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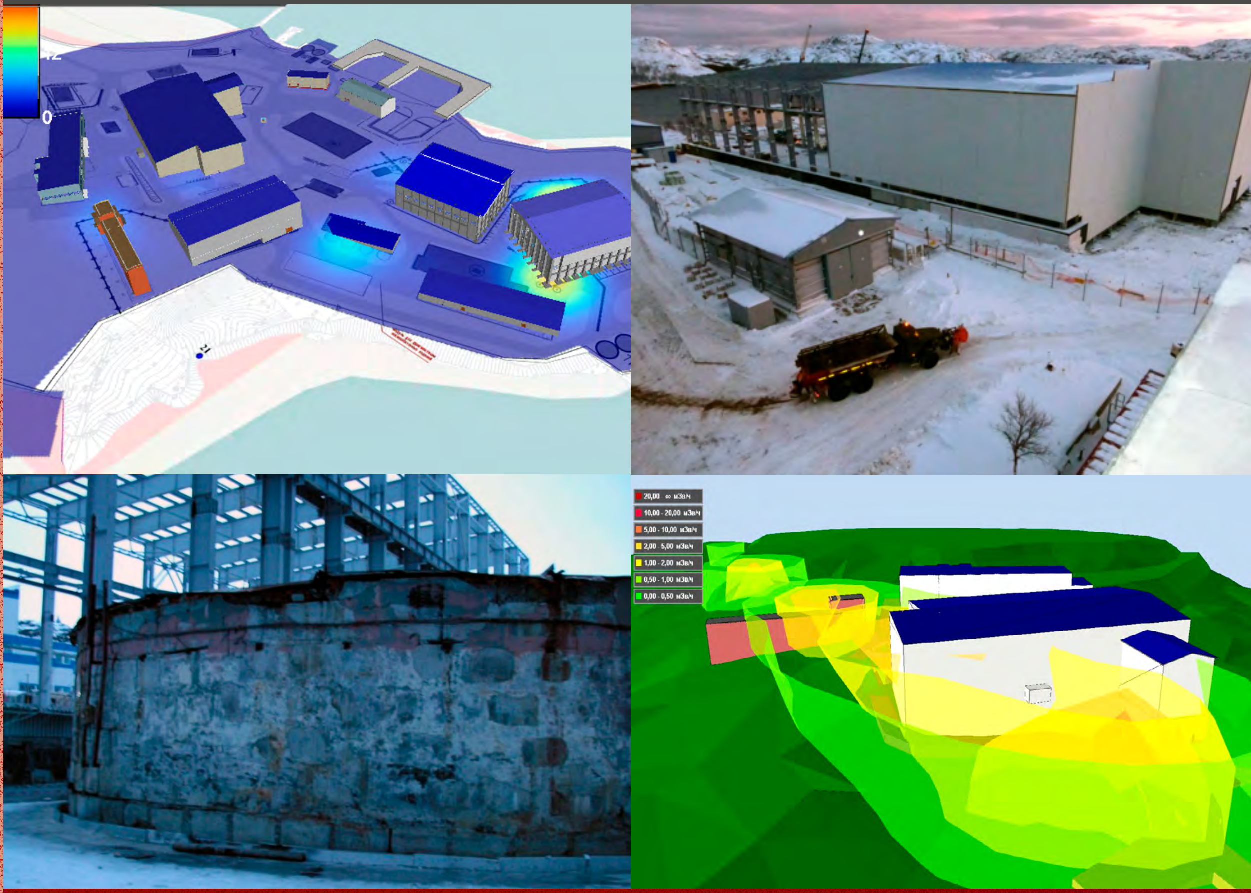

Regulatory Cooperation Program between Norwegian Radiation Protection Authority and Russian Federation

Results of projects completed from 2010 to 2015

Reference:
Siegien-Iwaniuk K, Sneve M K, Strand P, Kiselev M , Romanov V, Shandala N K. Regulatory Cooperation Program between Norwegian Radiation Protection Authority and Russian Federation. Results of projects completed from 2010 to 2015.
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Key words:
Regulation of legacy, remediation, radiation protection, nuclear legacy, spent nuclear fuel, radioactive waste, contaminated land, emergency preparedness and response, environmental monitoring, adiological environmental impact assessment, worker protection, public protection, protection of the environment, regulatory compliance.

Abstract:
This report describes work carried out between 2010 and 2015 within the regulatory cooperation program of the NRPA and Russian Federation. It focuses on development of improved regulatory documents, procedures and other features of supervision of remediation activities being carried out at the Site for Temporary Storage of spent nuclear fuel and radioactive waste at Andreev's Bay and related facilities in northwest Russia.

Referanse:
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Emneord:
Regulering av avfall, utbedring, strålevern, historisk radioaktivt avfall, brukt kjernebrensel, radioaktivt avfall, forurenset jord, beredskap og respons, miljøovervåking, radiologisk konsekvensutredning, beskyttelse av miljøet, overholdelse av regelverk.

Resymé:
Rapporten beskriver arbeid som ble utført fra 2010 til 2015 innenfor myndighetssamarbeidet mellom Strålevernet og Russland. Det fokuserer på utvikling av regulerende dokumenter og prosedyrer for sikker håndtering av brukt kjernebrensel og radioaktivt avfall som er lagret ved anlegg i Andrejev-bukten og tilsvarende anlegg i Nordvest Russland.

Head of project: Malgorzata K. Sneve
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Regulatory Cooperation Program between Norwegian Radiation Protection Authority and Russian Federation

Results of projects completed from 2010 to 2015

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Executive Summary

This report describes work carried out between 2010 and 2015 within the regulatory cooperation programs of the Norwegian Radiation Protection Authority, with the Federal Medical-Biological Agency of Russia and with the Directorate of State Supervision over Nuclear and Radiation Safety of the Ministry of Defense of the Russian Federation. It focuses on development of improved regulatory documents, procedures and other features of supervision of remediation activities being carried out at the Site for Temporary Storage of spent nuclear fuel and radioactive waste at Andreeva Bay and related facilities in northwest Russia. Topics included:

- emergency preparedness and response;
- control of doses to workers;
- control of doses to the public;
- protection of the environment;
- independent environmental monitoring;
- visualisation and prognosis of radiation environment on site and in buildings;
- personnel reliability monitoring, and
- work in support of safe dismantling of marine nuclear facilities.

All activities were funded by Norwegian Ministry of Foreign Affairs through Norwegian Plan of Action

Many important regulatory documents and procedures have been prepared within the cooperation programs and then approved within the regulatory framework of the Russian Federation. In addition, new information on the radiation and radio-ecological conditions at sites in northwest Russia has been collected and analysed, as well as tools for their visualisation. These tools support the understanding of possible impacts on the environment, the management and optimisation of radiation exposure of workers and the public, and training of staff involved in hazardous operations. Tools and procedures for monitoring the performance reliability of those staff have also been developed and applied. In combination, these results contribute to the continuing development and enhancement of an overall safety culture.

These activities were a natural continuation of projects developed after completion of an initial regulatory threat assessment carried out in 2005. At the end of the period, it was timely to update the initial threat assessment and the report of that work has formed the basis for continuing regulatory cooperation projects, taking into account progress with the program of industrial projects and developments in international recommendations and guidance. The continued application and development of this regulatory work is considered to be very important, given the hazardous nature of the next phase of remediation activities that are linked to recovery, making safe, and transport of SNF and RW from their present poor storage conditions.

As well as a holistic view of radiation protection issues, the program has been designed to engage with all relevant regulatory authorities in Russia, and to include dialogue with operators and other appropriate organizations. In addition, information from the program is shared widely with the international community, though participation in workshops and conferences and in the successful publication of program results in peer reviewed journals.

In addition the experience gained is being applied in other areas of Russia and in other bilateral cooperation programs with countries of Central Asia and Ukraine. It is further hoped that the results will be used in the continuing update and enhancement of international recommendations and guidance concerned with nuclear legacies.

List of Abbreviations and Acronyms

ALARA	As Low As Reasonably Achievable
CERAD	Centre for Environmental Radioactivity, Norway
DCRL	Derived Consideration Reference Levels
DSS NRS	Directorate of State Supervision over Nuclear and Radiation Safety of the Ministry of Defense of the Russian Federation
EC	European Commission
EDIS_STS	Expert-and-Diagnostic System of risk monitoring of the performance reliability violation of persons involved in operations at STS
FMBA	Federal Medical-Biological Agency of Russian
FMBC	Burnasyan Federal Medical Biophysical Centre
FSUE	Federal State Unitary Enterprise
GIS	Geo-Informational System
HPZ	Health Protection Zone
IAEA	International Atomic Energy Agency
IAS RBP	Information and analytical system on radiation protection of workers
ICES	International Center for Environmental Safety
ICRP	International Commission on Radiological Protection
NFME	Nuclear facility of marine engineering
NRHF	Nuclear radiation hazardous facility
NRPA	Norwegian Radiation Protection Authority
PPP	Psycho-physiological prices
PRM	Performance Reliability Monitoring
RHF	Radiation Hazardous Facilities
ROSATOM	State Nuclear Energy Corporation of Russia
Rostechnadzor	Federal Environmental, Industrial and Nuclear Supervision Service
RUERS	Russian Unified Emergency Rescue Service
RW	Radioactive Waste
SA	Supervised Area
SevRAO	Northern Federal Facility for Radioactive Waste Management
SNF	Spent Nuclear Fuel
SRI IMM	Scientific Research Institute of Industrial and Marine Medicine
STS	Site of Temporary Storage for SNF and RW, formerly designated as Shore Technical Bases
TIBUR_TSP	Visualization soft/hardware training tools for use in combination of EDIS_STS
WBC	Whole Body Counter
ZPMP	Zones of emergency protective measure planning

1 Introduction

1.1 Background

In April 1994, the Norwegian Government presented Report No. 34 on nuclear activities and chemical weapons in areas adjacent to Norwegian northern borders. As a result, the Norwegian Ministry of Foreign Affairs drew up a Plan of Action, which was implemented from April 1995. The activities under the Plan were categorized into four prioritized areas:

- safety measures at nuclear facilities;
- management, storage and disposal of radioactive waste and spent nuclear fuel;
- radioactive pollution in northern areas; and
- arms-related environmental hazards.

For 2013-2017 timeframe, Norwegian government updated categorization and pursued activities in seven areas:

- emergency preparedness;
- environmental monitoring
- cooperation with relevant Russian competent authorities;
- nuclear non-proliferation and physical safety;
- nuclear power plants (NPPs);
- spent nuclear fuel (SNF) and radioactive waste; and
- radioactive sources.

The Site for Temporary Storage (STS) of spent fuel (SNF) and radioactive waste (RW) at Andreeva Bay contains one of the largest radioactive inventory in the northwest Russia and is located just 45 km from the Norwegian border [1]. The degradation of the infrastructure of the former shore technical base after termination of its active operation resulted in significant degradation of the SNF and RW storage. Therefore, the environment became contaminated with radioactive material. The potential for additional release of contamination due to acute and continued prolonged further degradation of the stored fuel, and the spreading of this contamination, in addition to irregular and extreme radiation conditions at the Andreeva Bay STS, generated a substantial continuing threat of radiological risks for workers, the public and environment, locally and regionally and across national borders. As a part of the national policy of the Russian Federation in the field of remediation of nuclear legacy sites, the Plan of the environmental remediation of the Andreeva Bay STS was established in 2002. The consistent implementation of this Plan involves the restoration of the area up to the brown field state. The main tasks of the environmental remediation were set out as follows:

- Preparation and removal of the SNF, solid and liquid RW from the STS area;
- Remediation (demolishing or conservation) of building and construction;
- Reclamation of the site.

The regulatory authority in the Russian Federation responsible for nuclear and radiation safety supervision at Andreeva Bay is the Federal Medical Biological Agency of Russia (FMBA). As part of the Norwegian Plan of action, the Norwegian Radiation Protection Authority (NRPA) has operated a regulatory cooperation program with the FMBA for over ten years. Improvement and update of the regulatory basis and procedures for supervision of the above tasks have been the main focus of that cooperation, taking into account the abnormal conditions at the site, on-going developments in international recommendations and guidance, and good practice in other countries. The intention is that the necessary regulatory supervision should be carried out efficiently, to assist the timely and effective implementation of industrial projects. Progress with that work up to the end of 2009 was reported in [2, 3, 4].

The STS Andreeva Bay was previously a military base and some aspects of management of the legacy are still under the supervision of the military authority, the Department of State Supervision over Nuclear and Radiation Safety of the Ministry of Defence of Russia (DSS NRS). Following the success of regulatory cooperation with the FMBA, a further cooperation agreement was set up between the NRPA and the DSS NRS. Initial work in that area was reported in the NRPA report series [5]. This described the joint development by the DSS NRS and the FMBA of new regulatory guidance on “Safety Provision while Managing Radioactive Waste Containing Nuclear Materials at the Enterprises of the State Atomic Energy Corporation “Rosatom” in the northwest of Russia”. A second stage of work was completed in 2012 [6] covering the preparation of draft regulatory guidance document entitled: "Methodology for Evaluating the Compliance with Nuclear and Radiation Safety Requirements of Contractors Performing Dismantlement of Nuclear Submarines, Nuclear-Powered Surface Ships and Nuclear Service Ships Decommissioned from the Navy". This draft was subsequently officially approved by the relevant state authorities.

1.2 Objectives and Scope of this Report

Recognizing the continuing relevance and success of the program up to that time, the Norwegian government updated the Plan of Action in 2009, as reported in [7]. At the same time, the NRPA was given responsibility for implementation of key features of the Plan.

This report describes work carried out in projects completed as part of that continued program concerned with northwest Russia in cooperation with the FMBA and the DSS NRS in the period after the work mentioned above up to 2015. These projects covered the following topics:

- Emergency Preparedness and Response (PRACTICE, STRATEGY)
- Control of Doses to Workers (WBN, REMEDIATION)
- Protection of the Public and the Environment: Independent Environmental Monitoring and Assessment (ENVIRONMENT)
- Visualization and Prognosis of Radiation Environment on Site and in Buildings (DOSEMAP2, DATAMAP- GIS, DOSEMAP3)
- Personnel reliability monitoring. (PRM2, PRM3)
- Decommissioning and radioactive waste management (SATO)
- Monitoring of the effectiveness and assessment of the safety culture
- Updated threat assessment from regulatory authority perspective (THREAT)

Work was carried out by specialists of the Burnasyan Federal Medical Biophysical Center (FMBC), a technical support organization of FMBA, the International Center for Environmental Safety, and the Research institute of Industrial and maritime Medicine, with further contributions from specialists of SevRAO and Rosatom as well as NRPA and the Centre for Environmental Radioactivity (CERAD).

An important feature of the work has been science that underpins regulatory developments. Accordingly, the program included scientific workshops, involving participants from international and other national agencies, as well as presentation of papers at conferences, and the production of peer reviewed papers for publication in scientific journals. Important examples are discussed in the following sections that describe the work in each topic. References are included at the end of each section.

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2 Emergency Preparedness and Response (PRACTICE, STRATEGY)

2.1 Project objectives and activities

The accident at the Fukushima Dai-ichi nuclear power plant Fukushima in Japan resulted in significant review in the area of emergency preparedness, consideration of a new concept of classification of radiation accidents and medical support integration into the overall strategy of protective measures.

Noting the responsibilities of FMBA, the focus of projects in this area is improvement of the health care provision in the event of an accident. Consideration was given to two aspects, development of a general strategy for regulation and control of the emergency preparedness and accidents or incidents during radioactive substance transport. The overall objectives were:

- To improve the strategy of regulation and control of emergency preparedness by FMBA
- Development of criteria and general methodology for comparative assessment of radiation hazardous facilities as applicable for tasks of assessment of preparedness and planning of health care provision in case of radiological accident
- Provide recommendations regarding medical and protective measures in case of radiation event when transporting radioactive substances.

When selecting the strategy of emergency planning and response, a significant role is played by incorporation of regulatory activities and medical support into the overall strategy of emergency preparedness, including planning of protective measures on the basis of the analysis of potential threats and specific implementation of doses to the population in a particular infrastructure and location of a radiation hazardous facility. Accordingly, the specific project objectives included:

- Support of the FMBA's local regulatory bodies in emergency planning and preparedness of the health care provision within FMBA of Russia;
- Enhancing interaction between operators under regulatory supervision by FMBA's local regulatory bodies, and regulatory bodies, which execute the state functions of the radiation safety supervision and regulation;
- Identification of areas to develop the strategy of the radiation safety regulation of workers and the public, and health care provision in case of radiological incidents and accidents at facilities and sites of Murmansk region and adjacent areas under the regulatory supervision of FMBA;
- Ranking the sites in the northwest Russia depending on potential radiation hazard taking into account international approaches;
- Evaluation if the regulatory supervision is sufficient at the radiation hazardous facilities of the northwest Russia.
- Preparation and elaboration of practical measures when working out operation of expert and work groups to assess the radiation consequences of emergencies.
- Working out communication of the regulators responsible for operation of the FMBA's of Russia regional institutions.
- Operative preparation of the regulatory documents in case of transport radiation incidents.
- Performance of the accident consequences mitigation.

Project activities included:

- Analysis and systematization of the contemporary international and national documents
- Analysis of postulated radiological accidents, hazard categories, planning of emergency measures
- Medical and demographic characteristics relevant for planning of urgent protective measures (30-50 km zone)
- Peculiarities and quantitative characteristics of agricultural production in the vicinity of the selected facilities (100 km zone);
- Analysis of preparedness of institutions of the FMBA of Russia and general characteristics of medical institutions (30 km zone)

To support this work a substantial roundtable meeting was organized at which the key relevant Russian organizations were able to present and discuss their roles and organizational interfaces: "Important goals in radiation safety regulation during planning and carrying out health-care measures in case of radiation accidents and incidents at sites and facilities of the northwest Russia being under service of the Federal Medical-Biological Agency" in Murmansk, October 7-8, 2013, regarding to development of the approved list of positions on regulation of radiation safety and emergency preparedness.

