Strålevern Rapport 2005:17

Initial Threat Assessment

Radiological Risks Associated with SevRAO Facilities Falling Within the Regulatory Supervision Responsibilities of FMBA

Statens strålevern

Norwegian Radiation Protection Authority
Postboks 55
N-1332 Østerås
Norway

Reference:
Ilin L., Kochetkov O., Simakov A., Shandala N., Savkin M., Sneve M. K., Børretzen P., Jaworska A., Smith G., Barraclough I., Kruse P., “Initial Threat Assessment. Radiological Risks Associated with SevRAO Facilities Falling Within the Regulatory Supervision Responsibilities of FMBA”. StrålevernRapport 2005:17. Østerås: Norwegian Radiation Protection Authority, 2005.

Key words:
Threat Assessment. Radiological Risks. SevRAO Facilities. Health Regulatory. Supervision Responsibilities. Radioactive Waste Management.

Abstract:
The purpose of this initial threat assessment is to obtain a view, from the regulatory perspective of FMBA, of the most important issues which require supervision and regulatory development, regarding work which has to be carried out at the Andreeva Bay and Gremikha. The main radiological threats have been identified and actions to reduce the threats have been proposed. Situations where regulations and procedures for workers on-site need to be developed have been identified. This will be a basis for further development of Russian regulation and procedures.

Referanse:
Ilin L., Kochetkov O., Simakov A., Shandala N., Savkin M., Sneve M. K., Børretzen P., Jaworska A., Smith G., Barraclough I., Kruse P., “Initial Threat Assessment. Radiological Risks Associated with SevRAO Facilities Falling Within the Regulatory Supervision Responsibilities of FMBA”. StrålevernRapport 2005:17. Østerås: Statens strålevern, 2005. Språk: engelsk.

Emneord:
Trusselvurdering. Radiologisk risiko. SevRAO`s anlegg. Regulerende helseovervåkning. Oppsyn av ansvar. Håndtering av oppbrukt radioaktivt avfall.

Resymé:
Formålet med denne initiale trusselvurderingsrapporten er å gi regulerende myndigheters (FMBA) syn på de viktigste områder som krever overvåking og regulativ utvikling når det gjelder arbeid som må gjennomføres i de forurensede områdene i Andreeva bukten og Gremikha. De største radiologiske truslene har blitt identifisert og tiltak for å redusere disse trusler har blitt foreslått. Situasjoner hvor reguleringer og prosedyrer må utvikles for arbeiderne på områdene har blitt identifisert. Dette vil danne basis for videreutvikling av russisk regelverk og prosedyrer.

Head of project: Malgorzata K. Sneve
Approved:

Per Strand

Per Strand, director, Department for Emergency Prepardness and Environmental Radioactivity.

---

58 pages.
Published 2005-12-10.
Printed number 300 (05-12).
Cover design: LoboMedia, Oslo.
Printed by LoboMedia, Oslo.

Orders to:
Norwegian Radiation Protection Authority, P.O. Box 55, N-1332 Østerås, Norway.
Telephone +47 67 16 25 00, fax + 47 67 14 74 07.
www.nrpa.no
ISSN 0804-4910

StrålevernRapport 2005:17

Initial Threat Assessment

Radiological Risks Associated with SevRAO Facilities Falling Within the Regulatory Supervision Responsibilities of FMBA

Leonid Ilin, Oleg Kochetkov, Anatoly Simakov, Natalya Shandala, Mikhail Savkin
Institute of Biophysics, Russia

Malgorzata K. Sneve, Peer Børretzen, Alicja Jaworska,
Norwegian Radiation Protection Authority

Graham Smith, Ian Barraclough, Phil Kruse
Enviros, UK

Statens strålevern

Norwegian Radiation
Protection Authority
Østerås, 2005

Innhold

Initial Threat Assessment – Executive Summary

The Norwegian Government, through a Plan of Action implemented by the Ministry of Foreign Affairs (MFA), is supporting Russian efforts to improve radiation protection and nuclear safety in North-West Russia. Some of this work is directed to the improvement of waste management and remediation operations at the Shore Technical Bases (STBs) operated by Federal Enterprise SevRAO at Andreeva Bay and Gremikha on the Kola Peninsula. Some work has already been carried out at these sites and underpins the current work plan.

Attention is focussed at these sites due to the very poor storage conditions that exist for the significant inventories of spent nuclear fuel (SNF) and radioactive waste (RAW). The handling of these dangerous materials to put them into a safe condition is especially hazardous because of their degraded state. Furthermore, significant quantities of radionuclides have already escaped into the ground around the storage facilities. The potential for spreading of this contamination and for further releases creates additional hazards, both locally and on a regional scale.

The extreme radiological conditions at Andreeva Bay and Gremikha present novel difficulties for regulatory supervision of operations. The existing regulations were developed for routine conditions of SNF and RAW management, and there are also regulations for emergency situations. However, the current situation at these two sites is such that some essential routine operations cannot be performed in accordance with either of the existing regulations: dose rates are higher than allowed by the routine regulations, but the situation is not classed as an emergency. Furthermore, remedial actions that would be needed to improve the situation are also not permitted under the current regulatory regime. A set of improved procedures, including special norms and rules that would allow essential operations and remedial actions to be carried out, needs to be developed for this unusual situation, which is the legacy of past activities.

MFA's strategy includes not only support to industrial projects, but also support to Russian regulatory bodies, to ensure that work is carried out in compliance with Russian Federation (RF) law, taking account of international recommendations and other national good practice as relevant in the RF. Accordingly, MFA through the NRPA, has set up a programme of cooperation with the Federal Medical–Biological Agency (FMBA), which is the primary radiation protection authority in the RF.

The overall objective of the collaboration is to promote effective and efficient regulatory supervision of SevRAO activities at Andreeva Bay and Gremikha within the scope of responsibilities of FMBA. Within this scope, the cooperation is being implemented through three specific projects addressing regulatory supervision in the following three areas:

- Radiation exposure of workers;
- Radiation exposure of the public; and
- Emergency preparedness and response.

An early step in each of the three projects has been to assess the radiological threats currently existing and presented by the work which has to be carried out at the STBs. The purpose of this initial threat assessment[1] is to obtain a view, from the regulatory perspective of FMBA, of the most important issues which require supervision and regulatory development.

It is noted that the basic laws of the RF on use of radioactive materials and radiation protection provide a full basis for operation. However, given the special situation of the STBs, this threat assessment is intended to identify:

- The main radiological threats to workers and the public which require regulatory attention;
- The main requirements for risk assessment, i.e. those issues which will require most urgent and/or detailed analysis;
- Any relevant additional regulatory requirements, and the nature of the safety work instructions to be developed by the operator; and
- Key issues in the implementation of the regulatory process.

It is recognised that the findings in this report are of a preliminary nature and should provide a basis for further development of the three projects.

Radiological threats

The main radiological threats at Andreeva Bay and Gremikha can be summarised as follows (in approximate order of priority):

1. At both bases, there are storage areas containing highly active materials (spent nuclear fuel, and a range of liquid and solid radioactive wastes) and severely contaminated parts of the territory. Dose rates in parts of the sites exceed 1 mSv/h.
2. The territory and area of water next to the STB Andreeva Bay is contaminated by ^{90}Sr, ^{137}Cs and ^{60}Co, from local sources of radioactive contaminations. Abnormal levels of ^{137}Cs in the ground are observed in three areas of the Andreeva Bay site, the highest values being up to 10^6 Bq/kg close to Building 5 (a building used in the past for SNF storage). Soil samples taken in Zaozersk, show concentrations of ^{137}Cs and ^{90}Sr that were not higher than 50 Bq/kg, much lower than on industrial site and decreasing with distance from the site. Local concentrations of ^{137}Cs in soil in Gremikha village reach 2400 Bq/kg.
3. Concentrations of ^{137}Cs in bottom sediments of the coastal strip next to the STB areas in Andreeva Bay vary from <20 to 600 Bq/kg depending on distance from the mouth of the brook. Content of ^{137}Cs in the brook water also varies within the range <20-500 Bq/l near Building 5. Local contamination of seaweeds and periphyton in the area of vessel anchorage is more than a factor of ten higher (>2500-4600 Bq/kg) than in seaweeds from elsewhere in the STB area, whereas contamination of bottom sediments (600 Bq/kg at vessel anchorages) varies only by a factor of about three. Comparable levels are observed in areas at Gremikha.
4. Average annual concentration of ^{90}Sr and ^{137}Cs in the atmosphere at Andreeva Bay are ten times lower than acceptable levels activity, but are much higher than background levels in the Murmansk region.

---

[1] The term initial threat assessment is used to avoid confusion with the rather precise terminology associated with the term “risk assessment”. The threat assessment is a preliminary, qualitative review of risks and hazards providing outline details to enable additional effort and resources to be focussed on those areas that most require attention.

5. Activity concentrations of ^{137}Cs in the sea water in Andreeva Bay are similar to background levels. Nevertheless trace radioactive contaminations of sea water in the area of berths in Andreeva Bay are noted. Concentrations of ^{137}Cs in the sea water area of Gremikha STB are approximately twice those in the open sea.
6. Assessment of real public radiation exposure doses on the basis of available data is difficult, because many parameters of radiation-hygienic situation have not been researched. Namely, there are no adequate data on the level of radionuclides in drinking water and foods (including venison, fish, wild plants).
7. There is little data on the existence of radionuclides in soils and their migration in the environment in Andreeva Bay and Gremikha.

