The experience gained by this collaboration is very important to establish partnerships on all levels of executive power across the CIS.

The Minsk Conference about this work (March 18-22, 1996) may serve as a good example of successful cooperation. The complex approach of international groups to solving the task of how to overcome the greatest nuclear accident of the XX century is reflected in its proceedings.

8.b. Cooperation with the Commission of European Community within the framework of TASIS program

Cooperation between the Ministry on Emergencies of the Russian Federation and CEC within the framework of the TASIS program has been less successful. This is due to the fact that there is not a capable infrastructure in Russia to permit the planning and implementation of the project, and that Russian specialists, mainly from the affected regions, are not closely involved with the work.

In 1995, within the framework of the TASIS program, it was planned to start a project costing about 400,000 ECU to train medical personnel in thyroid cancer therapy.

This program is expected in total to complete 3-4 projects concerning Chernobyl.

8.c. Cooperation with the International Union of Radioecologists

At the end of 1995, a protocol of agreement was signed between the Ministry on Emergencies of Russian Federation and the International Union of Radioecologists about a project of Program of Independent International Expertise called the "Assessment of the Actual State and Ecological Safety of the Alienation Zone and Influence to the Adjacent Zone."

This project (costing 900,000 ECU) is being carried out by the initiative of Ukrainian Minchernobyl with the participation of the Ministry on Emergencies of Belarus and that of Russia.

The Ministry on Emergencies supports the cooperation of Ukrainian and Belarussian scientists and will assist with the Program.

8.d. Cooperation with UNESCO

The program of cooperation between the USSR and UNESCO surrounding Chernobyl problems was established in June of 1990.

According to the "UNESCO-Chernobyl" Program, 235,000 US dollars were provided for purchase of equipment, reconstruction of buildings, and training of specialists-psychologists for three centers of socio-psychological rehabilitation being created in Uzlovaya (Tula region), Nikolskaya Sloboda (Bryansk region) and Bolkhov (Orel region).

Additionally, UNESCO gave 12,000 US dollars for equipment to be used of the childhood sport schools in Novozybkov, the Bryansk region.

In its first stage, the "UNESCO-Chernobyl" Program foresaw implementation of 70 projects on the territories of Russia, Ukraine and Belarus concerning the liquidation of the Chernobyl APS accident consequences. Taking into consideration certain priorities, 30 projects were selected for realization including 9 on the Russian territory. In order to oversee their implementation, the Coordinative Council was created consisting of representatives of Belarus, Russia, Ukraine and UNESCO. The projects listed below are being carried out successfully:

- Project No. 1 "Language Support" has been carried out from 1992 until the present.
- Project No. 18 "Associated Schools"; within its framework the spread of knowledge is expected among pupils about prophylactic measures in case they stay in the areas affected by the Chernobyl APS accident.
- Project No. 32-33 "Creation of Zones of Socio-Economical Development". Such zones will be created in Gagarin, the Smolensk region.
- Project No. 42-45 "Culture" has been in place since 1993. The exchange of art exhibitions, musicians has been taking place. The International Seminar "Children of Chernobyl" was held in France in 1994.
- Project No. 79 "Sport Equipment" was conducted in Novozybkov, the Bryansk region.

8.e. Cooperation with the World Health Organization (WHO)

From 1991 to 1994, 6 projects of WHO's program were carried out in Russia: "Medical Aspects of the Chernobyl Accident" IPHECA, "Thyroid", "Hematology", "Epidemiological Register", "Sustaining Activity (Biological and Physiological Dosimetry)" and "Pre-Natal Injury of Brain". The Bryansk and Kaluga regions of Russia, which are the most polluted with radionuclides, were covered by these projects.

The IPHECA (International Program on the Health Effects of the Chernobyl Accident) program's budget for three affected countries constituted 20 million US dollars received by WHO mainly from the government of Japan. Russia received unique diagnostic and dosimetric equipment through this program, as well as hardware costing a total of nearly 6.5 million US dollars. The use and operation of the equipment purchased are under the supervision of WHO.

51 Russian specialists were trained in foreign centers which accounts for part of the IPHECA program's budget. 16 Russian medical specialists visited Japan (Hiroshima and Nagasaki) in 1992-1994 at WHO's expense to participate in a one-month training course on medical equipment.

The IPHECA program is oriented to diagnosis of diseases and analysis of their possible relationship with irradiation factors. Regretfully, medical assistance to the people who revealed pathology is not included within the framework of this program.