Fig. 1 The participants of the roundtable in Murmansk, October 2013.

2.2 Project outputs and discussion

The initial outputs included:

- Development of criteria for evaluation of the potential radiation hazard, associated with the analysis of possible design basis and beyond design basis radiation accidents at the considered facilities, as well as the characteristics of their locations (demography, agriculture) and health care infrastructure.
- Development of recommendations for the FMBA's regulatory bodies on activities in case of threat and development of radiological accident and Reference materials including some mapping and numeric material to justify the proposed criteria for evaluation of the potential radiation hazard.
- Development of general strategy of management and control of emergency planning and preparedness by regulatory bodies, enhancing the emergency preparedness of the FMBA's institutions in the northwest Russia.
- Examination of practice to support the emergency readiness of regional bodies of FMBA for the incidents with radiation substances being transported and international experience for this issue.

- Development of methodological and organizational basics for the interaction of working groups of regulators and supporting experts
- Implementation of practical measures to practice the interaction and training of emergency services of operators, regulators and expert groups

From this work it was recognized that practical measures needed to be prepared for working out operation of expert and working groups to assess the radiation consequences of emergencies and to provide recommendations regarding medical and protective measures in the case of radiation events during transportation of radioactive material. The findings revealed problems in organization of interaction and response both at the local level within the FMBA system and at the level of the external responsible agencies (SC ”Rosatom” etc.).

These issues were discussed at a workshop organized in Sochi, on 20-21 September, 2011. Here, the practice of regulatory bodies and FMBA’s teams was presented in different modes (normal operation, increased preparedness and emergency), as well as practice of the Norwegian authorities. The exchange of views and transparent discussion of relevant issues of emergency response and interaction when mitigating consequences of transport accidents between the professionals from different agencies at the workshop showed an effective form of prioritizing emergency planning, preparedness and interaction.

Next stage of the project was a case study, performed for the purpose of the comparative threat assessment on selected radiation hazardous facilities (RHF) with different types of potential hazard, and different conditions of allocation (Fig. 2, Tab. 1) applied to the problems of emergency preparedness and planning of health service.

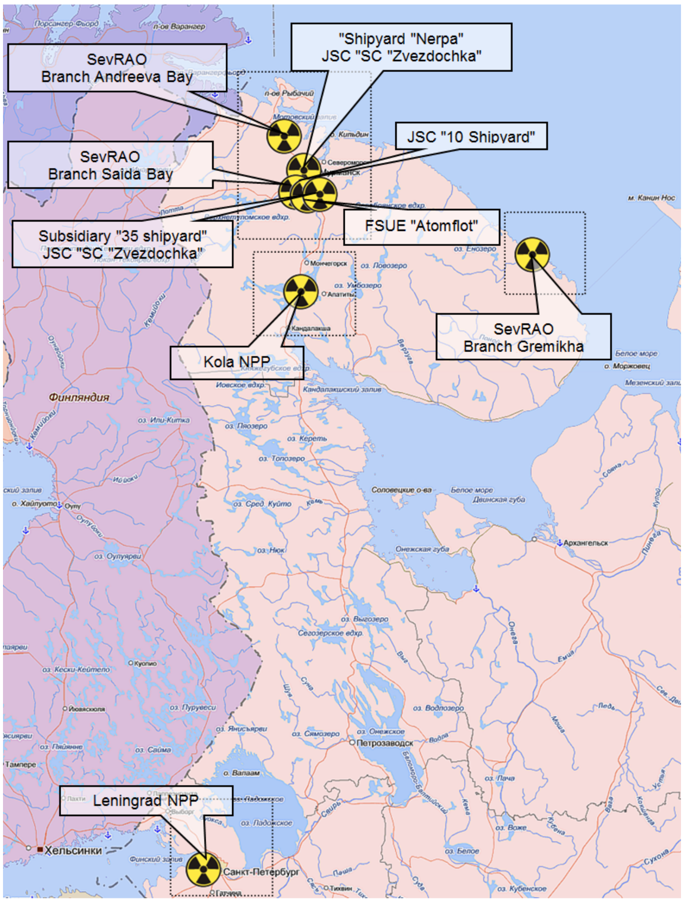

Fig. 2 Radiation hazardous facilities in the Northwest region.

To develop a common methodology for the comparative evaluation of threats in relation to the assessment of the preparedness and planning of health provision in the case of radiological accidents, the following main areas of research have been identified:

- rating categories of potential hazards (threats) based on analysis of the consequences of postulated radiological accidents;
- study of medical and demographic characteristics of importance when planning emergency protective measures (30-50 km zone);
- study of the special features of agricultural production in the vicinity of the selected facilities (100 km zone);
- analysis of the preparedness of FMBA's institutions and general characteristics of medical institutions (30 km zone).

Table. 1- Categories of threats and size of zones of emergency protective measure planning (ZPMP)

Radiation hazardous facility	**Sources of radiation hazard**	**Category of facility according to OSPORB-99/2010**	**Category of threat according to IAEA-TECDOC-953**	**ZPMP, km (according to OSPORB-99/2010)**	**ZPMP, km (according to IAEA-TECDOC-953)**
Kola NPP Leningrad NPP	Nuclear reactor	I I	I I	25 25	25 25
Shipyards:					
"Nerpa";	Naval reactor	I	II	5	0.5 - 5
"10th plant";		I	II	5	0.5 - 5
"Atomflot";	TPC and TC, SRW and LRW	II	II	not required	0.5 - 5
"35th plant";		III	III	not required	not required
SevRAO faciites:					
"Gremikha";	Degraded SNF, Damage of the compartment with SRW	I	II	Not set	0.5 - 1
"Andreeva Bay";		I	II	Not set	0.5 - 1
"Saida Bay"	Treatment and storage of SRW	II	II	HPZ	<0.5

Performed studies were subjective and largely relied on expert judgment and intuitive ideas of the importance of a factor (criterion) in the aggregate ranking of potential hazard (threat). No original studies have been performed in the field of the probabilistic analysis and simulation of consequences of the postulated radiological accidents. It was assumed that these results are reflected in the relevant project documentation and site-specific emergency plans. At the same time it was noticed that the list of potential radiological accidents, dimensions of the zone of planning of protective measures, values of operational dosimetry values for operative assessment of the radiation situation, requires the further clarification or development.

A relatively new area in this study was an attempt to assess the potential hazard, not only on the basis of ideas about manmade sources of hazard, but also taking into account the most significant factors arising from potential exposures doses to the public and how they might affect the application of the infrastructure for health provision in the vicinity.

Performed the analysis of technological, demographic, agricultural and medical factors helped to identify generalized characteristics for all significant criteria for comparison of the facilities. In the analysis function of the quantitative assessment of potential hazard was used, which is based on a combination of the model of atmospheric effluent transport (Fig.3A) and the distribution of population within the circular zones at different distances from the effluent source (Fig 3B).

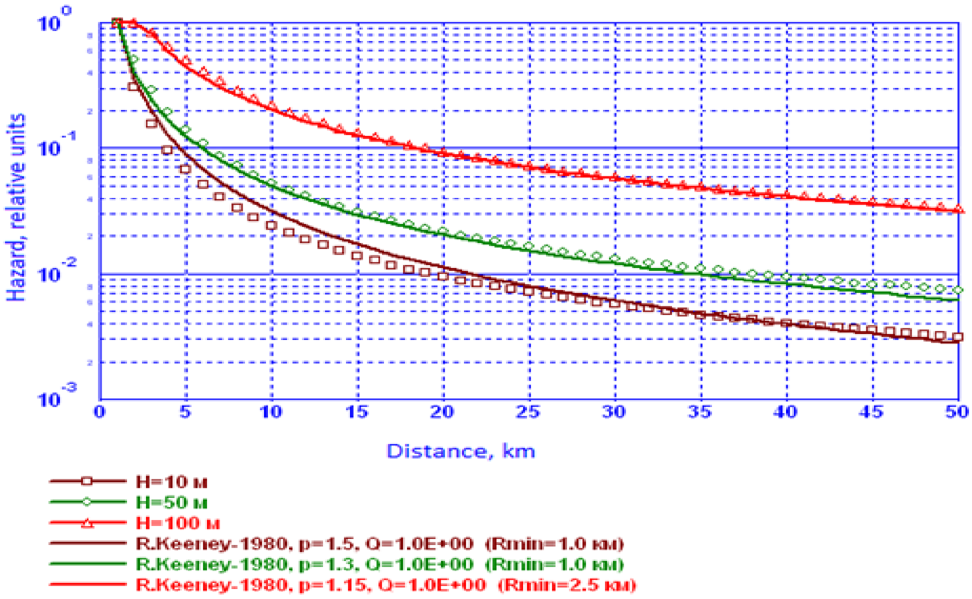

Fig. 3a Distribution of the hazard function depending on the distance from a radiation hazardous facility for various heights of release H, and approximation of these data using the model of R. Keeney.

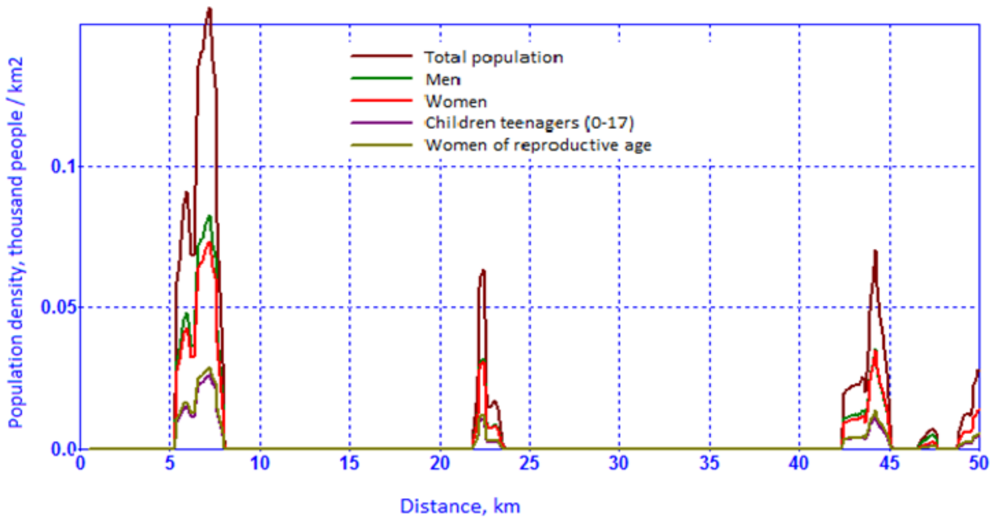

Fig. 3b Example of the population density distribution in the 50-km zone in RHF "Branch Andreeva Bay".

Fig. 4 illustrates the results of the hazard function assessment. It should be stressed that these assessments were being made per unit activity released. Therefore, the obtained differences are due only to demographic factors. At the same time, the results demonstrate stability in result for atmospheric dispersion.

Comparative assessments of various locations over actual material on resources and volumes of agriculture, special features of export and import, as well as taking into account the food ration of different groups of the population within 100 km zones of the facilities demonstrate different contributions of the “agricultural factor”. It should be noted that regions with the highest value have developed dairy production and cultivation of leafy vegetables (iodine food chain), as well as fishing and fish farming.

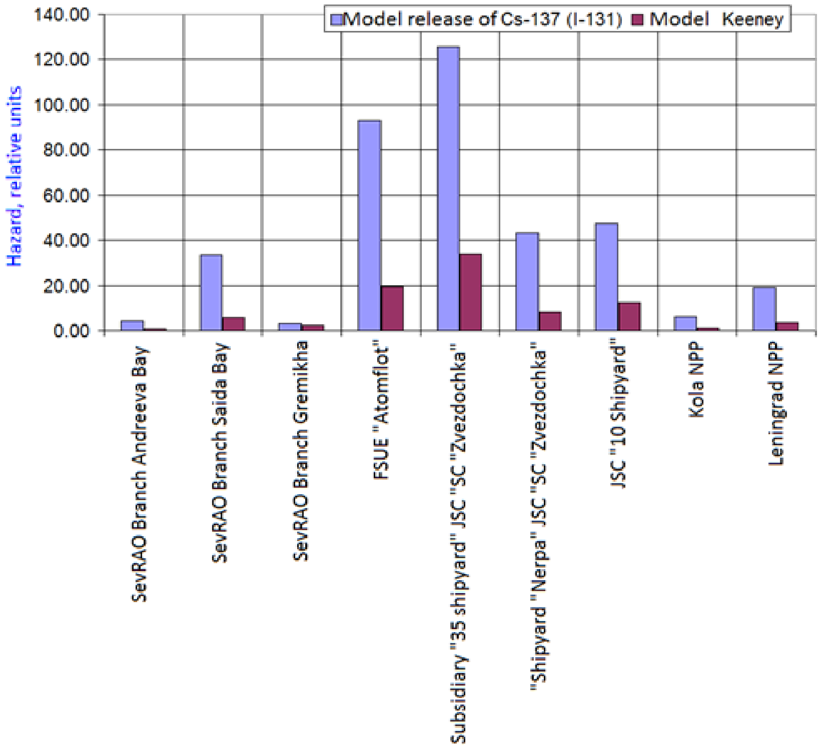

Fig. 4 Comparative assessment of hazard being calculated on the basis of parameters of the population distribution at the effluent of the unit activity of Cs-137 and I-131 nuclides and using the R. Keeney model.

Obtained results lead to conclusion that for locations of the Leningrad and Kola NPPs, planning the limiting consumption of contaminated food is an important constituent in the overall complex of protective measures. At the same time, at locations of SevRAO facilities, the value of the agricultural use of the land is relatively lower or insignificant (Fig. 5).

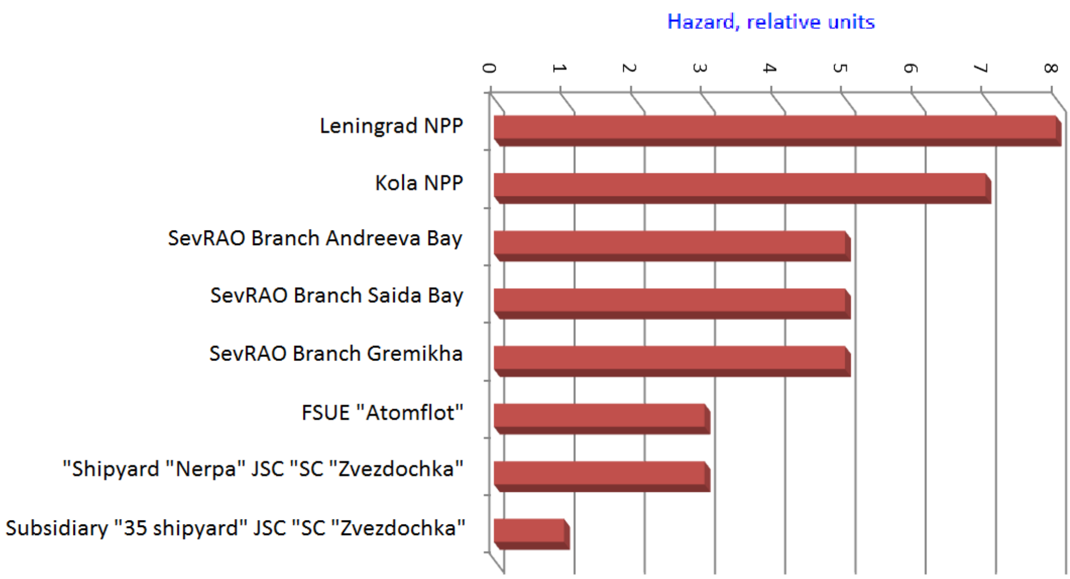

Fig. 5 Relative hazard of facilities in terms of the "agriculture" criterion.

Summarizing, it is clear that these estimates took into account only the demographic factor in combination with the selected model of distribution of the release in the atmosphere, i.e. without considering quantitative estimates of the discharged activity under various scenarios of emergency, but concluding remark is that use of different models of the spatial hazard distribution of RHF leads to significantly different results at an integrated assessment of the threat to the population. This however indicates the stability of the relative estimates of hazard for different models of distribution of the radioactive materials release in the atmosphere.

There is a need to mention that the probability of beyond design basis radiation accidents is extremely low. They can be associated with the initial events, which are not directly related to disorders and failures in basic operating procedures. Only these types of very-low-probability radiation accidents can have radiological consequences for the population and the environment outside the nuclear and radioactive facilities. Such accidents are considered in the design documents and necessary protective and health care actions are planned for them.

In course of research studies of health ensuring population in the Murmansk and Leningrad regions, characteristics of the territorial health care institutions were examined. According to the analyzed data, including material on emergency drills and training, the potential threats of radiation exposure to the personal of facilities, the environment and the population of the northwest Russia are systematically reduced. First of all this applies to enterprises of SevRAO. Construction of replacement facilities of the Leningrad NPP producing reduction of risks and threats in the densely populated district of the Leningrad region should be especially noted.