Actions to reduce the threats

As indicated above, the Andreeva Bay and Gremikha village (STB) sites comprise a range of radioactive sources, including spent nuclear fuel, liquid and solid radioactive wastes, and areas of environmental contamination. Given the very high dose rates existing, it is important to prioritise and schedule actions to control these sources in order to ensure that the hazards are minimised appropriately. There would be significant advantage in removing spent nuclear fuel as the first priority as outlined below.

The current very high dose rates on-site mean that, under present conditions, any on-site operations carry a significant health risk. The very high dose rates are thought to be largely attributable to the spent nuclear fuel (SNF) and high level radioactive wastes (RAW), e.g. SNF in dry storage areas 2A, 2B and 3A at Andreeva. The present storage conditions for these materials are unstable and liable to deterioration, such that these conditions also constitute a significant and increasing accident risk. Thus, while the removal of SNF would entail a significant increase in occupational doses, and a temporary increase in the probability of an accident occurring while the SNF is removed, it is envisaged that, in the long-term, the removal of SNF would result in a significant reduction in both the on-site dose rates and the risk of serious accidents. This would allow other on-site operations to be conducted more safely (and hopefully within the normal regulatory regime).

A programme of work to remove the SNF from the dry storage cells at Andreeva Bay promptly has been proposed, but would require special regulations for working in abnormal conditions on-site. An alternative programme of work, involving infrastructure improvements on-site so that work can be carried out within existing regulations for normal conditions, has also been formulated, but the infrastructure improvements would require several years' work before removal of the SNF could begin (allowing the possibility of further deterioration). The aim is to find the optimum solution whereby the SNF can be removed as soon as possible, without breaching fundamental safety norms.

It is also clear that more information is required to fully characterise the condition of other wastes and sources of contamination on-site. Once the SNF has been removed the improved dose-rate conditions should make it possible to determine the condition, risks and dose rates implied by the other waste streams more effectively. On the basis of this information, priorities for further clean up and waste treatment actions may then be identified. It may then be possible to carry out those activities under regulations for normal conditions.

There is no information to suggest that off-site contamination levels require urgent action. However, there is little information about radiological conditions off-site, and a number of specific data gaps have been identified related to the levels and movement of radionuclides in the environment. Although this is of lower priority than the removal of SNF, it would be possible to gather off-site information at the same time to inform the development of regulatory criteria for long-term planning for rehabilitation and site de-licensing.

Provisional regulatory activities

In order to undertake any programme of work to mitigate the threat posed by SNF on the sites that can be agreed between operator and regulator, assessment of the following factors will be required:

1. The current situation: dose rates, worker and public doses under current conditions; the risk to workers and the public from accidents (before any action); and the likely development of the situation (including changes in the dose rates and accident risks) if no action were taken.
2. The risks of undertaking remediation work: detailed identification of work procedures; doses and accident risks implied by different procedures; and identification of appropriate procedures to reduce the probability and/or impact of potential accidents
3. The future situation: residual doses and risks following different remedial action strategies.

Supporting this work, regulations and procedures for workers on-site need to be developed that can be applied to abnormal situations while remaining within the existing legal norms.

In parallel, activities can be undertaken preparatory to future decision making on the decommissioning and eventual de-licensing of the sites and any necessary cleanup in the surrounding areas. The main preparatory activities would aim to:

1. Obtain better information on radiological conditions off-site, and how these are changing due to conditions on-site (this information can also be an input to defining the current situation); and

2. Develop regulatory criteria and guidance for the cleanup of contaminated areas and de-licensing of the sites.

1 Introduction, objectives and scope

The Norwegian Government, through a Plan of Action implemented by the Ministry of Foreign Affairs (MFA), is supporting Russian efforts to improve radiation protection and nuclear safety in North-West Russia. Some of this work is directed to the improvement of waste management and remediation operations at the Shore Technical Bases (STBs) operated by Federal Enterprise SevRAO at Andreeva Bay and Gremikha on the Kola Peninsula. Some work has already been carried out at these sites and underpins the current work plan.

Attention is focussed at these sites due to the very poor storage conditions that exist for the significant inventories of spent nuclear fuel (SNF) and radioactive waste (RAW). The handling of these dangerous materials to put them into a safe condition is especially hazardous because of their degraded state. Furthermore, significant quantities of radionuclides have already escaped into the ground around the storage facilities. The potential for spreading of this contamination and for further releases creates additional hazards, both locally and on a regional scale.

The extreme radiological conditions at Andreeva Bay and Gremikha present novel difficulties for regulatory supervision of operations. The existing regulations were developed for routine conditions of SNF and RAW management. However, the situation at these sites is such that the existing regulations are not applicable, but actions to remedy the situation are not permitted under the current regulatory regime. An improved regulatory process, including development of special norms and rules, is required to take account of this unusual situation.

MFA's strategy includes not only support to industrial projects, but also support to Russian regulatory bodies, to ensure that work is carried out in compliance with Russian Federation (RF) law, taking account of international recommendations and other national good practice as relevant in the RF. Accordingly, MFA through the NRPA, has set up a programme of cooperation with the Federal Medical–Biological Agency (FMBA), which is the primary radiation protection authority in the RF.

The overall objective of the collaboration is to promote effective and efficient regulatory supervision of SevRAO activities at Andreeva Bay and Gremikha within the scope of responsibilities of FMBA. These responsibilities include the following activities associated with extremely hazardous operations and emergency situations, both on-site and off-site:

- Regulatory supervision of radiation safety of workers and the public;
- Monitoring of the on-site and off-site environment related to health protection of workers and the public;
- Epidemiological control;
- Cooperation with local authorities;
- Definition of preventive risk reduction measures;
- Medical services related to extreme conditions and emergencies;
- Scientific research in the areas of hazardous situations, assessment and mitigation of health impact, and requirements for medical remedial action.

Within this scope, the cooperation is being implemented through three specific projects addressing regulatory supervision in the following three areas:

- Radiation exposure of workers;
- Radiation exposure of the public;

- Emergency preparedness and response.

Project 1. Regulatory Supervision of Radiation Exposures of Workers

This project has the primary objective to develop criteria and regulatory guidance to improve the radiological conditions of personnel working at SevRAO facilities, focusing on Andreeva Bay. Tasks and related deliverables include:

- Preparation of a description and justification of the status of all technological operations relating to SNF and RAW management at Andreeva Bay.
- Development of guidance on hygienic norms for doses to personnel exposure in routine, abnormal and emergency/remediation situations in the management of SNF and RAW. This needs to take account of both: the existing generic requirements and the site specific working and radiation conditions at Andreeva Bay.
- Development of guidance on the application of means of protection of personnel at SevRAO facilities.
- Development of final guidance "Sanitary rules of radiation safety for work at SevRAO facilities" taking into account the output from the above tasks and analyses of experience in management of SNF and RAW.

Project 2. Regulatory Supervision of Radiation Exposures of the Public

This project has the primary objective to develop norms and standards and supporting regulatory guidance for application during and upon completion of rehabilitation of Andreeva Bay and Gremikha. Tasks and related deliverables include:

- Review and collation of independent data on the radiation situation and radiation control in areas on and around the sites.
- Reports on: "Methods for conducting radiological assessment during rehabilitation activities"; and "Methods for organisation of radiation control".
- Development of radiation criteria and norms providing socially accepted guarantees of public radiation safety during and after rehabilitation of the sites.

Project 3. Regulatory Supervision of Emergency Preparedness for Response

This project has the primary objective to provide regulatory guidance on the planning of radiological and medical emergencies management of relevance to SevRAO facilities, focusing on Andreeva Bay. Tasks and related deliverables include:

- Review of international and national methods.
- Development of transparent explanation of organisational responsibilities with regards to emergency preparedness, operators and regulators.
- Development of the regulatory basis for requirements for emergency preparedness.
- Guidance on medical and sanitary planning for emergency situations.
- Training in medical emergency preparedness for radiation emergencies.

The programme of work for 2005–2006 focuses on the hazards arising from the currently planned industrial projects of SevRAO. Coordination with SevRAO is a vital component in the provision of support at a regulatory and operational level, as enshrined in the ‘2 + 2’ model.

Taking all of the above into account, an early step in each of the three projects has been to assess the radiological threats currently existing and presented by the work which has to be carried out at the STBs. The purpose of this initial threat assessment[2] is to obtain a view, from the regulatory perspective of FMBA, of the most important issues which require supervision and regulatory development.

It is noted that the basic laws of the RF on use of radioactive materials and radiation protection provide a full basis for operation. However, given the special situation of the STBs, this threat assessment is intended to identify:

- The main radiological threats to workers and the public which require regulatory attention;
- The main requirements for risk assessment, i.e. those issues which will require most urgent and/or detailed analysis;
- Any relevant additional regulatory requirements, and the nature of the safety work instructions to be developed by the operator; and
- Key issues in the implementation of the regulatory process.

