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Radiation legacy of the 20th century: Environmental restoration

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FOREWORD

As a result of events in the last century, mainly related to the development of nuclear energy, mankind has been forced to deal with the restoration of the environments which contain radioactive residues. Historically, the first areas requiring environmental restoration were those where the mining and milling of uranium and thorium ores were conducted and those affected by the processing and application of concentrated natural radionuclides, such as radium-226. In the second half of the century, when technologies were developing and radiation hazards were not clearly understood, a number of substantial discharges of fission products, some accidental, others deliberate, occurred resulting in the contamination of both production sites and local inhabited areas, for example, the Mayak facility in Urals, Russian Federation, and the Sellafield facility in the United Kingdom. Nuclear weapons tests conducted in the 1950s and 1960s led to radioactive contamination of some large continental areas (Semipalatinsk, Nevada, Maralinga) and of islands in the Pacific Ocean. The largest nuclear reactor accident, which occurred at the Chernobyl Nuclear Power Plant in 1986, caused the radioactive contamination of extensive territories in Europe.

The operation of nuclear facilities has led to the accumulation of large amounts of spent nuclear fuel used both for civil and military purposes as well as to the production of high level radioactive waste. In some facilities, a significant fraction of the spent fuel and radioactive waste, mainly originating from the early period of nuclear power, is stored in conditions which do not meet present safety requirements, for example, surface water bodies and underground cavities. Of the nuclear facilities now undergoing decommissioning, some are in conditions which threaten to create environmental contamination, for example, floating disused nuclear submarines. Accidents at some of these facilities could lead to contamination of both local and distant areas due to river, marine and atmospheric transport.

A number of scientific meetings have been devoted to various aspects of the environmental restoration of contaminated areas. At the International Symposium on the Restoration of Environments with Radioactive Residues held in Arlington, United States of America, from 29 November to 3 December 1999, many aspects of the rehabilitation problem were discussed with primary attention dedicated to the problems in the USA as the host country. In comparison, at the International Conference on “Radiation Legacy of the 20th Century: Environmental Restoration” (RADLEG-2000) held in Moscow, Russian Federation, from 30 October to 2 November 2000, a special focus was on the radioactive legacy of the countries of the former Soviet Union (FSU) and eastern Europe. By means of reviews and case studies, the conference assessed the overall situation with respect to the contaminated sites and sources of potential environmental contamination and evaluated the achievements of rehabilitation and remediation programmes as well as identifying future needs in this field.

This conference was organized by the Ministry of the Russian Federation for Atomic Energy (MINATOM) in co-operation with the International Atomic Energy Agency (IAEA), the European Commission (EC) and the Russian Academy of Sciences (RAS). It was co-sponsored by the International Science and Technology Centre, Russian Nuclear Society, Belgian Nuclear Research Centre SCK-CEN, All-Russian Research Institute for Chemical Technology and CH2M Hill International (USA). The conference was attended by 266 participants from 16 countries and 6 international organizations with 49 papers presented orally and 64 presented as posters. All of the orally presented papers as well as opening statements, summaries of the discussions and conference conclusions containing both major scientific findings and practical recommendations, are included in the present publication. The IAEA officer responsible for this publication was M. Balonov of the Division of Radiation and Waste Safety.

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OPENING SESSION
WELCOME ADDRESSES

E.O. ADAMOV

Ministry of Atomic Energy of the Russian Federation,
Moscow, Russian Federation

In the Russian Federation, we have, for the past decade, been endeavouring to establish an environmental restoration programme, but there is a problem of financing. The United States launched such a programme in the 1980s. The programme was to cost over US $200 billion, and half way through 1999 work costing over US $150 billion remained to be done. That is not too much for an affluent country like the United States, which started well before the Russian Federation.

When considering the man-made disasters of the 20th century, it is fair to ask whether those associated with the utilization of nuclear energy for military and peaceful purposes were the most severe. For example, many will recall the state of the river Rhine 25–30 years ago — a river which has since been thoroughly cleaned up; many will recall pictures published in the 1960s of a policeman in the Japanese city of Osaka wearing a respirator that looked like a gas mask — a scene which you will not witness if you visit Japan now. I deliberately mentioned Germany and Japan because they have not engaged in nuclear weapons development but have nevertheless had serious man-made environmental problems — with which they have coped successfully. On the other hand, those who have visited the Kola peninsula are unlikely to have seen any negative effects of the Kola Nuclear Power Plant, but they are also unlikely to forget how the area around the Monchegorsk Metallurgical Combine looks.

You will naturally all be wondering what I am going to say about the Chernobyl accident, so I shall now take up that subject.

All those who participated, in 1996, in meetings like the “One Decade after Chernobyl” conference held in Vienna will recall the uncomfortable questions about why so many people were evacuated for no sound environmental reason and why the almost 2000 children who had contracted thyroid cancer (a statistically significant consequence of the accident) did not receive the best possible medical treatment — or why it had been impossible for the international helpers to establish a statistically reliable picture of the public health situation in the affected areas before the accident.

As to the so-called liquidators and to the affected population in general, we all know that the impact of the Chernobyl accident was far less than, for example, the impact which the chemical plant accident in Bhopal, India, had on the people there. However, we have established for them social and medical arrangements comparable with those established for the Hiroshima and Nagasaki survivors — the results being a lack of motivation to work, hypochondria, fear and stress. We all know that parts of the areas affected by the Chernobyl accident have radiation levels lower than, for example, the state of Kerala, in India. Moreover, we all know that the 30-km zone around the Chernobyl Nuclear Power Plant was not very fertile and that far more land, of greater fertility, has been flooded in the course of hydroelectric power projects.

Until the early 1960s there were no serious safety standards, and those standards which did exist were often infringed in the course of nuclear weapons development and nuclear fuel cycle activities. Since the middle of the 1960s, thanks to good compliance with high safety standards, the morbidity among those working in the nuclear sector has been indistinguishable from that in the population as a whole, which has itself been exposed to an additional, man-made risk of only 10^{-5}–10^{-8}/year. I mention this in order to highlight the importance of ensuring that public resources are devoted to those environmental restoration problems which are of highest priority.

Why is so much attention paid to the impact of nuclear activities on people and on the environment? Of course, there is the harm which was done to the public consciousness by the completely unnecessary dropping of atomic bombs on Hiroshima and Nagasaki — and also the tendency of the mass media to focus not on real issues but rather on issues which lend themselves to a sensationalist approach and are likely to boost revenues. One real issue — perhaps the key one — is whether nuclear power will be recognized as essential for resolving the most daunting problem of the new century and the new millennium, the problem of mankind’s future energy supplies.

The fears of ordinary citizens, calmly smoking or drinking until they are blue in the face, are real fears. A hundred years ago, similar fears resulted in laws requiring that automobiles be preceded by someone carrying a flag, whereas now, in the Russian Federation, automobiles without catalyses are polluting our cities. Conferences like this one should not add to the fears of ordinary citizens, but help them to understand where their true interests lie in the face of the threat to mankind and the environment which now exists.

In the Russian Federation and elsewhere, the nuclear industry has proved that it is environmentally friendly. Conferences like this one should make that very clear, and they should also make it clear that in a country like the Russian Federation — with an annual national budget equivalent to only about US $20 billion — prioritization in the expenditure area is particularly important. In that connection, the calls being made for a move not towards greater nuclear power generation but towards greater use of coal — calls which we hear in the current “war” between RAO EEhS (the company controlling most of Russia’s electricity production) and Gazprom (the company controlling most of Russia’s oil and natural gas resources) — are very ominous.

Studies of our radiation legacy and efforts to rehabilitate contaminated areas should be part of an overall strategy for resolving our common environmental problems in a socially and economically sustainable manner. I hope you will also make that clear during this conference.

G. LINSLEY

International Atomic Energy Agency,
Vienna

On behalf of the Director General of the International Atomic Energy Agency (IAEA) I would like to welcome you to this Conference. As you know the Conference is organized by the Ministry of the Russian Federation for Atomic Energy (MINATOM) — the IAEA is one of the organizations which is cosponsoring the meeting.

This Conference, which is addressing the problems arising out of the legacy of environmental radioactive contamination is, in itself, a reflection of the concern and importance that all nations are nowadays giving to the environment and to its preservation. Yet it was only a few decades ago that there was an entirely different way of thinking about the environment. In the context of nuclear technology development, in that era, little attention was given to the environmental implications of the new developments, progress and production were the dominant considerations. In the early years of my own work I remember being introduced to the concept of “environmental capacity”, especially in the context of the disposal of wastes in the oceans, that is, how much radioactive material can an ocean accept without causing a radiation dose limit to be exceeded. This is a long way from the current environmental protection driven policies which seek to reduce concentrations of radionuclides to “close to zero” in the coastal waters of Europe (the OSPAR Convention).

The change in attitude towards the environment came about as a result of the visible effects on the environment of certain types of pollution e.g. acid rain, and was soon reflected internationally, first, at the UN Conference on the Human Environment in Stockholm in 1972, and more recently at the UN Conference on Environment and Development, which included the Rio Declaration, in 1992.

While these Conferences marked changing attitudes to the environment in general, it was the ending of the “Cold War” that brought about the real prospect of improving and restoring the environments which had been affected by radioactive contamination, due mainly to military related activities.

We are still at the early stages of this work — we still have to establish the full extent and nature of the problem, we are still developing appropriate restoration technologies and we are still trying to reach agreement on restoration safety criteria that, on the one hand, provide adequate protection for humans and the environment and, on the other hand, can be achieved within our available financial resources.

The IAEA has a role in all of these areas, firstly, by supporting conferences such as this and the one held in Arlington, USA last year — to which this meeting can be seen as a follow-up. The IAEA is also engaged in promoting information exchange on technology developments and has been active in building consensus on safety standards for the restoration of contaminated areas.

This Conference will have been a success if it promotes the exchange of new and useful information, if it allows us to learn useful lessons from the experience of others, and if it builds towards a consensus on what must be done and what can realistically be achieved given our often limited resources. I am confident that it *will be* a success.

D. GAMBIER

European Commission,
Brussels

Ladies and Gentlemen,

It is a pleasure for me to be attending this conference, which is supporting the ISTC.

The environmental issues affecting Russia and other countries of the former Soviet Union are very important for the whole of Europe. In September, the Commission's Commissioner for Research, Mr. Philippe Busquin, discussed with Russia's Minister Adamov the question of what could be done about those issues and concluded that assistance was a thing of the past; the emphasis should now be on science and technology co-operation between equal partners.

The science and technology co-operation agreement between the European Union and Russia, which is in the process of being finalized, will cover, inter alia, co-operation in the field of radioecology.

The European Commission is working together with Russia on several environmental issues — for example, the environmental situation in the Barents Sea. In addition, EURATOM's research programme includes radioecology projects in which Russian scientific institutions can participate as contractors or subcontractors.

Through the ISTC, the European Commission is supporting projects in Russia whereby people move away from military research to civilian research, and radioecology and the restoration of radioactively contaminated areas are undoubtedly suitable fields for such projects.

With regard to the RadLeg project, which is being supported by the European Commission, it is hoped that a market will arise for the information in the resulting database — information which will be useful in rehabilitation exercises.

When supporting such a project, the European Commission must bear in mind the question of self-sustainability; will the project provide for long-term employment? Much depends on continuing governmental support, which is absolutely essential. In addition, it is helpful to have the support of international organizations like the IAEA.

I believe that the RadLeg project will be self-sustainable to some extent if the Russian Government provides continuing support. It certainly deserves to be successful in the long term.

Yu.A. IZRAEL

Institute of Global Climate and Ecology,
Moscow, Russian Federation

Distinguished colleagues, I should first like to welcome you on behalf of the Russian Academy of Sciences.

The two topics of this conference — the radiation legacy of the 20^{th} century and environmental restoration — are important and related issues which should lead us to think also about how to prevent the future occurrence of radioactive contamination due to accidents involving nuclear and non-nuclear facilities and even to the normal operation of such facilities.

Many of you participated in the International Conference on Radioactivity after Nuclear Explosions and Accidents held here in Moscow from 24 to 26 April 2000, and the extensive discussions which took place during that conference will no doubt be highly relevant to this one.

A great deal of work has been done in studying radioactive contamination of the environment, and I have the feeling that many people think we know all — or nearly all there is to know about it. However, radioactive contamination of the environment is like a wild animal; you may have studied the habits of a particular specimen, but you cannot say much about the species as a whole. I would go as far as to compare radioactive contamination of the environment with a monster whose behaviour is constantly changing; from time to time we are surprised to discover, for example, the transfer of a radionuclide into a plant or along the food chain is proceeding in ways which differ not only as between different soil conditions but also as between different times, as if the radionuclide were ageing.

Consequently, while Minister Adamov gave us a brilliant insight into social and other aspects of environmental contamination, I should like to emphasize the importance of our continuing with the related scientific investigations — as a precondition for correct practical measures directed towards restoration and also towards the avoidance of environmental contamination in the first place. For we must realize that accidents are always possible, at both nuclear and non-nuclear facilities.

Very few of those present here today took part in the early work on developing nuclear weapons, but many took part in the effort to cope with the impact of the Chernobyl accident, and some of them are still carrying out Chernobyl-related scientific studies.

For even 14 years after the accident, it is still not clear why, after five days during which it had been cooling down, the crippled reactor started to heat up again, ejecting further radionuclides. We did not know whether to continue dumping lime on the reactor or lead — or to try something else. It was not clear which radionuclides would prove to be the most dangerous: strontium-90, iodine-131, tellurium-132, caesium-137, plutonium-239, plutonium-141? We shall no doubt be hearing about these radionuclides during this conference.

We need to understand these radionuclides when we are thinking about embarking on environmental restoration — their radioactive properties and also, for example, the ways in which they are transported in water. When restoring an area contaminated by radioactivity, we must not only do what is necessary but also avoid doing things that are unnecessary — or harmful. You can always clean up a contaminated area completely, but, quite apart from the excessively high costs incurred, you may, for example, by removing the topsoil so as to ensure that no plutonium-239 remains — create a dust bowl. That is one of the issues we should consider at this conference.

After the Chernobyl accident, scientists began studying not only the radioactive contamination resulting from that tragedy but also the radioactive contamination resulting from nuclear weapons testing and from other activities. Various international organizations became involved, and I am very glad that they did. In expressing my appreciation to those organizations, I would emphasize that their involvement has benefited not just the Russian Federation but all countries, for radioactive contamination of the environment can occur anywhere on our planet. Dealing with it requires the joint efforts of scientists at both the national and the international level.

I hope that this conference will be a valuable follow-up to the International Conference on Radioactivity after Nuclear Explosions and Accidents held here in April and that the two conferences will lead to further fruitful deliberations regarding the severe radiation contamination problems which so many of our countries have inherited.

SESSION 1

OVERVIEW OF AREAS CONTAMINATED WITH RADIONUCLIDES AND ASSOCIATED INTERNATIONAL PROJECTS

THE RADIATION LEGACY OF RUSSIA

V.A. LEBEDEV
Ministry of the Russian Federation on Atomic Energy,
Moscow, Russian Federation

Abstract

Nuclear weapons making and testing, operation of enterprises of the nuclear industry, of military and civilian nuclear fleet, as well as peaceful nuclear explosions – all that led in the USSR to release of radioactive products into the environment. In some parts of the FSU radioactive contamination exceeded permissible levels. The necessity of remediation of such territories became evident. The most part of the contamination resulted from major radiation accidents in Kyshtym (19570 and Chernobyl (1986).
Today those objects, as well as some sites of radwaste storage and disposal, written-off nuclear submarines with non-unloaded spent nuclear fuel, some floating and on-shore repositories of nuclear fleet's radwaste and spent nuclear fuel, pose a potential hazard to the biosphere.
Appropriate measures aimed at decreasing their impact on the population and environment are needed. Such measures should include both restoration of contaminated lands and social support programs for the population affected by radiation. The main task of the rehabilitation is reduction of consequences of internal and external exposure of the people, creation of necessary conditions for efficient and safe economical activities. Concrete objectives should be determined, as well as principles and standards to ensure radiation safety when conducting remediation works, and also – specifications for evaluation of the lands condition prior to their remediation, criteria of decision-making, rehabilitation planning, techniques of the lands' restoration and recommendations for their future uses.
The Russian Federal special program "Radioactive Waste and Spent Nuclear Materials Management, Utilization and Disposal for 1996–2005" envisages studies on Russia's radiation legacy's assessment on the basis of up-to-date information technologies of computer-based systems for data collection, storage and processing for accounting and analysis of information on availability, origin, physical & chemical characteristics, location of radioactive materials on the territory of Russia. In the last years the works were carried out successfully within the framework of the International Science & Technology Center # 101 KURGAN and # 245 RADLEG and of some other international and national projects.

1. INTRODUCTION

During more than a half a century after the World War II military and civilian uses of atomic energy in Russia have led to creation of nuclear industry, accumulation of huge arsenals of nuclear weapons. The emergence of radiation factor in economic and military activities, nuclear weapons creation, testing and reduction made urgent the task of assessment of the radiation legacy after the Cold War ending and long-term forecasting of consequences of the impact on the biosphere and noosphere.

The problem of radiation legacy still remains the most important object of attention of institutions and enterprises of the Russian nuclear industry, as well as foreign experts and a number of international organizations. Collection and analysis of data on various elements of the radiation legacy and their impact on the environment and population health are a top priority task, from the point of view of both outlays for rehabilitation and prevention or reduction of probable damage in future, taking into account nuclear energy use in various spheres of human activities, that must be based on improvement of hygienic standards and means of radiation control.

2. THE STATE OF THE ART

Nuclear weapons production and testing, operation of nuclear industry's enterprises, military and civilian nuclear fleet and nuclear peaceful explosions in the USSR led to release of radioactive products into the environment. Radioactive contamination in some parts of the USSR exceeded permissible limits. The necessity of restoration of such territories became imminent. An overwhelming part of the contamination resulted from major radiation accidents in Kyshtym (1957) and Chernobyl (1986).

Today the objects, as well as some sites of radioactive waste storage and disposal, written-off nuclear submarines with unloaded spent nuclear fuel (SNF), on-shore and floating SNF and radwaste repositories of the nuclear fleet, are potentially hazardous to the biosphere.

For the present in Russia about 650 mln. m^3 of liquid and solid radioactive wastes with total activity about 2.0 billion Ci have been accumulated. In the Table 1 distribution of the amount of radwaste by origin and place of storage is presented. More than 90% of the radwaste — from former military activities for nuclear weapon-grade materials production — is concentrated at the sites of Minatom of Russia. Besides, at the sites of Minatom and other agencies of Russia about 12,000 tons of SNF are kept with total activity of about 8.2 billion Ci.