An important constituent of the regulatory activities is the development of unified methods for assessing the potential emergency hazard and possible health effects as a basis for emergency planning based on the principle of reasonable sufficiency and realism. Taking this into account the priority in the development of the strategy is to integrate the emergency response system of FMBA of Russia into a single state system of prevention and mitigation of emergencies, RUERS (Russian Unified Emergency Rescue Service), based on the address of interagency cooperation with industry systems of the Rosatom, Emercom, and health authorities of subjects and territories of the Russian Federation. Planned activities fall within the following areas:

- development of a common methodology for emergency medical response and overcome the health consequences of radiological accidents in current realities and prospects of development of SevRAO;
- development of expert-and-analytical systems to support for prediction and assessment of the health consequences of radiological accidents based on integration with information-and-analytical systems of technical support centers under the system of the State Corporation Rosatom;
- development of quantitative methods for assessing preparedness and medical property reserves planning to address health consequences of radiological accidents;
- development of emergency response infrastructure in regional emergency centers under FMBA and specialized rapid response teams.
- development of unified and standardized guidelines for preparedness, logistics equipment and training of medical personnel to work in an emergency.

Events are based on a holistic and systematic coverage to improve the emergency preparedness system of health service support of SevRAO, covering organizational and scientific-and-technical aspects.

The main finding of the studies presented is, that emphasis of research and development should be put rather on radiation protection of workers than the public combined with formulation and implementation of the principles of a strong safety culture. The full set of analyzed information shows that the potential threats of radiation exposure to workers of the facilities, the environment and the population of the northwest region of Russia are being systematically reduced.

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3 Control of Doses to Workers (WBN, REMEDIATION)

3.1 Project objectives and activities

Dose prediction and planning with respect to workers involved in radiation hazardous operations is an important component of organizational measures when implementing the optimization principle. NRPA together with FMBA of Russia has performed a series of projects aimed to monitor the changing radio-ecological situation and to improve capabilities in radiation protection of workers, as well as to enhance regulatory supervision.

From 2010 – 2014, activities focused firstly on control of internal exposure of SevRAO workers, which are and will be involved in technological operations of SNF management and RW treatment. This included improved methods for internal dose monitoring of SevRAO workers using the special calibration of spectrometers and establishing the procedure of monitoring of internal contents of α and β emitters in irregular situations.

The second part of work included development of the regulatory Guidance “Radiation Protection of Workers and the Public during Remediation of Nuclear Legacy Sites”. This contains requirements for main aspects of the personnel and public protection during remediation both of radioactively contaminated sites of industrial facilities in the course of their decommissioning and areas contaminated due to radiological accidents and nuclear weapon tests. It is based on the postulate that radiation safety during remediation of areas under radionuclide contamination is sufficient if technical means and organizational measures, provided by the remediation project, ensure non-exceeding the basic dose limits to workers and the public.

The main activities included:

- Analysis of radionuclide composition generated during the SNF and RW management, in the course of which a possibility of the radionuclide incorporation into the human organism exists.
- Improved methods for radionuclide measurements using the SevRAO whole body counter (WBC).
- Development of approach for arrangement of an expert system for assessment of individual internal dose and the uncertainties.
- Development of methods for internal dose calculation for each relevant radionuclide, taking into account uncertainties.
- Development of an algorithm for examination of workers during the SNF and RW management to evaluate any radionuclide intake, its distribution by organs, dynamics of its excretion, and assessment of doses to whole body and some organs.
- Clarification of intakes of α emitters and the associated committed doses in the irregular situation, including the express method for the content determination of uranium and transuranic elements in terms of measurement of gross alpha activity in urine.
- Analysis of available national and international regulatory and methodical documents on assurance of radiation protection of workers and the public during remediation of contaminated areas.
- Development of Guidance “Radiation Protection of Workers and the Public during Remediation of Nuclear Legacy Sites”.

3.2 Project outputs and discussion

Work completed supplemented the system for internal dose monitoring of the SevRAO workers with methodical documents, in compliance with the requirements of health and epidemiological supervision to support monitoring of the SevRAO personnel under normal operational conditions of radiation sources as well as under emergency exposure.

In the first step, intake composition of radionuclides generated in the course of SNF and RW management was analyzed and the list of relevant radionuclides was developed, accounting for the mixture of radionuclides which might be encountered by workers. Consideration was given to possible intake via ingestion, inhalation and through the skin, in normal and abnormal work conditions. Work has been performed by analyzing literature data and data of the SevRAO dosimetry service. Radionuclides resulted from irregular situations at SevRAO and critical organs, which might be exposed, are gathered in Table 2.

Table 2. Potential distributions of radionuclides originated from emergency release in the body of the personnel involved in operations at SevRAO

Radionuclide	*Organs and tissues*						
	Lung	*Liver*	*Bone*	*Pancreas, spleen*	*Kidney*	*Thyroid*	*Whole body*
^{54}Mn	+	+					+
^{60}Co	+	+					+
^{88}Rb		+		+			+
^{89}Rb		+		+			+
^{90}Rb		+		+			+
^{90}Sr			+				
^{124}Sb	+		+				+
^{125}Sb	+		+				+
^{131}I						+	
^{132}I						+	
^{133}I						+	
^{134}I						+	
^{135}I						+	
^{134}Cs		+		+			+
^{137}Cs		+		+			+
^{138}Cs		+		+			+
^{139}Cs		+		+			+
^{141}Ce	+		+				
^{144}Ce	+		+				
^{152}Eu	+		+		+		
^{154}Eu	+		+		+		
^{238}Pu	+	+	+				
^{239}Pu	+	+	+				
^{240}Pu	+	+	+				
^{241}Pu	+	+	+				
^{241}Am	+	+	+				

At the time of the work, the abilities of the dosimetry service in irregular situations were limited to measurement in the human body with acceptable accuracy only ^{137}Cs, ^{134}Cs and ^{60}Co.

Analysis of data from SevRAO dosimetry service showed that monitoring of radionuclide intake by workers was carried out selectively for some workers, by measurement of ^{137}Cs in the whole body, ^{131}I in thyroid, ^{60}Co, ^{137}Cs, ^{54}Mn, ^{51}Cr in lung. For measurement has been used WBC installation USK "Gamma Plus". Results of monitoring showed that under normal conditions of work intake of ^{137}Cs is trivial and intake of other radionuclides was below detection limit.

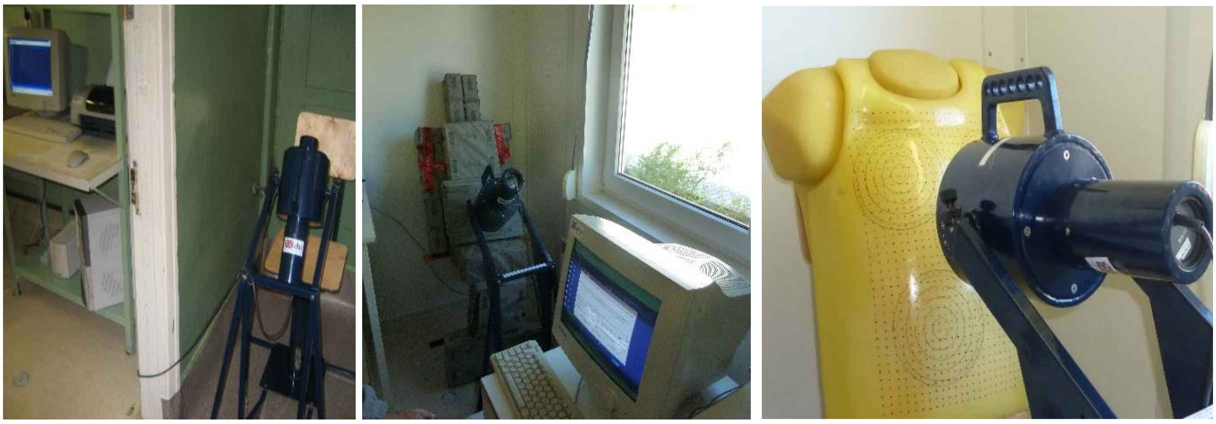

Fig. 6 SevRAO spectrometer USK "Gamma Plus No0325-SICh", in the middle and on the right – with phantoms "Spasatel" and "Alderson".

Performed examination of radionuclide release composition during potential emergencies (generic case) at SevRAO showed that significant contributions in the internal dose might come from ^{60}Co (about 3 %), ^{90}Sr (about 20 %), ^{137}Cs (about 50 %) and ^{241}Am (about 27 % in total). In case of the beyond design basis accident with a spontaneous chain reaction, releases can include radioactive iodine (mainly ^{131}I). Measurements were performed using human phantoms: "Spasatel" with ^{137}Cs radionuclide and "Alderson" [25] with ^{60}Co, ^{152}Eu and ^{241}Am radionuclides (Fig. 6).

Phantoms were scanned at the computer tomography, then using software OEDIP and SABRINE [25, 26] their scans voxel - phantoms (mathematical phantoms fig.7A and fig.7B) [30] have been developed. For voxel – phantoms, each mentioned radionuclide and for the scintillation detector with NaI(Tl) crystal (63x63 mm) used in USK "Gamma Plus No0325-SICh", the gamma spectrum was calculated using a Monte-Carlo method [29]. Measured spectrums from phantoms were compared with the calculated ones. The results confirmed the quality of calibration within 15% for ^{137}Cs, ^{60}Co, ^{152}Eu and ^{241}Am.

Results of calibration and examination of radionuclide release compositions in case of potential emergencies in SevRAO facilities were gathered to develop and certify "The Method for activity measurement of gamma emitting radionuclides in the human body using the WBC universal spectrometric complex USK "GAMMA-PLUS". The method is based on measurement of gamma spectra using scintillation gamma spectrometer and subsequent spectra treatment by the specialized software "Progress". Application results in activity measurement of incorporated gamma emitters in the whole body (^{137}Cs), lung (^{60}Co) and thyroid (^{131}I), as well as analysis of radionuclide composition. The method also regulates procedures of preparation and conducting measurements, storage and presentation of results. The software estimates the uncertainties of measurement for each specific measurement. The minimum measurable specific activity by Cs-137 (whole body) is 5 Bq/kg at uncertainty (P=0.95) not higher 30%.

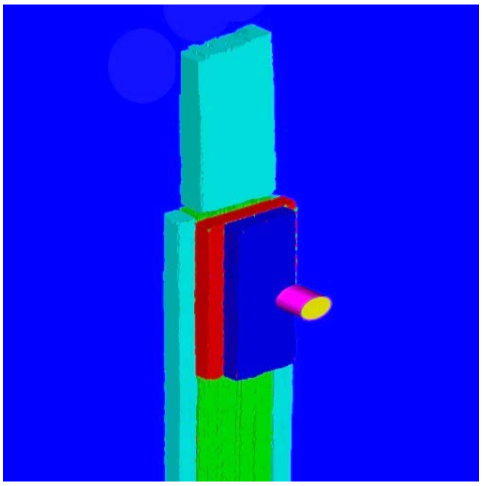

Fig. 7a Voxel-phantom "Spasatel"

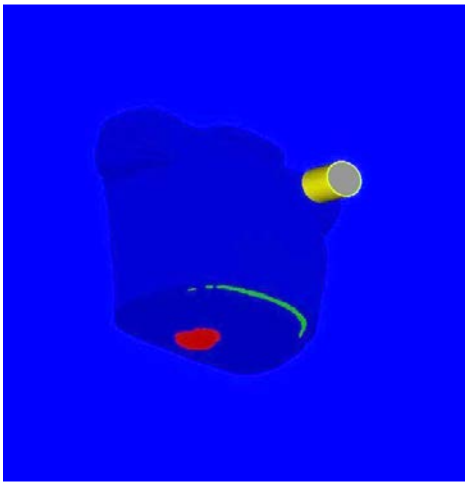

Fig. 7b Voxel-phantom "Alderson"

The next step necessary to have the expert system for dose assessment under normal operation of radiation sources and in case of special monitoring, e.g. after exposure in emergencies, accidents and unusual incidents, requires numerical method for interpretation results of individual radionuclide activities incorporated in the human body measurements. This allows interpretation of the measurement results in terms of committed effective dose and intake – in case of the routine monitoring, and in terms of equivalent dose to organs and intake – in case of the special monitoring.

The general approach to occupational internal dose monitoring is based on the up-to-date theory of the internal dose generation [7 - 14] and requirements of the regulatory documents [1 - 6]. Internal dose value is determined by calculation, based on the results of measurements performed within the group and individual dose monitoring [3, 24]. Under the project a document on "Method of calculation of effective internal dose to workers on the basis of activity measurement of gamma emitting radionuclides in the human body using WBC" was developed and certified.

Individual monitoring involves a series of biophysical measurements of workers over the calendar year (and/or the entire period of work at the facility under control). In this case, biophysical measurement (i.e., within individual dose monitoring) means either the WB -based measurement of radiation induced by radionuclides incorporated in the human body, or measurement of the radionuclide excretion rate (generally, radionuclide concentration is measured in the urine, sometimes, in feces, or, in case of tritium, in exhaled vapor). The required frequency of measurement under the routine monitoring depends on metabolic properties of the radionuclide, sensitivity of method for measurement and acceptable uncertainty in dose assessment [4, 5, 13]. Additional measurements within the special monitoring are made when the result of routine monitoring demonstrates a possibility of abnormal exposure.

Based on above presented activities special monitoring procedure has been prepared, as well as the method to determine alpha emitting radionuclides in the human body in situation when special monitoring is required.

General algorithm of the personnel examination within the special monitoring consists of additional measurements over the first and some next days since the detected acute intake, followed by the significant clarification of individual committed effective dose of the worker. Generally, the routine monitoring uses one of the alternative methods for measurement: either the WBC or excreta monitoring.

Additional measurements within the special monitoring should be conducted at least by two alternative methods for measurement specifying different processes and specific behavior of radionuclides in the body. For example, when using the direct WBC-based method as a routine one, measurement in different geometries and measurement of the radionuclide concentration in the urine may serve as additional methods. Both methods can be used in a complementary fashion.

Requirements for radiation protection of workers are provided by projects on remediation of sites contaminated with radionuclides. However, in such projects the designers mainly provide warranties of mandatory compliance with radiation protection regulations and rules and do not include the full list of activities. Monitoring of radiation exposure to workers during treatment of materials containing radioactive substances complies with norms and rules of the national and international documents. The Radiation Safety Standards (NRB-2009) [1] establish annual dose limits for workers and the public for the following regulated values: effective dose, annual equivalent dose to the lens of the eye, the skin, hands and feet.

Under one of projects the guidance, which includes a set of hygienic and organization activities and requirements, was developed, implementation of which shall be provided by the remediation project to assure non-exceeding of the main dose limits for workers and the public and continuous dose reduction in compliance with the principle of optimization.

Additionally it includes requirements for the main aspects of the personnel and public protection during remediation of contaminated sites and its framework results from the tasks identified on the basis of analysis of the regulatory documents on radiation safety and protection of workers and the public during remedial operations at contaminated sites. The scope of the Guidance covers:

- radioactively contaminated sites of industrial facilities in the course of their decommissioning;
- areas contaminated due to radiological accidents;
- areas contaminated due to nuclear weapon tests.

Document is intended for institutions of the FMBA of Russia engaged in the federal state health epidemiological supervision, and institutions, engaged in planning and execution of works on remediation of radioactively contaminated areas.

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4 Protection of the Public and the Environment. Independent Environmental Monitoring and Assessment (ENVIRONMENT, DATAMAP- GIS)

4.1 Project objectives and activities

An important trend in the development of radiation protection principles is to develop and apply the concept of supporting protection of human health, including protection of the environment, as represented by the stable functioning of ecosystems and conservation of biodiversity. International organizations including the International Commission on Radiological Protection (ICRP) and International Atomic Energy Agency (IAEA) [1-5] have issued recommendations reflecting the increased interest of the world scientific community in the radiation protection of non-human biota and appropriateness of environmental regulation. In many respects, these recommendations serve as a basis to develop national regulations and rules in radiation safety taking into account environmental aspects of radiological protection.

According to the above references, the system for safety and protection assurance should be generated in order to provide adequate protection of the environment against harmful effects of radiation. This requires analyses to determine the relevant protection criteria, assessment of radiological impacts and concentrations of radionuclides in environmental media for comparison with derived standards, such as Derived Consideration Reference Levels (DCRLs), and use of results in comparison of expected effectiveness of available options for remediation.

Between 2005 and 2009, several relevant projects were completed in the NRPA-FMBA cooperation program, as referenced in section 1, in the course of which:

- the radiation ecological situation was assessed;
- the Criteria and regulations for STS remediation were developed, as well as guidance for their application for three possible options of environmental remediation (conservation, conversion and liquidation);
- Guidelines were developed for radiation control and monitoring at different stages of the STS operation;
- additional radio-ecological criteria were developed with respect to contamination of the marine environment, as well as a corresponding database, and
- a computer map of radio-ecological data for the STS Andreeva Bay was developed.

A geo-information system (GIS) was developed for keeping and retrospective use of all collated site information, control and monitoring on the base of up-to-date computer technology application, and automated informational support of regulation and decision making system during remediation. The natural next step was to implement the system, conduct training for operators on using the software, their methodological support and software optimization.

After implementation of the GIS, project work shifted its focus to assessment of man-made radioactive contamination impact on the terrestrial and freshwater environments on the STS site. This included testing the sufficiency (or insufficiency) of existing human based protection criteria to provide protection of the environment.

Main activities included:

- Implementation of geo- information system.

- Additional examination of radio-ecological conditions at the STS Andreeva Bay, especially taking account of the progress of industrial remediation work at the site.
- Improvements in the prognostic assessment capability of the information-and-analytical system, including development of an algorithm for dose calculations for reference animals and plants, and analysis of the sufficiency of available data.
- Prediction of radiation exposure to reference organisms and analysis of the sufficiency of standards for the protection of humans to adequately protect other biota at the site.