Accordingly, Section 2 sets out the issues identified within the three projects and Section 3 develops the common conclusions. References are provided in Section 4 and a list of acronyms and abbreviations is given at Section 5.

It is recognised that the findings in this report are of a preliminary nature and should provide a basis for further development of the three projects.

---

[2] The term initial threat assessment is used to avoid confusion with the rather precise terminology associated with the term “risk assessment”. The threat assessment is a preliminary, qualitative review of risks and hazards providing outline details to enable additional effort and resources to be focussed on those areas that most require attention.

2 Threat Assessment

2.1 Worker Protection Aspects

2.1.1 Key facilities

At present, the spent nuclear fuel (SNF) stored at Andreeva Bay is in block dry storage (BDS) – storage cells just below the ground surface – at three locations on the site (referred to as 2A, 2B and 3A) and in type-6 (TUK-6) containers on the ground surface at location 2A [Rosatom, undated; Strategic master-plan, 2004; NRPA, 2004].

SNF storage conditions at each BDS site, and in type-6 containers, each have their own specific issues, for which some novel technologies will have to be defined for removal and treatment of irradiated fuel assemblies (IFA).

The BDS at location 2A is the best example of conditions appropriate for the dry storage of SNF. Water is absent from practically all of the cells as the construction reliably prevents ingress of rain or groundwater. This block is covered by a shed made from demountable sections: these demountable sections are temporarily removed when work is being carried out on the BDS. Steel plugs with lead bushes close all of the cells, and this makes the cell-opening process easier. Inspection of the radiation situation at the SNF storage areas showed (according to information from NIKIET [2004]) the lowest gamma dose rates (0.01–0.25 mSv/h) at location 2A. For this reason, specialists from NIKIET have proposed that a stable working area for work to re-package IFAs from all of the SNF storage areas should be established at location 2A [NIKIET, 2004].

The 2B site also has a shed made from demountable sections. However, in contrast to the 2A site, all of the storage cells at 2B are filled with water. Activity concentrations in the water in some cells are reported by NIKIET to reach 10^{-2} Ci per litre (0.37 GBq/l) [NIKIET, 2004]. Approximately half of the cells at location 2B are closed both by concrete plugs in steel shells and by metallic lids. Removal of the concrete plugs is a labour-intensive operation and requires development of a special tool. Measured gamma dose rates at the surface of the storage block are 0.04–0.88 mSv/h, i.e. three to four times higher than those at location 2A.

After the cells at location 3A were filled with IFA containers in 1985, the block was covered with concrete slabs and a ruberoid waterproof covering. Concrete plugs close the storage cells. Since 1985, this storage block has not been opened and there is no information available regarding the state of the SNF inside. The existing covering does not provide the contents with adequate protection from the weather. It is therefore assumed that rain and groundwater infiltrate into the 3A storage cells as at location 2B. The most unfavourable radiation situation is observed at location 3A: the measured gamma dose rates at the cover surface (on the concrete slabs) are in the range 0.05–1.15 mSv/h [NIKIET, 2004], i.e. up to five times higher than at location 2A.

2.1.2 List of problematic themes

Analysis of technological decisions in SNF management

The following strategy has been proposed for the removal of the SNF stored at Andreeva Bay [NIKIET, 2004a; NIKIET, 2004b]:

- Test recovery, re-packaging, and transportation to PA Mayak of a consignment of 84 containers of IFAs from location 2A.

- Organisation, on the part of location 2A from which the SNF has been removed, of a working area for re-packaging other SNF;
- Recovery, re-packaging and transportation to PA Mayak of further containers of IFA from location 2A, to clear a place for temporary storage of new IFA containers and containers for damaged SNF;
- Removal of IFA containers from location 2B to the working area, re-packaging of IFAs, and transportation to PA Mayak;
- Removal of IFA containers from location 3A to the working area, re-packaging of IFAs, and transportation to PA Mayak;
- Removal of IFAs from type-6 containers and loading into new containers;
- Recovery, re-packagng and transportation to PA Mayak of the remaining IFAs from location 2A site; and
- Preparation and implementation of transportation of damaged SNF to PA Mayak.

This option for fuel management (option I, proposed by the Research and Development Institute of Power Engineering, NIKIET) minimises the time until the SNF is removed from the site and the cost of the work, whilst the providing necessary safety at work. According to preliminary estimates, it would reduce by at least 6–7 years the duration of SNF storage before its treatment, because it does not require new infrastructure to be constructed on the site before work starts.

Option II, proposed by the All-Russian Research and Design Bureau (VNIIPIET), includes the creation of new infrastructure, such as "hot cameras", temporary storage sites, a new road, additional change rooms for personnel, decontamination points, and a new ship for container transportation. On the one hand, this will increase the safety of SNF management operations when they are carried out, particularly the re-packaging operations. On the other hand, it would not change the basic nature of the work that has to be carried out in the most radiation hazardous conditions, namely recovery of the SNF from the storage cells and removing water from the containers, and transporting them to the re-packaging point.

Moreover, the time spent building infrastructure improvements would increase the time for which SNF is kept in unsatisfactory conditions, with water in many of the containers and storage cells. This is more dangerous from the point of view of fuel degradation, and could lead to a worsening of the radiation situation (for example, there is evidence of activity levels in water doubling within a year of SNF storage at location 2B storage). The doses that will have to be incurred when the SNF is finally removed could rise as a consequence. Furthermore, by the time the new infrastructure has been created, a qualitative change of fuel state may have occurred, which would make it impossible to use the currently developed methods and equipment intended for fuel management and also probably leads to the application of radiochemical methods of fuel management directly at STB.

In addition, both maintenance of the BDS and the necessary building work for the new infrastructure will have to be carried out in conditions of enhanced radiation exposure, which could lead to additional exposure and an increase of the workers' integrated exposure of the lifetime of the project. Creation of additional infrastructure will also cause an additional decommissioning burden, with generation of additional amounts of RAW.

Thus, one could suppose that measures to mitigate one type of risks, by constructing additional safety barriers for SNF treatment, might cause a greater increase in other risks, for example due to significant acceleration of fuel degradation from prolonged storage in abnormal conditions [NIKIET, 2004 a, b].

At this time a final decision on the preferred option has not been made. In practice, there is likely to be a balance necessary in order to ensure sufficient infrastructure is in place to carry out operational aspects safely, without unnecessary delay resulting in a disproportionate increase in risk. There may be some aspects deemed so important, such as the protection of the public in the event of an accident, they may delay operations in order to put the necessary measures in place. It is therefore likely that an 'Option III' will be adopted, including the optimal (from the point of view of personnel radiation safety) combination of features of options I and II.

Accordingly, we consider that the participation of regulatory bodies and their support organisations, in particular, the Institute of Biophysics (IBPh), in the evaluation of proposed project decisions is expedient.

In the light of the above, methodical approaches are analyzed below for evaluation of:

- The potential hazards from carrying out technological SNF management operations in the BDS areas, of the kind that would be needed urgently in any approved design option; and
- The potential personnel exposure arising from an emergency in the course of such operations.

Prediction of personnel exposure doses at SNF management and their consequences mitigation at SevRAO facilities

According to the options presented above, a number of risks exist during SNF management in BDS located at Andreeva Bay. These risks are connected with SNF management operations in the process of normalizing storage conditions or removing SNF for treatment. The risks include possible overexposure due to emergencies arising from natural phenomena (floods, waterspouts etc.).

To assess the potential consequences – in terms of personnel doses in implementing operations, in accident situations, and in the case of operations to mitigate the consequences of an emergency – it is necessary to perform some predictive calculations based on:

- Definition of possible emergency scenarios during the storage and removal of SNF for treatment (with a list of initial events and substantiation of final state);
- Definition of list of remedial actions necessary to mitigate the consequences of an accident, including a chronology detailing the order and duration of actions to be taken; and
- Carrying out, where possible, experimental simulation of emergency scenarios in a safe and controlled manner in order to measure appropriate radiation parameters. The scenarios, such as an IFA getting stuck during a lifting operation, would be simulated in controlled conditions using remote monitoring equipment. Given their role in developing regulatory documents, it is important for IBPh to be present during these experiments to provide them with a detailed understanding of the operations.

For currently available project solutions [NIKIET, 2004a, b], some development scenarios of possible emergencies have been practically defined, together with a list of instructions for necessary emergency/remediation technological operations. Data are still missing on the time (duration) required for the performance of these operations.

To carry out an experimental simulation of emergencies for further measurement of radiation situation parameters, it is necessary:

- To define a list of emergencies, which can be simulated in real conditions of BDS (and in future, at other facilities, in SNF transportation, etc.);
- To define adequate measures to meet requirements of nuclear and radiation safety during the emergency simulations so that they do not result in any hazard for personnel and investigators;

- To define a team of members to participate in each emergency simulation (direct participation is assumed of specialists from IBPh, NIKIET and SevRAO) ;
- To define the equipment and procedures needed; and
- To make and to approve a program of organisation and implementation of works where mention would be made of obligatory safety measures.