The total area of lands contaminated with radionuclides as a result of activities of the Minatom's enterprises within the limits of their observation zone is about 480 km^2 (Table 2). The most part of the contaminated territories is related to sanitary & protective and observation zones of the enterprises. It is connected with emergency situations and incidents, which have led to one time releases of radioactive substances. About 15% of the total area contaminated with radionuclides have the highest levels of γ-radiation exposure rate-above 200 μR/h (Table 3).

At enterprises of nuclear fuel cycle, nuclear weapons complex, at research institutions the contamination is determined by radionuclides of caesium, strontium, plutonium; at ore mining and processing enterprises, nuclear fuel manufacturing plants it is determined by uranium, radium, thorium nuclides.

The most part of the contaminated areas (94%) falls on the "Mayak" combine neighborhood, that is linked with its foregoing activities. A State special complex program of the Russian Federation on social and radiation rehabilitation of the population and lands of the Urals region affected by the "Mayak" Industrial Association activities had been authorized (for the time period till 2000).

TABLE 1. RADIOACTIVE WASTES (RW) AND SPENT NUCLEAR FUEL (SNF) IN THE RUSSIAN FEDERATION, AS OF 01.01.2000

Ministries, agencies and organizations	Liquid RW		Solid RW		SNF	
	M^3	Ci	M^3	Ci	T	Ci
Minatom of Russia: uranium ore mining and processing; uranium isotope enrichment; nuclear fuel manufacturing; electric power production at NPPs; SNF reprocessing; RW and SNF storage and disposal	$5.2 \cdot 10^8$	$2.2 \cdot 10^9$	$2.3 \cdot 10^8$	$3.1 \cdot 10^8$	12,000	$8.0 \cdot 10^9$
Defense Ministry of Russia (Navy): nuclear ships and submarines operation and dismantling	$1.5 \cdot 10^4$	$1.9 \cdot 10^2$	$1.3 \cdot 10^4$	$8.0 \cdot 10^2$	70	$2 \cdot 10^8$
Rossudostroyeniye (Federal Agency for Shipbuilding)	$2.6 \cdot 10^3$	$5.5 \cdot 10^2$	$1.5 \cdot 10^3$	$2.1 \cdot 10^4$	-	-
Ministry of Transport of Russia: nuclear icebreakers operation and dismantling	$4.0 \cdot 10^2$	1.0	$1.5 \cdot 10^3$	$2.1 \cdot 10^4$	10	$4.7 \cdot 10^7$
“Radon” special combines: processing and disposal of radioactive materials used in medicine, scientific research, industry	-	-	$2.0 \cdot 10^5$	$2.1 \cdot 10^6$	-	-
Total	$5.2 \cdot 10^8$	$2.2 \cdot 10^9$	$2.3 \cdot 10^8$	$3.1 \cdot 10^8$	12080	$8.2 \cdot 10^9$

TABLE 2. LANDS CONTAMINATED WITH RADIONUCLIDES AT ENTERPRISES OF THE MINATOM OF RUSSIA, AS OF 01.01.2000, km^2

Enterprise	Total	Production site	Sanitary and protective zone	Observation zone
Priargun Mining&Chemical Association	8,53	7,33	0,78	0,42
Mining&Metallurgical Plant (Lermontov)	1,34	1,07	0,27	-
Machine-Building Plant (Elektrostal)	0,26	0,01	0,13	0,12
Novosibirsk Plant of Chemical Concentrates	0,15	0,07	0,08	-
Moscow Plant of Polymetals	0,016	0,002	0,014	-
Chepetsk Mechanical Plant (Glazov)	1,35	1,34	0,01	
Zabaikalsky Mining&Enrichment Combine	0,04	0,04	-	-
“Mayak” Industrial Association	452,16	38,46	217,54	196,16
Mining&Chemical Combine (Zheleznogorsk)	4,70	4,29	0,07	0,35
Siberian Chemical Combine (Seversk)	10,39	10,09	0,30	-
Kirovo-Chepetsk Chemical Combine	0,70	0,17	0,15	0,38
All-Russia Research Institute of Technical Physics (Snezhinsk)	0,13	0,13	-	-
Research Institute of Atomic Reactors (Dimitrovgrad)	0,39	0,15	0,24	-
Total	480,32	63,25	219,64	197,43
Without “Mayak”	28,16	24,79	2,10	1,27

TABLE 3. LANDS CONTAMINATED WITH RADIONUCLIDES AT ENTERPRISES OF THE MINATOM OF RUSSIA WITH EXPOSURE RATES ABOVE 200 μR/HOUR, AS OF 01.01.2000, km^2

Enterprise	Total	Production site	Sanitary and protective zone	Observation zone
Mining&Metallurgical Plant (Lermontov)	1,03	1,018	0,012	-
Machine-Building Plant (Elektrostal)	0,261	0,009	0,132	0,12
Novosibirsk Plant of Chemical Concentrates	0,14	0,07	0,07	-
Moscow Plant of Polymetals	0,001	0,001	-	-
Chepetsk Mechanical Plant (Glazov)	0,062	0,059	0,003	-
“Mayak” Industrial Association	65,70	17,70	38	10
Mining&Chemical Combine (Zheleznogorsk)	0,203	0,19	0,013	-
Siberian Chemical Combine (Seversk)	4,191	4,026	0,165	-
All-Russia Research Institute of Technical Physics (Snezhinsk)	0,01	0,01	-	-
Research Institute of Atomic Reactors (Dimitrovgrad)	0,081	-	0,081	-
Institute of Physics and Power Engineering (Obninsk)	0,001	0,001	-	-
Total	71,68	23,08	38,48	10,12
Without “Mayak”	5,98	5,38	0,48	0,12

TABLE 4. RESTORATION OF CONTAMINATED LANDS AT ENTERPRISES OF THE MINATOM OF RUSSIA IN 1993-1999, THOUS. m^2 [1, 2]

Enterprise	1993	1994	1995	1996	1997	1998	1999
Priargun Mining & Chemical Association	5,0	280	140	100	–	–	–
Almaz State Enterprise	124	18	–	–	133,5	–	–
Novosibirsk Plant of Chemical Concentrates	1,5	–	0,8	1,0	0,8	2,1	20
Moscow Plant of Polymetals	3,8	0,5	0,1	–	0,4	–	0,1
Siberian Chemical Combine	9986	7838	305	–	–	–	–
All-Russia Research Institute of Chemical Technology	–	–	2,0	–	0,01	0,7	0,3
Institute of Theoretical and Experimental Physics	0,1	0,03	–	0,02	0,03	0,01	0,01
All-Russia Research Institute of Experimental Physics	–	30	–	–	–	–	–
TOTAL	10120	8168	448	101	135	2,8	20

In 1993-1995 at the Siberian Chemical Combine 18 km^2 of lands contaminated as a result of 1993 accident and industrial activities in preceding years were remediated.

TABLE 5. LIST OF FIRST PRIORITY WORKS ON RESTORATION OF CONTAMINATED LANDS AT ENTERPRISES OF THE MINATOM OF RUSSIA FOR 2001-2010, $км^2$ [1,2]

Enterprise	2001-2005	2006-2010
Priargun Mining & Chemical Association Hydro-Metallurgical Plant	4,50 0,528	2,50 -
Machine-Building Plant Novosibirsk Plant of Chemical Concentrates Moscow Plant of Polymetals Chepetsk Mechanical Plant Trans-Baikal Ore Mining & Enrichment Combine	0,04 0,04 0,015 0,23 0,016	0,12 0,046 - 0,24 0,07
Mining & Chemical Combine Siberian Chemical Combine Kirovo-Chepetsk Chemical Combine	0,347 1,90 0,529	0,068 2,00 -
All-Russia Research Institute of Experimental Physics All-Russia Research Institute of Chemical Technology Radium Institute	0,050 0,0022 0,0022	0,050 - 0,001
Total	8,3	5,2
In total under the program-13,5 $км^2$		

The rehabilitation works are being conducted at a slow pace (Table 4). The areas restored in last years and destined for use as construction sites or for sanitary & hygienic purposes are as follows: 1996-0.10 km^2; 1997-0.135 km^2; 1998-0.003 km^2; 1999-0.02 km^2. Rehabilitation of 13,5 km^2 of contaminated lands is planned to be carried out by 2010 (Table 5).

3. THE ELABORATION AND IMPLEMENTATION OF THE STATE TECHNICAL POLICY IN THE FIELD OF RADIATION LEGACY MANAGEMENT

The Government of the Russian Federation authorized the Federal Special Program "Radioactive Waste and Spent Nuclear Materials Management for 1996-2005" by its Decree # 1030 of October 23, 1995. Enterprises and institutions of 16 ministries and agencies take part in implementation of the Program's actions, the Minatom of Russia being determined as the state customer of the Program. (Fig. 1).

The program is aimed at elaboration and realization of the state technical policy, when handling radioactive wastes (RW) and spent nuclear fuel (SNF), on the basis of observation of the up-to-date specifications to ensuring radiation, nuclear and environmental safety.

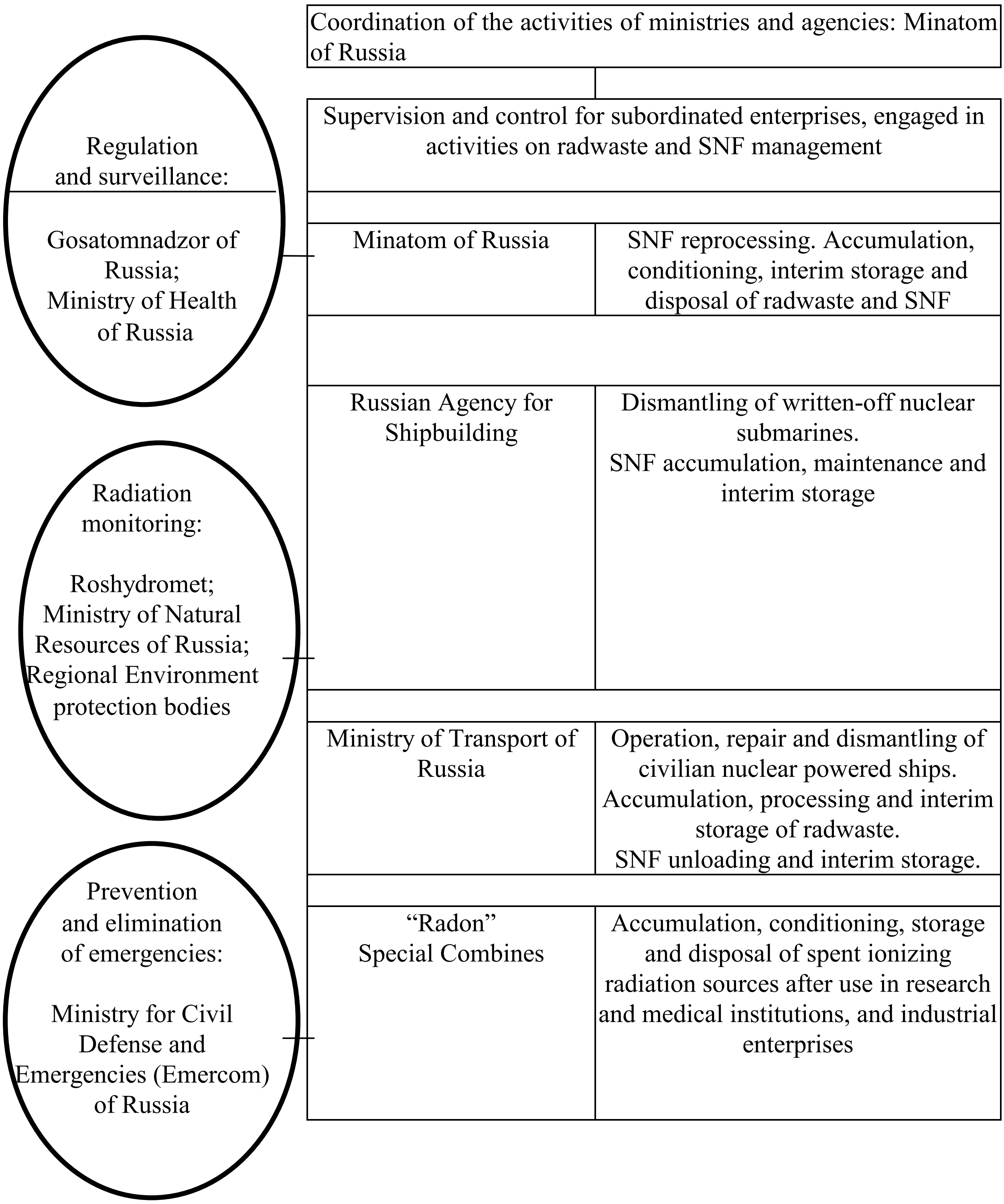

FIG.1. Coordination of the activities of ministries and agencies in the area of radioactive wastes management.

The main objective of the program are consistent and purposeful efforts for minimization of radiation impact on the population and the personnel, natural environment protection against radioactive contamination at all stages of management wastes accumulated as a result of past and current activities for providing the country’s defense capability, nuclear power production and in scientific research.

The program of ensuring environmental safety while the RW and SNF management, remediation of contaminated lands is many-sided and sophisticated one, including various types of operation of enterprises of the nuclear power industry and nuclear fuel cycle, nuclear weapons sector, civilian nuclear fleet and nuclear Navy, as well as research and designing institutions and specialized enterprises for RW processing and disposal (the *Radon* special combines).

4. THE RESULTS OF WORKS IN THE MAIN SECTORS OF THE RADIATION LEGACY OF RUSSIA

4.1 Uranium ore mining, enrichment and processing, uranium isotope enrichment, nuclear fuel manufacturing

At uranium ore mining & milling enterprises more than 300 million tons of solid wastes have been accumulated for the present (dumps of barren rocks and unamenable ores, etc.) and about 60 million m^3 of liquid wastes in tailings dumps. Their total activity brought about by radionuclides of uranium and their decay products is about 189 thousand Ci. The total area occupied by the dumps is 9.871 km^2, including 1.03 km^2 with exposure rate above 200 μR/hour.

At the former enterprise *Almaz* (the Stavropol Land) the total area of contaminated lands is 1.67 km^2 , including 0.45 km^2 within the limits of the production site. Tailings dumps of the hydro-metallurgical plant are the major environmentally hazardous object. A restoration project planned for 10 years envisages phosphate containing gypsum accumulated as a result of apatite processing at a fertilizers production plant to be used as the isolation material.

At chemical & metallurgical enterprises for nuclear materials and fuel elements production more than 600 thousand m^3 of liquid RW and about 5 million tons of solid RW, containing radionuclides of uranium, thorium and their decay products with total activity above 4200 Ci, are accumulated. The total area of lands contaminated with the radionuclides is 1.868 km^2, including 0.464 km^2 with exposure rates from 200 to 1000 μR/h.

4.2 Nuclear power plants

The radwaste processing at NPP sites is aimed at the waste conversion into a stable physical & chemical form, which would to maximum degree prevent the radionuclide release outside the limits of the matrix material and engineered barriers (Table 6).

On the basis of the Federal Radwaste Management Program a working program of the *Rosenergoatom* concern for radwaste management at nuclear power plants was elaborated. The main tasks in this field are NPPs' equipping with appropriate facilities for radwaste processing as well as restoration and construction at the NPP sites of radwaste storage facilities, ensuring environmental safety of the plants. For that purpose the optimal radwaste management strategy is determined for each nuclear power plant, issuing from the real financial situation, on the basis of assessment of the NPP operation experience, actual achievements of the home and foreign science and engineering in this field.

The issue of spent nuclear fuel (SNF) storage is becoming aggravated at nuclear power plants, first of all those with RBMK type reactors. The final solution is to be found out concerning the outline of RBMK reactors' spent nuclear fuel management. Long-term aqueous storage of

SNF leads to the fuel's gradual deterioration and makes the last stage of the SNF management more expensive. In 2001 within the framework of the 2nd stage of the RT-2 plant at the Mining & Chemical Combine in Zheleznogorsk it is supposed to start construction of a "dry" SNF repository, which could provide safer storage conditions.

TABLE 6. AMOUNTS OF RADWASTE GENERATED (PER ANNUM)AND THEIR CHARACTERISTICS FOR DIFFERENT TYPES OF NUCLEAR POWER UNITS [3]

Waste types	VVER-440	VVER-1000	RBMK-1000
Boiler residue sent into liquid radwaste storage facility, m^3/year	120-170	220-230	1000-1200
Mean salt content in the boiler residue, g/L	300-400	300-400	200-250
Total amount of salts, t /year	50	90	250
Specific activity of the boiler residue, Bq/L	$2{\cdot}10^6$	$2{\cdot}10^6$	$2{\cdot}10^6$
Low-level activity sorbents, m^3/year	8.0	16	62
Specific activity, Bq/kg	$1{\cdot}10^8$	$4{\cdot}10^7$	$4{\cdot}10^7$
High-level waste, m^3/year	3.0	5.3	22
Specific activituy, Bq/kg	$2{\cdot}10^9$	$2{\cdot}10^9$	$2{\cdot}10^9$
Perlite, m^3/year	-	-	9.0
Specific activity, Bq/kg	-	-	$1{\cdot}10^8$
Solid radwaste, m^3/year	200	300	400

4.3 Research nuclear reactors and nuclear research centers

In 1999 there were 50 operating research nuclear reactors, critical and sub-critical assemblies (of the total number of 109) in Russia, 53 facilities were put in a laid-up mode of operation or in a stage of decommissioning, there were also 6 facilities in construction. Spent nuclear fuel from the research facilities was concentrated mainly at the sites of Russian Research Center "Kurchatov Institute", Institute of Physics and Power Engineering, Research Institute of Atomic Reactors, Sverdlovsk Branch of the Research and Development Institute of Power Engineering, St.Petersburg Institute of Nuclear Physics of the Russian Academy of Sciences and Karpov Research Physical & Chemical Institute's Branch in Obninsk. The SNF interim storage facilities are filled up to 80% on average. Increased outlays for SNF transportation and reprocessing led to practically complete cessation of its removal from the research centers.

The main tasks in this sector are as follows:

- disassembling and putting into dead storage of research nuclear reactors, critical assemblies and test benches, liquid radwaste underground disposal sites;
- creation of facilities for radwaste conditioning, restructuring or elimination of radwaste storage facilities;
- decontamination of technical equipment, production compartments, buildings and territories.

4.4 Military nuclear materials production and radiochemical reprocessing of spent nuclear fuel

The main tasks to be solved at enterprises of the Department of Nuclear Fuel Cycle of the Minatom of Russia (“Mayak” Industrial Association, Siberian Chemical Combine, Mining & Chemical Combine) are as follows:

— creation of complexes for conditioning of all kinds of radwaste accumulated at radiochemical plants of the Minatom of Russia;

— putting into dead storage and/or liquidation of put out of service reservoirs, sludge storage facilities, basins and ponds used for radwaste interim storage;

— closing down of put out of service liquid radwaste underground disposal sites;

— technological process and technical equipment development for conditioning of radwaste resulted from dismantling and putting production nuclear reactors into stand-by mode of operation;

— cleaning-up of Yenisei and Tom’ rivers’ floodplain areas from radioactive contamination resulted from production nuclear reactors’ operation;

— cleaning-up of structures, industrial compartments and equipment contaminated with radionuclides.