4.2 Project outputs and discussion

In order to register the dynamics of the radio-ecological situation and predict its evolution in the current and changing circumstances of STS remediation, over 2008-2012, within the DATAMAP and DATAMAP-GIS projects, the computer map of radio-ecological data was developed and introduced into use.

The software was installed and implemented in the FMBA Regional Management office in Snezhnogorsk city and in the environmental laboratory of SevRAO at Andreeva Bay. Taking into account first users' comments, amendments and supplements were introduced into the software and its description, to:

- improve the accuracy of construction of the STS radiation situation grids;
- automate the grid construction process;
- generate and import the user maps into Rockville

During the work, the detected errors were corrected and the stability of the software operation for the algorithm generation of the route construction and dose calculation for this route was improved. Another important task was russification of the software to the possible extent. All terms, which have not Russian analogues, are explained in the software description. After introduction of all amendments, the software and User Manual were submitted to pass the certification according to GOST R ISO/MEC12119-2000 "Information technology. Software packages. Quality requirements and testing".

An important goal was to demonstrate whether the completed works on the site remediation have resulted in changing radiation situation on-site and beyond STS, in the supervised area.

Over 2010, the terrestrial and marine media samples (soil, vegetation and bottom sediments) were collected in the supervised area (SA), health protection zone (HPZ), and in the controlled access area (CAA). Gamma dose rate was measured outdoors and in the observation boreholes on-site at the STS. Simple sample mass varied from 1kg (soil samples- collected by layers, at depths 0-10 cm and 10-20 cm from the surface) to 20kg (seawater and drinking water samples). After the preliminary treatment, the collected samples have been conveyed to the FMBC to check the radioactive material contents.

To plan the soil sampling points, the GIS system was used to identify and display priority areas for additional measurements, either because of expected high rates or because of high uncertainties. At the first stage gamma dose rate was measured in points, which are relatively uniformly distributed by different STS areas. Following processing, software was used to identify the areas to carry out additional measurements. Obtained results were used to determine points for soil sampling (Fig. 8A). Samples of the bottom sediments were collected on the coast behind Building 5 (3 samples), in two points near the wooden pier, 5 meters from the water edge (coast line) under the highest tide (Fig. 8B).

Fig. 8A Points for the soil sampling on the industrial site

Fig. 8b Points for sampling the bottom sediments

The vegetation samples were collected at the CAA (5 samples), HPZ (10 samples) and in the SA (10 samples) (Fig. 9).

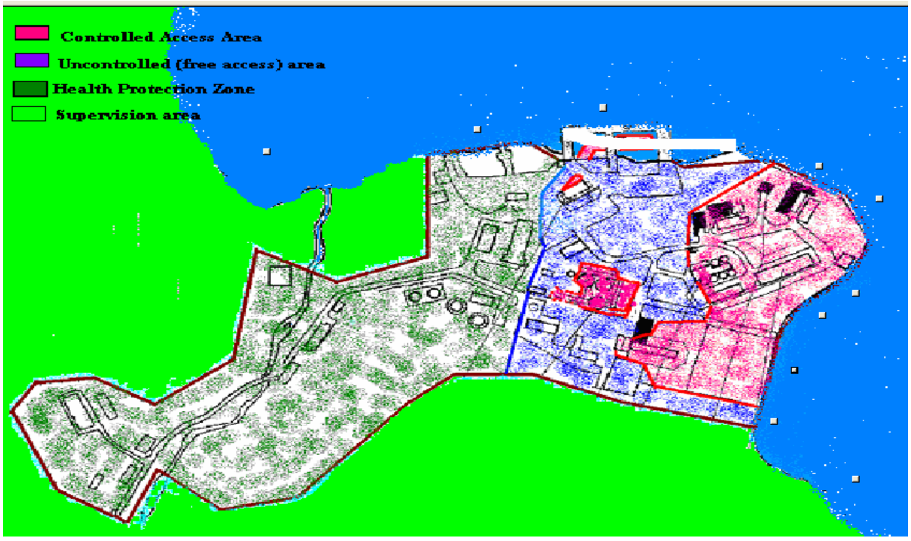


Fig. 9 Plan of the site zoning at SevRAO Andreeva Bay Facility

Using gamma spectrometers with semiconductor (FMBC) and scintillation detectors (SevRAO Andreeva Bay Facility), gamma emitting radionuclides (60Co, 137Cs etc.) were identified in samples of the environmental terrestrial and water media. Gamma survey is illustrated on Fig. 10.

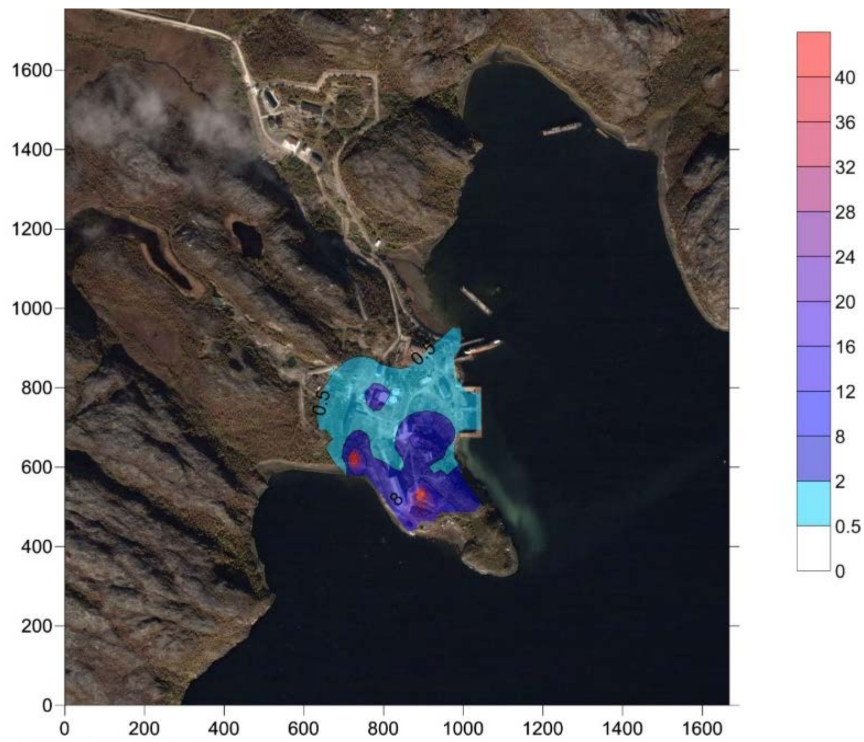


Fig. 10 Gamma dose rate on the STS site in 2010.

In the controlled area: the dose rate varies from 0.07 to 103.63 µSv/h. Maximum gamma dose rates have been registered near the radiation hazardous facilities and in the area of the former stream close to building 5. Here, gamma dose rates originated from the contaminated soil and from radioactive material inside the radiation facilities.

In the radiation safety area: here, maximum gamma dose rates (0.2 – 7.34 µSv/h) were observed on the border with the CAA close to the radiation facilities.

In the rest of the industrial site and SA: the dose rate on the border according to the associated data was 0.13 µSv/h ranging from 0.07 to 0.14 µSv/h. Here, gamma dose rate is due cosmic radiation, radiation of natural radionuclides, and dose rate does not differ significantly from those typical for the Murmansk region, about 0.1 µSv/h with a maximum in 0.2 µSv/h. Fig. 11 shows sampling points of the environmental media in SA with their assigned numbers.

Measurements showed contamination of the soil surface with 137Cs and 90Sr, in some parts of the STS industrial site. Values were 100 and more times higher than the background values typical for this region. Soil contamination with 137Cs is 4-20 times higher than 90Sr. Contaminations of soil and vegetation are interrelated. The highest contamination both of soil and of vegetation is typical for CAA. The highest radioactive contamination of soil within the STS area is near the site for open storage of SRW, near the dry stream bed, and around the Dry Storage facility.

The mean 137Cs and 90Sr contents in soil and vegetation outside the area of radiation safety control, i.e., beyond the industrial site, are about the background value typical for uncontaminated regions of the Northern Russia.

Fig. 11 Points of sampling in SA

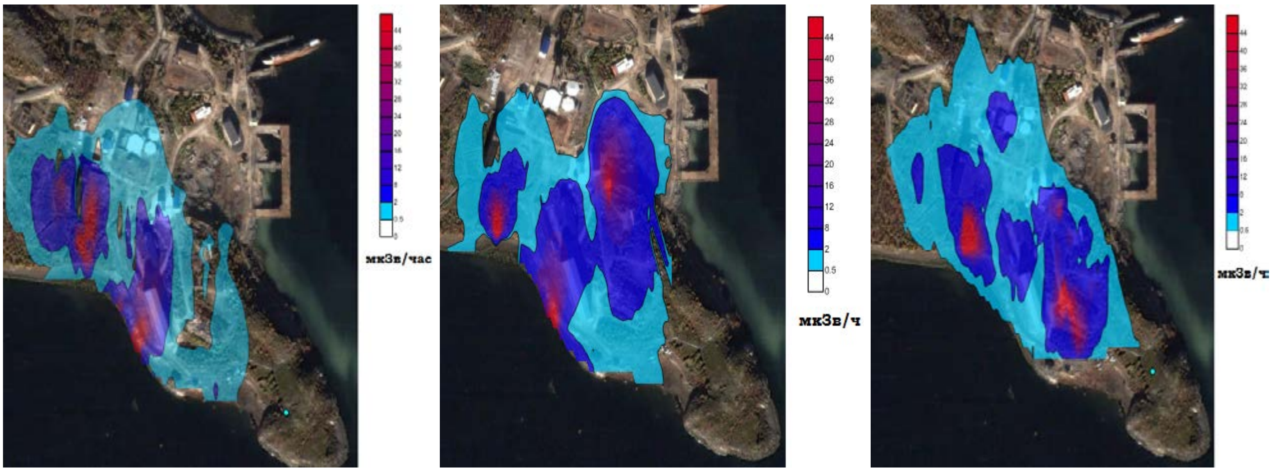
In April 2012 a joint expedition of NRPA and FMBC experts was made to Andreeva Bay STS to make additional measurements and sampling of soils and bottom sediments. 6 soil samples have been collected in three points within the HPZ and 2 samples of bottom sediments. Due to significant changes at the industrial site – construction of new buildings and dismantlement of the crane at the Dry Storage Facility – some reference points examined in 2010 were that time off access because of construction operations. During expedition, gamma dose rate measurements were performed in 529 points on STS site (Fig. 12). All carried out sampling of the environmental media was done in compliance with the requirement of the legal methodical recommendations and special documents on the health care monitoring of radioactive material contents in the environmental media.

Fig. 12 Points of gamma dose rate measurement, April 2012

Recommendations for application of the GIS by FMBA Regional Management and by SevRAO staff were developed as part of the project work. The document recommends the procedure of application of the information and analytical computer system when assessing the radiation situation in the area. These

Recommendations can also be used by the radiation safety services of SevRAO when planning organization and optimization of radiation hazardous operations.

In 2012, in order to assure radiation protection of workers before the beginning of the SNF extraction operations, operations aimed at normalizing the radiation situation in relevant buildings were performed and the concrete covers above the SNF cells were removed and their shielding effect temporarily lost. Therefore, gamma dose rate in this area became higher. In December 2012, biological protection was set; thereby the radiation situation in this area became significantly better in comparison with 2010 (Fig. 13).



2013 2012 2010

Fig. 13 Dose rate at the industrial site, 2010-2013

Overall, the data indicate a reducing trend in gamma dose rates across the site, but with potentially important temporary increases as remediation work proceeds.

The next step in NRPA-FMBA cooperation was to develop the method for assessment of radiological impact on biota based on comparison of doses with biological effects to reference animals and plants.

ICRP has established some reference set of organisms (deer, duck, frog, rat (mouse), trout, flat-fish, beer, crab, earthworm, pine, wild grass, kelp) [1]. However, use of such limited set of the reference organisms arguably does not satisfy all requirements for impact assessment. Hence, this ICRP set could be supported by information on other reference organisms in case, where e.g. to include animals and plant specific for the particular ecosystems under assessment.

At the sample sites in different STS areas, the Environmental Laboratory of the Andreeva Bay Facility identified the habitat forming species of plants (species-edificators) and species-dominants, see Table 3.

The Environmental Laboratory measured radionuclide concentrations in different plant species. The study of growth showed that the Motley grass and Willow-herb (Chamaenerium angustifolium) are the most representative species in respect to the manmade radionuclide concentrations in the Controlled Area. The presence of ^{60}Co is typical only for the Black crowberry (Empetrum nigrum). Larger flora are represented mainly by the Squat birch (Betula humilis), actively growing in the area of the site 3 and in the dry brook bed. Therefore, for the purpose of dose calculation the Motley grass and the Squat birch (Betula humilis) were used as the reference organisms.

Table 3. Plant species growing within different areas at the site

Area	Species-edificators	Species-dominants
Controlled Access Area (CAA)	Willow-herb (Chamaenerium angustifolium) Motley grass (grasses, sedge)	Black crowberry (Empetrum nigrum) Goat willow (Salix caprea) Meadow horsetail (Equisetum pratense)
Health Protection Area (HPA)	Chin meadow (Lathyrus pratensis) Crow pea (Vicia sepium) Great nettle (Utrica dioica) Motley grass (grasses, sedge)	Hairgrass Soddy (Deschampsia caespitosa) White clover (Trifolium repens) Willow-herb (Chamaenerium angustifolium)
Health Protection Zone (HPZ)	Moss (esp. Bryophyta) Meadow horsetail (Equisetum pratence) Roundear willow (Salix aurita) Drooping birch (Betula pendula)	Cotton grass (Eriophorum sp.) Rhododendron palustre (Ledum palustre) Saxifraga (Saxifraga sp.) Dwarf birch (Betula nana) Black crowberry (Empetrum nigrum) Dwarf cornel(Cornus suecica)
Uncontrolled Area (UA)	Motley grass (grasses, sedge)	Willow-herb (Chamaenerium angustifolium)
Supervision Area (SA)	Motley grass Meadow horsetail (Equisetum pratence) Black crowberry (Empetrum nigrum)	Dwarf birch (Betula nana) Cotton grass (Eriophorum sp.)

In order to evaluate the impact of the radioactive contamination on animals, the following were chosen: earthworm (Lumbricidae sp.), moor frog (Rana arvaiis), Norway lemming (Lemmus lemmus). These representatives of fauna are typical for the studied region and live directly on the industrial site.

For each reference species (Motley grass, Squat birch (Betula humilis), earthworm (Lumbricidae sp.), moor frog (Rana arvaiis), Norway lemming (Lemmus lemmus)), the relevant dose patterns/ dosimetry models have been developed and the base of biological and ecological data is under development to include information on habitat, population, life expectancy, the amount of offspring etc. Main restrictions of this approach are due to difficulties of extrapolation of results received for the reference species to other species and ecological conditions. The radiation exposure assessment for each of them is rather complicated task and a large increase in the number of such species may lead to an excessively complex process.

According to the findings of the radiation situation monitoring, performed at Andreeva Bay STS since 2005, and taking into account the radio-ecological data, areas within the HPZ with potential negative impact on biota were identified (Fig. 14).

Fig. 14 areas for assessment of radiation exposure to biota.

As part of the assessment work, it was decided to check if the current standards of protection applied to humans for each remediation option would be sufficient to protect other biota. Table 4 sets out the alternative remediation options, the current dose constraints set by FMBA for different people for each option and the corresponding radionuclide concentrations in soil which, according to standard dose assessment models, would result in the dose set as the dose constraint.

Table 4. Regulatory Dose Constraints and Corresponding Radionuclide Activities in Soil

Remediation Option	Exposed Group	Dose constraint applied to residual contamination, mSv year^{-1}	Corresponding radionuclide concentrations in soil, Bq kg^{-1}	
			Cs-137	Sr-90
Conversion	Personnel Group A (HPA)	3	8.17E+04	5.75E+06
	Personnel Group B (CA)	1	2.32E+04	1.63E+06
	Public (SA)	0.1	5.26E+02	3.70E+04
Conservation	Personnel (industrial areas)	2	4.63E+04	3.26E+06
Liquidation	Public (industrial areas)	1	5.26E+03	3.70E+05
	Public (SA)	0.1	5.26E+02	3.70E+04

Table 5 sets out the assessed dose rates to biota in Table 3 for each of the different remediation assuming they grow in or occupy soil contaminated at the levels in Table 4, calculated using the ERICA assessment tool [6]. Also tabulated are the relevant DRCLs for the respective biota.

In some cases the dose rates corresponding to the dose constraints exceed the DCRLs (highlighted bold). In addition, actual measurements in limited areas of the site also suggest that DCRLs are exceeded locally, although it should also be noted that the contamination is patchy. The assessment demonstrates that for any option of future use of the STS site, under the compliance with the remediation criteria, any negative impact on the representative organisms is not expected within the supervision area.

Nevertheless, occurrence of possible negative effects for the lemming, birch and motley grass populations on the site is indicated during remediation work, even if dose constraints on workers are met.