In 1994, the budget of the IPHECA program was exhausted. The results of the implemented studies were generalized in a report "Medico-Radiological Research in Prior Directions" published by WHO at the end of 1995. The pilot project "Thyroid" has become a permanent project. It is also planned to continue research on the "Dosimetry" project. A new project "Liquidator" has also been formulated and approved.

8.f. Cooperation within the Russian-German Dosimetry Program

In 1991-1993, the Russian-German Dosimetry Program was carried out successfully to solve the problem of how to define radiation burden on the population and environment of the territories of the Russian Federation affected as a result of the Chernobyl catastrophe. The German side gave to Russia 4 movable research laboratories equipped with whole body counters, devices to measure radioactivity of environmental samples, and two camping-vans. The total cost of the equipment was 1.25 million German marks. Nearly 200,000 people living on polluted areas of Russia were observed as a result of this joint project.

8.g. Cooperation with the USA

According to a treaty between the government of the Russian Federation and the government of United States of America, an agreement was concluded about collaboration in the field of studying radiation effects in order to minimize the influences of radiation pollution on human health and the environment. The planned budget of this program is 1 million US dollars. The projects are planned to look at the radiation consequences of the activity of the production corporation "Mayak" in the South Ural. The cooperation plans in the future to include projects related to the consequences of the Chernobyl APS accident and nuclear weapons tests at the Semipalatinsk testing ground.

8.h. Cooperation with France

The French public organization "Rotary Club" supplied, as humanitarian aid, an immuno-pharmic laboratory costing 162,000 francs to the All-Russia Centre of Radioecological Medicine (St. Petersburg), and trained service personnel. Besides this, the organization provided technical maintenance for two years.

On June 23, 1993, according to a commission of the Russian Government, an agreement was concluded with the Medical Committee on Nuclear Safety of the French Republic about a cooperation in the field of studying the consequences of radiation accidents and exchanging knowledge of how to control post-accident situations. At present, works on implementing this agreement is being continued.

8.i. Cooperation with Japan

Cooperation with Japan at an official level started in 1990 based on an agreement between the Japanese government and the USSR. Within the framework of this cooperation, Japanese scientists of the Radiation Effect Research Foundation (RERF), National Institute of Radiological Sciences (NIRS), University of Hiroshima, University of Nagasaki and others have been involved. The experience in Japan of overcoming the after-effects of the atomic bombing of Hiroshima-Nagasaki provided valuable information to the USSR, later the CIS, scientists to cope with the consequences of the Chernobyl catastrophe. Other than the official level, the Sasakawa Memorial Health Foundation launched the "Chernobyl Sasakawa Project" in 1991 to provide medical services financed at 5 billion yen over five years. They created 5 clinical centers and have examined more than 130,000 children around the contaminated territories in Russia, Belarus and Ukraine. There are also many other NGOs in Japan carrying out humanitarian activity to help the sufferers of the Chernobyl catastrophe.