At the “Mayak” IA works were carried out on the Karachai lake filling up with soil (since 1951 the lake had been used for discharge of medium-and high-level liquid radwaste). Stage-by-stage liquidation of the water reservoir was started in 1988. For the present, as a result of carrying out restoration actions the Karachai lake average area has reduced by more than three times (to 100 thousand m^2), that has allowed to decrease significantly the windy carrying away of radioactive aerosols from the water surface and shore line. Presently the works are coming to end.

At the Mining & Chemical Combine by the moment of the Program’s authorization two of three production uranium-graphite reactors had already been shut-down. Many years operations of the reactors led to accumulation of radioactive silts in ponds for the production cooling, storage and reloading, and also to contamination of the Yenisei River floodplain areas. As a result of the single-pass reactors’ shutdown the radionuclide discharge into the Yenisei River has reduced by more than ten times, and for the present the water surface exposure rate does not exceed values set by the authorized rules beginning with the discharge point.

Works have been carried out in order to bring the shut-down AD and ADE-1 reactors into nuclear-safe condition. Works are being conducted now on preparing the reactors to long-term laying up: about 70% and 40% of the necessary amount of works have been carried out at the AD and ADE-1 reactors, respectively. Works on the radiochemical plant’s decommissioning are on. One of the actions to be performed is the storage-reservoirs’ discharge from radwaste and their decontamination followed by putting into dead storage.

Preparatory works are being carried out on abolition of open radwaste storage ponds (Nos. 354, 354a, 365, 366), a project is being developed for long-term radwaste and spent nuclear fuel storage in the M & CC mining workings.

4.5 Military and civilian ship propulsion nuclear power facilities, their service enterprises, waste repositories, sunk and dumped objects

By the RF Government's Decree No. 518 of May 28, 1998 "On Measures for Acceleration of Dismantling of Nuclear Submarines and On-Surface Nuclear-Powered Ships Put out of the Combat Service in the Navy and Environmental Rehabilitation of the Navy's Radiation-Hazardous Objects" the Minatom of Russia is determined as the works' state customer and coordinator.

For the present 184 nuclear submarines have been written-off from the Navy (Table 7). 108 of them are in the North-West Russia (the Murmansk and Archangel Regions), 76 ones – in the Far East (the Primorsk Land and Kamchatka Region) [4].

TABLE 7. NUCLEAR SUBMARINES DECOMMISSIONING IN RUSSIA (VERIFIED DATA AS OF THE END OF DECEMBER 2000) [4]

Submarines	Northern Fleet	Pacific Fleet
Written-off from the Navy	108	76
With unloaded SNF from the reactors	48	32
With SNF non-unloaded from the reactors	60	44
Dismantled with formation of single-, three-and multi-compartment units	42	18
Sent to plants for scrapping	29	

Spent nuclear fuel is not unloaded from the most part of the written-off nuclear submarines. 42 nuclear submarines in the North-West of Russia and 18 ones in the Far East nave been dismantled with formation of single-, three and multi-compartment units.

A number of the nuclear submarines were written-off more than 10-15 years ago, and such a long staying afloat has led to emergence of defects in the vessels' structures. Most of the submarines with non-unloaded SNF on board have lost leak-tightness of the main dead-weight tanks and can sink. The nuclear submarines with non-unloaded SNF make serious radiation hazard to the environment.

In this connection in the Murmansk and Archangel Regions, Primorsk land and Kamchatka the issues of environmental and radiation safety, i.e. the level of protection of people, natural environment and vitally important interests of citizens, the society, the state against harmful effects while carrying out works on the nuclear submarines dismantling, are becoming particularly urgent.

The Minatom's strategy aimed at solving problems of making normal the radioecological situation in those regions includes:

- acceleration of the rates of SNF unloading from nuclear submarine reactors and ensuring the SNF safe management;

— removal of SNF from floating and on-shore repositories, which do not meet the authorized rules of SNF safe management;
— land remediation and decontamination of structures at on-shore technical bases of the Navy;
— ensuring of all the safety aspects (radiation, nuclear, explosion, fire, stability and non-sinking) while the ships' maintenance at moorings;
— creation of radwaste management infrastructure, including construction of reactor compartments' storage facilities;
— construction of regional burials for radwaste disposal.

In order to rise the efficiency of the process of management and decision-taking on the issues of nuclear submarine decommissioning an information & analytical system is being created now to support realization of the industrial operations on complex utilization of nuclear submarines and on-surface nuclear-powered ships. More detailed information concerning the system is given in [5].

In the Murmansk Region, besides objects linked with dismantling of nuclear submarines, the *Imandra* floating technical base, providing works on SNF unloading from the nuclear ice-breakers' reactors, and *Atomflot* repair & technological enterprise of the Murmansk Marine Steamship Lines, engaged in reprocessing of nuclear ice-breaker fleet's liquid radwaste, are operating.

In the near years the following tasks are to be solved under the Federal special program:

— up-grading of the operating facilities and creation of new ones for the purpose of radwaste conditioning and storage at the *Atomflot* enterprise, ship-repair enterprises of the Russian Agency on Shipbuilding and of the Navy;
— creation of technical means for processing of radwaste generated in the process of dismantling and decommissioning of on-shore engineered constructions and auxiliary vessels for nuclear technological service, providing the radwaste disposal;
— working out of technological processes and making technical means for utilization of nuclear submarine reactor compartments and nuclear powered ships' reactors;
— up-grading of the operating SNF storage facilities and construction of new ones at objects of the Minatom of Russia, Russian Agency on Shipbuilding, Ministry of Transport of Russia and the Navy;
— completion of mitigation of consequences of the nuclear accident in Chazhma Bay [3].

A comparative study of activity of radwaste dumped in the Arctic seas, North Atlantic and Far East has been carried out by specialists of the RRC *Kurchatov Institute* [6]. For the present the total activity of radwaste dumped in those regions has reduced essentially, and now it is 113, 430 and 529 kCi, correspondingly (Fig.2). The data are put into the IAEA databank. It has been established with confidence that the image of the Arctic as a region with the potentially most hazardous radiation situation has nothing in common with reality.

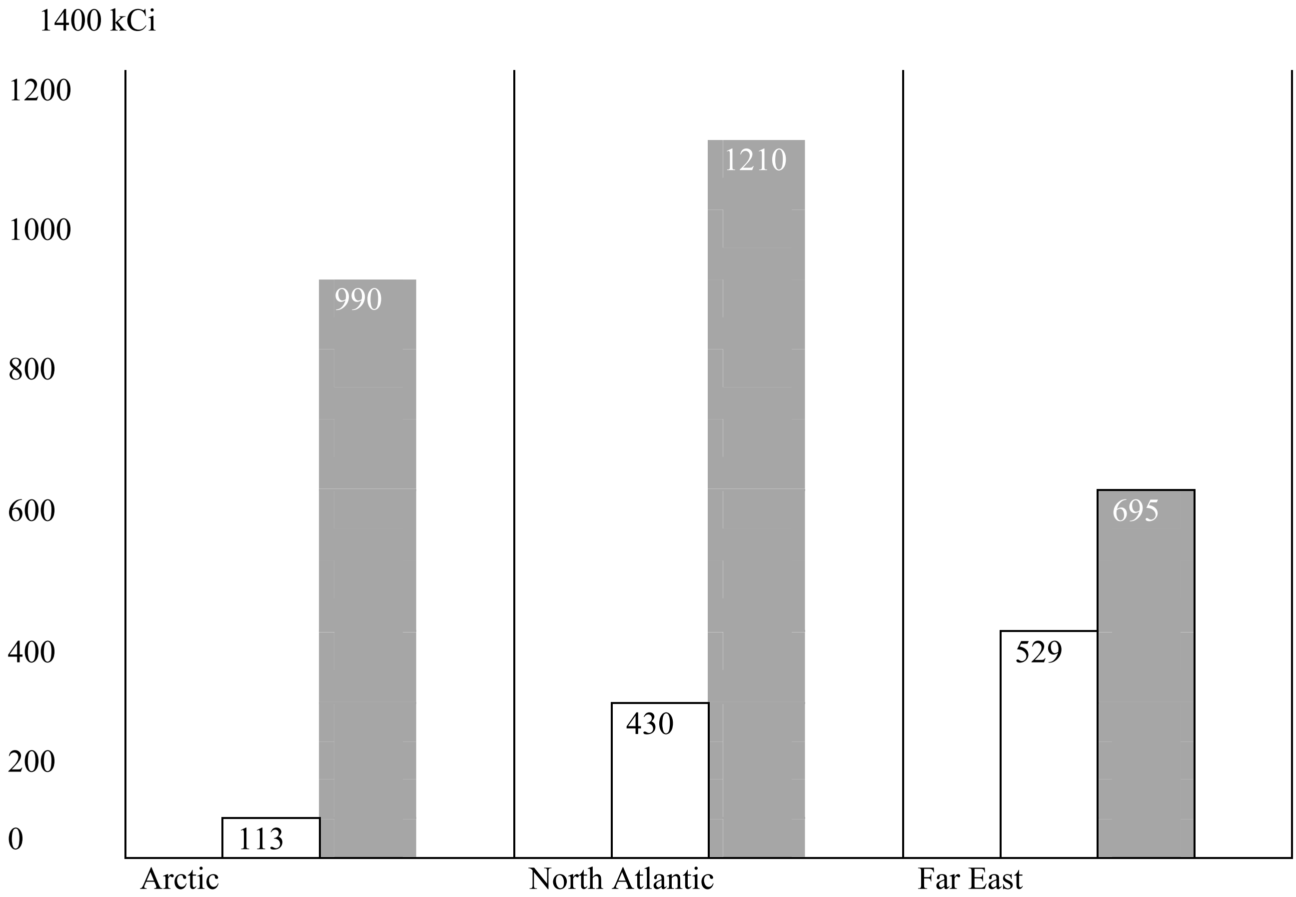

FIG.2. The total activity of the formerly dumped radwaste [6].

□ -in 1999 (taking into account the radioactive decay).

■ -at the moment of dumping.

Dose up-takes by critical groups of population of coastal areas of the Arctic, North Atlantic and Far East in result of consuming sea food products supposedly contaminated with radionuclides were evaluated. The doses were shown not to exceed tenths and hundredths fractions of a percent of natural radioactive background exposure. Basing on the data, a conclusion has been made on the absence of radiation hazard linked with formerly dumped radwaste. The conclusion is included into the final report on the International Arctic Seas Activity Program (IASAP).

4.6 Peaceful nuclear explosions

In the time period from 1965 to 1988 at 50 objects in the territory of Russia 81 nuclear explosions were conducted for various experimental, industrial and scientific research purposes. The explosion sites and their technological destination are shown in Fig.3 [7]. In total 84 charges were detonated with energy yields from 0.3 to 38 kt (at two objects camouflet explosions were conducted). The total energy yield of peaceful nuclear explosions reached 0.75 Mt or 2% of the value for all underground nuclear explosions in the FSU. Central zones of underground nuclear explosions are, as a matter of fact, solid and liquid radwaste burials, containing mainly ^{90}Sr, ^{137}Cs, ^{3}H and α-emitting radionuclides disposed in various hydro-geological environment.

Radioecological situation at about 30% of the peaceful nuclear explosions' objects in the near 10 years is forecasted to be unstable, and it will depend on a number of factors:

- radioactive products' yield as a result of explosion;
- the time and conditions of the object's operation;
- probability of hydro-geological effect resulted from neighboring oil & gas fields and water-pumping wells on the explosion's central zone.

Depending on the listed factors and turned out in reality or forecasted radioecological situation, the following groups of explosions can be distinguished, according to the degree of radiation risk:

(1) Emergency objects (incomplete camouflet action explosions): Globus –1, Kraton-3, Kristall and Taiga.

(2) Objects with unstable radioecological situation, which is changing in the process of operation and by influence of other factors: Butan, Grifon, Gelii, Kama-1, Kama-2, Magistral, Sapfir-1, Sapfir-2.

(3) Objects temporarily closed down, which need remediation or can in perspective undergo external hydrodynamic influence: Dniepr, Vega, Tavda, Kvarts-3, Rubin-1, Neva, Gorizont-2, Pirit, Angara.

The first group's objects are the most hazardous, at the second group's objects the radiation hazard is changing occasionally and is under control of operating organizations.

The Federal special program "Nuclear and Radiation Safety of Russia for 2000-2006"envisages realization of actions aimed at providing of environmental safety in regions, where the underground peaceful nuclear explosions had been conducted.

The main tasks for the near period of time:

- to carry out examination of the underground peaceful explosions sites and compose environmental passports describing the radiation situation in the regions where the peaceful nuclear explosions had been conducted;
- to put into dead storage or abolish, if necessary, technological structures, to clean up contaminated territories and provide the radwaste confinement.

Under the Federal special program works were carried out on examination of underground peaceful nuclear explosions sites, the main attention being paid to emergency objects: *Kraton-3* (Yakutia), *Globus-1* (Ivanovo Region), *Taiga* (Perm Region) and *Kristall* (Yakutia), and also – to operating objects: *Grifon* (Perm Region), *Benzol* (Tyumen Region), *Butan, Kama-1, Kama-2* (the Republic of Bashkortostan).

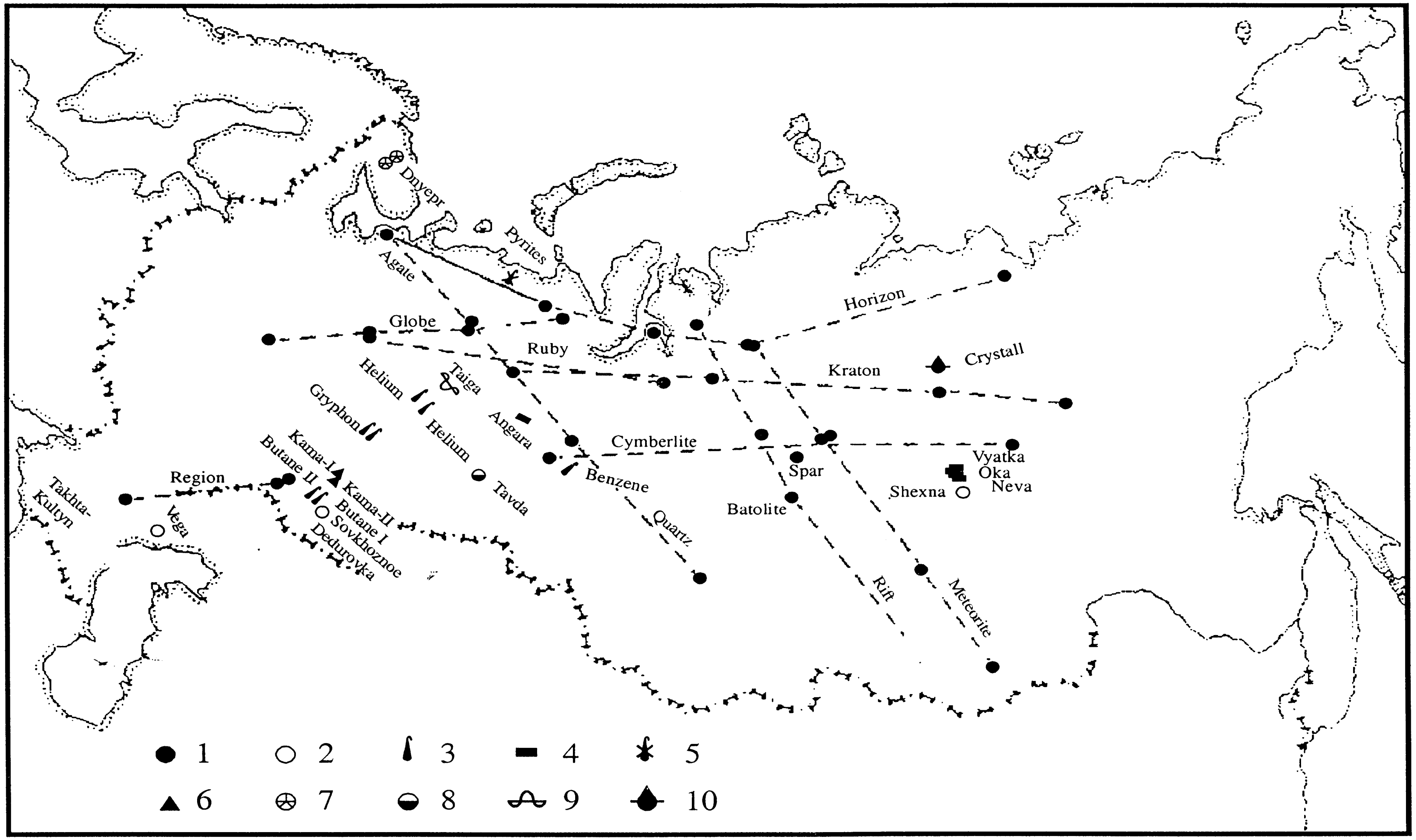

FIG.3. Sites of conducting of underground peaceful nuclear explosions: 1-deep seismic exploration of the ground (seismic profiles); 2 –creation of underground reservoirs in salt; 3-intensification of oil extraction at the stage of operation; 4 – intensification of oil and gas inflows at the stage of exploration; 5 – liquidation of oil gushers; 6 – burial of liquid toxic wastes; 7 – ore crushing; 8 – underground storage facility in clay; 9 – ground excavation; 10 – ground loosing.

On the basis of a tripartite agreement between the Minatom of Russia, the Republic of Sakha (Yakutia) and the *Alrosa* Joint-Stock Company a feasibility study is being carried out for a project of restoration of the *Kraton-3* and *Kristall* objects' contaminated lands.

In accordance with the new radiation safety rules and regulatory documents, criteria of radiation safety while remediation of contaminated lands have been worked out. The situation at emergency objects *Globus-1* (Ivanovo Region) and *Taiga* (the North of Perm Region) still remains to be the most complicated and indefinite because of the lack of a source of financing [3]. In summer 2001 at the *Taiga* object radioecological studies are planned to be carried out for the purpose of working out measures on sanitary & protective zone formation.

4.7 Specialized *Radon* enterprises for low and medium level radwaste management

The main goal of the *Radon* special combines' activities is the population and natural environment protection against the impact of radioactive materials.

The *Radon* special combines provide services on taking and storage of low and medium level radwaste resulted from activities of industrial enterprises, research institutions, medical organizations and other objects of the national economy, using radioactive materials and ionizing radiation sources, and also perform examinations and elimination of consequences of radiation accidents and cleaning up of radioactively contaminated sites at the territories under their jurisdiction.