Table 5. Assessed biota Dose Rates for the Different Remediation Options compared with the corresponding DRCLs

Remediation Option	Site	Representative organisms	Dose rate maxima, mGy d^{-1}	DCRL, mGy d^{-1}
Conversion	STS Industrial Area	Moor frog	67.2	10-100
		Motley grass	**14.6**	1-10
		Lemming	**148.9**	0.1-10
		Earth worm	0.6	10-100
		Birch	**43.9**	1-10
	STS Supervision Area	Moor frog	0.4	1-10
		Motley grass	0.1	1-10
		Lemming	1.0	0,1-1
		Earth worm	0.1	10-100
		Birch	0.3	1-10
Conservation	STS Industrial Area	Moor frog	38.1	10-100
		Motley grass	8.3	1-10
		Lemming	**84.4**	0.1-1
		Earth worm	0.4	10-100
		Birch	**24.9**	1-10
Liquidation	STS Industrial Area	Moor frog	4.3	10-100
		Motley grass	0.9	1-10
		Lemming	**9.6**	0.1-1
		Earth worm	0.1	10-100
		Birch	2.8	1-10
	SA	Moor frog	0.4	10-100
		Motley grass	0.1	1-10
		Lemming	1.0	0.1-1
		Earth worm	0.1	10-100
		Birch	0.3	1-10

According to the ICRP recommendations, for an existing exposure situation, if the DCRL are exceeded, the goal should be to reduce exposure to the acceptable levels taking into account the associated radiological and non-radiological consequences. The application of international recommendations on protection of the environment in existing exposure situations is discussed further in [7], including this example as a case study. This includes consideration of the need to consider the areal extent of the population of interest and the appropriate assessment of dose rates, as discussed in [8].

4.3 References for section 4

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5 Visualization and Prognosis of Radiation Environment (DOSEMAP2, DOSEMAP3)

5.1 Project objectives and activities

Currently SevRAO is carrying out operations concerning SNF and RW management at STS Andreeva Bay. Operations are necessarily performed under conditions of degraded containment barriers and other hazardous circumstances. However, in order to provide an appropriate remediation solution, extensive work on SNF removal, RW treatment and rehabilitation are still to be undertaken. To meet safety requirements, the NRPA-FMBA cooperation program has included a series of projects to facilitate regulatory supervision of radiation safety of workers. The primary objective was to develop a tool to optimize personnel radiation protection during remediation of SevRAO facilities taking into account the abnormal condition.

In the first stage within DOSEMAP and DATAMAP projects, the regulatory and methodical basis to optimize radiation protection of SevRAO workers was developed. Next step was development of an information and analytical system on radiation protection of workers (IAS RBP) to monitor and support control of radiation exposure during STS remediation, and at the stage of building and operation of the new complex for SNF management and RW treatment (see references in section 1).

Between 2009 and 2012 under the DOSEMAP2 project, a team of experts adapted the database on individual doses to workers and data base on the radiation situation parameters to the practice of the radiation protection regulation bodies. In next step a GIS was implemented to continue supplementing and improvement of the regulatory and methodical basis.

Optimization of the management strategy and radiation safety improvement requires different tools. Instead of incorporating all features into one big application, the decision was made to divide software into 3 different tools with different purposes. Work done with support from the Norwegian Institute for Energy Technology led to production of:

- Andreeva Planner
- Andreeva Procedure Creator and Trainer
- Andreeva Terrain Viewer

In the DOSEMAP3 project work continued on IAS RBP application as a practical tool for regulatory supervision of workers. The main activities included:

- Development of practical and methodical support at SevRAO facilities to put factual information about the radiological condition in a Database.
- Practical methodological support of the Database and IAS RBP operation in the Regional Management office 120 of FMBA and at the SevRAO Facilities, including preparation of relevant guidelines:
    - «Application of the Databases of the radiation situation parameters and doses to workers for the purpose of personnel radiation protection regulation».
    - «Application of the Databases of the radiation situation parameters and doses to workers for the purpose of arrangement and implementation of radiation hazardous operations».
    - «Control of radiation protection of workers during the SNF and RW management».
- Development of the integrated multilayer map and a new mapping interface within IAS RBP.

– File generation for tracing of personnel routes on the STS Andreeva.
– Amendment of the User Instruction of IAS RBP, operational testing at STS Andreeva and at Regional Management-120 of FMBA, and certification of the software.

5.2 Project outputs and discussion

Under DOSEMAP2 project the Instructions for users of both databases, on individual doses to workers and on the radiation situation parameters and guidelines have been developed. The first - "Application of the informational and analytical system for individual dose prediction to regulate radiation safety of workers at SevRAO Branch of FSUE "RosRAO" - takes into account the suggestion on reasonability to implement the single methodical document to regulate the procedure of application of the information and analytical system for dose prediction to regulate radiation safety of workers. The second- "Control of radiation protection of workers of SevRAO – branch of FSUE "RosRAO" during the SNF and RW management" provides extensive use of this complex for the purpose of radiation protection control with respect to workers of SevRAO when:

– Organizing radiation monitoring;
– Planning radiation hazardous operations;
– Implementing the protection optimization principle with respect to workers;
– Setting reference levels;
– Selecting workers to carry out radiation hazardous operations;
– Organizing education and training for workers;
– Enhancing safety culture.

Additionally upon completion of the DOSEMAP 2 project, two interim reports have been prepared:

– "Practical and methodical support of work at the SevRAO facilities to put the factual information in the Databases";
– "Development of the Guidelines "Application of the informational and analytical system for individual dose prediction to regulate radiation safety of workers at SevRAO".

In 2011, project DRIVE "Dynamic visualization of the radiation situation at Andreeva Bay STS" was launched with participation of FMBC and Norwegian Institute of Energy Technology. Information accumulated in the database of the IAS RBP was used as initial data in this project.

The tools from the DRIVE project allows for interactive walk through scenarios in a safe virtual environment. Virtual scenarios can be easily defined by inserting virtual objects representing content in the real world. Typical environment content such as a reactor hall and virtual objects can be dragged and dropped into the environment and positioned. Personnel can perform sequences of actions, such as moving, picking up tools and doing work. It is also possible to supply the environment with radiation data, supporting both measurements as well as calculations based on radiological information. Radiation can be visualized in various ways and information on the instant dose rates as well as the accumulated doses of personal is supplied [1].

The DRIVE project enables test plans and procedures for various work tasks involved in handling of spent fuel. The VR technology is also a valuable tool to support the making of the needed documentation and for training of operations. Intensive training before the real operation takes place may be effective for reducing radiation exposure dose, workload and for enhancing safety. In addition, DRIVE provides the project team with an effective medium in presentations to the public as well as for communicating with the management and the licensing authorities. DRIVE produced 3 tools:

– **The Andreeva Planner** (AP) is a desktop 3D tool for simulating work scenarios, with radiation visualization and dose-rate charts for scenario participants. AP is based on the generic planning and training software developed for the LNPP and ChNPP projects and will also form the basis for the proposed project. This will allow for real time visualization of measured dose rates based on interpolation algorithms. Provided the location and characteristics (i.e. type of isotopes and their activity) of radiological sources are known, AP is also able to calculate dose rates real-time, quantify the contribution from various radioisotopes and take into account the effects of shielding. Given the knowledge of activities of specific isotopes (if available), the future radiation situation can also be predicted by taking into account the half-life of the dominating isotopes.

– **The Andreeva Procedure Creator and Trainer** (APCT) is used for training personnel practicing work tasks in a safe virtual environment before actually doing the tasks in real life. This could lead to reduced work times, resulting in reducing worker exposure and overall doses. Two or more trainees are able to train on a predefined work procedure in a 3D VR world. Collaborative training allows for training on a procedure involving real-time cooperation between the trainees when performing a task. An instructor is setting up the training scenario for each individual trainee including the level of guiding and the incidents that the trainee may experience. The instructor is able to log the trainee's actions during training and evaluate the trainee's performance.

– **The Andreeva Terrain Viewer** is a cross-platform software tool for visualizing large virtual terrains. It is based on NASA World Wind Java, a cross-platform, open source virtual globe developed by NASA and the open source community for use on personal computers. The virtual terrain is built up using elevation data and satellite imagery from NASA Worldwind's geodetic database. The software can be extended and interfaced with other software in order to create more dynamic virtual environments. By combining geodetic terrain data with radiological information and visualization, the software will be able to provide wide-area dynamic visualization of the radiation situation in selected areas.

As a continuation of Russian-Norwegian collaboration in this area DOSEMAP3 was implemented; work was continued on optimization of the IAS RBP of Andreeva Bay SevRAO Facility up to the level supporting real IAS RBP use for the purpose of regulatory supervision of RP of workers. Goal of optimization IAS RBP, was to each worker should understand the benefit from using computer system. For this purpose the procedure of IAS RBP use has been simplified significantly. The regulatory-methodical documents were aimed on improvement of control of radiation protection of workers both by Regional Management-120 under FMBA of Russia, and by SevRAO facilities in order to:

– Execute regulatory functions in radiation protection optimization by Regional Management-120 under FMBA of Russia;

– Execution functions in planning radiation hazardous operations by SevRAO.

Under the project, a graphic based interface with integrated multi-layer map of the industrial site, as well as constructions at Andreeva Bay on the visualization computer software were completed. An integrated multilayer map allows to input routes for industrial site and inside buildings. The map consists of a set of topographical maps and schemes for each room with detailed 3D-models of the main buildings. All map objects are in unite geographic coordinate system. Each object on the map is on a separate layer and can be disabled for the convenience of the operator. The map itself is three-dimensional and interactive. It was established on the basis of geo-information system ”Google.Earth“. All files with maps are stored on the hard drive of the computer, and the user is able to work without an internet connection.

Fully realistic 3D - models of 10 buildings at STS Andreeva Bay and 2D-schemes of buildings, including floor plans, which are tied to a single geographic coordinates, allowing them to use a single map, were created. In addition, for the rest of the buildings schematic 3D-models are created. See figures 15 and 16 for examples.

Realistic 3D-models of the main buildings can be "dismantled by the floors" to remove the roof from the building, drawing out the route at different levels. Models contain all the elements of real structures - windows, bars, stairs, doors, etc. New multilayer map allows adding special objects, such as special construction equipment for improving realism of the model.

In case of IAS RBP same approach as in DRIVE project was used. Software was divided. One of the tools ”TesnovKML“ was created for routes input of personnel on the basis of the integrated multi-layer topographic map. The program is designed as a separate cross-platform application. Software includes the possibility to add the information to radiation-hazardous work file for each employee.

Fig. 15. Integrated multi-layer topographic map

Fig. 16. Integrated multi-layer topographic map. Each floor of the building is presented as a separate layer, so it is possible to remove the roof to draw a route indoors.

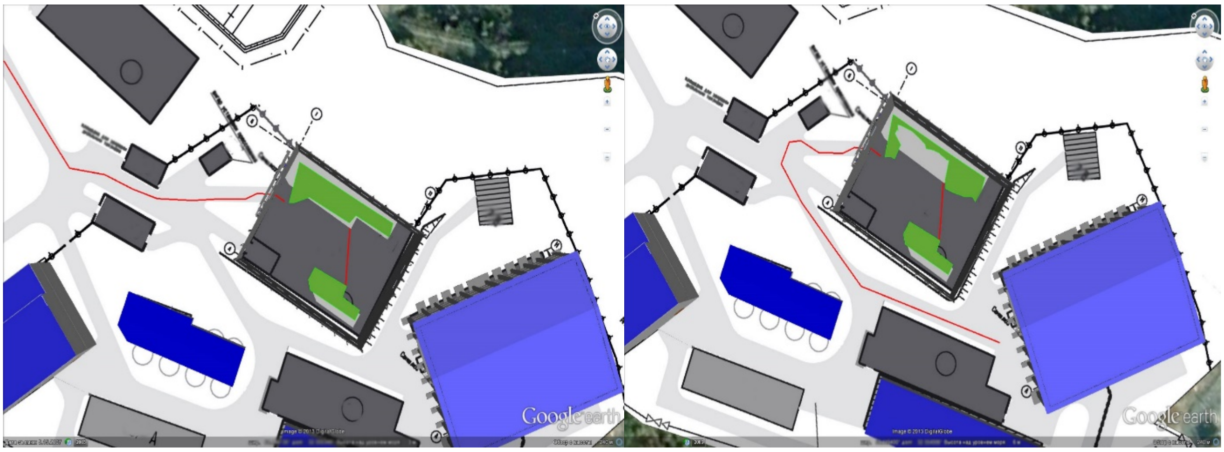

Fig 17. Route input on map – 2 polygons (painted green) and 2 paths (red). After the route was created, it's possible to edit as many times as you need.

The goal of DOSEMAP-3 project was an improvement of radiation safety during the STS remediation by optimizing IAS RBP of the SevRAO Andreeva Bay Facility. The second important challenge was to improve the program through creation a friendly user interface, available for the operators and the regulator, i.e. common users. The developed software got the working title «EasyRAD». EasyRAD is dedicated to:

- calculation of radiation fields using input measured data;
- viewing of radiation fields;
- dose calculation of input employee's routes.

Initial measurement data are input through **Mazur Interface**. In the main window user will find four tabs:

- Radiation fields calculation; facilitates the choice of building and date (having initial measurement data) for the radiation field calculation
- Radiation fields view; helps you to choose the building (or industrial site) and date for the radiation field, scheme and measured data view.
- Route dose calculation;
- Export/Register.

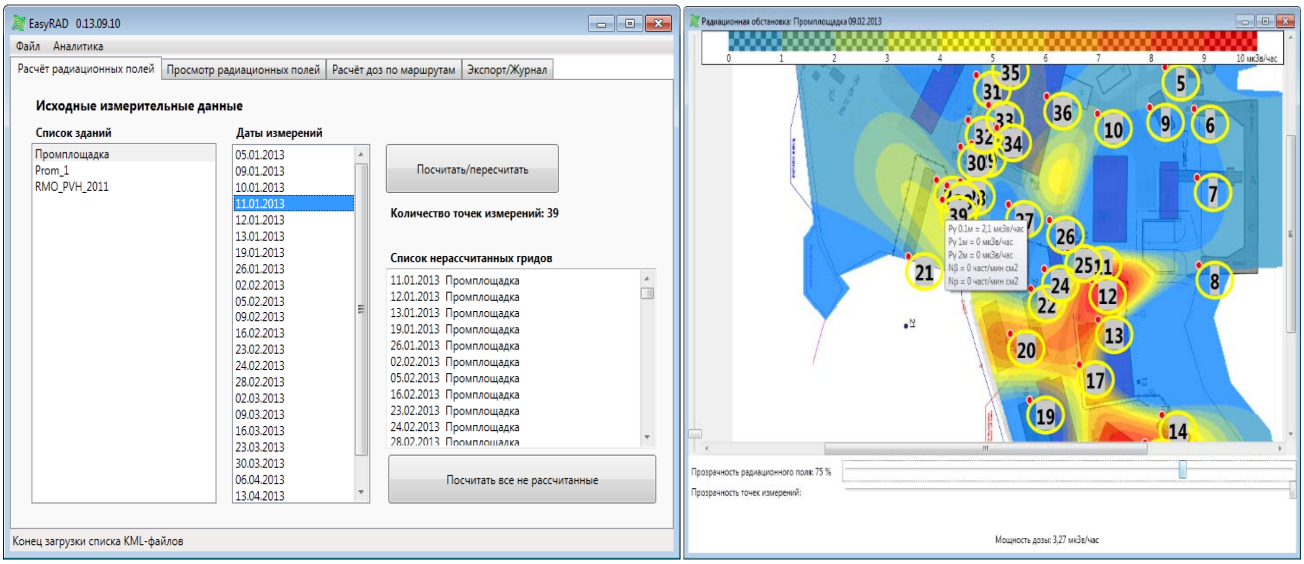

Fig 18. Window "Radiation situation view".

The computer information-and-analytical system for dose prediction developed under DOSEMAP Projects is based on Rockville software [2]. In 2011, this software was subject to positive certification tests. In April 2012, the NRPA experts visited STS Andreeva. During the visit, operation of the geo-information system was demonstrated.

Today, the software complex IAS RBP is introduced in normal practice of FMBA Regional Management-120 and by staff at STS Andreeva Bay. A detailed manual has been developed; the software has been certified; the personnel are going to use this system during operations to support control of exposures during SNF recovery from the degraded stores.

The Information and analytical system can also successfully be used at other sites, during such operations as the SNF removal from the cases and caissons of the storage facility of Lepse supplying vessel of the atomic powered ice-breaking Fleet of Russia after the relevant adaptation of the current IAS RBP version.

By facilitating improved planning and communication, many unwanted incidents might be avoided. Among the planning tools that seek to accomplish this are ALARA (As Low As Reasonably Achievable) support tools. Virtual reality based ALARA tools have the potential to being useful for minimizing doses but also for improving communication between involved parties, and thus safety.

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6 Performance reliability monitoring (PRM 2, PRM 3)

6.1 Project objectives and activities

Today, there are two main approaches to assessment of the reliability of the human factor at facilities with radiation and nuclear hazardous technologies. In the first one, the main regulatory efforts are directed to the personnel education and intensive introduction of the safety culture principles at nuclear sites and facilities. It is based on the recognition that the well-educated worker, when observing all prescribed occupational rules and instruction, would not make mistakes affecting the safety of the facility. Generally, the occupational specific characteristics of the worker are not controlled.

Recognizing the significance of this approach, it should be noted that literature data on increasing number of violations in facility operation, including potentially hazardous operations, demonstrates a direct connection between the errors made by personnel and incompliance of the current psycho-physiological conditions of the worker with occupational requirements. Just due to such incompliance knowledge, skills and experience accumulated in the course of educational can be reduced (even lost, in critical cases).

In 2009 NRPA supported the second phase of activities regarding performance reliability monitoring. The project was among the important steps in arrangement of the organizational and technical system for assurance of the performance reliability of workers involved in the SNF operations. Within this work, the pilot version of the expert-and-diagnostic information system for risk monitoring of the performance reliability violation (“EDIS_STS”) has been developed and transferred to CMSCh-120 to be used in pre-shift and annual medical psychological (psycho-physiological) inspections of the SevRAO workers. Introduced technology is to obtain the safety culture indicators and integral assessment of its level.