IX LIST OF IMPORTANT PUBLICATIONS BY RUSSIAN SCIENTISTS ON CHERNOBYL

1. "Information to IAEA about the Chernobyl NPP Accident", *Atomnaya Energiya*, **61**(5), 301-320, 1986 (in Russian).
2. "Ecological Consequences in the Natural Environment in the Area Contaminated by the Chernobyl Accident", UNESCO Report to XIV Session, Nairobi, June 1987.
3. ASMOLOV V.G., BOROVOI A.A., DEMIN V.F., KALUGIN A.K. *et.al.*, "The Chernobyl Accident: One Year After", *Atomnaya Energiya*, **64**(1), 3-23, 1987 (in Russian).
4. "Problems of Ecological Monitoring", Scientific-practical Conference, Bryansk, 1991 (in Russian).
5. KRISHEVA I.I. ed., "Radioecological Consequences of the Chernobyl Accident", USSR Nuclear Society, 1991 (in Russian).
6. "Radioecological, Medical and Social-Economical Consequences of the Chernobyl Accident: Rehabilitation of Territories and Inhabitants", All-Russian Conference, 1995 (in Russian).
7. BURLAKOVA E.B. ed., "Consequences of the Chernobyl Catastrophe: Human Health", Center for Russian Environmental Policy, Moscow, 1996.
8. ZAKHAROV V.M. and KRYSANOV E.YU. ed., "Consequences of the Chernobyl Catastrophe: Environmental Health", Center for Russian Environmental Policy, Moscow, 1996.
9. ADAMOV E.O., IONOV A.I., PODLATSOZ L.N. *et.al.*, "Extended Analysis of the First Phase during the Accident Process at the 4th Reactor of ChNPP", First International Working Group for Severe Accident and Their Consequences, Nauka, Moscow, 1990, pp. 33-38 (in Russian).
10. ADAMOV E.O., VAZINGER V.V. *et.al.*, "Qualitative Evaluation of the Effects of Possible Disturbances at the Time of the Chernobyl Accident", *ibid.*, pp. 48-68 (in Russian).
11. IZRAEL YU.A. *et.al.*, "Radioactive Contamination in the Environment in the Zone of the Chernobyl NPP Accident", *Meteorologiya i gidrologiya*, 1987, No. 2 pp. 5-18 (in Russian).
12. Izrael Yu.A., "Chernobyl: Contamination in the Environment", Gidrometeoizdat, Leningrad, 1990 (in Russian).
13. IZRAEL YU.A. *et.al.*, "Radioactive Contamination by Caesium-137 in the European Part of CIS Territory in 1992 as the Result of the Chernobyl NPP Accident", Metodika i Nekotory Rezultatwi Aviatsionnoy Gamma-semki Radioaktivnogo Zagryazneniya Territorii Evropeiskoy Chast Rossii, Gidrometoizdat, St.Petersburg, 1994, pp. 16-51 (in Russian).
14. POPOVA O.N., TASKAEV A.I. *et.al.*, "Genetic Stability and Variability of Seeds of Grass Population in the Zone of the Chernobyl NPP Accident", Nauka, St.Petersburg, 1992 (in Russian).
15. KOZUBOK G.M., TASKAEV A.I., *et.al.*, "Radiation Effects on Coniferous Forest in the Zone of the Chernobyl NPP Accident", Syktyvkar, 1990 (in Russian).
16. "Effects of Radioactive Contamination on the Ecosystem on the Ground in the Zone of the Chernobyl NPP Accident (1986-1996)", Trudwi Komi Nauch. Tsentra Uralskoy Otdeleniya RAN, No. 145, Syktyvkar, 1996 (in Russian).
17. MERWIN S.E. and BALNOV M.I. ed., "The Chernobyl Papers", Vol.I, Research Enterprises, Washington, 1993.
18. YAROSHINSKAYA A.A., "Chernobyl: Top Secret", Drugie-Berega, Moscow, 1992 (in Russian).
19. YAROSHINSKAYA A.A. ed., "Nuclear Encyclopedia", Blagstvoritelny Fond Yaroshinskoy, Moscow, 1996 (in Russian).
20. SOKOLOV V.E., RYABOV I.N., RYABTSEV I.A. *et.al.*, "Effect of Radioactive Contamination on the Flora and Fauna in the Vicinity of Chernobyl Nuclear Power Plant", Soviet Scientific Reviews, Section F, Harwood Academic Publishers. 1994.
21. "Medical Aspects of the Chernobyl Accident", IPHECA report, WHO/EHG 95.19, 1995 (in Russian).
22. "Transfer of Radionuclides to Animals, Their Comparative Importance under Different Agricultural Ecosystems and Appropriate Countermeasures", EC-Experimental Collaboration Project No. 9, Final Report, ECSC-EC-EAEC, Brussels, 1996.
23. "Radiation Dose to Liquidators", *Byulleten Natsionalnogo Radiatsionno-Epidemiologicheskogo Registra*, **2**, Obninsk, 1995 (in Russian).
24. TSYB A.F., "Development of the All-Union Register for the Sufferers from Radiation of the Chernobyl Accident", *Meditsinskaya Radilogiya*, 1989, No. 7, pp. 3-6 (in Russian).
25. IVANOV V.K., TSYB A.F. *et.al.*, "Radiation-Epidemiological Analysis of RSMDR Data about Participants in the Liquidation of the Chernobyl NPP Accident", *Atomnaya Energiya*, **78**(2), 121-127, 1995 (in Russian).
26. NIKIFOROV A.M., SHANTYR I.I. *et.al.*, "Radiation Dose to the Participants in the Liquidation of the Chernobyl Accident", International Conf. One Decade after Chernobyl: Summing up the Consequences of the Accident, Vienna., April 8-12, 1996. pp. 192-194 (in Russian).
27. KARPOV V.B., YAKOVLEVA N.G. *et.al.*, "Some Characteristics of Health Status of Liquidators of the Chernobyl Accident, Inhabitants in the Contaminated Territories and Participants of Nuclear Weapon Experiments", ibid., p. 338 (in Russian).
28. IVANOV E.V., BALONOV M.I. *et.al.*, "Concentration for Radiation, Medical and Social Protection of Inhabitants Suffering from Radiation Accident", ibid., pp. 342-343 (in Russian).

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