2.1.3 Development of normative-methodical documents for radiation safety regulation

Task 2 of the project will include preparing the following scientific and methodical documents:

1. A scientific report, including results from analysis of radiation monitoring data from the Radiation Safety Service (RSS) of Branch 1 of SevRAO, and results of measurements of the radiation situation parameters in the principal working areas of BDS personnel, made by specialists from IBPh. Results of measurement of the following factors will be presented in the report:

- Dose rates of external beta radiation;
- Dose rates of external gamma radiation;
- Dose rates of external neutron radiation;
- Whole-body dose rate distribution;
- Activity concentrations and physical-chemical parameters for radioactive aerosols; and
- Surface contamination levels.

2. These real quantitative results of measurement of radiation exposure factors are essential for the further accomplishment of the project, because they serve as initial data for:

- Prediction of personnel doses for the performance of technological operations in SNF and RAW management;
- Prediction of personnel doses in carrying out emergency and remediation works;
- Development of recommendation on the application of means of individual protection (MIP) in real SevRAO conditions;
- Development of recommendation on the application of means of collective protection of personnel in real SevRAO conditions;
- Development of final guidance ”Sanitary Rules of Provision of Radiation Safety at Operations at the SevRAO Facilities”;
- Development of guidance ”Hygienic Norms of Personnel Doses for Routine, Abnormal and Emergency/Remediation Situations in the Management of RAW and SNF”.

This document is the basic component of the system of personnel radiation safety for works on SNF and RAW treatment. Based on assessment of the probability of abnormal or emergency situations arising, a prospective categorisation will be developed of the whole complex of operation on SNF and RAW management. Observance of set norms for each particular type of work (including routine, abnormal and emergency/remediation) will ensure that the main dose limits of personnel exposure will not be exceeded. All planned technological operations have to be divided into categories of radiation safety and appropriate protective measures will be elaborated for each of categories, including:

- List of principal working places and conducted operations with prediction of possible abnormal and emergency situations;
- Application of means of collective personnel protection in real SevRAO conditions;
- Application of personnel MIP in real SevRAO conditions;
- Requirements that certain work be performed only in accordance with a special permission warrant;
- Specific requirements for organisation of radiation control; and
- Organisation of sanitary disinfestations regime for decontamination of personnel, etc.

A list of the principal working places and operations to be carried out is needed for further analysis and designation of the appropriate status to these operations, which may be defined on the basis of predictions of possible abnormal and emergency situations. This list is an essential prerequisite for Task 4 (designation of appropriate status to technological operations) and Task 3 (Methodic Guidance "Application of means of individual, local and collective personnel protection at operations at SevRAO facilities").

Methodical Guidance "Application of means of individual, local and collective personnel protection during operations at SevRAO facilities"

Development of the guidance "Application of means of individual, local and collective personnel protection at operations at SevRAO facilities" serves as a necessary step towards ensuring personnel safety during performance of works related to the collection and treatment of radioactive waste and removal of SNF from storage. Lack of this document would have a negative effect on the accomplishment of work at the SevRAO facilities for the following reasons:

- Currently, SevRAO personnel use means of individual protection (MIP) which were applied earlier in the atomic Navy. These MIP are not appropriate to conditions of implementing work in the open air in harsh climatic conditions; and many of these MIP are antiquated and are not certificated in accordance with the Order of Certification of MIP operating at facilities and plants of Federal Medical-Biological Agency and Federal Agency on Atomic Energy;
- When conducting works on removing IFAs from storage, effective means of individual and collective protection from external exposure are needed, as well as those related to the intake of, and skin contamination with, radioactive materials. Taking into account high gamma dose rate from the IFAs, the means of individual and collective protection must minimise:
    - restrictions on the worker's movements,
    - any restriction of the worker's vision;
    - the physiological load (e.g. the weight the worker has to carry); and
    - any reduction in efficiency.

The Guidance will contain recommendations on the use of those MIP that meet the given requirements and on the development of novel MIP to meet the requirements;

- When performing works related to collection, cutting and packing of containers with large amounts of radioactive waste (mainly metals) at the SevRAO facilities, different tools are applied to cut scrap metal. It is well known that during this work aerosols are generated that contain radioactive substances together with a whole complex of toxic chemical substances. In these conditions, protection from inhalation hazards is required, namely MIP with autonomous sources of clean air;

- Application of a range of highly effective MIP in the conditions of SevRAO facilities requires generation of a support system for their use, including creation of a special laundry, disposal of old MIP etc;

- FMBA carries out state sanitary epidemiological inspection of the application of means of individual and collective protection. Application of means of protection in SevRAO conditions has its own specific issues, so an order of supervision implementation should be described in the Guidance.

- The set of MIP available at SevRAO facilities has to be in total accordance with the specifics of possible emergencies at a given plant, so an order for generation of emergency stock of MIP must be formulated in the Guidance and a system must be developed for ensuring individual and collective personnel protection in the case of a potential radiation accident.

As the Guidance “Application of means of individual, local and collective personnel protection at operations at SevRAO facilities” serves as a component of a set of normative methodical documents on ensuring radiation safety of SevRAO personnel and on prevention of possible emergencies, its development is a necessary condition of implementating work within the contract. The main proposals of the Guidance will be included as a special section in the final Guidance developed within Project 1.

Justification of technologic operations status during RAW and SNF management.

As noted by NIKIET [2004], performance of technological operations directed to temporary storage of SNF, its removal from current stores at the STBs and to management of existing and future arisings of RAW, as well as further works related to the rehabilitation of STB territories are, and will be, carried out in conditions of an unfavourable radiation situation.

Through planning and defining categories of radiation-hazardous work (RHW) it is possible to predict the levels of potential exposure, and to design appropriate measures to minimise personnel exposure. This categorisation of RHW is one of the key organisational measures directed to ensuring radiation safety.

It seems to be expedient to separate works with particularly high potential hazard, i.e. radiation-hazardous works, from the other work necessary for management of SNF and RAW in Andreeva Bay and Gremikha village provided by the project.

Operations are defined as RHW where there are conditions of real or potential radiation hazard, where the radiation situation resulting from the work location is such that individual effective dose of worker, calculated on the basis of conservative assessments, may exceed a value of 20 mSv/year. RHW are divided into the following categories (Table 1)

Table 1. *Classification of radiation-hazardous works (RHW)*

RHW category	Maximum individual effective dose, mSv/year
RHW IV category	20–30
RHW III category	30–40
RHW II category	40–50
RHW I category	>50

RHW of categories III and IV must be carried out in accordance with a special permission warrant and special programs guaranteeing radiation safety, developed by administration and agreed with local (territorial) authorities of State Sanitary Epidemiological inspectors.

RHW of categories I and II must be carried out in accordance with a special permission warrant and special programs guaranteeing radiation safety, developed by administration and agreed with the Federal authority of State Sanitary Epidemiological inspectors.

These measures have to ensure that the main dose norms (limits) are not exceeded.

To justify the allocation of the various technologic operations involved in SNF treatment to the appropriate categories of RHW, predictive assessments must be performed of possible personnel exposure doses in accordance with the aforementioned methodic approaches.

During the process of carrying out the operations to remove the SNF from storage at the STBs (recovery from the BDS, repackaging and transportation of IFA) a number of unplanned events may occur, possibly due to personnel mistakes, equipment failures or for other reasons – these are described in detail in NIKIET [2004]. These unplanned events may lead to a departure from the normal operations potentially resulting in breaching of set dose limits and, finally, a radiation accident.

Taking this into account, all of the technological operations on SNF treatment may be divided into:

- Routine technological operations – technological operations carried out in accordance with the project as planned, and approved in appropriate technological regulations;
- Abnormal technological operations – technological operations, whose accomplishment is accompanied by deviations from the project design and/or technological regulations, and/or resulting of the set limits for normal operation, but without radiation accident arising;
- Emergency/remediation technological operations – technological operations, whose performance takes place after a radiation accident has occurred and is directed to stopping the release and mitigating its consequences.

At SevRAO facilities the unfavourable radiation conditions mean that abnormal and routine technological operations, as well as emergency/remediation ones, may be considered as RHW.

Justification of technological operation status (defining appropriate categories of potential radiation hazard) and their type (routine, abnormal and emergency/remediation) is a necessary step in the development of Guidance “Hygienic norms of personnel exposure doses in implementation of routine, abnormal and emergency/remediation works in management of RAW and SNF” and serves as one of the components of a system for personnel radiation safety regulation at SevRAO.

The completion of Task 5, development of final Guidance “Sanitary Rules of Provision of Radiation Safety at Operations at the SevRAO Facilities”, is a overall stage of work within both Project 1 and the principal aspects of Projects 2 and 3.

Developing of final Guidance “Sanitary Rules of Provision of Radiation Safety at Operations at the SevRAO Facilities”

During the planning phase of Project 1 it has been assumed that SevRAO will propose project decisions in the final form of planned technological operations for SNF and RAW treatment and rehabilitation of territories, buildings and constructions at SevRAO facilities in Andreeva Bay and Gremikha village [NRPA, 2004]. However, work within these projects has been protracted, and this could affect the content of the final Guidance, which has to be prepared within time period set in the Project 1. Currently, it does not seem likely that the final Guidance will be able to cover regulation of radiation safety of the personnel and population during performance of the whole set of works on SNF and RAW handling and on rehabilitation of territories, buildings and constructions of SevRAO facilities.