The primary objective was to improve safety by improvement of the personnel training through the introduction of a psycho-physiological supporting system of the personnel training/retraining at SevRAO.

Implementation of the simulator "TIBUR_TSP" is aimed at developing the skills of optimal operation in normal and extreme conditions, as well as prevention of psychosomatic disorders associated with long-acting stressors / radio-phobia of the SevRAO workers.

To implement this objective, the following tasks were planned:

- Defining key psycho-physiological functions of SevRAO workers directly involved in SNF management, which, functions, are actualized during carrying out the occupational activity.
- Justifying the simulation gaming model supporting actualization of the key psycho-physiological functions in occupational specific merits to carry out the activity.
- Developing a model sample of the soft/hardware complex on the basis of interactive simulation training games with biological feedback in the virtual environment, which helps to actualize and monitor psycho-physiological functions of the worker with a parallel registration of precise and rate parameters of the simulated activity.
- Developing criteria for assessment of psycho-physiological “price”, performance reliability, strategy of behavior of the human under different streams of information and actions in the gaming virtual environment controlled using biological feedback.
- Developing proposals on generation of soft/hardware tools for interactive simulation 3D – models of real workplaces of workers involved in SNF management, using sensor control of the model parameters.

Developing proposals on the optimization of the SevRAO personnel training/retraining process using the findings of its psycho-physiological support.

6.2 Project outputs and discussion

The pilot versions of soft/hardware training tools “TIBUR_TSP” were developed based on interactive simulation training games in a virtual environment with biological feedback, which helps to actualize and control occupational specific, in terms of performance of real activity, psycho-physiological functions of SevRAO workers involved in SNF management.

A significant increase in human reliability at facilities with RHF results from the introduction of psycho-physiological support. We first mean here the dynamic assessment of psycho-physiological “price” of operations performed. Introduction of the mentioned assessment is especially useful during the personnel training using simulators, when objective data on the quality of each operation performance by the worker according to the action scenario are available.

The scientific background of interrelationship between the quality of the action performance and the associated psycho-physiological “price” are laid in the P.K. Anokhin’s theory of the functional systems and in the K.V. Soudakov’s theory of the systematic quantum of behavior. The practical consequence of these theories is the fact confirmed by numerous studies that the high-skilled workers are characterized by low psycho-physiological “price” of each operation performance within the structure of activity. The quality of individual operation can be assessed in terms of time, accuracy and other parameters characterizing the occupational effectiveness. At that, the more complex is the operation, the higher is the psycho-physiological “price” of activity. We examined the astronauts in the course of training manual docking of the transport ship to the orbital space station and revealed that, in space flight, those astronauts carried out the docking better, whose psycho-physiological occupational “price” was lower.

Thus, the psycho-physiological “price” of the operation performance is an additional criterion of the skill development level and important indicator to regulate the educational/training process. The combination of effectiveness of some operations and their psycho-physiological “price” is a characteristic, which we defined in 1989 as “reliability of activity” of the human. The reliability of activity means the ability of a person to perform the prescribed functions timely with the given quality keeping at the same time the psycho-physiological “price” of the activity within the acceptable limits. To assess it we need data under simultaneous dynamic registration of time and precision parameters of activity and characteristics of psycho-physiological functions. This is possible only under simulator training.

Previously, education/retraining of workers at SevRAO facilities were carried out generally in a form of lectures. There are no multifunctional simulators (similar, e.g., used in the training of the operating personnel of NPP), which help to complete comprehensive training of the personnel, including emergency one. Therefore, an urgent task was development of interactive training simulators to recreate the actual conditions and situations in the virtual environment using interactive and realistic 3D-models. Their practical application will help to evaluate psycho-physiological “price” of the activity and strategy of behavior of the worker in irregular situation.

The first step in this task solving was development of the integrated system based on interactive simulation learning games in the virtual environment, that allows updating and monitor occupationally significant, in terms of real activity, psycho-physiological functions of workers (attention, attention distribution, perception etc.). It is based on the methods of cognitive psychology, psycho-physiology and adaptive bio-control (management). Figures below illustrate visualization of the modeled operational exercise.

Fig. 19. Example visualizations of the modeled operational exercise.

Application of the technology of adaptive bio-control will help to improve the self-regulation skills of the worker in the stress situation, to control physiological reactions and psychological conditions under factual occupational activity.

The development of TIBUR_TSP was based on the following concepts:

- In the technical-organizational systems, the human is the weakest link, whose errors in work can cause a variety of incidents and accidents.
- When performing important tasks, in most cases the probability of human error is determined by the severity of mental and emotional stress related to the mechanisms of functional systems that implement specific activities.
- Increasing mental and emotional stress causes additional mobilization and energy resources; this is reflected in the increase in psycho-physiological prices (PPP) of activities performed.
- A high level of PPP, on the one hand, increases the risk of psychosomatic disorders, on the other - is accompanied by a decrease in functions of perception, attention and ability to concentrate memory, and, in general fall in cognitive capabilities, spatial-and-temporal coordination and motor-and-coordination interaction.

The use of hard/software and information tools combined in TIBUR_TSP is intended to reduce PPP. Simulator training of SevRAO workers involved in the SNF operations is implemented in two directions:

- training to implement jobs, which are the most difficult for the particular person, that require application of the same psycho-physiological functions, as in a real working conditions, thus promoting the formation of an optimal strategy for the implementation of activities under difficult conditions.
- training of the student to apply methods ensuring the removal or reduction of mental and emotional stress through the use of self-regulation mechanisms in normal and stress conditions.

Using a virtual gaming environment saturated with elements close to the operational work operations in order to develop the skills of self-regulation to help to implement own backup capabilities of the student in the direction of optimal response to any work, including an extreme situation.

Development of the hard/software for the pre-shift express control of the psycho-physiological conditions were performed to improve the pre-shift medical inspection of workers involved in the SNF management. Prior to now, the permit-to-work was issued only following the measurement of blood pressure and interview, not assessing the compliance of the psycho-physiological characteristics of workers with the occupational requirements.

The final version of the software for the for the industrial model of the expert-and-diagnostic system for risk monitoring of the performance reliability violation of workers involved in the SNF management has been developed taking into account comments and proposals of CMSCh-120. Those comments related to uncomfortable reading of the psychological test questions on the 3.5 inch screen of the pocket digital assistants (PDA) as applicable to weak-eyed persons; the comments also deal with the stylus application by older persons when reacting to the stimulus signals of the psycho-physiological methods. Having those comments in mind the PDAs in the industrial model of the “EDIS_STS” have been replaced by the 10-inch netbooks and the associated software has also been changed.

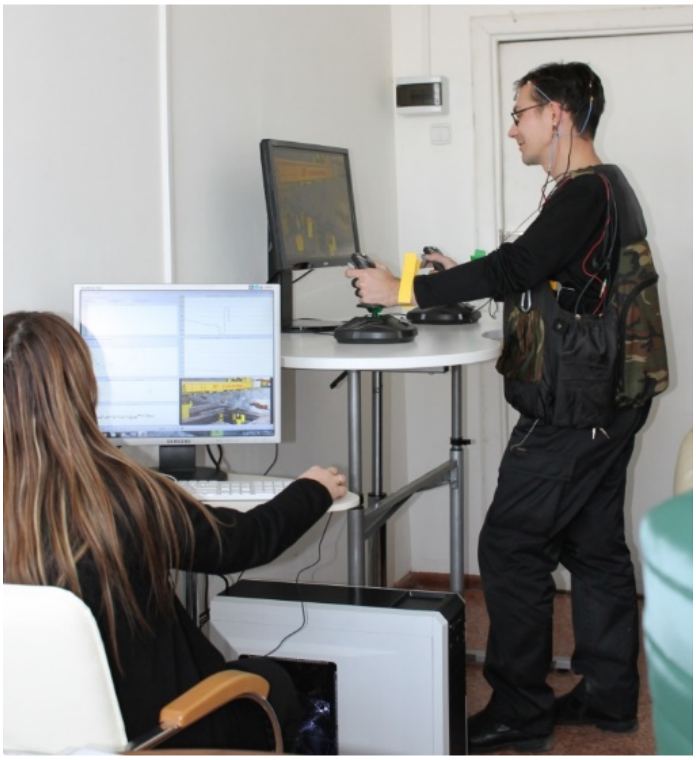

Fig. 20 Testing the software and hardware.

The development of the methodical recommendations for evaluation of the occupational reliability and pre-shift psycho-physiological control of workers involved in the SNF management was being carried out for the purpose of arrangement of the regulative and methodical basis of the mentioned inspection performance.

Performed analysis of available regulatory documents on the safety culture at radiation and nuclear hazardous facilities, showed that by today general scientific and methodological basis has been developed to facilitate introduce the conceptual provisions of the safety culture into the practice of its application at radiation and nuclear facilities and sites in order to identify positive and negative features of organization in terms of nuclear and radiation safety of different nuclear facilities and sites.

On the basis of the proposals on the safety culture assessment at SevRAO facilities, the questionnaire has been first developed for “internal” assessment of the safety culture. This questionnaire helps to obtain the initial data for development of the quantitative criteria for assessment of the safety culture characteristics and attributes. It is based on characteristics, attributes and indicators recommended by the IAEA documents.

Conducting all activities helped to supplement the organization-technical system of the performance reliability control with respect to the SevRAO workers with the set of hard/software and information tools to provide psycho-physiological support of the personnel training at radiation and nuclear hazardous facilities and sites.

At the same time, the most complicated fragments in the real activity of the worker, requiring high stress of functional systems of the organism reflecting psycho-physiological “price” of working operations performed in the routine and stress circumstances have been identified. The identified facts will serve as a basis to form adequate and timely corrective and preventive actions, making justified managerial decisions to reduce their negative impact on the performance reliability of the worker and his occupational health.

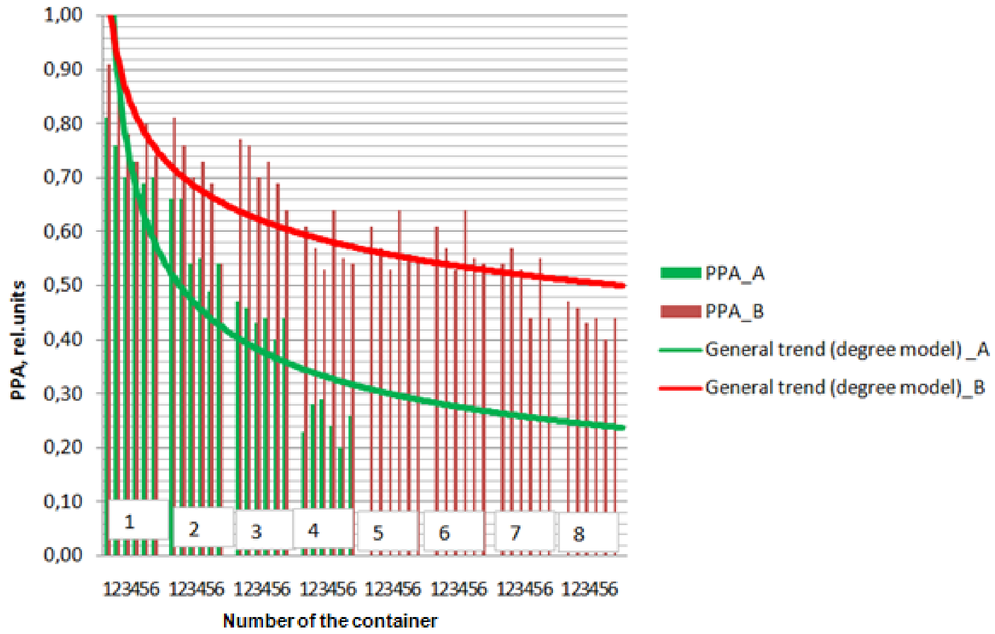

Fig.21 Dynamics of psycho-physiological "price" of activity of students A and B.

According to Fig. 21, with the improvement of skills in the model management not only the performance indicators improve, but also the level of psycho-physiological "price" of activity reduces. The reduction level depends on individual features of students.

In addition to training and perfecting the numerous motor skills, advantages of TIBUR_TSP include: diagnosis of excessive stress - a precursor to reduced effectiveness and reliability of the relevant worker, the identification of the most difficult operations for individual employees, addressed by construction of individual based training and informed monitoring of professional reliability of the individual, thereby reducing the possibility of errors.

The findings of the work completed are aimed at further improvement of the current system of psycho-physiological support of facilities with potentially hazardous technologies under FMBA of Russia through increasing the reliability of the human factor.

6.3 References for section 6

1. Shceblanov VY, Sneve MK, Bobrov AF. Monitoring human factor risk characteristics at nuclear legacy sites in northwest Russia in support of radiation safety regulation. Journal of Radiological Protection 2012, 32(4): 465-477.

7 Dismantling of marine nuclear objects (SATO)

7.1 Project objectives and activities

Russia has a large number of nuclear facilities of marine engineering (NFME), including nuclear-powered submarines, ships and vessels with nuclear power plants, nuclear service ships, floating nuclear power-and-heating plants, generators and dismantled nuclear submarines blocks stored afloat. Increase in volume of work on NFME maintenance, first, on their dismantlement, potentially increases a radiation hazard both for the population of the Russian Federation and neighboring states near the relevant ship repair yards.

Most of the NFME were built in the time of the Soviet Union. During their design, building and modernization the radiation safety standards of previous generations (Sanitary regulations of work with RM and IRS-1960, NRB-69, NRB-76/87) inadequate to meet the up-to-date radiation requirements were used. Bringing up to date the above is an objective precondition for the evolution of radiation safety system improvement and specialization during the repair and dismantlement of NFME.

Works on NFME dismantlement has already been started. The preparation works (SNF and RW unloading, ship transferring in a berth-connected position, etc.) has been performed on some ships, including in some cases, complete dismantlement.

In order to ensure radiation safety and to organize sanitary-epidemiological supervision over continuing dismantling activities, the following practical tasks were solved in the project:

- Program of assessment of a radiation safety system state at an enterprise performing works on NFME decommissioning and dismantling, was worked out and implemented.
- Guide “Ensuring Radiation Safety and Prevention of Environment Contamination in the Process of NFME Decommissioning and Dismantling” was worked out.
- Radiation control procedures (four ones) were worked out, and they passed metrological testing.
- Suggestions on the improvement of in-process control program of enterprise-performers were elaborated.
- Radiation-hygienic survey of the industrial, sanitary protection and observation areas of enterprise-performers was implemented.
- Monitoring of occupational internal exposure at the enterprise-performers was carried out.

The work was carried out by a multi-expert team led by the Scientific Research Institute of Industrial and Marine Medicine (SRI IMM).

7.2 Project outputs and discussion

At present, the work on dismantlement of the Lepse floating technical base at the Nerpa shipyard and of the Volodarskiy at the SevRAO facility at Saida Bay are under way. The works are performed in compliance with the dismantlement projects mainly developed according to reference [1].

In respect to radiation issues, the dismantlement of the Lepse is recognized as a particularly hazardous activity and one of the most complicated ones due to the poor state of the SNF on board [2]. During the performance of works under the conditions of high radiation, the important factor for safety assurance is the control of radiation exposure of workers both at the workplaces and in the adjacent site areas, such as the sanitary protection area and observation area. In the framework of the project, the four procedures for radiation control were elaborated and tested. The given procedures take into account the peculiarities of the abnormal work tasks and increased the reliability of radiation exposure control.

Based on one of the developed procedures, radio-ecological surveys of areas around three NFME dismantling enterprises located in the Murmansk and Arkhangelsk region were carried out in 2013. Fig. 22 and 23 present the photographs of environmental sampling sites in the observation areas of FSUE “Atomflot” and SRY “Nerpa”.

*Fig.*22 Sampling in the FSUE “Atomflot” *observation area.*

Fig.23 Sampling in the SRY “Nerpa” observation area.

The radiaion survey of the OJSC “TcS “Zvyozdochka” territory in Severodvinsk town was implemented in 2014. Figure 24 presents environmental sampling site in the observation area.

Fig. 24 Area for environmental sampling in the OJSC “TcS “Zvyozdochka” observation area.

The results established that at the time of surveys the radioactive contamination of the environment from the works was absent. The measured radiation indices included gamma dose rate; specific activities of soil, vegetation, bottom sediment, sea-water and atmospheric aerosols in the surveyed territories. It was noted however, that for measurements of activity concentrations in some environmental media, more efficient methods would be an advantage, including better understanding of uncertainties.

Assessment of radiation consequences of possible accidents during NFME dismantlement was made. Accidents accompanied by radionuclides emissions in the atmosphere and discharges in the water area of enterprises were considered. It was shown that during the discharges of radionuclides in the ponds the radiation consequences for the population are radiologically negligible. Based on the above the prognosis was implemented only for the accidents with gas-aerosol emissions (Fig. 25).