The main tasks of the *Radon* system are as follows:

- to equip the special combines with up-to-date complexes for radwaste and spent ionizing radiation sources' conditioning;
- to up-grade the existing radwaste repositories and auxiliary engineered structures and to construct new ones;
- to create computerized radwaste accounting systems [3].

5. LEGAL & REGULATORY AND INFORMATION SUPPORT OF WORKS IN THE FIELD OF RADWASTE, SPENT NUCLEAR MATERIALS AND RADIATION LEGACY MANAGEMENT

In accordance with the Federal special program "Radioactive wastes and spent nuclear materials management, their utilisation and disposal for 1996-2005" a complex of works is being carried out on creation of up-to-date system of regulatory documents in the field of radwaste and spent nuclear materials management. Works carried out by the Minatom of Russia, Gosatomnadzor (Federal Authority for Nuclear and Radiation Safety) of Russia, State Committee of Russia on Environmental Protection and the Ministry for Health Care of Russia resulted in development and putting in force in 1998 of a regulatory document "The Conception of Formation of a Structure of the System of Rules, Regulating the Ensuring of Radioactive Waste Management Safety". On the basis of the conception a structure, including 22 regulatory documents, has been developed [3].

One more direction of the Federal special program's implementation is the inventorying of sites of radwaste and SNF concentration at enterprises and institutions of various departmental subordination. On the basis of the inventorying of sites of radwaste and SNF concentration conducted in 1993, the State Cadastre of Sites of Radwaste and SNF Concentration for 89 subjects of the Russian Federation was composed. In 1998 works on creation of regional and departmental cadastres of accumulated radwaste and contaminated lands wads continued. In 2000 a regular detailed inventorying of sites of radwaste and SNF concentration was started. It has to be completed in 2001. Further development of the works is linked with functioning of the State System of Radioactive Materials and Radioactive Wastes Accounting and Control [8] and also – with formation and support of the Environmental Geoinformation cadastre of the Minatom of Russia (Fig.4).

The first systematic description of the USSR radiation legacy was initiated in 1993 by the Russian Academy of Sciences, Minatom of Russia, Kurchatov Institute and International Institute for Applied Systems Analysis (IIASA). Russian experts, using the IIASA recommendations, in 1994 developed a special proposal to the ISTC. The ISTC project # 245 "Development of a sophisticated computer based data system for evaluation of the radiation legacy of the former USSR and setting priorities on remediation and prevention policy" (code name RADLEG) was launched in June 1995 under financial support of the European Union and Sweden. Relative to RADLEG # 101 project KURGAN intended for studies of radiation situation in seas, surrounding the FSU territory, and some other environmental projects are also funded through the ISTC.

A representative set of organizations – initiators of the ISTC # 245 RADLEG project – made it possible to attract practically all of the authority institutions and agencies of Russia with wide expertise in the studies of various aspects of the Soviet nuclear complex for the purpose of data integration and the database development. This allows to ensure the representative staff of experts and high level of the data credibility. More than 20 russian institutions and agencies took part in the project's works for the time periods 1995-1996 (phase 1) and 1998-2000 (phase 2), the number of individual project participants was above 250. Formation, development and use of the international RADLEG data system on the FSU radiation legacy is described in report [10] presented at the "RADLEG-2000" conference.

The principal results of the RADLEG project are as follows:

- an analytical overview of the main military and civilian sectors of the FSU nuclear activities. It was prepared jointly with the IIASA and published in February 2000 as a book titled "The Radiation Legacy of the Soviet Nuclear Complex" (EARTHSCAN Publications Ltd ., London);
- an data system, including a public accessible database on all types of radiation source-terms with user's interface held in the RADLEG computer center of Minatom and geo-referenced information systems;
- a pilot GIS-project, describing the radionuclide contamination of the Yenisei River floodplain downstream the discharge point of the Mining & Chemical combine of Minatom, currently of special interest to experts in radiecology.

The RADLEG project results were presented and approved at several tens of national and international scientific & technical meetings and conferences. Expert evaluation of more than 100 radiation-hazardous objects and territories in the FSU was carried out for the purpose of setting priorities for further studies.

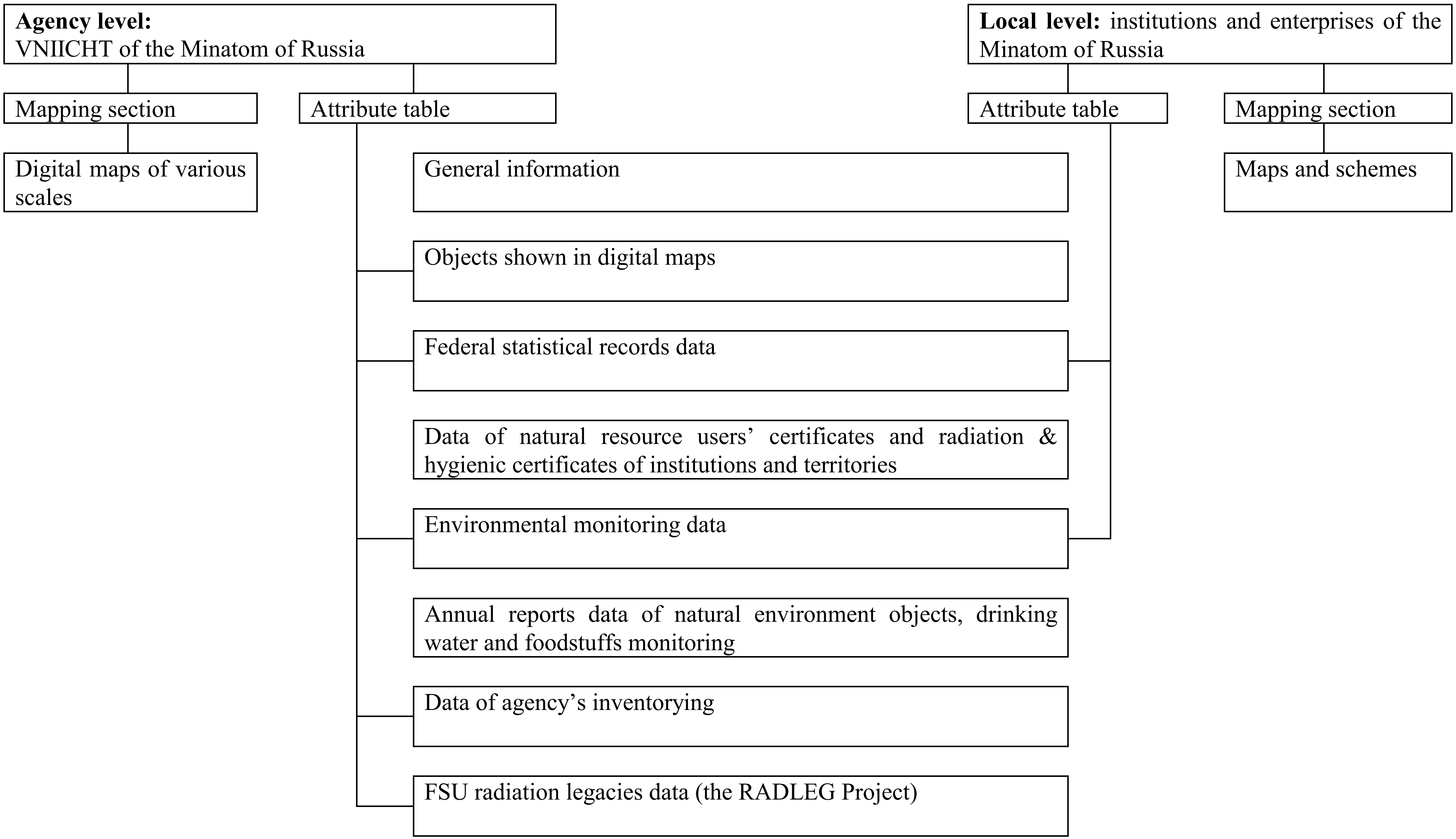

FIG. 4. The structure of the environmental geo-referenced information cadastre of the Minatom of Russia

As a preliminary assessment of the expert opinions made in 1998 shows, the industrial giants of the Soviet nuclear complex (the “Mayak” Industrial Association, the Mining & Chemical Combine on the Yenisei River and the Siberian Chemical Combine near Tomsk), where liquid and solid radwaste have been accumulated for decades, cause the greatest anxiety. Chernobyl, the North-West of Russia and the Central Federal District are ranked the next.

An interagency group of experts from institutions of the RAS, Minatom of Russia and RRC “Kurchatov Institute” has prepared a proposal for future development of the works. Within the framework of a new project Development of a Sophisticated Information System Including a Meta-Database and Regional Radioecological Cadastres for Assessment of the Radiation Impact on the Environment and Population. *Evaluation Study of the North-West of Russia and Krasnoyarsk Region.* Short Title: Radioecological Information System (RadInfo) formation of a meta-database, which would allow to initiate an evaluation study of the radiation impact on the population and environment with the aim of countermeasures development, is supposed to be started on the basis of the existing data system. The meta-database is intended to include only brief information from topical, regional and local databases and references, which would allow addressing to the databases for more detailed information.

For the present special agreements on information exchange between the RADLEG information system designers and institutions-owners of the topical, regional and local databases have been prepared. Results of the works will be used for creation of the environmental geoinformation cadastre of the Minatom of Russia. The first stage of the works includes development of a statute, a model, as well as methodical and regulatory documents on the cadastre compiling.

Beginning since 1998 the RADLEG project closely collaborates with the international SCOPE RADSITE project, integrating four regions of the world: USA, European Union, FSU countries and Asian states. An outline of studies suggested by the RADSITE project envisages stage by stage movement from source-terms description to countermeasures development. The FSU section is based on use and further development of the RADLEG data system. New information mainly gained from archive data processing comes not only from Russian organizations, but also from Kazakhstan, Ukraine and other CIS member-states.

CONCLUSIONS

We can state today that there is no region in Russia with deep and irreversible changes of *flora* and *fauna* objects caused by the effect of radiation. The part of radiation risks in the sum of general risks for human health and life (environmental contamination with toxic chemicals, transport accidents, social risks) is negligibly small. Thereat, the Minatom of Russia does not consider it possible, even to the lowest degree, to weaken its attention to issues of the population and natural environment protection against probable negative effect of radiation factors. The task of the natural environment preservation in areas of functioning of the nuclear industry’s enterprises and nuclear power plants, remediation of lands contaminated with radionuclides, remains to be one of the top priority in the Ministry’s activities.

It is evident that efforts on restoration and prevention of eventual activity releases into the biosphere will be linked with huge expenditures and will take many decades. Moreover, the economic situation in Russia and in a number of other states with radiation inheritance dictates that the expenditures for the environmental risk reduction are possible only if it is of vital importance. And this means that a very difficult and controversial choice should be made in setting priorities on remediation and prevention policy.

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SUMMARY OF THE IAEA ARLINGTON SYMPOSIUM ON THE RESTORATION OF ENVIRONMENTS WITH RADIOACTIVE RESIDUES

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Abstract

This paper summarizes the contents, results and conclusions of a Symposium organized by the International Atomic Energy Agency (IAEA) on "Restoration of Environments with Radioactive Residues", held in Arlington, Virginia, USA from 29 November to 3 December 1999. The present Conference may be seen as a follow-up to the Arlington Symposium but with the emphasis shifted from the experience of, predominantly, the USA to that of eastern Europe and the Russian Federation.

1. INTRODUCTION

In recent years the problem of radioactively contaminated environments has been increasingly recognized as important and in need of attention. The end of the "Cold War" refocused the policies of governments and brought about increased efforts worldwide towards the restoration of such environments. The new focus on environmental restoration has brought with it the recognition that there are no internationally accepted radiological standards for guiding environmental restoration. Nations have proceeded with restoration activities using 'ad hoc' criteria often based on radiological criteria intended for different purposes. Meanwhile, the relevant international organizations have been developing guidance appropriate to the restoration of contaminated environments. IAEA issued provisional guidance in 1997 [1] and ICRP published a report in 1999 [2].

With this background and in the knowledge that there is a considerable divergence of approach to the subject of decision making on environmental restoration between countries, the IAEA decided that it was an opportune time to organize an international symposium on "Restoration of Environments with Radioactive Residues". The Symposium was hosted by the US Government in Arlington, Virginia from 29 November to 3 December 1999 and was held in cooperation with the Department of Environment (USDOE), the Environmental Protection Agency (USEPA) and the Nuclear Regulatory Commission (NRC).

The Symposium had as one of its objectives the promotion of information and experience exchange in this subject area, but in addition the intention of the organizers was to focus the Symposium on the principles and criteria for guiding clean-up decisions rather than on the technologies being developed and used for restoration of affected areas.

The present Conference may be seen, from the IAEA's perspective, as a follow-up or continuation of the Arlington Symposium but with the emphasis shifted from the USA towards exploring the experience of eastern Europe and the Russian Federation.

2. STRUCTURE OF THE SYMPOSIUM

The IAEA, with the help of an Advisory Committee, designed the Arlington Symposium to promote the discussion of important issues and, where possible, the drawing of conclusions.

For this purpose a significant amount of time was allowed in the sessions for discussion and debate. The oral presentations were selected by the Committee to give a view of all important situations involving restoration and at the same time to give a global view of the subject. By this means it was intended that a) all the main types of contamination situation and b) all important radiological issues, would be addressed. These objectives were achieved by the presentation of a number of case studies intended to examine different types of restoration situation. The presenters were asked to address, in each case, the assessment approach, the radiological criteria used for decision making and its rationale and finally the resulting situation. Towards the end of the Symposium an analysis of the case studies was presented with the intention of looking for differences and similarities of approach and of drawing conclusions.

Prior to this, the Symposium had started with two sessions giving a) an overview of the world situation with respect to environmental radioactive contamination and b) international and national radiological principles and criteria for guiding restoration.

3. OVERVIEW OF THE CONTENT OF THE SYMPOSIUM

Session 1. Global Overview of Affected Areas

World (UNSCEAR review), USA, Russia, Europe, China, Iran.

Session 2. Restoration Principles and Criteria

ICRP, Germany, USA, Russia, France.

Session 3. Case Studies:

Nuclear test sites - Pacific Islands (USA), Maralinga (Australia)

Legacy of Discharges - France

Accidents – Goiania (Brazil), Satellite reentry (Canada), Chernobyl (Belarus, Russian Federation), South Urals (Russian Federation).

Mining and Milling - Australia, Canada, South Africa, USA, Germany

Residues from Practice Termination – NPP decommissioning (USA), Radium production (Belgium), Waste disposal (USA)

Session 4. Critical Analysis of the Case Studies

Session 5. Role of Public Participation

Session 6. Closing Session

4. HIGHLIGHTS OF THE SYMPOSIUM

Basic principles (Session 2*)*

The presentation of the new ICRP guidance on Protection of the Public in Situations of Prolonged Exposure by its Chairman, Professor Roger Clarke was an obvious highlight in the

Symposium. (now issued as ICRP Publication 82 [2]). This report extends the recommendations of ICRP publication 60 by applying the concept of intervention to aid decision making in the restoration of areas affected by residues from non-practice situations. The essence of the restoration guidance is “do more good than harm” and the document explains approaches towards achieving this end. It applies the well established principles of justification (of the restoration action), and once justified, the optimization of the radiation protection associated with the action.

It recognizes that the use of the public dose limit could lead to disproportionate expenditure of resources if used in the context of restoration of areas. Instead it recommends that restoration decisions should be guided by the results of site specific optimization and advocates the use of “averted dose” as a tool for determining the optimum action and action level. However, it also propose some generic action levels; these are the total annual dose above which intervention action should almost always be taken (100 mSv/year) and below which intervention action would not normally be justified (10 mSv/year) (“total dose” here means the dose due to exposure to the residual radioactivity plus that due to the natural radiation background).

Subsequent presentations on national principles and criteria and on case studies showed that, at the present time, approaches being adopted and applied nationally for all types of contamination situation follow the principles generally used for practice situations, that is, optimization of protection within the bound of a constraint upon individual annual dose.

The discussions surrounding this fundamental difference in policy pervaded the entire Symposium.

Case Studies (Session 3)

Nuclear testing sites

In this session an interesting discussion and debate started over the question of whether the restoration of residues from nuclear weapons testing should be regarded as a practice or as an intervention situation. Nuclear weapons testing was certainly a planned operation, but there were some mistakes and accidents resulting in more widespread contamination than originally planned. It was recognized that the restoration of all nuclear weapons test sites to within public dose limits would involve massive costs and therefore that access restriction may be the only practical solution for the most contaminated areas. This then raises the question, often debated in the context of radioactive waste disposal, of the acceptability of leaving burdens of cost and responsibility for future generations.

Accidents

The presentations and discussions on accidents, their consequences and the related environmental restoration revealed the important role of the public in decisions on environmental restoration. The public in affected areas is rarely satisfied by anything less than a return to the pre-accident condition. This target may be achievable for very small scale accidents or spills but is not feasible for larger scale accidents such as Chernobyl. However, even in these circumstances, the public is not prepared to accept standards, which would not be acceptable to people living in unaffected “normal” areas. This position has conditioned many of the post-accident restoration policies and the public dose limit of 1 mSv/year is the most used “standard” in these situations.

Termination of practices involving residues

For situations identified unambiguously as "practices" there seems to be good agreement on the policy for guiding restoration. The case studies and discussion showed that optimization (of some type) constrained by a dose constraint, dose limit or risk limit was a widely used approach for setting restoration targets. The value of the latter is usually 1 mSv/year or some fraction of it or its risk equivalent.

5. CRITICAL ANALYSIS OF THE CASE STUDIES

The following is the author's selection of points raised by the critical analysis presentations and discussion. (Session 4)

Practices versus interventions

It was evident from the case studies and discussions that there are problems in reaching agreement on whether a given situation is a practice or an intervention. The example of the nuclear weapons test sites was mentioned earlier, another example is that of historic abandoned practices-a practice or an intervention? According to the guidance of ICRP, the difference in the applicable criteria would be considerable! In discussion, the point was made that problems of public acceptance can be expected if experts disagree on such important interpretations.

The analysis (by experts familiar with ICRP concepts) indicates that many of the situations identified as practices in the case studies should have been treated as interventions. In fact, only a few of the case study situations were treated as interventions and they were: Maralinga-nuclear test site (Australia), Wismut-historic mining residues (Germany), and Olen-historic radium processing site (Belgium).

Averted dose versus residual dose

The use of averted dose in optimization studies can be effective in helping to find the optimum radiation protection solution. However, the approach is difficult to explain to non-experts. Further, people affected by restoration decisions are more concerned by the dose rate which will remain after restoration-the residual dose. Radiation protection arguments in the context of environmental restoration may, therefore, be more successful if they are presented in terms of residual dose.

Public dose limit

The public dose limit is often used as the dose "target" for restoration operations. This is usually because of the acceptability to the public of well established national and international standards-even when they were originally established for different purposes. The public resists accepting standards, even with a good rationale, which are higher (more relaxed) than those being used in areas not affected by radioactive contamination.