Our current view is that the final guidance is likely to focus on the following tasks:

- Guaranteeing radiation safety of SevRAO personnel during works in the most radiation-hazardous conditions, in which SNF will be removed from the storage cells, water removed from the containers, and the SNF transported to the point of re-packaging. These operations will be urgent whatever option is pursued (I or II, or a combination of them - see Section 2.1.2 above), and will need to be carried out with relatively small changes of available technology;
- Guaranteeing personnel radiation safety in the event of abnormal and/or emergency situations, which can arise during SNF removal from the storage cells, removing water from SNF containers and their transportation to the point of re-packaging;
- Guaranteeing radiation safety for personnel and population in subsequent rehabilitation by means of elaboration of criteria for residual contamination of the territory, buildings and constructions of SevRAO facilities with radioactive substances, considering different possible options for their decommissioning (unrestricted use, limited use as a facility using radioactive materials, limited use as an industrial facility not using radioactive materials, etc.)
- Justification of selection of optimal project decisions (from the point of view of guaranteeing radiation safety) by means of developing requirements for: the design of technology for SNF and RAW handling; the application of means of individual and collective personnel protection; equipment and procedures for radiation monitoring; and permitted personnel exposure dose values in implementation of routine, abnormal and emergency/remediation works etc.

In the later stages of Project 1 it is planned that new experimental data will be obtained of real parameters values characterizing the radiation situation for a whole set of SNF management actions. Some predictive assessments will be carried out of the changing radiation situation during the rehabilitation of lands, buildings and constructions at SevRAO facilities. A task to develop new Guidance related to guaranteeing radiation safety at operations at SevRAO facility, based on finally approved decisions for the industrial project, will take place if these decisions are taken within the time frame of Project 1.

The proposed structure of final Guidance from Project 1 – “Sanitary rules for ensuring radiation safety during SNF treatment operations” – is given below:

I Scope
II Normative references
III General proposals
IV Requirements for organisation and performance of technological processes of irradiated fuel treatment
V Requirements for equipment, tools and auxiliarees
VI Requirements for ventilation organisation
VII Requirements for personnel
VIII Personal hygiene of staff*
IX Means of individual, local and collective personnel protection
X Population safety quaranteeing*
XI Organisation of radiation dosimetric control
XII Radiation accidents prevention and mitigation of their consequences
XIII Decommissioning of SevRAO irradiated fuel storages**
XIV Medical quaranteeing of radiation safety*

** - dark background illustrates those sections of the Guidance which will be included in the document only if information on conditions specific for SevRAO facilities is available;*

***- this section may be included in the document subject to future progress in taking decisions on the industrial project.*

2.2 Public Protection Aspects

2.2.1 Site description

The STBs – complexes of SNF and RAW, both solid and liquid, - are located in closed administrative-territorial formations (CATFs): CATF Zaozersk Andreeva Bay of Kola Bay and CATF Ostrovnoy (Gremikha village on the Barents coast).

Andreeva Bay STB is one of the biggest sites for SNF and RAW storage in the Northern Fleet. According to data from 2004 there is about $1{,}3\times10^{17}$ Bq SNF in three storage areas, with decay cooling of more than 25 years (the time for which SNF has been in storage). The main radionuclides in the SNF and RAW are fission products ^{137}Cs and ^{90}Sr. Actinides comprise less than 1% of the total activity now, but will be important for long term management of RAW. The total activities of solid (SRW) and liquid radioactive waste (LRW), mainly from ^{137}Cs and ^{90}Sr, are $6{,}6\times10^{14}$ and $4{,}5\times10^{12}$ Bq respectively . There is considerably less SNF at STB Gremikha, the total activity being less than 10% of that in Andreeva Bay storage, while the amount of SRW is about 20 times less than at Andreeva Bay [Strategic Master-Plan, 2004].

Development of criteria and standards for rehabilitation of the STBs in Andreeva Bay and Gremikha village requires detailed analyses of the radiation situation in these regions.

A number of organisations conduct studies of the radiation situation e.g.: SevRAO, Navy, CSSES 120, RSC “Kurchatovsky Institute”, NIKIET, ISCES Rosatom. The most rigorous studies are conducted by

NIKIET, but as a rule, these studies are limited to the industrial site. The work conducted by NIKIET shows that the overall radiation situation in STB areas is characterised as “adverse with a tendency to worsen” [NIKIET, 2004a], although, to date, regulatory standards have not been exceeded.

According to CSSES 120 data, the radiation situation in 2004 was characterised as “quiet”, and doses to personnel as insignificant [CSSES–120, 2004]. Analyses of doses to the personnel of groups A (classified radiation workers subject to individual monitoring) and B (other workers on the site) indicates an increase in the amount of radiation-hazardous work carried out at Gremikha, and a tendency for the average effective dose to increase (1,57 mSv in 2004 in comparison with 1,15 mSv in 2003). In Andreeva Bay, in contrast, the average effective dose in 2004 (0,35 mSv) was 1,9 times lower than in 2003 (0,66 mSv). At the same time the radiation situation in North-West Russia, including Murmansk Region, was characterised as satisfactory [CSSES of Murmansk region, 2003], as exposure of the public is below appropriate standards. The potential threat is that the situation could worsen unpredictably if measures are not taken to improve the management with SNF and RAW. The situation could also worsen temporarily as a result of such measures, but in the longer term such measures are necessary to permanently remove the threat.

The goal of this part of Project 2 is to collect existing data on the radiation situation in STB areas from available sources, to analyze the materials and to assess radiation hazard and threats from the STBs. This is intended to give an indication of pressing tasks for FMBA in fulfilling its regulating functions.

When analyzing available data, special attention in the report was paid to the factors that had not been taken into account in previous studies, and which could have significant impact on doses to the population and on the ecology of the region.

There is a difference between the Norwegian and Russian approaches to protect biota. In Russia there are no specific criteria related to non-human biota. However, taking account of the sparsely inhabited character of the Russian north, criteria for radiological protection of non-human biota might be required.

The applicability of corresponding criteria in Scandinavian countries will be discussed.

2.2.2 Assessment of radiation situation of the environment in the STB area in Andreeva Bay and Gremikha village

STB in Andreeva Bay

Andreeva Bay, situated 5 km from Zaozersk, is one of the biggest sites for RAW and SNF storage of the Northern Fleet. Storage and administrative buildings occupy about 2 hectares. Detailed examinations of the radiation situation at Andreeva Bay STB have been conducted, mainly focusing on the industrial site and along the shore line in the immediate vicinity of the facilities located on the site [Kurchatovsky Institute, 1997, 2000; NIKIET, 2004a, 2004b; CSSES–120, 2003, 2004; NRPA, 2004]. There are no settlements in Andreeva Bay. The sanitary shelter zone (SSZ) has the same borders as the site territory. The surveillance area (SA) comprises the site territory and surrounding areas within a radius of 10 km from the point of SNF shore storage [NIKIET, 2004a].

Current radioecological knowledge of the situation at the site

The radiation situation in the SSZ (the STB area) was assessed using results from dose monitoring, analyses of ground samples taken from points on the shore line, and analyses of water and bottom sediment samples (Tables 2 and 3). The environmental study plan conducted by Navy specialists jointly with RSC “Kurchatovsky Institute” [Kurchatovsky Institute, 1997, 2000] is presented in Fig.1. Numbers in circles indicate sampling sites.

As can be seen from data in Table 3, ^{90}Sr/^{137}Cs ratios fluctuate in a wide range. This indicates the presence of local radioactive contamination centres with different activity levels. Elevated ground activity concentrations of ^{137}Cs have been measured:

- in the area of Berth 1 (points 24 and 25 on the plan) – up to 4000 Bq/kg;
- in the lowland area between the site of SNF and SRW storage and the vessels junkyard (point 3) – up to $2 \cdot 10^4$ Bq/kg; and
- at Building 5 along the brook (points 1 and 2) – up to 10^6 Bq/kg [Kurchatovsky Institute, 1997; NRPA, 2004].

The total ß activity of radionuclides was measured in seaweeds, periphyton and benthic organisms at the water edge at berths of special vessel anchorage and SSZ [NIKIET, 2004a]. The total ß activity concentrations in hydrocolous organisms are presented in Table 4. Total ß activity concentration comprises all ß–nuclides present in the measured samples: the measuring equipment is calibrated for the ß–emitting nuclides ^{40}K or ^{90}Sr.

As can be seen from Table 4, contamination of seaweeds and periphyton in the area of special vessel anchorage is approximately 12–19 times (more than an order of magnitude) higher than for seaweeds collected elsewhere in the SSZ. Contamination of bottom sediments varies by a factor of three. Our preliminary conclusion is that this shows that there is accumulation of man-made radionuclides in water organisms.The specified situation should be confirmed by additional research, as the given activity concentration levels could cause significant impact on the environment. The accumulation of radionuclides in hydrocolous organisms can also result in increased levels in seafood products.