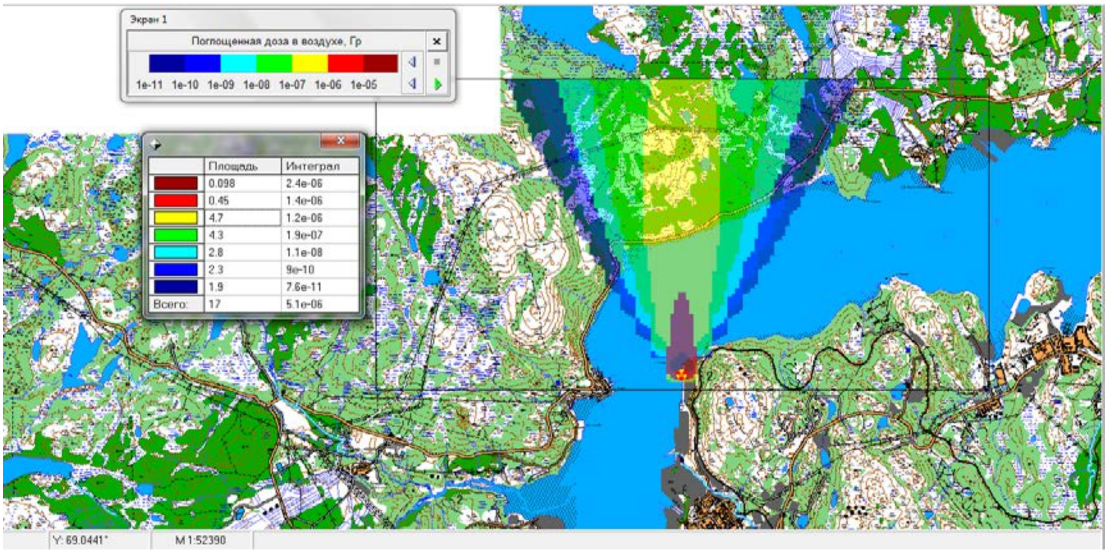

Fig.25 Forecast results of radiation accident consequences.

The findings suggest that for NFME dismantlement works the most severe consequences can take place in case of a fire occurrence during the SNF unloading from storage facility. However, for the scenarios considered, the radiological consequences would small and the protective measures for the public would not be required.

Taking into account the data contained in the NFME dismantlement projects and the results of study of real work conditions, it was developed the regulatory Guide “Ensuring Radiation Safety and Prevention of Environment Contamination in the Process of NFME Decommissioning and Dismantling”. In development of the document all the current legislative and normative requirements of the Russian Federation in the field of radiation safety were taken into consideration. The structure and content of the document meet the requirements for the structure, statement and drawing-up of sanitary-hygienic documents [3, 4].The draft of the document was reviewed by the organizations performing works on NFME dismantlement and carrying out control over and supervision of the performed works. Developed requirements apply to every enterprise of the shipbuilding industry and State Corporation Rosatom carrying out works on decommissioning and dismantling of any type of nuclear service ships.

7.3 References for section 7

1. Detail design on management of radioactive waste being generated in the process of SNF unloading and dismantlement of the Lepse floating technical base at FSUE “Atomflot”. Safety Analysis Report. System for LRW Management. Report D29.03-06 on Task 17 of Contract NDEP-005-1-002. Inv. No. 11-00160. Book 1, 2011.
2. Sneve MK, Bergman C, Westerlind M et al. Phase 1 of the Regulatory Lepse project. Project report. NRPA Report 2001:4. Østerås: Norwegian Radiation Protection Authority, 2001. http://www.nrpa.no/filer/b9b5908d74.pdf (02.03.2016)
3. General requirements to the structure, content and completion of sanitary-hygienic and epidemiological normative and procedural documents. Guide R 1.1.004-94.
4. General requirements to the structure, content and completion of sanitary-hygienic and epidemiological normative and procedural documents of the state sanitary-epidemiological standardization system. Guide R 1.1003-96.

8 Monitoring of the effectiveness and assessment of the safety culture

8.1 Project objectives and activities

Between 2014 and 2015 two projects were implemented within the framework of cooperation between the NRPA and the DSS NRS, this cooperation being aimed at improving the oversight over nuclear safety and technical aspects of radiation safety when managing the nuclear legacy of military activity in the northwest Russia and in other regions of the Russian Federation.

The objective of the first project was to develop requirements for monitoring the effectiveness and suggest how to further improve the procedure of state supervision over DSS NRS of NRHF, and the safety of the personnel, the public and the protection of the environment in the northwest Russia during the works aimed at remediating the nuclear legacy.

The main tasks of the work were:

- analysis of the existing legal and regulatory framework (legal acts and regulatory documents) and the practical application and effectiveness of the existing requirements in the context of legacy remediation;
- development of requirements for the organization and the procedures for monitoring the effectiveness;
- development of requirements for the composition of documents and information based on the collection, processing and analysis of the monitoring;
- definition of effectiveness parameters that can be used to review and assess execution of the function of state supervision by DSS NRS in the specified field of activity;
- definition of performance indicators and decision-making criteria based upon the results of monitoring the effectiveness.
- development of the final Draft Guide "Methodological Instructive Regulations for Monitoring the Effectiveness of State Supervision over Nuclear and Radiation Safety at Dismantling of Nuclear Powered Submarines, Surface Ships with Nuclear Installations, Nuclear Service Vessels Retired from the Navy”

The objective of the second project was to develop requirements for conducting the assessment of Safety Culture during decommissioning and dismantlement of nuclear powered and nuclear service vessels that have been retired from service in the Navy.

The main tasks performed in the frame of the specified decommissioning and dismantlement work were:

- analysis of the current legal framework (legal acts and regulatory documents) and the practical application and effectiveness of the existing requirements to support and enhance safety culture;
- analysis of international safety standards documents in order to determine the possibility to apply the recommendations specified in them when assessing safety culture;
- development of criteria to assess safety culture;
- development of methodical principles relating to the organization and procedure to conduct assessment of safety culture, including the composition of documents and information to be collected and reviewed;
- development of requirements for the criteria that could be used in the identification of "growing" points for decision-making concerning improvement of the safety culture; and

- development of the final Draft Guide "Methodology to Assess Safety Culture at Decommissioning and Dismantlement of Nuclear-Powered Submarines, Surface Ships with Nuclear Installations, Nuclear Service Vessels Retired from the Navy”

8.2 Project outputs and discussion

Decommissioning and dismantlement of nuclear powered and nuclear service vessels is a major task in the field of providing national safety and security in the Russian Federation and is one of lines of activities to improve the environmental situation in the country. The work is of a complex nature as its support involves implementation of a whole set of production and technological processes and organizational activities.

In the Russian Federation the compliance monitoring of objects and works with the requirements established by international treaties of the Russian Federation, federal laws and other regulatory legal acts of the Russian Federation in the field of nuclear energy is implemented in the form of federal state supervision in the field of the nuclear energy use.

The relevant authority in the field of state supervision over nuclear and radiation safety in the decommissioning and dismantlement work is the DSS NRS.

The developed Guide "Methodological Instructive Regulations for Monitoring the Effectiveness of State Supervision over Nuclear and Radiation Safety at Dismantling of Nuclear Powered Submarines, Surface Ships with Nuclear Installations, Nuclear Service Vessels Retired from the Navy” contains the requirements for:

- the organization and the procedure for monitoring the effectiveness;
- the composition of documents and information based on the collection, processing and analysis of which the monitoring is conducted;
- the parameters used for review and assessment of the effectiveness of state supervision in the specified field of activity;
- the criteria for decision-making based upon the monitoring results.

The Guide is intended for use by the DSS NRS, as well as by organizations and enterprises engaged in the activities relating to the decommissioning and dismantling of ships with nuclear installations and nuclear service vessels retired from the Navy, including the management of spent nuclear fuel and radioactive waste generated during decommissioning and dismantlement.

The second Guide developed under the cooperation document: "Methodology to Assess Safety Culture at Decommissioning and Dismantlement of Nuclear-Powered Submarines, Surface Ships with Nuclear Installations, Nuclear Service Vessels Retired from the Navy” is aimed at assessment of the safety culture, as discussed n references [1, 2].

With all individuals and organizations engaged in the activities relating to the decommissioning and dismantlement facilities belonging to the "nuclear legacy", safety culture must be formed through the necessary personnel screening, training and exercise in each field of activity impacting safety, and through the establishment and strict observance of discipline with a clear allocation of personal responsibility of managers and performers, through the development and strict compliance with the requirements of current manuals for the implementation of works and their periodic update in the light of the gained experience. All such persons should be aware of the nature and extent of impact of their activities on safety. They should be fully aware of the consequences that may result from failure to comply with regulatory documents and related work instructions.

Sound procedures and good practices are not fully adequate if merely practiced mechanically. This leads to a proposition that safety culture requires all duties important to safety to be carried out correctly, with alertness, due thought and full knowledge, sound judgement and a proper sense of accountability.

To properly assess safety culture, one must consider the contributions of all organizations affecting it. Therefore, when assessing safety culture in different organizations (governmental, operational, technical support) one should consider, as a minimum, the local regulatory authority, the management of a company or a corporation and that of the organization itself.

Safety culture is needed to achieve safety for nuclear facilities and therefore one must be able to assess it for its improvement and maintenance at an optimal level. The assessment should comply with the general trends in the operation of a particular nuclear facility so that the presence of safety problems at the nuclear facility should allow tracing their connection to the problems of safety culture. However, it would be prudent to anticipate and try to identify the indicators that could warn about the possibility of the existence of problems before they occur. These indicators will not "measure" safety culture, they will rather point at the need to "look for drawbacks" in order to improve various parameters that contribute to safety culture.

To derive the method of assessing safety culture at nuclear facility, it is necessary to link a number of parameters and concepts to the facts based on the specifics of activity types in the field of nuclear energy. In the presence of correlation, it is possible to assess the effectiveness of safety culture in some cases. This could improve the understanding of the principles of safety culture that in general cannot be observed directly.

In the specified field of activities the issues of building safety culture and its assessment are associated with the need for interaction between legal entities directly involved in the decommissioning and dismantling of nuclear facilities, and RW and SNF management, including the DSS NRS. Therefore, there is a need to achieve a common approach to understanding of safety culture and its assessment.

In this regard, assessment of safety culture at all stages of decommissioning and dismantling is in line with the priorities required for achieving the public policy objectives in the field of nuclear and radiation safety, i.e. sequential decrease to an acceptable level of anthropogenic impact on the population and the environment while using atomic energy.

Noting the above, the Guide “Methodology to Assess Safety Culture at Decommissioning and Dismantlement of Nuclear-Powered Submarines, Surface Ships with Nuclear Installations, Nuclear Service Vessels Retired from the Navy”, sets forth the procedure to assess safety culture based upon the results of inspections (audits, checks) of compliance with mandatory requirements by the organizations and continuous actove engagement among relevant arts of the organisations.

8.3 References for section 8

1. Gareyev YuM, Bobrov AF, Scheblanov VY, Peshkova OO. Methods of assessing the radiation safety culture of enterprises of SevRAO. In: Proceedings of the 8th International Interdisciplinary Congress "Neuroscience for Medicine and Psychology" Sudak, Ukraine 2012: 132.
2. Bobrov AF, Gareyev YuM, Scheblanov VY. Means and methods to assess safety culture when managing spent nuclear fuel and radioactive waste at temporary storage sites. In: Proceedings of the VIII International Nuclear Forum "Safety of Nuclear Technologies: Safety Culture at Nuclear Facilities". 9-13 September 2013, St. Petersburg.

9 Preparation of SNF and RW for transport by sea

9.1 Project objectives and activities

SNF and a variety of RW will be arise from remediation, decommissioning and dismantling activities that have been described above. In many cases, due to the legacy history, the SNF an RW will have special characteristics that are different from typical planned activities and routine operations. These abnormal characteristics have to be taken into account in the subsequent transport of the materials to other sites for further treatment, interim storage and disposal. The objective of this project was to develop recommendations and requirements for ensuring nuclear and radiation safety when managing SNF and RW generated and accumulated during decommissioning and dismantling of nuclear powered and nuclear service vessels retired from the Navy, in preparation for their sea transportation.

The main activities of the project of the work were:

- Analysis of the existing regulatory and legal framework establishing the requirements to ensure nuclear and radiation safety, when managing SNF and RW generated and accumulated at decommissioning and dismantling of ships with nuclear installations and nuclear service vessels retired from the Navy, in preparation for their transportation by sea.
- Development of the requirements to ensure nuclear and radiation safety, when managing SNF and RW generated and accumulated at decommissioning and dismantling of ships with nuclear installations and nuclear service vessels retired from the Navy, in preparation for their transportation by sea, taking into account the existing and planned for formation volumes of SNF and RW, as well as the main traffic streams and possible accidents during the works.
- Development of the final Draft Guide "Requirements for Ensuring Nuclear and Radiation Safety when Managing Spent Nuclear Fuel and Radioactive Waste Generated and Accumulated at Decommissioning and Dismantling of Ships with Nuclear Installations and Nuclear Service Vessels retired from the Navy, in Preparation for Their Transportation by Sea".

The project work was carried out by a multi-expert team led by the International Center for Environmental Safety.

9.2 Project output and discussion

Key features of the Guide, which has now been approved within Russian regulatory framework, include:

- General Provisions
- Terms and Definitions
- Itemization of the regulations that justify and support the content of the current guide
- Actions taken to meet nuclear and radiation safety requirements
- Requirements for personnel
- Technical and technological requirements
- Requirements for documentation

The preparation of this guide illustrates the holistic nature of Norwegian and Russia regulatory cooperation, i.e., in supporting management of next steps in management of waste after work on decommissioning and dismantling.

10 Updated Threat Assessment (THREAT)

10.1 Project objectives and activities

In compliance with government policy in the field of nuclear and radiation safety, Russia has developed a national program for decommissioning of the nuclear legacy, which includes the STS at Andreeva Bay and Gremikha. The complexity of the problems associated with these sites has required the development of a special program of work in the field of regulatory supervision, which is implemented by institutions of FMBA of Russia. In order to develop an opinion on the most important issues requiring supervision and enhanced regulation a threat assessment was carried out and completed in 2005 [1]. The results of this threat assessment laid the foundation for the three key areas for improving regulation in the field of radiation safety and protection of workers, the public and environment. Much work has been done in all these areas since 2005, as reported in earlier sections of this report.

Taking into account the site remediation plans, including intensification of SNF and RW management in the nearest future, the main goal of the THREAT project was to develop an updated threat assessment of radiological risks. To this end, the current state of regulatory supervision of STS remediation has been analyzed in terms of the progress reached in minimization of radiological threats.

10.2 Project outputs and discussion

Analysis of activities aimed at normalization of the radiation situation at SevRAO sites being carried out over 2005-2012 confirms the significant progress in assurance of radiation protection of workers involved in preparation and implementation of SNF removal. Radiation protection of workers involved in remediation of Building 5 (Fig. 26, 27) is a priority but not yet completed. This situation can be regarded as a threat during continuing remediation operations.

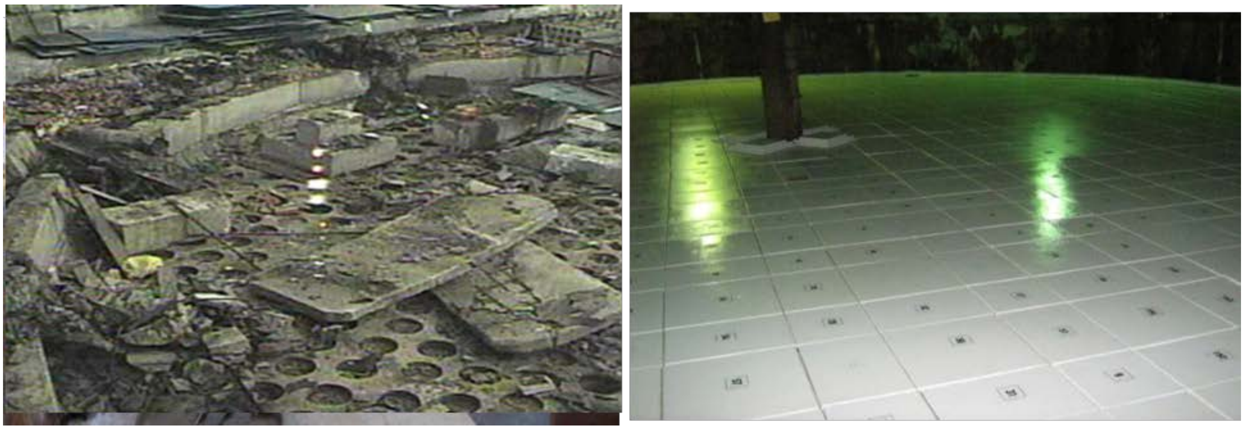

Fig. 26 Works to normalize radiological situation at 2A DSF. The left side – before remedial works, the right side – after remedial works.

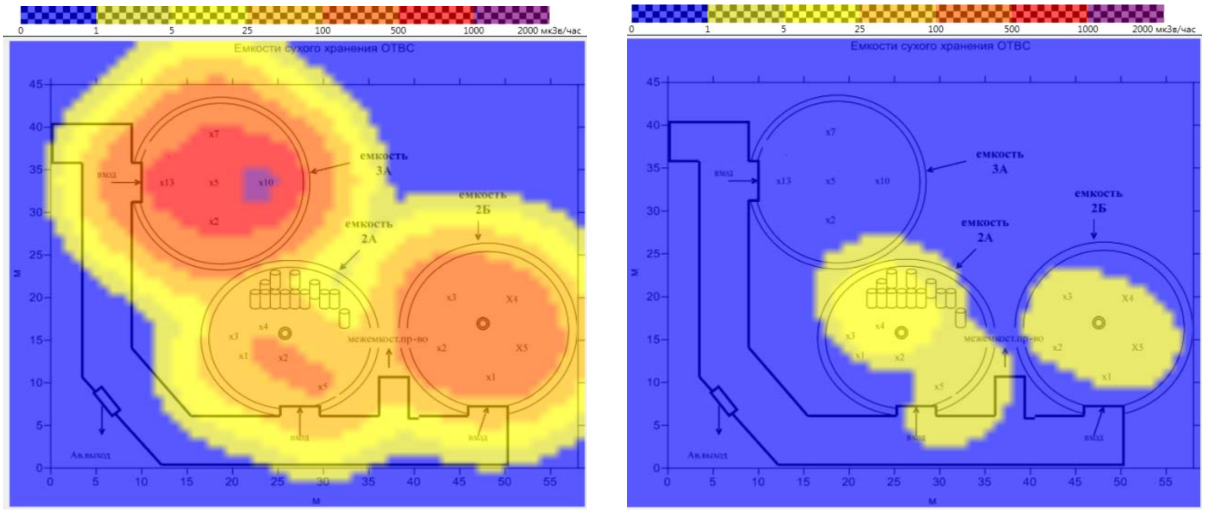

Fig. 27 Dynamics of the radiation situation in the DSF building during remedial operations (2009-2012).