Decision aiding versus decision making

An important point, emphasized in the discussions at Arlington, is that radiation protection guidance is only one of the factors which have to be considered by decision makers. Other factors include public opinion, legal constraints, political considerations and economics.

However, it is important to distinguish between decision aiding and decision making. It is the role of the radiation protection expert to give the best professional advice, even if it is subsequently ignored by the decision maker because of political or public opinion considerations. The radiation protection expert should not anticipate the opinion of the public in giving his view, for example, by accepting the public dose limit as a restoration target, rather, these considerations should be left to the decision maker. The discussion at the Arlington Symposium indicated that a possible confusion of roles might exist in this context.

6. FINAL REMARKS

The Symposium was successful in its aim of promoting information exchange between experts from different countries and with varied environmental restoration experience. The discussions were extensive and broad in scope; they raised many interesting and sometimes controversial issues.

The Symposium showed that there is a significant discrepancy between the restoration policy advocated by the international organizations and the policies currently being adopted nationally.

It remains to be seen whether or not the new radiation protection guidance of the international agencies will find acceptance in countries faced with difficult decisions related to the restoration of areas affected by radioactive residues.

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OVERVIEW OF ISTC PROJECTS RELATED TO THE ENVIRONMENT

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Abstract

The field of ENVIRONMENT is the largest of the 14 technology areas within the International Science and Technology Center (ISTC). As of June 2000, more than 160 environmental projects have been selected for funding; this equals about 19% of all approved ISTC projects, one of the highest of all ISTC application areas. Provided funds total about US $55 million, 22% of the ISTC's allocated budget. The statistics verify that ENVIRONMENT is the most active technical area in reviews and funding in the ISTC. In general terms, this fact documents the strong interest of the financing parties in environmental purposes and indicates their desire to support the effort in the development of improved processes and innovative technologies for the solution of urgent environmental problems and for their future prevention in the CIS. The content and objectives of the approved projects include the following topics: Radioactive Waste Treatment and Disposal, Monitoring and Instrumentation, Modeling and Risk Assessment, Remediation and Decontamination, Environmental Health and Safety, Seismic Monitoring, and Pollution of Air and Water. The projects are devoted to nuclear and non-nuclear environmental issues in similar proportion.

1. INTRODUCTION

The field of ENVIRONMENT (ENV) is the largest of the 14 technology areas within the International Scientific and Technology Center (ISTC). As of September 2000, 436 ENV project proposals related to the environment have been submitted to the ISTC Secretariat (more than 75% of them from Russia). This amount is 16% of the received total of 2702 proposals; the amount of requested funds is allocated to more than US$120 million.

Up to GB XXIII in November 2000, 357 project proposals were considered by the financing ISTC Parties; from this number, 187 projects were approved for funding; this equals nearby 20% of all approved ISTC projects. The ENV success ratio between funded and considered proposals is 52%, one of the highest of all ISTC application areas. The allocated amount of provided funds is more than US $60 million; this is 20% of the ISTC budget. These statistics verify that ENVIRONMENT is the most active technical area in reviews and funding of ISTC activity.

The contents and objectives of the projects involve the following topics: Radioactive Waste Treatment and Disposal, Monitoring and Instrumentation, Modeling and Risk Assessment, Remediation and Decontamination, Environmental Health and Safety, Seismic Monitoring, and Pollution of Air and Water. The projects are devoted to nuclear and non-nuclear environmental issues with similar weight.

About 138 Russian and CIS institutions are involved as project leaders or participants (see section 4). The most active institutions submitting proposals to the ISTC have been the following (see Table 2): VNIIEF (Arzamas-16), VNIITF (Chelyabinsk-70), VNIINM Bochvar (Moscow), NIIIT (Pulse Techniques, Moscow), VNIPI Promtekhnolgyi. (Moscow), Khlopin Radium Institute (Moscow), MIFI (Moscow), and NIIKHT (Moscow).

About 400 institutes, companies, and governmental organizations from the United States, the European Union, Norway, Japan and the Republic of Korea are participating in the projects as collaborators.

2. OVERVIEW OF THE PROGRAM, RECIPIENTS, AND FUNDS

The International Science and Technology Center was created to redirect the expertise of weapon scientists from Russia and other CIS countries toward civilian activities. The ISTC finances and monitors science and technology projects with peaceful

applications and promotes scientific and technical cooperation between the CIS, Western, and Japanese collaborators.

SUBMISSION OF ENV PROJECT PROPOSALS BY ISTC MEMBER STATES

As of September 2000, the ISTC has received 436 proposals (16% of the total 2702 submitted to the ISTC) related to environmental problems and goals (ENV) at various stages of development. The field of ENV, including nuclear waste management, is the biggest and one of the most intensive activities of the ISTC. The distribution of proposals to the different ISTC member states is shown in Table1.

TABLE 1. NUMBER OF ENV PROJECTS SUBMITTED BY ISTC MEMBER STATES

Countries	Number of projects	%
Russia	327	75
Kazakhstan	48	11
Other	61	14
Total	**436**	**100.0**

The figures show that institutions and organizations from Russia have provided 75% project proposals in this application area, followed by project proposals from Kazakhstan, Belarus and Kirgizstan. In addition, some Russian institutions are participants in a number of proposals from other CIS members.

CIS INSTITUTIONS SUBMITTING ENV PROPOSALS

About 212 Russian and CIS institutions are involved in these proposals as leading institutes or enterprises. The following institutions (all in Russia) have been the most active in submitting projects in the field of environment; see Table 2.

The effort in submitting project proposals does not correspond to the success in the acquisition of funds: VNIITF is the most active and has sent 34 ENV proposals, VNIIEF has sent 28 proposals, VNIPI Promtekh-15 proposals, Bochvar Institute-13 proposals, however, has received a relative high level of funds.

APPROVED ENV PROJECTS, THEIR LOCATIONS AND FUNDING

For the consideration and discussion of ISTC activities in the field of ENV, it is necessary to focus on those project proposals which were considered and decided on (approved or deferred) including the XXIII. GB Meeting on November 1, 2000. This constitutes a total of 357 ENV project proposals, from which 187 (52%) projects are funded. In the field of approved projects, Russian institutes and enterprises have the biggest share, with a total of about 75% in the number of proposals and in financial funds.

A look at the locations of the funded institutions, where projects are underway, reveals a disproportionate distribution within Russia. The performance in Figure 1 indicates that about 58% of the projects and 63% of the provided money is concentrated in Moscow and the Moscow Region, Snezhinsk, and Sarov. In principle, this fact reflects the local distribution of the military science capacity of the former SU, which was concentrated in these regions. However, compared to the situation in 1997, there is a remarkable increase of projects and funds, dedicated to other regions in Russia and CIS members states.

TABLE 2**.** PROPOSAL NUMBER AND FUNDS OF THE MOST ACTIVE INSTITUTIONS IN ENV

#	**Institute**	**Number of submitted proposals**	**Provided Funds, mlns. $**
1.	VNIITF, Snezhinsk (Chelyabinsk-70)	34	4,8
2.	VNIIEF, Sarov (Arzamas-16)	28	3,7
3.	VNIPI Promtekh, Moscow	15	1,9
4.	Khlopin Radium Institute, Moscow	15	1,7
5.	NIIIT (Pulse Techniques), Moscow	14	1,0
6.	VNIINM Bochvar, Moscow	13	3,6
7.	MIFI, Moscow	12	1,1
8.	NIIKhT, Moscow	8	1,9
	Total	**138**	**19,7**

Moscow, M-Region, Snezhinsk, Sarov	**110**	37 Mil $
Other	**77**	22 Mil $

The allocated amount of funds for approved ENV projects is US $54.3 million or about 20% of the total provided money. These numbers confirm, that the field of environment contains the biggest share of funds; in addition, the "success ratio" of submitted (to the Parties) and funded projects (52%) is higher than in other large application areas. In general, this fact documents the strong interests of the financing parties in environmental purposes and may indicate their desire to support the effort of the project proposers in the evaluation and development of improved processes and innovative technologies for the solution of urgent ENV problems and for their future prevention in the CIS.

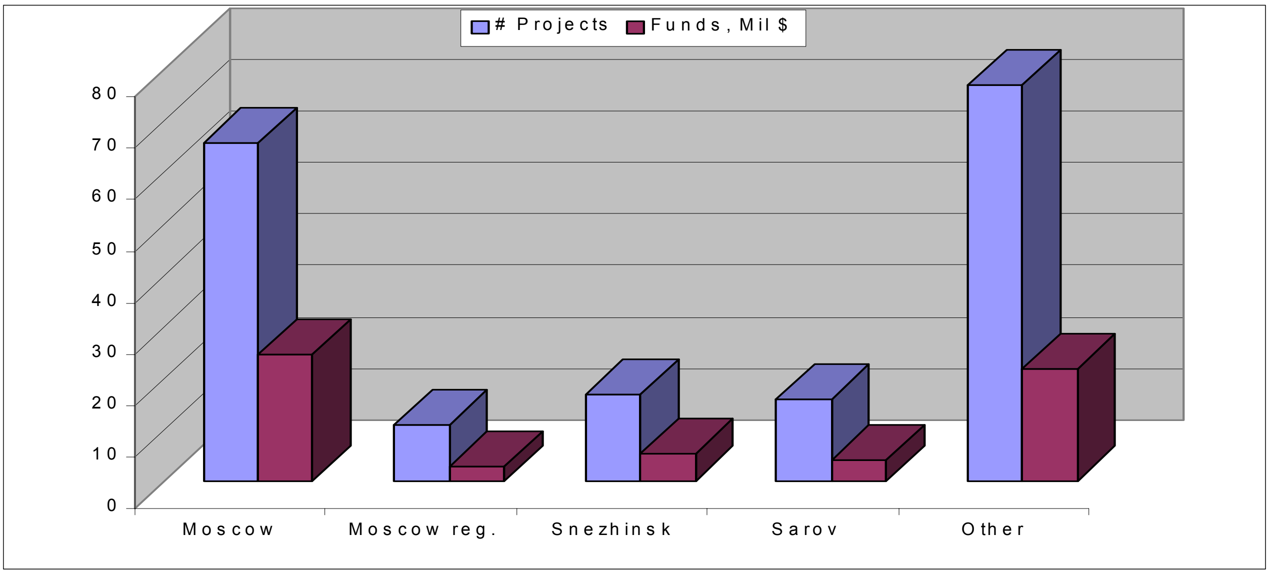

FIG 1. local distribution of funded projects.

INVOLVEMENT OF THE PARTIES

The involvement of financing ISTC Parties in funding the projects (allocated funds and involvement in the number of projects) is presented in Tables 3 and 4:

TABLE 3. ALLOCATED FUNDS FOR ENV BY THE PARTIES

Funding Party	**Funds, Mil $**	**Funds,%**
US	25,5	43
EU	16,8	28
Japan	10,6	18
Partners	2,9	5
Others	3,3	6
TOTAL	**59,3**	**100**

This table shows that the US holds the biggest share of financial support in the ENV area, followed by the EU and Japan.

TABLE 4. PARTICIPATION OF THE FUNDING PARTIES IN ENV PROJECTS

Funding Party	**Number of ENV Projects**	**%**
US	101	54
EU	84	45
Japan	27	14
Partners	10	5
Others	32	17

Note: The total number of projects in this table is more than 187 and sum of percentage is more than 100%, because several of the projects are co-funded by the parties.

COMPLETED PROJECTS IN THE FIELD OF ENVIRONMENT

About 55 ENV projects have been completed. Their final reports have been provided or already approved. A number of projects will be continued; some most important completed projects are as follows:

Radwaste Treatment/Disposal: Feasibility Study of technologies for accelerator based conversion of military-Pu and long-living radwaste (0017); Disposal and long-term storage in geological formations of solidified radwaste from military Pu production and reprocessing of spent fuel (0059); Development of induction slag melting of radwaste (0143); Criteria of safe long-term storage of radwaste from Pu-production (Krasnoyarsk) in rock massif (0307, continued 0307-2); Database on various rock and soil properties as disposal sites for radwaste (0261, cont. 0793); Elaboration of database on geological, hydrological a.o. parameters from deep wells as a possible radwaste storage site (0262, cont.794).

Solid Waste Pollution and Control: Development of electrokinetic and chemical methods for rehabilitation of soil and ground water contaminated by radionuclides and heavy metals (0016); Creation of a database for ash micropheres from coal power stations in the Russian Federation (0214).

Modeling/Risk Assessment: Development and testing of models of migration of radioactivity in groundwater (0051); Development of scientific/methodolodic database for diagnostics and forecast of state and risk from dumped radwaste at the bottom of Barents/Kara and Sea of Japan(0101-2, cont.?); Development of a sophisticated database for evaluation of Radiation Legacy in former USSR and setting priorities on remediation and prevention (0245, cont. 245-2).

Environmental Health and Safety: Evaluation of potential health risks of public and workers resulting from the release of toxic and radioactive substances in the Chelyabinsk Area (0060); Biomedical and analytical aspects of chemical safety of the Biosphere (0162).

Monitoring and Instrumentation: Monitoring Krypton-85 (0002); Environmental radiation ambient monitoring system (0085); Mobile remote sensing system based on tunable transmitter for environmental monitoring (0240).

NEWLY SUBMITTED PROPOSALS

Since October 2000, the number of newly submitted project proposals confirm the ongoing involvement in the ENV-area. This activity furthermore reflects the need for real actions and initiatives for solutions of environmental pollution problems with highest priority in Russia and other members of the CIS.

3. DISTRIBUTION AND TOPICS OF ENVIRONMENT-RELATED PROJECTS

3.1 Project Groups according to Application Codes (Taxonomy)

The distribution of all approved/running projects, as well as the submitted proposals, within the ENVIRONMENT categories (Taxonomy) is represented in Table 5, corresponding to the current ISTC Application Codes:

TABLE 5. ISTC APPLICATION GROUPS ON ENVIRONMENT, PROJECT NUMBER, AND FUNDS

Name of the group	*Projects Considered*	*Number of Approved*	*Ratio, % Approv./Submit.*	*Funds (Mil $)*	*Funds (%)*
Modelling and Risk Assessment	52	32	61,54%	7,7	12,90%
Monitoring and Instrumentation	85	40	47,06%	11,7	19,70%
Radioactive Waste Treatment	41	25	60,98%	12,6	21,21%
Remediation and Decontamination	36	19	52,78%	4,9	8,18%
Seismic Monitoring	29	15	51,72%	6,4	10,73%
Waste Disposal	27	17	62,96%	5,1	8,59%
Solid Waste Pollution and Control	10	6	60,00%	2,7	4,56%
Air Pollution and Control	27	14	51,85%	3,5	5,93%
Environmental Health and Safety	23	9	39,13%	3,0	5,10%
Water Pollution and Control	20	9	45,00%	1,8	3,05%
Other	7	1	14,29%	0,1	0,06%
Total	*357*	*187*	*52,38%*	*59,3*	*100,00%*

3.2 Topical Application Groups, Unique Aspects of Environment-related Projects, and Foreign Collaborators

TOPICAL APPLICATION GROUPS

The representation in Table 5 indicates the following ranking of provided funds within the different application groups: “Monitoring and Instrumentation” and “Radioactive Waste Treatment”, each on a high funding level, together have about (40%) of the funds, followed by projects from “Modeling and Risk Assessment” (13%), “Seismic” (11%), “Waste Disposal” (9%), “Remediation and Contamination” (8%) which hold more than the other 40% of the provided money. Altogether, about 80% of the funds are spent on these six application areas.

The graphical presentation of these ENV areas in finances and their relation to the project number is given in Figure 2. This graphic also indicates considerable distinctions in the project expenses for different application groups: Radioactive Waste Treatment and Seismic projects have an average cost of US $500K, while the expenditure for projects on Monitoring and Risk Assessment is only half of this amount, namely, between US $250K and $300K. One reason for these differences is the need for more expensive tests and hardware investments in radioactive waste investigations. However, the ratio between nuclear and non-nuclear projects is close to one. About 100 of the approved ENV projects are considering nuclear problems; the remaining ones focus on other environmental issues, which confirms that the non-nuclear area is not neglected.

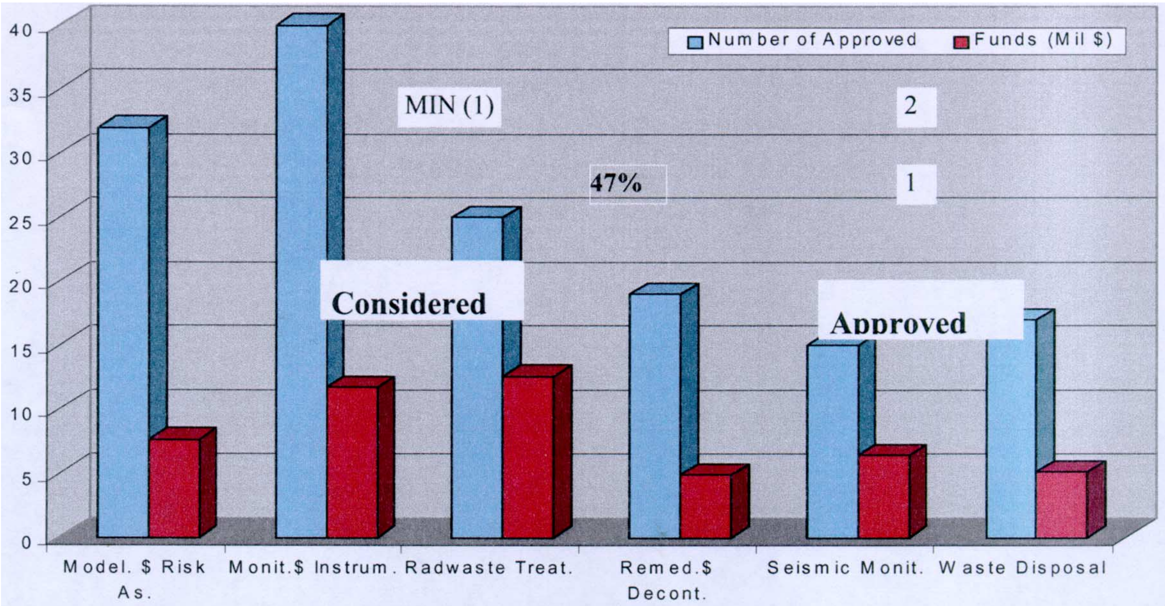

FIG 2. Six topical application groups claim more than 80% of the provided funds in the field of environment.

On the one hand, the obvious emphasis on these five application groups reflects the reality of an enormous number of ecological disasters in Russia and other member states of the CIS, as well as the requirement for their clean-up and remediation. Objective necessities, international concern, and the demands of people, initiated and supported by public opinion, have consolidated efforts, especially in the fields of "Monitoring and Risk Assessment" connected to the "Treatment and Disposal" of nuclear waste. People want to know the truth about the burden and its risks. Additional, the area of seismic events and activities in Mid-Asia and the Transcaucasus are growing interest.