According to the data in Tables 2–4, the SNF storage facilities are a source of contamination of the Andreeva Bay territory, contaminating soil along the brook from Building 5 (which was used in the past for SNF storage) and the water in it. The territory and water of the coastal strip of STB is contaminated by ^{90}Sr, ^{137}Cs and ^{60}Co. Concentrations of ^{137}Cs in bottom sediments of the coastal strip vary from <20 to 600 Bq/kg depending on distance from the mouth of the brook. Content of ^{137}Cs in the brook water also varies within the range <20-500 Bq/l near Building 5. The range characterises the samples taken at different times: in the period April–May, 1999, at the same sites. Activity concentration of ^{60}Co in the soil of the coastal zone was found to be 13– 52 Bq/kg. (NIKIET 2004b)

***Figure 1**. Sampling sites from the environmental study plan conducted by Navy specialists jointly with RSC "Kurchatovsky Institute" [Kurchatovsky Institute, 1997, 2000].*

***Table 2.** Results of study of samples from the environment in the SSZ (the industrial site) at SSZ of Andreeva Bay STB*

# in plan	Type of samples	Sampling site	^{137}Cs, Bq/kg
1	Water	Brook from building 5	<20-500*
2	Water	Brook in creek	<20
3	Water	Spring near the road	<20
4, 5	Bottom sediments	Andreeva Bay	<20-600*
6, 7, 8	Bottom sediments	Andreeva Bay	50
4	Bottom sediments	Andreeva Bay	130
5	Bottom sediments	Andreeva Bay	600
3	Ground	Slope BDS	<20-180*
3	Ground	Near the road at BDS 2A	180
3	Ground	Slope BDS	1600

** The range characterises the samples selected at different times (in the period for April - May, 1999) in the same specified place. This variation is probably connected to process of thawing of snows.*

Table 3. *Concentrations of Cs-137 and Sr-90 in environmental media in the territory of industrial site of Andreeva Bay STB*

# in plan	Date of sample	Place of sample	Type of samples	^{137}Cs, Bq/kg	^{90}Sr, Bq/kg	^{90}Sr/ ^{137}Cs
1	03.05.99	Brook from building 5	Water	45	150	3,3
1	30.04.99	Brook from building 5	Water	310	200	0,65
3	19.05.99	At the road BDS 2A	Ground	180	360	2,0
3	19.05.99	At the road BDS 2A	Ground	<20	240	12,0
3	19.05.99	Strip at PEK-50	Ground	450	7500	16,6
3	14.05.99	Slope BDS	Ground	550	670	1,2
3	14.05.99	Slope BDS	Ground	550	<20	0,04
4	14.05.99 20.05.99*	Andreeva Bay	Bottom sediments	130	80*	0,61
5	14.05.99 20.05.99*	Andreeva Bay	Bottom sediments	600	90*	0,15
7	20.05.99*	Andreeva Bay	Bottom sediments	<20	<35	1,75
8	21.05.99	Andreeva Bay	Bottom sediments	<20	70	3,5

* *Note: results of the study correspond to the indicated date of sample collection*

Table 4. *Total β activity concentration in hydrocolous organisms in the Andreeva Bay STB*

Place of sample cutting	Name of samples	Activity concentration, Bq/kg
At berth of special vessel anchorage	Seaweeds	$46,7\times10^2$
	Periphyton	$25,3\times10^2$
	Benthos	$2,07\times10^2$
	Bottom sediments	$6,03\times10^2$
Sanitary shelter zone	Seaweeds	$2,52\times10^2$
	Periphyton	$1,98\times10^2$
	Benthos	$1,15\times10^2$
	Bottom sediments	$2,11\times10^2$

Current radioecological knowledge of the situation off-site

Available material on the radiation-hygienic situation off-site around the Andreeva Bay STB is rather limited. Information on radioactive contamination of the territory within the SA surrounding the base (which includes Zaozersk*), has been reported [Kurchatovsky Institute, 2000; CSSES–120, 2003, 2004]. Available information can be characterised in the following way:

- Gamma background dose rates in the Zaozersk territory are in the range 0,1–0,2 μSv/h. According to CSSES–120, [2003, 2004], average values of gamma background are the same throughout the territory, within the SSZ, in the SA, and in the inhabited areas, being 0,09 – 0,11 μSv/hour in all areas. These are at typical levels of gamma background found in non-mountainous areas of Russia
- According to [CSSES–120, 2003, 2004], the average annual concentrations of ^{90}Sr and ^{137}Cs in the atmosphere air of the SSZ and SA are <0,03–0,7 and <0,22 - 0,7 Bq/m^3 respectively. (Unfortunately, the exposure times of the aspirating filter are not specified). These values are ten times lower than acceptable activity concentration levels of ^{90}Sr and ^{137}Cs in the atmosphere [NRB-99].
- In samples of soil taken in Zaozersk, the content of ^{137}Cs was not higher than 50 Bq/kg. Table 5 presents concentrations of ^{90}Sr and ^{137}Cs in soil and vegetation, taken at distances of 500–3000 m from the industrial site at Andreeva Bay STB. Levels presented in Table 5 are much lower than those on the industrial site, and decrease with distance from the site.
- In moss samples taken to the south-east of the site, the concentration of radionuclides were 4,1–64,1 Bq/kg for ^{137}Cs, and for ^{90}Sr ranged from below the lower limit of detection of the applied method to a maximum measured value of 3,9 Bq/kg [Kurchatovsky Institute, 2000].
- Measurements for berries (blackberry) were 203,1 Bq/kg for ^{137}Cs, and12,5 Bq/kg for ^{90}Sr [CSSES–120, 2004].

(The results given above for moss and blackberries are single results of the study, on the basis of which it is impossible to be sure that the measurements were adequate and correct.)

- The activity concentration of ^{137}Cs in sea water within 20 m of the shore was 5–7 Bq/m^3 whereas background for the given area is ~10 Bq/m^3 [Kurchatovsky Institute, 2000]. These data are in good agreement with the results of a study of the Barents Sea in 1970–1990 [Vakulovsky C.M., 2003].
- Concentrations of ^{137}Cs, ^{232}Th, ^{60}Co, ^{40}K in the sea water in Andreeva Bay and in fresh water of lakes Podkova, Pitievoe, and the brook at CPP-12 are at similar levels: <4, <8, <7, and <40 Bq/m^3, respectively. Total activity is also the same everywhere [CSSES–120, 2003]. Such uniformity between concentrations in sea and fresh water is not typical and shows insufficient sensitivity of applied methods of analyses. The available data on the concentrations of radionuclides in sea water and fresh reservoirs show the need for additional research of fresh water, as a change in the concentration of man-made radionuclides is possible as a result of migration with underground waters or run-off from the ground surface.

---

* The city was founded in 1958, was renamed several times: Zaozerny, Severomorsk -7, Murmansk-150, Zapadnaya Litsa. The territory of Zaozersk is 775 hectares. There are more than 20 thousand inhabitants in approximately 112 houses in the city, containing 8 streets and 4 side streets.

***Table 5**. Concentrations of radionuclides in soil and vegetation off-site near the Andreeva Bay STB in 2004*

Place of sample	Type of sample	Distance from the source, m	^{137}Cs, Bq/kg	^{90}Sr, Bq/kg
Brook valley CPP1	Soil	500	12,3	4,11
Brook valley CPP1	Vegetation	500	4,4	0,70
Road near CPP	Soil	1000	8,32	2,34
Road near CPP	Vegetation	1000	1,04	1,79
Road near stadium	Soil	1500	7,93	3,21
Road near stadium	Vegetation	1500	1,11	0,66
Road lake Podkova	Soil	3000	6,33	3,14
Road lake Podkova	Vegetation	3000	0,93	0,61

Predictive assessments, carried out by [CSSES-120, 2003], of exposure of the public under normal conditions of work at the STB are given. The most exposed individuals in the population of Zaozersk town are estimated to receive 9,5 –19,0 nSv/year, and in the area of the villages Nerpichiya and Bolshaya Lopatka, 40-81 and 19-38 nSv/year respectively. Individual maximum doses to the population closer to the SSZ border will not exceed 1 μSv/year. However, these estimates, particularly the assessments of internal exposure, are in our opinion, of a rather hypothetical nature. It is unclear what food intake rates were assumed for calculation: it is quite probable that the real diet of the Murmansk Region population was not taken into account. Furthermore, there are no correct data on concentrations of significant radionuclides in food products. In particular, there are no data on concentrations in local wild foods (venison, fish, and wild vegetation), and the contribution from local foods could be large because of features of radionuclides migration in Arctic regions. Therefore the given estimates should be reviewed.

STB in Gremikha village

Gremikha village is situated on the east coast of the Kola Peninsula[*]. A plan of Gremikha is shown in Figure 2. The base is approximately 350 km from the entrance to Kola Bay, on the border of the area of water that is free from ice throughout the winter. The distance of the STB from the populated areas of Ostrovnoy and Gremikha village is 1,5–2 km by land. The technical base territory covers 6,4 hectares, whereas the general area of the site (including the settlements) is about 15 hectares. The land perimeter of the base is 0,68 km, and the perimeter by the coast line is 0,655 km. There are 18 buildings and constructions on the territory of the technical base that are considered to represent significant radiation hazards.

Data on of the radiation situation on the STB territory at Gremikha are scarce [Ostrovnoy Branch No. 2, 2001, 2004; CSSES–120, 2003, 2004; Vasiliev А.P., 2005].