The status of safety culture at the facility is especially relevant because of the next stage of SNF management operations, which are particularly hazardous. The analysis of the safety culture based on a personnel survey characterizes it as improving but also revealed negative aspects which have been used to develop corresponding recommendations on how to improve the situation.

The analysis of the current status of the medical support of emergency preparedness in general, confirms the significant progress in this field of regulation, however it is necessary to refine the cooperation between medical services under FMBA of Russia and emergency units of the facility involved in prevention and mitigation of the radiological accident consequences at facilities and sites of the northwest region. These issues are included in a draft program of actions developed under the Project, which are aimed at improvement of effectiveness of the radiation safety regulation and preparedness of health-care provision in case of a radiological accident at SevRAO facilities. The results of the radiation monitoring over 2005-2013 are a positive indicator of the effectiveness of remediation measures, and prove the radiation situation in continuing operations as meeting up to date standards, with no tendency for deterioration.

Based on the analyzed information on radiation safety at the current stage of the site remediation, recommendations have been prepared for how to enhance supervision in the key areas of regulation taking into account the next stage of remedial operations.

Noting the threat factors established in 2005 [1], it is important to note the minimization of such factors carried out with support of the NRPA-FMBA cooperation program, as reported in reference [2]. The main threat identified is still the large amount of degraded SNF and RW, which are stored under irregular conditions.

Based on the results of researches carried out over the period 2004-2014, the detailed analysis of all completed studies on the assessment of radiation protection of workers, the public and environment and has been performed including achievement in regulation of this problem. Findings of such analysis are given in [3].

10.3 References for section 10

1. Ilin L, Kocketkov O, Simakov A et al. Initial threat assessment: radiological risks associated with SevRAO facilities falling within the regulatory supervision responsibilities of FMBA. NRPA Report 2005:17. Østerås: Norwegian Radiation Protection Authority, 2005. http://www.nrpa.no/filer/acd3f4ea98.pdf (02.03.2016)

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11 Cooperation with other Russian Federation authorities and wider international engagement

11.1 Objectives and activities

The activity to dismantle nuclear-powered submarines and other NFME is of a very complex nature and its support involves implementation of a whole set of technological processes and organizational activities, including regulatory supervision.

One complicating aspect is the transition of regulatory responsibilities from military to civilian control, in practice from the Directorate of State Supervision over Nuclear and Radiation Safety of the Ministry of Defense of the Russian Federation (DSS NRS) to FMBA. Accordingly regulatory guides have been developed jointly with particular reference to control of radiation exposure and radioactive materials arising from NMFE dismantling and remediation at STS sites [1] and [2].

Similar cooperative work has been carried out in the period covered by this report to upgrade regulatory capabilities in the area of radiation safety control and supervision during radioisotope thermoelectric generators decommissioning and transportation, in this case with the Russian Federal Environmental, Industrial and Nuclear Supervision Service, (Rostechnadzor) [3].

A further feature of the work has been to maintain good technical contact with experts in operator organizations, to ensure that regulatory work is relevant and timely while also maintaining strict adherence to the roles and responsibilities of the separate organizations.

This work and that described in the previous sections has been widely shared with the international community, including the Contact Expert Group of the IAEA and through a series of workshops, conferences and journal papers [4 – 11]. The intention has been to ensure that Norwegian and Russian regulatory cooperation is able to learn from the experience in other countries and the latest developments in international recommendations. The work is also relevant to other legacy sites in Russia [12] and elsewhere.

Noting the success in the above work and effective working methods developed, NRPA has commenced regulatory cooperation projects with appropriate authorities in countries of Central Asia and with Ukraine [13, 14].

11.2 References for section 10

1. Sneve MK, Roudak S et al. Dismantlement of nuclear facilities decommissioned from the Russian navy: enhancing regulatory supervision of nuclear and radiation safety. NRPA Report 2013:3. Østerås: Norwegian Radiation Protection Authority, 2013. http://www.nrpa.no/filer/563be18b06.pdf (02.03.2016)
2. Roudak SF, Sneve MK, Bulatov OR et al. Enhancement of regulatory supervision of the nuclear legacy in northwest Russia: involving the military authorities. NRPA Report 2011:10. Norwegian Radiation Protection Authority, 2011. http://www.nrpa.no/dav/dbb0a10c01.pdf (02.03.2016)
3. Cooperation between Norwegian and Russian Regulatory Authorities: NRPA and Rostechnadzor. NRPA Bulletin 14:2011. Østerås: Norwegian Radiation Protection Authority, 2011. http://www.nrpa.no/dav/8a0a65bc72.pdf (02.03.2016)

4. Sneve MK. Regulatory supervision of management of spent fuel in northwest Russia. In: Proceedings of 15th International High-Level Radioactive Waste Management Conference (IHLRWM 2015), Charleston, SC, April 12-16, 2015. La Grange Park, Illinois: American Nuclear Society, 2015.

5. Sneve MK, Smith GM. Regulating the path from legacy recognition, through recovery to release from regulatory control. Radiation Protection Dosimetry 2014; 164(1-2): 1–4.

6. Shandala NK, Filonova AA, Shchelkanova ES et al. Radiation survey at Andreeva Bay sites of temporary storage of the spent nuclear fuel and radioactive waste. Journal of Medical Radiology and Radiation Safety 2014; 58(2): 5-12.

7. Sneve MK, Kiselev M, Persinko A et al. International cooperation on regulatory supervision of legacies arising from nuclear accidents. International Experts' Meeting on Decommissioning and Remediation after a Nuclear Accident, 28 January – 1 February 2013. Vienna: International Atomic Energy Agency. http://www-pub.iaea.org/iaeameetings/IEM4/29Jan/Sneve.pdf (02.03.2016)

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10. Seregin VA, Novikova N, Sneve MK et al. Radio-ecological regulations for remediation of the sites for temporary storage of the spent nuclear fuel and radioactive waste. In: Proceedings of 13th International Congress of the International Radiation Protection Association, IRPA13, Glasgow, 13-18 May, 2012. http://www.irpa.net/members/P11.02.pdf (02.03.2016)

11. Sneve MK, Kiselev M, Shandala NK. Radio-ecological characterization and radiological assessment in support of regulatory supervision of legacy sites in northwest Russia. Journal of Environmental Radioactivity 2014; 131: 110-118

12. Suslova KG, Romanov SA, Efimov AV et al. Dynamics of body burdens and doses due to internal irradiation from intakes of long-lived radionuclides by residents of Ozyorsk situated near Mayak PA. Journal of Radiological Protection 2015; 35(4): 789–818.

13. Zhunussova T, Sneve M, Romanenko O et al. Threat assessment report: regulatory aspects of the remediation and rehabilitation of nuclear legacy in Kazakhstan, Kyrgyzstan and Tajikistan. NRPA Report 2011:5. Østerås: Norwegian Radiation Protection Authority, 2011.

14. Norwegian Radiation Protection Authority. Regulatory Cooperation in Ukraine. NRPA Bulletin 09:2015. Østerås: Norwegian Radiation Protection Authority, 2015.

12 Continuing projects and related activities

Noting the above success, cooperation between NRPA and FMBA is continuing in support of regulatory supervision of legacies in northwest Russia. In February 2015, Norwegian-Russian Regulatory Cooperation program initiated a new set of collaborative projects with the links to previous ones, as follows.

Organization of emergency exercise with international participation on the assessment of the preparedness and response in the event of a radiological accident at the STS Andreeva Bay

This project is to arrange and conduct an emergency exercise with international participation. The main objective is to assess the effectiveness of actions between all participants using the computer methods for simulating the radiation situation as well as to assess the technical and psychological preparedness of the medical team personnel and groups to mitigate and minimize consequences of a radiation accident.

Radiation protection support during SNF and RW removal operations at STS Andreeva Bay

Between 2015 and 2018 large-scale operations are planning to be conducted at the STS Andreeva Bay facility, divided into the three stages:

1. SNF removal from the Dry Storage Facilities
2. Removal of spent fuel assemblies from Building number 5.
3. Removal of RW accumulated during the previous operation of the facility and those being generated at the stage of SNF removal.

With reference to these actions, a project has been developed aimed at enhancing the regulatory functions of the territorial bodies under FMBA of Russia. The findings and results of the project are to be used for increasing radiation protection of workers and the public during radiation hazardous operation e.g. removing of SNF assemblies and RW from STS Andreeva Bay.

Tasks of the project include:

- Analysis of the proposed solutions and operational technology procedures for the SNF and RW removal; the compliance of these solutions and procedures with the current regulatory documents.
- Assessment of the radiation parameters in the main working areas.
- Assessment of doses to workers.
- Development of the activities to optimize protection of workers and the public.

Ecological assessment of environment during remediation of the STS Andreeva Bay

Scientific support of the regulatory developments is one of key points included in NRPA’s regulatory cooperation. With this in mind, comprehensive study of the environmental conditions around STS and ecological assessment of the terrestrial ecosystems by bio-indication methods is an important part of remedial activities and their regulation. Growing trend in the recent development of radiation protection principles includes the concept of supporting both protection of human health and the environment, through maintenance of stable functioning of ecosystems and biodiversity. Output with the completion of the project will be comprehensive and structured information on dynamics of monitored parameters of the STS Andreeva radio-ecological situation.

As well as supporting control of current radiation exposures, this information is necessary to support the prognosis of future conditions at the site according to alternative remediation strategies, and thereby will support the selection of the most appropriate remediation actions.

Scientific support of IAS RBP for the purpose of regulatory supervision of STS remediation works of the STS Andreeva Bay.

In order to monitor the changing exposure conditions and to improve capabilities in radiation protection of workers, in 2012-2014, under DOSEMAP-3 project the Information and analytical system on radiation protection of workers (IAS RBP) was developed. IAS RBP consists of components compatible with each other:

- Mazur Interface- interface to input initial measured data;
- EasyRAD – to analyze the radiation situation;
- TesnovKML- to input routes of the personnel.

Using this software it is possible to solve tasks associated with regulatory control of workers radiation exposure and efficient regulatory supervision of STS remediation works connected with accumulation of measured data, calculation of radiation fields, input of the personnel routes and basic radiation situation analysis. Crucial to safety in coming hazardous operations is the effective implementation of the software at STS Andreeva Bay, which is the main objective of the ongoing project.

Improvement and implementation of the soft/ hardware training complex for workers involved in the spent nuclear fuel and radioactive waste management.

This project is the third in the series concerning professional reliability monitoring. The main outputs have been the pilot version of the expert-and-diagnostic information system for risk monitoring of the performance reliability violation and a soft/hardware system to train and perfect the motor skills, taking into account the psycho-physiological price control of the activity. The main objective of the current project is to generate the testing model for soft/hardware training and introduce it into the system of training or retraining of workers involved in hazardous SNF and RW operations.

13 Conclusions

Between 2009 and 2015 a range of projects was completed as part of the bi-lateral regulatory cooperation program between the NRPA and Russian Federation authorities focusing on nuclear legacies in northwest Russia. Topics included comprehensive consideration of radiation protection issues connected with remediation of the STS Andreeva Bay.

The main finding of the studies performed under cooperation in the area of emergency preparedness and response is, that emphasis of research and development should focus on radiation protection of workers, combined with formulation and implementation of the principles of a strong safety culture. The full set of analyzed information shows that the potential threats of radiation exposure to workers of the facilities, the environment and the population of the northwest region of Russia are being systematically reduced.

In particular, the following regulatory materials concerned with emergency preparedness and response were developed within the cooperation program:

- Criteria for evaluation of the potential radiation hazard associated with the analysis of possible design basis and beyond design basis radiation accidents at the considered facilities, as well as the characteristics of their locations (demography, agriculture) and health care infrastructure.
- Recommendations for the FMBA's regional offices on activities in case of threat and development of radiological accident and reference documents including mapping and numeric material to justify the proposed criteria for evaluation of the potential radiation hazard.
- General strategy of management and control of emergency planning and preparedness by regulatory bodies, enhancing the emergency preparedness of the FMBA institutions and other relevant bodies in northwest Russia.
- Methodological and organizational basics for the interaction of working groups of regulators and supporting experts.

Additionally an evaluation was performed of emergency readiness of regional bodies of FMBA to respond to incidents with radioactive substances under transport, review of international experience for this issue and implementation of practical measures to practice the interaction and training of emergency services of operators, regulators and expert groups

Between 2010 and 2014, part of activities was focused on control of internal exposure of SevRAO workers, who are and will be involved in technological operations of SNF management and RW treatment. This included improved methods for internal dose monitoring of SevRAO workers using the special calibration of spectrometers and establishing the procedure of monitoring of internal contents of α and β emitters in irregular situations. The second part of work included development of the regulatory Guidance "Radiation Protection of Workers and the Public during Remediation of Nuclear Legacy Sites". This contains requirements for main aspects of the personnel and public protection during remediation both of radioactively contaminated sites of industrial facilities in the course of their decommissioning and areas contaminated due to radiological accidents and nuclear weapon tests. Work completed supplemented the system for internal dose monitoring of SevRAO workers with methodical documents, in compliance with the requirements under normal operational conditions and during emergencies.

In order to register the dynamics of the radio-ecological situation and predict its evolution in the current and changing circumstances of STS remediation, over 2008-2012, within the DATAMAP and DATAMAP-GIS projects, a computer map of radio-ecological data was developed and implemented. Additionally, improvements in the prognostic assessment capability of the information-and-analytical system, including development of an algorithm for dose calculations for reference animals and plants, and analysis of the sufficiency of available data were introduced. Additional monitoring of radio-ecological conditions at the STS Andreeva Bay, was also performed, especially taking account of the progress of industrial remediation work at the site.

Between 2009 and 2014 under the DOSEMAP2 and DOSEMAP3 projects, a team of experts adapted the individual worker dose and area radiation parameter databases to the practical supervision of radiation protection by regulation bodies. Activities included practical methodological support to the Regional Management office 120 of FMBA and staff at the SevRAO Facilities in use of the databases and related software tools. Corresponding documentation was also provided, as follows:

- «Application of the Databases of the radiation situation parameters and doses to workers for the purpose of personnel radiation protection regulation»,
- «Application of the Databases of the radiation situation parameters and doses to workers for the purpose of arrangement and implementation of radiation hazardous operations»
- «Control of radiation protection of workers during the SNF and RW management».

There was also developed an integrated multilayer map and a new mapping interface for tracing and optimization of personnel routes on the STS Andreeva site.

Under the continued project on personnel reliability management, pilot versions of soft/hardware training tools “TIBUR_TSP” were developed based on interactive simulation training games in a virtual environment with biological feedback. These help to actualize and control occupational specific psycho-physiological functions of SevRAO workers during hazardous tasks connected with SNF management.

In order to ensure radiation safety and to organize radiation health supervision over continuing dismantling activities, a program of assessment of radiation safety at an enterprise performing decommissioning and dismantling of marine nuclear vessels was carried out. Additionally, the regulatory guide “Ensuring Radiation Safety and Prevention of Environment Contamination in the Process of NFME decommissioning and dismantling” was developed.

The continued development and enhancement of safety culture, and its effective integration within all activities, are seen as an underlying basis to state supervision over nuclear and radiation safety, leading to protection of workers, the public and the environment. Therefore, two methodology guides were developed within the cooperation program to support evaluation of progress of in these areas connected with remediation of the nuclear legacy in northwest Russia:

- Methodological Instructive Regulations for Monitoring the Effectiveness of State Supervision over Nuclear and Radiation Safety at Dismantling of Nuclear Powered Submarines, Surface Ships with Nuclear Installations, Nuclear Service Vessels Retired from the Navy
- Methodology to Assess Safety Culture at Decommissioning and Dismantlement of Nuclear-Powered Submarines, Surface Ships with Nuclear Installations, Nuclear Service Vessels Retired from the Navy

All listed below activities were a natural continuation of projects developed after completion of an initial regulatory threat assessment carried out in 2005. At the end of the period it was timely to update the initial threat assessment and the report of that work has formed the basis for continuing cooperation projects, taking into account progress with the program of industrial projects and developments in international recommendations and guidance. The continuation of this work is considered to be very important, given the hazardous nature of the next phase of remediation work, linked to recovery and making safe of SNF and RW from their present poor storage conditions

As well as a holistic view of radiation protection issues, the program has been designed to engage with all relevant regulatory authorities in Russia, and to include dialogue with operator organizations. In addition, information from the program is shared widely with the international community, though participation in workshops and conferences and in the successful publication of program results in peer reviewed journals.

In addition the experience gained is being applied in other areas of Russia and in other bi-lateral cooperation programs with countries of Central Asia and Ukraine. It is further hoped that the results will be used in the continuing update and enhancement of international recommendations and guidance concerned with nuclear legacies.

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StrålevernRapport 2016:1
Årsrapport

StrålevernRapport 2016:2
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