On the other hand, the high level of funds may indicate the interests and concerns of financing Parties in the evaluation of the potential dangers resulting from radiological consequences in the CIS (in particular, nuclear dumping sites in the Arctic Oceans including Novaya Zemlya and the Sea of Japan, contaminated areas in Northwestern Russia and Southern Urals, nuclear waste treatment and Pu-production facilities, disposal locations of high-grade radioactive materials).

UNIQUE ASPECTS OF ENVIRONMENT-RELATED PROJECTS

Problems and questions about the Environment, as well as solutions in this field, are very often complex and wide ranging. In general, they are initially determined and evaluated for criteria other than questions of innovation or technical elaboration. In the initial stage priorities in this area are focused not only on the development of improved or new technologies and their commercialization. New technologies in environment are foremost the outcome of an environmental policy, which meets ecological requirements and public demands. From those foundations appropriate laws and regulations for environmental clean-up and the prevention of future pollution is usually initiated; new and improved technologies are the tools to fulfill these requirements. For these reasons-public interest and the demands of a civilized community-the provision of public money is and will be needed and justified in order to facilitate the first steps toward a better environment.

This overview of the ENV-projects submitted to and funded by the ISTC reflects of the above mentioned facts: many project proposals in the field of environment have non-commercial objectives , which means, not all of them can be commercialized directly as technical devices and utensils or components of equipment. A rough evaluation shows that more than 50% of the approved ISTC projects are concerned with monitoring, remediation and risk assessment. Most of them focus on local conditions where the projects are being carried out. It is rational to expect that their original results will not be “bestsellers” on the world’s commercial market. Usually, public funds will be needed for such projects. Nevertheless, these investigations are necessary and often urgent in order to prevent danger and risks to human health and life and to raise public awareness. Furthermore, these projects may serve as the scientific basis for future environmental activities, such as clean-up, decontamination, etc. at other locations.

However, successful results of the remaining ENV-projects may be directly applicable for commercialization. The acquisition of interest and money from private investors (partners) for such projects is more realistic. The outcome of these projects will be improved know-how and/or prototypes of hardware devices, which can be offered on the world market in competition with other innovative product samples. Such innovations will make a real contribution to the development of tools and instruments for solving current environmental problems and the prevention of new ones in the future.

FOREIGN COLLABORATORS

The significance of ISTC-environmental activity is also represented by the number, the origin and distribution of the foreign collaborators. Altogether, more than 400 companies, institutes and governmental organizations are involved in ISTC-funded projects. The number collaborators from different countries is as follows:

— collaborators from the US (primarily National Laboratories involved)

— collaborators from member states of the EU

— from Japan, 8 from Norway and Korea.

In the US, the most active participants are Lawrence Livermore NL (involved in 29 projects), Sandia NL (19 projects) and Los Alamos NL (23 projects). Their engagement is focused on projects dealing with nuclear waste treatment and disposal, risk assessment, remediation and decontamination, and environmental health and safety.

In the EU, the most active collaborators are British Nuclear Fuels LTD (involved in 21 projects), CEA (France, 18 projects), Forschungszentrum Karlsruhe Technik und Umwelt (Germany, 10 projects), FZ Research Center Rossendorf (Germany, 5 projects) and the SGN Société Générale pour les Techniques Nouvelles (France, 5 projects). The projects’ application areas correspond to the US-collaborators’ main interests.

Leading collaborators from Japan are the Radwaste Management Center (9 projects), PNC-Power Reactor and Nuclear Fuel Development Co. (6 projects involved) and the Japan Nuclear Cycle Development Institute (3 projects); their participation is focused on projects concerning nuclear waste, monitoring, and environmental health and safety.

It is remarkable, that funding of a project by a party does not depend unconditionally on the involvement of a collaborator from the same party. In a number of projects, collaboration is established with representatives from other countries than the funding parties. This arrangement is highly appreciated, because it widens the chances for the integration of former weapon scientists of the CIS into the international community.

In fact, in most cases, the quality of collaboration within the framework of ISTC-projects is effective and successful. Moreover, among the established ENV-collaborators, there are a number of candidates for future cooperation within the framework of the ISTC Partner Program. Ten ENV Partner Projects are already underway.

4. CONCLUSIONS AND RECOMMENDATIONS

The Submission of new ENV-Project Proposals is ongoing.

Also in the field of Environment, the Matching of the Process of Demand, Supply and Implementation of improved and competitive technologies is crucial for the success of the entire action.

What is the role of the ISTC?

- Support of and assistance to innovation in ENV-technologies and processing (on the basis of general ISTC objectives).
- Back up and training of CIS-WMD-experts to present/offer their project results to the international community.
- Fostering collaboration and partnership with Western and Asian institutions for access to markets and commercialization.

What is the Result, which can be expected: Sustainable Conversion .

What is the Status of ENV in the ISTC now?

- ENVIRONMENT-the largest ISTC application area-most projects and most funds.
- All funding Parties strongly involved-funds and collaborators.
- Funds concentrated on Monitoring, Risk Assessment, Remediation and Radwaste issues.
- Partnership in ENV still at a low level (~5%).
- The ISTC has provided a considerable number of new and improved technologies, analyses and databases on ENV issues-a promising and reliable basis for future actions.

What is the need for the future?

- Emphazising technology orientated projects, developing devices, prototypes and improved ENV processes for broad applications.

- CIS institutions must find, with competitive products, access to the world markets, if desired preferably supported by collaborators and partners.

- Real clean-ups, decontamination and rehabilitation in the CIS should be established on the basis of Monitoring and Risk Assessment results already achieved, and initiated and fostered through Technical Assistance Programs, such as TACIS (EU) and similar bilateral actions with the United States (IPP, CTR etc.), Japan and other Parties.

- From these actions, the provision of public budgets (from the federal and local governments and regions) and private investment may initiated.

RADIOACTIVE CONTAMINATION OF THE TERRITORY OF UKRAINE AND PROBLEMS OF ITS REMEDIATION

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Abstract

The problems of the substantiation and implementation of a complex rehabilitation of the territory of the exclusion zone and the zone of absolute resettlement (EZ&ZAR) aimed at the recovery of its normal economic operation are considered. The principles, criteria, methods and scenarios of rehabilitation, concept of a full and partial rehabilitation, return of the population and maintenance of normal conditions of its residing and habitability are discussed.
The preliminary estimations of a capability of practical implementation of different directions of rehabilitation activity on EZ&ZAR territory obtained with GIS-technologies accounting for dynamics of radioecological conditions in natural and semi-natural ecosystems, state of the art of natural and technogenic objects on territory of EZ&ZAR are discussed. The priority practical activities on environmental protection, maintenance in a normal condition of phyto- and zoo-sanitary situation; forestry activity, activation of landscape-recovery processes etc. are considered.

The 15th year after the largest technogenic catastrophe during existence of a human civilization is completed. Among the heaviest consequences of this catastrophe is radioactive contamination of huge territories, where rural and urban population lives and agricultural production is continued.

1. RADIOACTIVE CONTAMINATION OF THE UKRAINIAN TERRITORY AND HUMAN EXPOSURE PATHWAYS

As a result of accidental release from the Chernobyl NPP, 53454 km^2 of the territory of Ukraine, 2293 settlements with population of 2326 thousand people including more than 610 thousand children were subjected to radioactive contamination. The problem of population protection has been aggravated by a non-uniform area contamination, complex radionuclide composition as well as physico-chemical properties of radioactive fallout. Together with the significant diversity of a soil-plant cover of the contaminated territory, the indicated factors have stipulated complex and diverse development of a post-accidental radiological situation at different time phases and resulted in multiple pathways of population irradiation.

The outcome of the conducted research has allowed to identify critical sources and pathways of the population exposure. The following factors determine levels of human exposure:

Characteristics of soil-plant cover (property of soils, type of phytocenosis) [1]. The agricultural ecosystem is characterized by essentially lower transfer of ^{137}Cs to plants in contrast to natural meadows. Transfer factors (TF) of ^{137}Cs to plants of natural meadows are higher than those for ploughed soils by 1 to 2 orders of magnitude depending on soils properties.

During the first period of post-accidental situation, the decrease rate of TF values for agricultural plants is by 2-3 times higher, than to grasses of natural meadows. Thus, the natural meadows are a critical link of ^{137}Cs migration in food chain. Among them, the natural meadows, formed on organogenous hydromorphous soils, are the most critical in radioecological attitude.

Non-uniformity of radionuclide soil deposition in combination with "diversity" of a soil cover can stipulate differences in contamination of critical food stuff (milk, meat) by ^{137}Cs up to 2-50 times within a settlement, the difference in ^{137}Cs soil deposition of adjoining haymakings and pastures is usually within factor of 1.5-2. The difference in contamination of milk and meat within the borders of administrative region is up to a factor 300, the difference in ^{137}Cs soil deposition is up to factor of 30 [1].

Characteristics of contamination. Different radionuclide composition of fallout on various tracks of the Chernobyl release and special mobility dynamics of radionuclides deposited in a form of fuel particles determine various significance of radionuclides in the population exposure. Though ^{90}Sr is characterized by higher solubility in natural conditions as contrasted with caesium radioisotopes, post-accidental long-term phase is usually called "The caesium phase" as just ^{137}Cs determines both external and internal irradiation doses. Contribution of ^{90}Sr to dose during first years has appeared minor as contrasted to ^{137}Cs. On territories contaminated mainly by fuel component of fallout with the commensurable content of both radionuclides, the mobility of ^{90}Sr during first years after the accident was low because this radionuclide was kept in a matrix of fuel particles [1]. As of 1992, 95-97% of the internal dose of the population living on contaminated territory of Ukraine, was determined by ^{137}Cs, and only a few percents-by ^{90}Sr [2,3]. In subsequent years in a number of settlements affected by fuel tracks of fallout, the contribution of ^{90}Sr to an annual effective dose has increased up to 15-54%, though the total dose did not exceed 1 mSv [2,3].

The territory of the Ukrainian Polessye can be referred to a category of *critical territories*, i.e. such, where the local population can receive annual dose above 1 mSv. The large part of this territory is covered by forests. Here are about 520 settlements, and the population is about 350 thousand person.

Main exposure pathway of both rural and urban inhabitants is the intake of radionuclides with food produced on contaminated soils. Thus, consumption of milk and meat contributes up to 90% to the intake of ^{137}Cs in local inhabitants. In a number of regions the wood products (mushrooms, berries, game, etc.) constitute an essential fraction of ^{137}Cs intake.

Large part of territories affected by fuel fallout and significantly contaminated by ^{90}Sr, where the contamination of food can exceed established permissible levels, is located in the Exclusion zone and zone of absolute resettlement. Nevertheless, on the territory contaminated by fuel component of the Chernobyl fallout or by superposition of fuel and condensed components the level of population exposure during first decades is determined by radioisotopes of caesium.

The decrease of ^{137}Cs transfer parameters in biological chains is rather low nowadays. The periods of the half-time of ^{137}Cs TF in a link “soil-plant” decreasing for meadows vary within 8-15 years, and that in agricultural ecosystem is about 12-25 years, i.e. comparable to a physical half-life of ^{137}Cs [1]. Thus, the radiological situation is now characterized by relative stability.

2. APPLICATION OF COUNTERMEASURES AND THEIR EFFECTIVENESS

The application of countermeasures in the agriculture of Ukraine has allowed to reduce essentially contamination of plant and animal products in public sector. Thus, the concentration of ^{137}Cs in milk has decreased by 15-20 times from 1987 to 1998. It has become the reason for introduction of tighter control levels for many kinds of food products. At the same time, the specific activity of ^{137}Cs in milk produced in private farms has decreased only by 4-6 times.

There is a tendency of increasing of agricultural production in private farms, in particular, in those located in zones of radioactive contamination. Production of milk, meat and potato has increased essentially. The indicated products are basic "suppliers" of radionuclides in an organism of the population. Because the natural meadows (including these in forests and on swamps) are used as a pastures and hay-makings for lactic cattle in private farms, flux of ^{137}Cs with milk, produced in private farms, is about 80%, and with milk, produced in a public sector-only about 20% from the total produced volume.

The information on the regularities of human exposure and particular annual effective doses formation are used as a basis for a zoning of territory of Ukraine according to the degree of radiological hazard and for planning of the appropriate countermeasures on contaminated territory. Nowadays, on Polessye territory 90-95% of population doses is formed at the expense of consumption a food stuff of local production. Such radiological situation determines selection of protective measures and tactics of their realization.

During 1986-2000, agrochemical and agrotechnical countermeasures directed to reduction of radionuclide accumulation in agricultural products were conducted on the area of agricultural lands more than 2.0 million hectares. The application of radical or surface improvement of meadows, which is one of the most effective countermeasures for limitation of ^{137}Cs transfer in "milk" chain, allows to reduce the contents of this radionuclide in milk up to 6 times. The decrease of internal dose for various settlements due to this countermeasure varied from 10 up to 30%.

Among other agrotechnical countermeasures, application of mineral and organic fertilizers in soil as well as liming of acid soils are used. As a result of application of these measures, the internal dose decline by less than 10% on the average. The application of countermeasures has allowed to produce milk and meat in the public sector, which meets permissible levels during last 7 years. Less favourable picture is in a private sector. The practical absence in Polessye regions of sufficient quantity of cultivated haymakings and pastures suitable for private cattle or preparation of pure forages has an effect.

In connection with deterioration of economic capabilities of the country, the amount of countermeasures has decreased essentially during last years (Fig.1), and its main application isthe remediation of private farms as well as pastures and haymakings for animal of private sector.

The effectiveness of countermeasures in agriculture varied in wide limits, depending on soil-climatic condition and characteristics of radioactive contamination. The cost of the averted collective dose of one man.Sv for a zone of absolute resettlement varies in range US$ 7.3-14.5 thousand, and for a zone of the reinforced radioecological control US$ 34-121 thousand.

From the economic point of view, the implementation of countermeasures is considered to be expedient when the cost of activities on preventing dose of one man·Sv is comparable to the cost of the total country's national product per caput.

For Ukraine this value varies last years in the range of US$ 1.5-3 thousand. This implies to recognize that many countermeasures applied in the Ukraine surpasses its economic capabilities, though a number of cases is indispensable taking into account their social and psychological significance. As a whole, estimation of cost of rehabilitation measures and effectiveness of used retaliation demands more detailed methodological consideration and calculation.

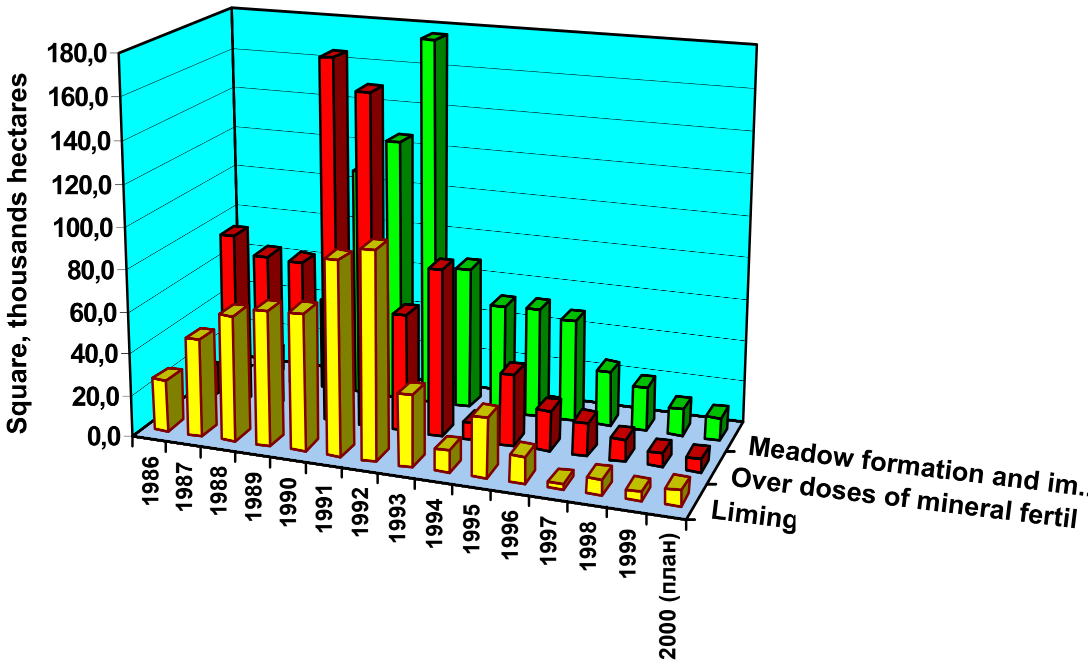

Figure 1 Dynamics of counter-measures on contaminated agricultural lands of Ukraine, thousands hectares

3. PROBLEMS OF RADIOLOGICALLY DANGEROUS TERRITORIES

The status of the contaminated territories is determined pursuant to the Laws of Ukraine "The legal status of the territory which was radioactively contaminated due to the Chornobyl catastrophe", "About the status and social protection of the citizens, which one have suffered owing to Chernobyl catastrophe".

ZONE OF ABSOLUTE RESETTLEMENT (ZARS)

The territories with ^{137}Cs deposition on soil of all types above 555 kBq·m^{-2}, as well as part of mineral and all organic soils with ^{137}Cs deposition of 185-555 kBq·m^{-2} are referred to a zone of absolute resettlement pursuant to the indicated Laws. 101285 hectares of agricultural land are withdrawn from use in the Kiev and Zhitomir regions. In the Zhitomir region about half of grounds (41825 ha) is withdrawn not only according to radiological parameters, but also because its productivity is low and economic usage is not expedient (Fig.2).