---

[*] The general extent of the berth front with coastal constructions is 6770 metres. The first settlements in Gremikha appeared at the end of the 19th Century. At present there is the old village of Gremikha and the newer settlement of Ostrovnoy, separated by a brook. The area is situated on the boundary between the Barents and White Seas, about 400 km to the east of Murmansk. In 2004, the population living in Gremikha was 1900 persons, and in Ostrovnoy 2900. There is an opinion that the berths, approach roads and other infrastructure existing around Gremikha village could be developed for off-shore fishing.

Current radioecological knowledge of the situation on the site

A radiation survey of the STB area and adjacent territory, conducted by different organisations, showed that spent heat-generating constructions (SHGC – spent fuel) and highly active SRW stored at the site for temporary storage of solid radioactive waste (STSSRW) present a significant environmental hazard. Activity from the site disperses on the STB territory of the base and in the adjacent area of water. Dose rates at a number of points on the site reach 10 mSv/h [Vasiliev A.P., 2005].

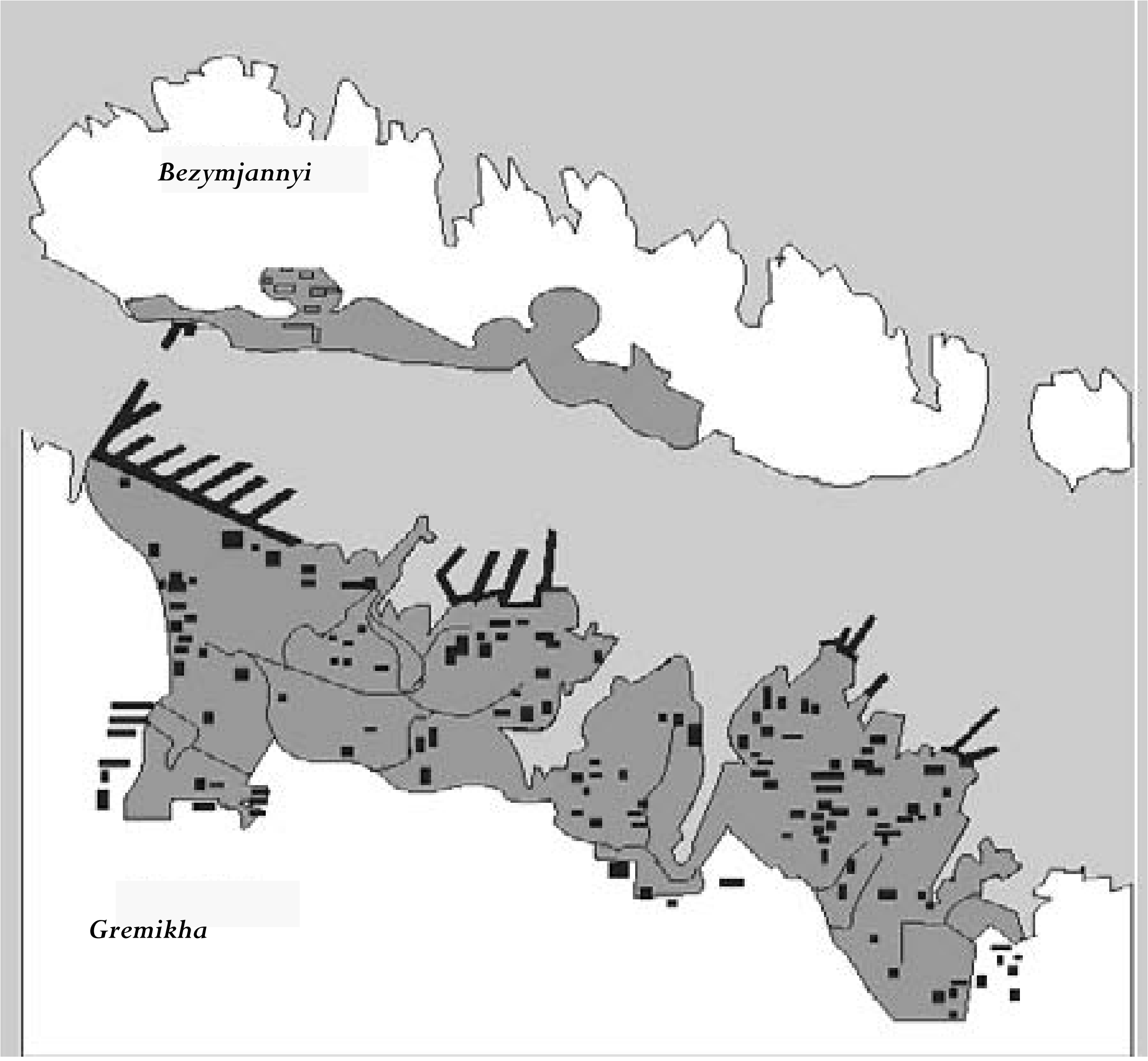

Figure 2. *Situational plan of Gremikha village*

The contamination of concern is mainly long lived radionuclides ^{137}Cs and ^{90}Sr. Local conditions are such that the rate of loss of activity from the STB soil ground by natural processes is low, so the primary levels of radioactive contamination in soil of the territory are approximately constant. Thus, the maximum specific activity in the upper layer of soil (to 10 cm) in the area of the dry dock are: $9{,}5\times10^5$ Bq/kg for ^{137}Cs; and $3{,}9\times10^5$ Bq/kg for ^{90}Sr. The most likely factors for this are wind-driven resuspension of radionuclides in soil from the STSSRW and repeated accidental spills of LRW [Ostrovnoy Branch No. 2, 2001]. However, it is difficult to determine which of these factors is the main cause of the contamination.

Table 6. *Specific activity of ^{137}Cs and ^{90}Sr in soil and vegetation on the territory of Gremikha STB*

Sample location	Type of samples	^{137}Cs, Bq/kg	^{90}Sr,Bq/kg
STSSRW p.A	Soil	$3{,}1\times10^{5}$	$9{,}0\times10^{4}$
STSSRW p.B	Soil	$6{,}8\times10^{4}$	$5{,}4\times10^{3}$
STSSRW p.C	Soil	$3{,}6\times10^{5}$	$2{,}4\times10^{4}$
Site LRW p.1	Soil	$1{,}2\times10^{3}$	$4{,}0\times10^{3}$
Site LRW p.2	Soil	$8{,}0\times10^{2}$	$4{,}0\times10^{3}$
Site LRW p.3	Soil	$6{,}0\times10^{2}$	$8{,}3\times10^{2}$
Site LRW p.4	Soil	$2{,}6\times10^{3}$	$3{,}5\times10^{4}$
Site LRW p.5	Soil	$2{,}3\times10^{3}$	$2{,}0\times10^{3}$
Site LRW p.6	Soil	$2{,}5\times10^{5}$	$1{,}2\times10^{2}$
Site LRW p.8	Soil	$1{,}8\times10^{5}$	$1{,}4\times10^{5}$
Area of drying of FT	Soil	$9{,}0\times10^{4}$	$8{,}3\times10^{3}$
Site LRW	Vegetation	$1{,}1\times10^{3}$	$5{,}7\times10^{4}$
STSSRW	Vegetation	$3{,}2\times10^{4}$	$9{,}1\times10^{3}$

Table 7. *Specific activity of ^{137}Cs and ^{90}Sr in soil and vegetation in SSZ of Gremikha*

SSZ Borders	Type of samples	^{137}Cs, Bq/kg	^{90}Sr, Bq/kg
Internal	Soil	15,0	26,0
Internal	Vegetation	<3,0	270
External	Soil	<3,0	<0.7
External	Vegetation	<3,0	69

Results indicating the contamination levels of soil and vegetation in other parts of the territory of the Gremikha industrial site are shown in Table 6. The contamination levels can be compared with those on the site of the Andreeva Bay STB quoted in the text above (for example, the highest levels of ^{137}Cs in soil at Andreeva Bay, at Building 5, are up to 10^{6} Bq/kg).

However, unlike at Andreeva Bay, there is not evidence of this on-site contamination being transferred to a significant extent to areas close to or outside the boundaries of the SSZ for Gremikha STB. The data available on concentrations of ^{137}Cs and ^{90}Sr in the soil and vegetation in the SSZ are comparable to the levels from global fallout (Table 7) [CSSES–120, 2004].

Almost no data exist on the physical or chemical forms of the radionuclides in the soil or their migration pathways in the environment at Andreeva Bay or Gremikha.

Activity concentrations in the atmosphere in the area of the STSSRW and the SSZ in 2004 have been reported to be less than 0.7 Bq/m^{3} for ^{137}Cs and less than 3 Bq/m^{3} for ^{90}Sr [CSSES–120, 2004]. However, other data for the same period indicate activity concentrations in the SSZ more than ten times higher: annual average concentrations are reported to be 37 Bq/m^{3} for both ^{137}Cs and ^{90}Sr [Ostrovnoy Branch No. 2, 2004].

There are no data on activity concentration levels of ^{137}Cs and ^{90}Sr in bottom sediments or seaweed in the coastal water. Levels of total beta activity in seeds in the areas of the dry dock and berth 8 are reported as 430 Bq/kg and 230 Bq/kg, respectively [CSSES–120, 2004].