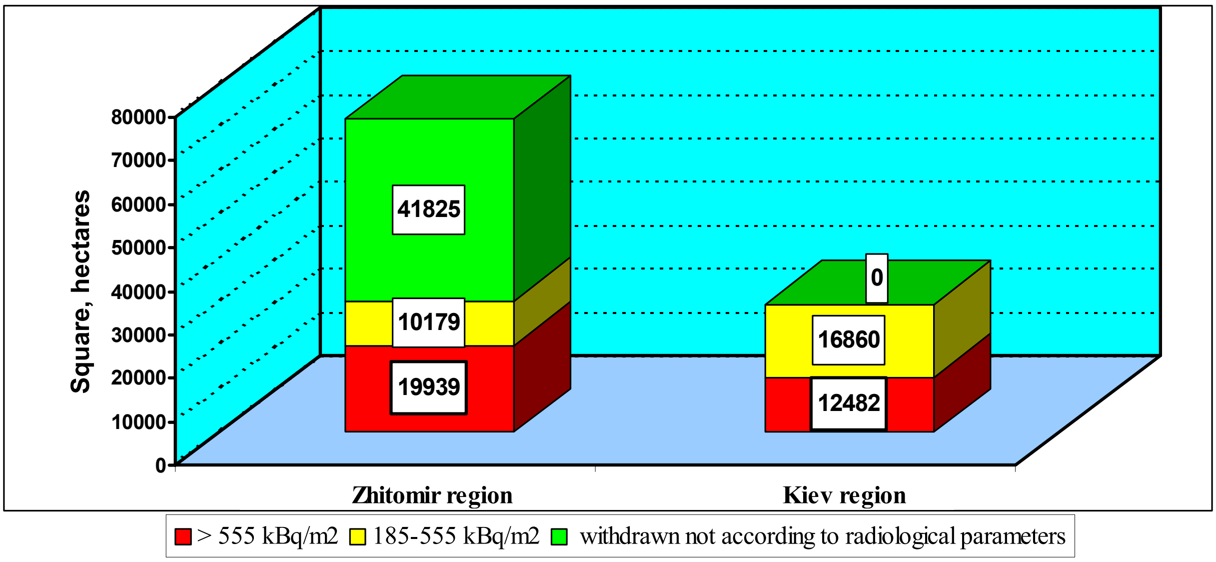

Figure 2 The areas of lands, deduced from a use in Zhitomir and Kiev regions of Ukraine, hectares

In this connection, the problem of mismatch of an actual radiological situation on a part of ZARS territory to criteria which are regulated in the existing acts should be resolved. With the termination of any activity on abandoned territories the major problem becomes observance of acceptable rules and principles of activity with the purpose not to admit both negative economic and ecological consequences for the environment and population of Ukraine.

One of the basic problems of ZARS is the problem of living of population on its territory that contradicts requirements of the legislation. The problem is aggravated by the requirement of the legislation to such territories that population can not count on maintenance of living conditions and normal habitability, solution of legal, medical, social and psychological problems and other kinds of protection from the state.

According to the data of dosimetric certification of the Ukrainian settlements subjected to radioactive contamination in dominant number of settlements on ZARS territory estimated exposure doses of the population do not exceed the tolerance levels. Thus, the prolongation of people resettlement today has lost the effectiveness and falls to category of little justified measures, as the averted dose, even by conservative estimations, does not exceed 15-30% of the committed life-time dose for 70 years. In this connection realization of rehabilitation measures on ZARS territory, is a real priority. It is necessary to mark, that this problem requires legal support of the decision on termination of resettlement.

In order to implement scientifically sound activities on the indicated territory, in 1997 the Program of remediation of lands of the Zhitomir and Kiev regions on the period 1998 to 2005 was developed [4]. The priority and sequence of activities on the remediation of abandoned lands is determined by a number of rules: the lands with lower contamination level are subjects of the first order return to normality; the best effect is reached on prolific soils; lands, which are laying within the borders of operational facilities or adjoin their territory are subject of a prime remediation; the priority is given to mineral soils with contamination density up to 555 kBq·m^{-2}; it is illogical to conduct nowadays the remediation of the land formed on organic soils with ^{137}Cs deposition above 111 kBq·m^{-2}.

Cost of averted collective dose of man·Sv for ZARS varies in the range of US$.7.3-14.5 thousand Costs of recovery of these lands will make (US$ on 1 ha) for: production of forages-340-390; cultivation of meadows-290-390; cultivation of grain, vegetable and other cultures-290-680; afforestation-580-680; garden seminaries-730-820. The income from economic usage of these lands within 3-5 years is expected to cover completely the costs spent for the restoration.

Within the framework of mentioned "Program of remediation of lands of ZARS …" during 1998-2000 in the Zhitomir region 2144 ha of agricultural land withdrawn from production is being transferred to pastures and haymakings as a reserve land, 188 ha of land are subject to afforestation. About 8 thousand hectares of land and 600 ha of Ladizhichi ponds on the territory of ZARS are prepared for economic usage.

THE EXCLUSION ZONE

The exclusion zone (EZ) is defined as a territory from which the population was evacuated in 1986. More detailed characteristics of EZ are described in the report of V.I.Kholosha et al "Comparative estimation of radioecological significance of natural and technogenic objects of the Exclusion zone" presented in these Proceedings. The territory with ^{137}Cs soil deposition above 555 kBq·m^{-2} or with ^{90}Sr soil deposition above 111 kBq·m^{-2} or plutonium soil deposition above 3.7 kBq·m^{-2} is about 1800 km^{2}.

The "Concept of the Chernobyl Exclusion zone on the territory of Ukraine" (1995) and project of the "Concept of activity in the Exclusion zone and the zone of absolute resettlement in the territory of Ukraine" (1998) determine system of principles and priorities on the mentioned territories with the purpose of minimization of ecological and social-economic consequences of the Chernobyl catastrophe as well as substantiation of capabilities and implementation of a complex remediation of the EZ territory. The remediation should be considered as process of implementation of a system of measures, directed on recovery of normal national economic operation of the Zone.

It is necessary to note, that the *remediation* is not only implementation of a number of countermeasures, which will lead to the result that the contaminated territory becomes suitable for national economic usage and residing of population without limitations (full remediation). The special feature of EZ territory is, that presently there is no population in it, and the personnel is located in the EZ temporarily. The remediation of such territories is of local, sample character and is relevant to key objects (partial remediation) without return of the population. The following kinds of activity are of primary importance:

- industrial activity, aimed on maintenance and decommissioning of the Chernobyl NPP, conversion of the "Shelter" to an ecologically secure system, reprocessing and dumping of radioactive waste etc., operation of appropriate infrastructure objects on EZ territory;
- industrial activity, directed to minimization of the radioactive release out of EZ borders;
- activity, directed to a non-deterioration of ecological situation on EZ territory;
- activity, directed to successful implementation of remediation measures.

For targeted implementation of mentioned activities the functional zoning of EZ, i.e. its division in separate parts is conducted. For each part of EZ the general strategy of the contents and dominant activities are defined. These allow for arrangements of the operational productions, units of an infrastructure, objects with radioactive wastes, degree and character of radiological contamination of environment, modern state of EZ ecosystems nowadays and its trends. The exclusion zone is divided in four functional parts (territories): industrial territory; territory of a prime remediation; reserved territory; territory of a general regime.

The industrial territory is a part of EZ, where the main activities, directed to minimization of consequences of Chernobyl catastrophe, are carried out: utilization of radioactive waste, conversion of the object "Shelter" to ecological secure system, maintenance and decommissioning of the ChNPP, preventing of radionuclide migration, in particular, protection of a floodland of the river Pripyat from splashing down during floodings, and also sanitary and fire precautions in forests etc.

The industrial territory is a significant part of EZ. It includes basic objects together with sites of terrain between them, particularly: ChNPP with object "Shelter" and infrastructure units; Industrial complex "Vector"; radioactive waste disposal facilities (RAWDF) and temporary storage of radioactive waste (TSRAW); the cooling pond; part of the river Pripyat floodland with water-protection facilities; settlements located in the EZ: towns Chernobyl and Pripyat.

The territory of the prime remediation as a whole is considered as a territory with the prospective of economic usage in nearest decades. Territory of the prime remediation includes, first, sites of EZ, where ecological conditions, according to available data, conditionally meet requirements of the Law of Ukraine "The legal status of the territory which was radioactively contaminated due to the Chornobyl catastrophe" with regard of the permanent residence of the population on contaminated territories.

The territory of prime remediation includes sites of EZ, where ecological conditions nowadays do not completely satisfy the requirements of the Law, but, as a result of implementation of some remediation measures is expected to meet them in the nearest decades. Besides, this part of EZ includes sites where remediation measures are expedient for improvement of the ecological conditions of EZ infrastructure and for limitation of distribution of radioactive contamination out of its boundaries. Main directions of remediation activity in boundaries of this territory will be forestry, and namely creation of resistant wood plantations, recovery, improvement and contents of water protection system. Implementation of research and small scale industrial activities in this territory is supposed.

The reserved territory consists of separate sites representing value of the nature: representative landscapes, rare species of flora and fauna, vital centers of Ukrainian fauna. Such sites require the status of a natural reserve, according to which any intervention in a natural course of self-development of ecosystems is prohibited and only implementation of indispensable measures to content these objects or conduct research with limited stay of personnel is admitted. The sites of reserved territory can be arranged in boundaries of the territory of a general regime and the territory of a prime remediation. Within EZ boundaries there exist ten objects of the natural reserve one of which has the State status (Il'in hydrological reserve), and 9 others are of regional value. The status of natural reserve was given to these objects before 1986. The maintenance of existing objects of the natural reserve and granting similar status to other sites of EZ is not foreseen by current legislation.

The territory of a general regime - part of EZ territory, non-homogenious with regard of radioactive contamination level. On all this territory, except of infrastructure objects and sites of reserved territory, the human activity is limited by indispensable measures for maintenance of a zone, including measures of nature protection, measures of EZ regime observance and preservation of cultural values as well as research activities.

For planning, assessment of feasibility and expediency of remediation in various sites of EZ modern methods of GIS-technology are used which accounts both for radiological conditions and conditions of natural and technogenic objects [5]. Taking into account the modern conditions of the territory (location of forests, meadows, flood-lands, sites with a ground-water level less than 1 meter, melioration systems, centers of the wreckers and illnesses etc.) the map-scheme of possible directions of remediation activity on EZ territory are constructed (see A. Arkhipov et al. "Use of GIS in the rehabilitation assessment of the Chernobyl exclusion zone", this issue).

The greatest area of EZ (more than 800 km^2) presents the site where reafforestation is considered to be expedient. On the territory about 300 km^2 implementation of water protection measures, including recovery of melioration system, is necessary. The special approach should be applied to sites of prime remediation, i.e. those lands where it is possible to carry out economic activities without limitations right now. This includes about 30 km^2 of the territory suitable for agriculture and about 180 km^2 qualified for forestry.

On the large areas of forests, former gardens and floodlands in total about 150 km^2, the centers of the wreckers and illnesses were formed. This situation requires intervention with the purpose of estimation of the hazard level and application of countermeasures for prevention of further development and for rejection of such centers.

The rehabilitation measures on the contaminated territories have been conducted since the first days of the accident. Absence of the legible international and national guidelines and experience on protection of the population at large scale emergencies, danger conditions in the early post-accident period have resulted in implementation of countermeasures without a well-timed estimation of their efficiency with regard of dose reduction, economic and social criteria.

From the economic point of view, the implementation of countermeasures is considered to be expedient and optimal when the cost of preventing the collective dose of one man·Sv is comparable with the cost of the gross national product per caput. For Ukraine this value varies last years at a level US$ 1.5-3 thousand. In general, estimation of the cost of remediation activity and efficiency of adopted countermeasures requires more severe and close methodical consideration and calculation.

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RADIATION HERITAGE OF THE PAST IN THE REPUBLIC OF KAZAKHSTAN

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Abstract

For the whole period of the Semipalatinsk Test Site (STS) operation 456 nuclear tests were conducted not only for the purpose of developing nuclear weapons but also as "peaceful" underground nuclear explosions. Apart from STS in Kazakhstan there are several testing sites where nuclear explosions were conducted for peaceful purposes. These are explosions of Batolit, Meridian, Region series, as well as Azgir and Lira sites.

In Kazakhstan there is great number of plants which have been involved in the development of nuclear weapons. Kazakhstan mining industry was the main supplier of natural uranium and non-ferrous metals necessary for production of nuclear-rocket weapons. Along with extraction of uranium ore there were complexes dealing with the development of nuclear technologies. For instance, the complex of unique reactor facilities situated at the former Semipalatinsk Test Site where nuclear rocket engines were tested. High-technological industrial BN-350 reactor complex belongs to a new generation of fast breeding reactors. BN-350 reactor is designed mainly for development of new nuclear technologies.

This paper contains generalized results of radiation investigations carried out in regions where nuclear experiments were conducted and nuclear facilities are located.

During the Cold War the Central-Asian region supplied the Soviet program of nuclear armaments by extraction of uranium ore and production of weapons materials for surface and underground tests. One of the significant examples is Kazakhstan. Low population density, vast territories not suitable for high farming, considerable reserves of minerals made Kazakhstan a region convenient for development and production of defense technology and armaments.

About 70% of all nuclear tests of the former USSR was conducted at Kazakhstan territory from 1949 to 1989. Most part of these including 113 air and surface explosions was conducted at the Semipalatinsk Test Site (STS). The testing of the USSR first atomic (1949) and world's first hydrogen (1953) bombs were carried out here.

Kazakhstan takes one of the first places worldwide on the quantity of explored uranium reserves (about 25%). For a long time (over 40 years) more than 20 deposits spread practically all over the Kazakhstan territory were exploited. The largest plants in this branch are Tselinny Mining-and-Chemical Complex (Central Kazakhstan), Ulba Metallurgical Plant, Irtysh Chemical-and-Metallurgical Plant (Eastern Kazakhstan), Precaspian Mining and Smelting Complex (Western Kazakhstan), ore management of Southern Kazakhstan.

In Kazakhstan there are five nuclear facilities including one power reactor (^{350}Bn, Aktau) and four research nuclear reactors, one of them is located in Alatau settl., Almatinskaya Oblast, and three-in the town of Kurchatov, Semipalatinskaya Oblast.

Thus, due to historical economic, geopolitical, social and other conditions Kazakhstan possesses nuclear materials reserves and double-purpose materials, plants for their mining and processing, infrastructure and scientific-technological potential of the former military complexes. During «perestroika» Kazakhstan has inherited economy non-adapted to the market needs, some fragments of industry and scientific-technological complexes. Under these conditions the problems related to military activities in the field of nuclear weapons and activity of uranium-extraction and uranium-processing industry became especially critical.

Having refused to possess nuclear weapons Kazakhstan is actively involved in the non-proliferation processes not only in foreign but in home policy also. This concerns different scopes of activity, diplomacy, science and technology, industry. Projects and programs implemented in Kazakhstan since 1993 are directed to eliminate nuclear, chemical and other types of weapons of mass destruction; develop systems for non-proliferation monitoring; prevent spreading and diversify experience and knowledge of experts engaged in defense industry; convert military-industrial complexes and technologies; extend cooperation in the field of nonproliferation.

One of the demonstrative examples of this activity is STS conversion.

In 1991 under decree of Kazakhstan President, the Semipalatinsk Test Site was closed. At the STS, during the last five years joint Kazakhstan-American teams have been conducting work on elimination of nuclear infrastructure (closure of Degelen tunnels, and liquidation of Balapan boreholes), on the development of seismic methods for nuclear tests monitoring. The mobile laboratory is created for operational monitoring of regions and facilities for radiation contamination. The execution of joint projects led to creation of scientific-technological basis, formed an international team of highly qualified experts, contributed to gaining experience in solving problems concerning liquidation of radioactive hazards.

The nuclear tests conducted at the Semipalatinsk Test Site from 1949 to 1989 created a rather complex radiation situation at the site that is evolving in time. Unfortunately, at present it is impossible to evaluate the dynamics of radioactive contamination due to absence in Kazakhstan of data on radiation conditions of 15-20 years' prescription. According to evaluations, as a result of conducted nuclear explosions approximately 9×10^{16} Bq of ^{137}Cs were introduced in the environment. This is important to know as today secondary effects of the territory contamination are developing that are connected with accumulation of fission products during underground nuclear explosions, especially in Degelen Mountain Complex where they are brought out to day surface by melt and rain waters. Therefore, in estimating ecological consequences of the nuclear tests one should consider all quantity of radioactive substances concentrated on the surface and underground.

Surface and excavation (underground with soil kick) nuclear explosions contributed mainly to the STS radioactive contamination. General view (aero-gamma-survey data) of the test site contamination by gamma-emitting radionuclides, mainly ^{137}Cs, is presented on the Figure 1.

One can see that the test site radioactive contamination by ^{137}Cs is not even and has the form of either lengthy "paths" due to air and surface explosions, or local spots different in the area and contamination level. Within the test site the regional background of ^{137}Cs is a bit higher than average global background on the Kazakhstan territory.

The other area of local contamination with ^{137}Cs is located in the southern part of the test site in the region of Degelen Mountain Complex. The territory contamination has a form of two "spots" of irregular shape. The size of the "spot" (soil deposition of 0.4 Ci/km^2) amounts to 4×6 km^2 and 3×4 km^2, maximal value is up to 2 Ci/km^2.

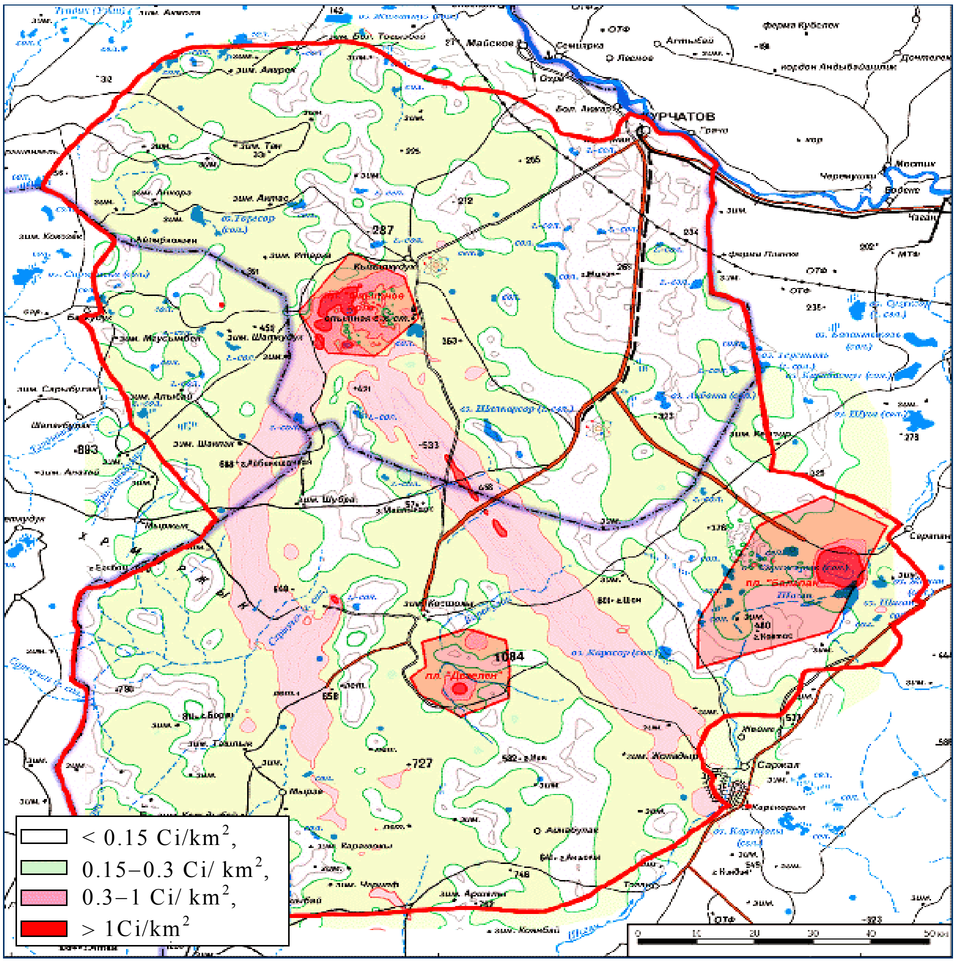

FIG 1. Aero-Gamma-Spectrometric Survey for ^{137}Cs (1991).

As a result of the survey of the Degelen massif conducted in 1992, water outpouring was registered in 27 tunnels and at 24 portal areas. This water is contaminated with radionuclides. The dose rate is 1-5 mR/h. The radionuclides are transferred with water fluxes which is followed by their sorption with soil and vegetation. So, the process of forming of Degelen Mountain Complex radiation conditions is far from completion and is progressing at present.

The results on strontium-90 measurements have shown that at the majority of studied points its soil deposition considerably exceeds the value of temporarily admissible levels that is 0.15 Ci/km^2.

Results of determination of plutonium and americium-241 content at the test site are rather poor. There are data available on a few hundred points obtained during analyses of water and soil samples from separate sections of the test site. These data do not allow making reliable conclusions about the level of contamination of the Test Site by alpha-emitting radionuclides. To solve this problem, more up-to-date and less expensive methods should be used to determine plutonium content and to study its physical and chemical forms in the Test Site soils.

Since 1996 according to the Agreement between RK and USA, the work was conducted at the Test Site on closing tunnel portals at the Degelen Massif and liquidation of Balapan site boreholes. The purpose of these activities along with the nuclear infrastructure elimination is the improvement of radiation situation at the former Semipalatinsk Test Site. As an example, the Figure 2 presents radiation conditions at the portal area prior to and after the tunnel closure. However, it should be noted that despite considerable scope of the work performed to study and eliminate consequences of nuclear tests and nuclear infrastructure, they cover only a small part of the Test Site.

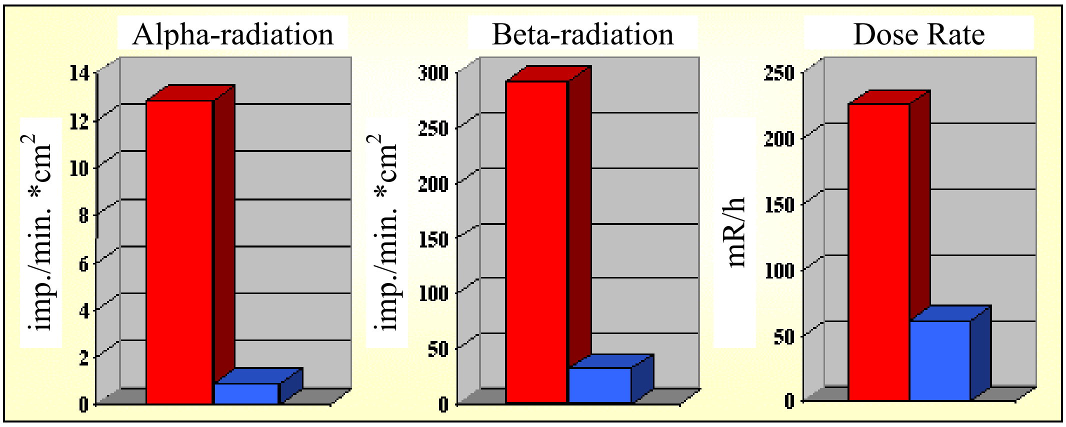

FIG 2. Average Values of Radiation Parameters Prior to (Red) and After (blue) the Tunnel Closure.

The former Semipalatinsk Test Site becomes more an international test site, "neutral strip" for solving "sensitive" questions of nuclear countries activity in the field of non-proliferation suggesting participation or presence of observers from the third parties (first of all-Russia) at the experiments and programs.

Apart from the STS, there are several other testing areas in Kazakhstan where nuclear explosions were conducted for peaceful purposes. These are explosions of Batolit, Meridian, Region series and Azgir and Lira sites.

NNC RK conducts a complex radioecological monitoring at radioactively hazardous facilities of Western Kazakhstan. Upon the work results, it is seen that the radioecological situation at Lira, Region-3, Mangyshlak objects is safe for population and the environment. However, radioecological situation at Koshkar-Ata storage facility for man-made waste is of highest concern. At present, the measures are developed to eliminate sources of menace for population living close to this facility.Semi-centennial history of nuclear weapons development left its radiation heritage. Today Kazakhstan in cooperation with experts from the leading organizations of foreign and CIS countries conduct joint research work and developments to heighten security all over the world.

EXPERIENCE OF THE REPUBLIC OF BELARUS IN SOLVING THE PROBLEMS OF REHABILITATION OF THE TERRITORIES AFFECTED BY THE CHERNOBYL CATASTROPHE

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Abstract

As the result of the Chernobyl accident, about a quarter of the Belarusian territory has been contaminated by radionuclides. More than one and a half million of people live on the contaminated territory. The legislation and radiological standards were developed in all spheres related to overcoming of the Chernobyl catastrophe consequences. Significant range of countermeasures is applied in agriculture. The system of social protection of all population categories is under implementation. Considerable part of work has been done to improve living conditions in the contaminated territories. The rehabilitation of the contaminated territories includes a complex of measures aimed at restoration of the economy, social infrastructure, physical and psychological health of people. Although a long time passed since the Chernobyl accident, a lot of problems of rehabilitation of affected areas still remain to be solved. In this regard, both national efforts and international collaboration are very important.

The Chernobyl catastrophe forced all the international community to look anew at radiological problems and environmental safety issues. Though the Republic of Belarus, Russian Federation and Ukraine are the countries most affected by the Chernobyl catastrophe, experience in overcoming of the consequences of this disaster is invaluable for all the world since in our technological century unfortunately no one can be insured against similar situations.

As the result of the Chernobyl accident, more than 23% of the Belarusian territory has been contaminated by radioactive caesium. Ten percent of the territories of the republic have been contaminated with radioactive strontium. More than one and a half million of people (equivalent to 1/6th of the country's population) live on the contaminated territories. Agricultural lands taken out from economic use occupy 6.7 thousand sq.km (whole area of Belarus is 210 thousands sq.km) including 2.64 thousands sq.km of agricultural lands. About 135 thousand people (the country population is 10.3 million people) were resettled from the most contaminated settlements. The level of mortality and morbidity has risen. At present more than 1000 cases of thyroid cancer related to radiological influence of Chernobyl disaster are registered.

It is evident that most of problems related to this accident should be resolved on the state level. That is why considerable part of the national budget is allocated to solve problems related to the Chernobyl catastrophe despite the difficult economic situation in the country. Thanks to the efforts of the state authorities, activities of specialists and scientists, many problems have already been settled.

The legislation and radiological standards were developed practically in all spheres related to overcoming of the Chernobyl catastrophe consequences. In the regions contaminated with radionuclides, a complex of measures to improve the level of medical care is implemented and monitoring of the people health is carried out. More than one and a half million people are regularly going through deep annual profound medical examination.

Significant range of countermeasures is applied in agriculture. It permits to control agricultural production and produce plant and animal products meeting permissible levels of radionuclides. The share of milk containing ^{137}Cs above the national permissible levels constitutes at present about 0.2% in the public sector of the whole country, although in some districts this index reaches 6 to 10%. Excess of admissible levels of ^{137}Cs content in meat is observed seldom; from 1996 to 2000 annual return of cattle from meat processing factories constituted just some hundred heads of cattle.

The number of the settlements with excess of radionuclides content in milk in private sector reduced more than twice for the last three years. The reason for this improvement is that we have established the system of radiation control and monitoring of food contamination which is reliable and functioning well.

The system of social protection of all population categories is under implementation. The basic elements of this system are:

— economic support of the population;

— rehabilitation of children, liquidators (recovery workers) and citizens living on the most contaminated territories;

— prolongation of holidays period;

— organization of the improved nutrition in schools and pre-school establishments.

Considerable part of work has been done to improve living conditions in the contaminated territories including:

— creation of gas pipelines;

— water supply;

— equipping of the settlements with services and utilities;

— construction of the facilities for medical and education purpose.

At the same time, the large scale of radioactive contamination, lack of experience in overcoming similar accidents resulted and are still resulting in many difficulties in decision-making. At present, it particularly refers to elaboration of the rehabilitation strategy of the contaminated territories. Issues of the rehabilitation territories relate to the most complex problems of the post-Chernobyl period. It is understandable that in elaborating and implementing the rehabilitation measures it is necessary to take into account radioecological, radiation and hygienic, social and economic, demographic and psychological factors.

Based on the analysis of radiation conditions, social and economic characteristics of the contaminated regions, experience of application of protective and rehabilitation measures it is possible to determine the following directions for rehabilitation of the contaminated territories:

- radiological, related to the complex of measures aimed at reduction of radiation impact on population;
- social and economic, related to restoration of normal living conditions of the population and creation of conditions for sustainable development of the contaminated regions.

The main elements of the **radiological component** of rehabilitation strategy are the following:

- development of the radiological control and monitoring system, improvement of the radiological standards;
- development and application of measures in agriculture and forestry to avert obtaining production not corresponding radiological standards;
- decontamination of social and cultural facilities.

The second element of radiological component of rehabilitation is of special importance. At present, about seventy percents of collective dose is delivered by intake of radionuclides with foodstuffs. That is why application of countermeasures aimed at obtaining products meeting admissible levels of radionuclides content is of great importance for the affected territories. For these purposes a whole set of protective measures is being implemented in the republic. It includes the following activities:

- liming of soils on arable lands contaminated by ^{137}Cs higher than 0.2 MBq/sq.m (5 Ci/sq.km) and ^{90}Sr contamination higher than 0.01 MBq/sq.m (0.3 Ci/sq.km), e.g. more that 40000 ha/year;
- application of mineral and organic fertilizers on the whole arable lands contaminated with ^{137}Cs higher than 0.04 MBq/sq.m (1 Ci/sq.km);
- application of pesticides for agricultural plants on lands with ^{137}Cs contamination higher than 0.2 MBq/sq.m (5 Ci/sq. km);
- improvement of hay lands and pastures for use by cattle of private and public sector farmers. Needs of the private sector is estimated as about 12000 ha and that of the public sector about 75000 ha. Due to lack of funds needs of the private sector are satisfied completely and for the public sector by principle “if anything remains”;
- application of caesium-binding sorbents. In Belarus production of boles (mainly for the public sector) has been organized. It satisfies all the needs (30.000 ton per year);
- radiation control including examination of agricultural lands, quality control of products by ^{137}Cs and ^{90}Sr.

Implementation of this complex of measures creates the preconditions for revision of admissible levels of radionuclides content in products and their reduction. It is important to say that requirements for admissible levels of ^{137}Cs content in Belarus (RDU-99) for majority of products are more strict that in Russia (SanPiN 2.3.2.560-96). Russian requirements are different from ours for milk and beef which are equal to 50 and 160 Bq/l, (kg), respectively, that means 2–2.3 times lower than Republican admissible levels (RDU-99). Admissible levels o ^{f90}Sr content for all products in Belarus are lower by 6 to 30 times than in Russia.

The problem of production of foodstuffs in accordance with the RDU-99 has not been completely solved. During the last three years practically all grain and potatoes were meeting republican standards set up for ^{137}Cs. However, in some districts of the Gomel region the content of ^{90}Sr in grain produced for consumption purposes was higher than appropriate standards.

The issue of production of quality foodstuffs in private sector is particularly acute. Based on the data of radiological control for 1997-1999 in 376 settlements of Belarus, there has been a number of cases observed when milk is produced with ^{137}Cs content exceeding 100 Bq/l.

Economic aspect of the problem is no less importance. Even in cases when agricultural production meets admissible levels of radionuclides content, in many farms it becomes uncompetitive. As estimated by Belarusian scientists, expenditures for rehabilitation activities in agriculture will constitute during the next five years more than 70 million dollars.

We have not stopped decontamination activities in Belarus. These activities are focused on socially important facility-kindergartens, educational establishments, medical institutions. Analysis shows that expenditures to avert exposure dose of 1 person-Sv does not exceed US $ 15 thousand thus corresponding to the adopted international criteria. At present two special enterprises in Gomel and Mogilev regions decontaminate some tens of such facilities annually.

Problems of **social and economic rehabilitation** relate to the most difficult ones to solve. Some of them have not even been solved and have become still more acute. After the accident negative changes in demographic situation are observed; intellectual, professional and technical potential has decreased; collectives are broken; economic indices have fallen down. Migration has negative influence on the quality of labor resources. It led to outflow of professional specialists. In two–three years after the accident we faced the problem of lack of specialists in the affected regions, mainly teachers and medical personnel. Agricultural sector feels serious lack of labor resources, not only of high-qualified specialists, but also of general personnel.

Social and economic rehabilitation assumes creation objective conditions to mitigate influence of the main risk factors. It is being concentrated on following directions:

- introduction of ecologically clean industries and changes of the industry structure in agriculture and forestry;
- creation of new working places through development of local enterprises and popular trades, local mineral resource development;
- construction of dwellings and infrastructure, improvement of living conditions for population and specialists;
- modernization of dwelling and municipal economy;
- formation of radio-ecological literacy of population;
- improvement of legislation and radiological standards.

The state does not have enough funds to reach pre-accident level of social and economic development in the affected regions. Therefore, particular importance is given to the creation of scientifically justified methodology of rehabilitation, which would permit to propose rational mechanism and ways to rehabilitation the economic activity. Transition to the policy of rehabilitation led to decrease of migration intentions of inhabitants of the affected territories. People appreciate very well such rehabilitation activities as construction of gas pipelines, water wells commissioning, reconstruction and construction of dwellings and facilities of social and cultural purpose.

Medical consequences of the Chernobyl catastrophe are stipulated by direct radiation influence. They are aggravated by accompanying factors (ecological, social and economical). We observe worsening of human health of people residing in the affected territories as compared to republican indices. First of all this is referred to thyroid pathology in children, which has been recognized as radiation-induced.

The complex of unfavorable factors of non-radiation nature have influenced somatic health of people. Thus, among the population, the share of people with chronically compensated and non-compensated forms of pathology has increased and accordingly the specific share of healthy people has decreased. Negative influence of the Chernobyl catastrophe consequences on human health is the main problem of the Chernobyl disaster. Legislation and all practical activity of all state authorities must be aimed at solving this problem.

— Medical assistance to population of the affected territories is based on the following principles:

— medical institutions of affected regions must work as usual;

— regular health check of certain categories of citizens affected by the Chernobyl disaster is carried out in accordance with the special orders of the Ministry of Health;

— rehabilitation and recuperation of the affected population is arranged according to acting legislation using rehabilitation centers situated on the territories in Belarus as a main priority;

— programs aimed at formation of healthy lifestyle of people living in the territories subject to rehabilitation must be carried out.

— Important tasks of the medical rehabilitation are:

— providing of medical institutions with modern equipment;

— preparation and improvement of medical specialists professional skills;

— reconstruction of working medical institutions and construction of new ones responsible for primary medical support;

— preparation and implementation of the programs of medical and psychological adaptation of population;

— providing of population with medicines;

— continuation of the regular health check of the population affected by the Chernobyl NPP catastrophe.

In development and implementation of programs of medical rehabilitation it is necessary to take into account necessity in providing of medical institutions with special equipment to reduce medical exposure dose.

The joint work of scientists and specialists of Belarus and Russian Federation under the **Program of Overcoming the Chernobyl catastrophe Consequences in the Framework of the Union of Belarus and Russian Federation for the years 1998-2000** is a serious contribution to solution of the above-mentioned problems. The objectives of this Program deal with the issues of radiation medicine and agricultural radiology, radiobiology and radioecology, radiation control and monitoring. Within the Program we have started to develop the unique methodological approach to radiological monitoring of environment; improvement and unification of methods for dose assessment; evaluation of post-radiation effects in conditions of chronic exposure; improvement and introduction of modern production technologies of foodstuffs and food additives as well as technology of management in agriculture, decontamination and other acute problems. There is a serious sense in continuing the work which has been started within the framework of the joint programs of the Union of Belarus and Russian Federation.

Many international programs and projects bring significant contribution to development of approaches to restoration of the contaminated territories and strategy of rehabilitation. First of all, these are the IAEA projects aimed at improvement of rehabilitation activities at the contaminated territories, including economical rehabilitation.

One of them is the project on reduction of external exposure in the contaminated settlements. During the project implementation the experience on decontamination is shared between participants, alongside with the experience on decontamination of private farms in rural areas. Such work contributes both to effective radiation protection of population and to psychological stabilization of people.

A logical continuation of the above mentioned project is the IAEA cooperation on rehabilitation of the contaminated territories through improvement of radiation protection infrastructure.

The IAEA project "Rape seed cultivation on territories contaminated by radionuclides for manufacture of food oil" envisages construction of industry in contaminated territory to manufacture food oil produced from rape seeds cultivated in the contaminated regions of southern part of the Gomel area of Belarus. Within the project the following two basic tasks will be solved:

- collective internal dose reduction through saturation of region with technical culture, and

- economic rehabilitation of the disaster affected farms.

The rehabilitation of the contaminated territories includes a complex of measures aimed at restoration of the economy, social infrastructure, physical and psychological health of people. In order to develop economic programs and to attract investments to the affected regions in the Gomel area, the Gomel Regional Economic Development Agency was created with assistance of the EU Tacis program. The main activity of the Agency is focused on work with the local communities to assist in self-employment of the population of the affected regions. A special Presidential Decree on tax privileges for seven most affected districts of the Gomel region is under preparation to attract investors.

The ETHOS project supported by the European Commission has been implemented in one of affected Belarusian regions since 1996. Within the framework of this project an untraditional approach on involving the population in management of radiological risks is developed, an attempt to optimize all countermeasures applied at local level in agriculture as well as actions of all structures and experts involved into the processes of rehabilitation has been made.

It would seem that almost 15 years after the accident the affected population and all the people in the affected countries have to be well informed both on consequences of the Chernobyl accident and about rules of behaviour in conditions of permanent health risk. Regretfully, the experience of dialogue with the people shows that the **strategy of public information** still has to be improved. This has been recognized by the European Commission which initiated a number of Tacis projects in support of development of means of informing of the population. Any measures demanding significant expenses of the state will not give desirable effect if the people do not protect themselves from existing radiological risks and stay illiterate with regard of radiological culture. To improve public radiological education, active involvement of experts is of primary importance.

Although a long time passed since the Chernobyl accident, a lot of problems of rehabilitation of affected areas still remain to be solved. In this regard, both national efforts and international collaboration are very important. It should be stressed that unique experience of the overcome of the Chernobyl accident consequences may be invaluable in case of any other nuclear failure.