Current radioecological knowledge of the situation off-site

- In 2003-2004 average values of gamma background, on-site and in Gremikha village respectively, were 0,095–0,12 μSv/h [CSSES–120, 2003, 2004].
- Activity concentrations of radionuclides in open pond water were relatively constant (for 54 samples) at: 160 Bq/m^3 of ^{137}Cs and 110 Bq/m^3 of ^{90}Sr [CSSES–120, 2003, 2004].
- Activity concentrations of forest berries in the SA off-site are measured to be 110 Bq/kg for both ^{137}Cs and ^{90}Sr, again relatively consistently over 21 samples [CSSES–120, 2003, 2004].

In our opinion, the quoted values require checking and verification. Furthermore, it is impossible to assess the overall influence of the facility on the environment on the basis of the limited data available. Individual effective doses to members of the public have not been calculated.

According to the available published data on the environment in Gremikha village [Ostrovnoy Branch No. 2, 2001], there appear to be elevated levels of ^{137}Cs and ^{60}Co in the soil (2400 ± 290 Bq/kg). in one area. On the basis of data on ^{137}Cs concentrations in the sea water, seaweed and bottom sediments in the area of berth 9, there appears to be no effect from the STB. Concentrations of ^{137}Cs in the STB area of coastal water – up to 20 Bq/kg – are found to be higher than in the open sea (~10 Bq/m^3). In seeds the concentration of ^{137}Cs changes from 1560 ± 160 to 1790 ± 230 Bq/kg; in lichens (moss) increased concentrations of ^{210}Pb (^{210}Po) and cosmogenic ^{7}Be have been found, apparently from atmosphere fallout; and in reindeer moss the concentration of ^{137}Cs has been measured as 210 ± 20 Bq/kg (compared to less than 0,4 Bq/kg for ^{60}Co).

2.2.3 Assessment of the radiation hazards and threats at the SevRAO facilities, taking into account the current knowledge of the situation and the regulatory supervision responsibilities of FMBA

Table 8 summarises source information on parameters characterizing the radiation situation on and off the STB site at Andreeva Bay. An assessment of the radiation hazard is provided through comparison with available radiation standards or, in their absence, with background contamination levels.

Table 8. *Assessment of radiation hazard from STB on the basis of comparison of measured parameters of radiation situation with normative standards or background levels.*

Parameter, units	**Real level at**		**Standard** [NRB-99]	**Background level**	**Radiation Hazard Evaluation**
	On-site	**Off-site**			
γ-background					
μSv/h	500–3000 max 25000	0,095–0,20		0,08 – 0,2	Off-site – within the limits, typical for the north region of Russia
Atmosphere air, Bq/m^{3}					
^{137}Cs	<0,22–0,7	<0,7	27	(1,0-3,0)×10^{-6}	Lower than acceptable levels, but above background
^{90}Sr	<0,03–<0,7	<3,0	2,7	(8,0-18,0)×10^{-6}	
Soil, Bq/kg					
^{137}Cs	<20–10^{6}	1–50		1-50	On-site: above background
^{90}Sr	<20–7500	0,5–30		1-20	
Water of sea, Bq/l					
^{137}Cs	0,02	0,005–0,007		0,006	^{137}Cs in the coastal line 3 times higher
^{90}Sr	No data	No data		0,004	
Water of open ponds, Bq/l					
^{137}Cs	<20-500	No data		0,001–0,01	On-site: ^{137}Cs and ^{90}Sr 1000 times higher
^{90}Sr	150-200	No data		0,005–0,02	
Bottom sediments, Bq/kg					
^{137}Cs	<20–1500	~6		~4	On-site: ^{137}Cs and ^{90}Sr several times higher
^{90}Sr	<35–90	No data			
Seaweeds, Bq/kg					
^{137}Cs	>1500	No data		~20	On-site: ^{137}Cs in 100 times higher
^{90}Sr	No data	No data			
Drinking water, Bq/l					
^{137}Cs	No data	No data	11,0		The data are absent

^{90}Sr	No data	No data	5,0		
Total α-radioactivity	No data	The data are absent	0,1		
Total ß-radioactivity	No data	The data are absent	1,0		
Parameter, units	**Real level at**		**Standard** [NRB-99]	**Background level**	**Radiation Hazard Evaluation**
	On-site	**Off-site**			
Main foodstuffs, ^{90}Sr / ^{137}Cs, Bq/kg (l)					
Bread	No data	No data	20 / 40		No data
Milk			25 / 100		
Meat			50 / 160		
Freshwater fish			100 / 130		
Potatoes, vegetables			40 / 120		
Mushrooms			50 / 500		
Berries		12,5/203,1	60 / 160		^{137}Cs –Above the Standard

Basic sources of radioactive contamination causing concern

The basic sources of radioactive contamination causing concern in Andreeva Bay [Kurchatovsky Institute, 2000; CSSES–120, 2003; NIKIET, 2004a; NRPA, 2004; Minatom, 2004;Vasiliev A.P., 2005] are:

- The brook flowing behind Building 5, and apparently also going under the building. Activity of water in the brook under Building 5 reaches 2×10^4 Bq/l. The water flow rate in the brook varies: in summer time it is 10–20 l/min. Gamma dose rates above the brook 5 metres from Building 5 is 0,03-0,04 mSv/h. In the area where the brook flows into the bay, gamma dose rate is 2,3 µSv/h. Grass collected near Building 5 contains 5×10^3 Bq/kg (dry weight) total beta-gamma activity[*].
- An unidentified source (or sources) of contamination of the sea water in the area of berths. Radionuclide concentrations of 1,1–2,2 Bq/l (compared to background concentrations of 0,22–0,26 Bq/l) have been noted.
- LRW storage in regular and unplanned places of storage: the tanks in Buildings 6 and 7; the basement of Building 6; the cells of BDS; and SRW storage areas.

---

[*] Activity concentrations of ^{137}Cs in the brook water have been constant for several years (since 1982) at about 4×10^6 Bq/m^3 (10^{-7} Ci/l). After completion of the construction of an intercepting trench to divert the water, the concentration of radionuclides in the brook (in the water and the bed) and bottom sediments in the coastal zone of Andreeva Bay near the brook remained at the former levels.

- Block dry storage (BDS) cells for SNF: three storage bunkers, where the concentration of radioactive aerosols exceeds background values by 100 times.
- Building 5, which was used in the past for SNF storage. Equipment, structures and concrete floors are contaminated with radionuclides. The building now contains about 1000 m^3 of SRW, with a total activity of $1,4\times10^{14}$ Bq;
- Construction 67A, a store for SRW. Wastes are stored in temporary packaging and sacks. The capacity is 1030 m^3 with total activity $7,6\times10^{12}$ Bq;
- Construction 67, in which containers of SRW are stored. The total activity is $0,6\times10^{11}$ Bq;
- Constructions 7 and 7A, buildings for SRW storage, respectively of capacity 1106 and 1140 m^3, containing activity of $1,0\times10^{13}$ Bq and $3,9\times10^{13}$ Bq; and
- Other sites of SRW storage, with total capacity of 1802 m^3 ($2,5\times10^{14}$ Bq).

The main sources of radioactive contamination of the environment causing concern in Gremikha village [Ostrovnoy Branch No. 2, 2001; Minatom, 2004;Vasiliev A.P., 2005] are:

- SHGC (spent fuel) storage, with an area of 1128 m^2 ;
- Spent extracted part (SEP – cores from liquid-metal-cooled reactors) storage (Building 1B) with an area of 694 m^2;
- 11 LRW storage sites with total area of 989,8 m^2;
- SRW storage with a total area of 2100 m^2;
- Temporary SRW storage with an area of 300 m^2;
- PEK-50 tanks for LRW storage in an area of 50 m^2;
- Pumping facility for reception and distribution of LRW.

SRW stored at Gremikha STB (a total volume of about 550 m^3; data for total activity are not available) is stored in constructions that do not correspond to current standards and rules, and are sources of radiation hazard. Gamma dose rates at the entrance to the site are 0.5–3 mSv/h, and the maximum dose rate measured is 25 mSv/h near the east wall.

The LRW at Gremikha STB (total volume about 2020 m^3 and total activity about $23,6\times10^{10}$ Bq) is also stored under conditions that do not correspond to current standards and rules. Due to problematic physical-chemical forms, processing of the LRW is complicated and so they represent further sources of radiation hazard with the possibility of uncontrolled of radionuclide migration.

Principal conclusions on assessment of existing hazards in STB areas in Andreeva Bay and Gremikha village from a perspective of FMBA regulating functions

The information available at present on the radiation situation off-site around the STBs is inadequate.

1 For the most part, radiation-hygienic monitoring of the environment of the STBs in Andreeva Bay and Gremikha village has been conducted on the industrial site and within the SSZ. The radiation situation on the industrial sites is relatively clear, whereas the situation in the surveillance area (SA) off-site requires additional examination especially on land.

2 Materials on the radiation situation off-site are extremely scarce or are absent altogether:

– The size of the SA for Gremikha STB is not clear, and there is no distinct border of the SA for Andreeva Bay STB.

– There is no clarity about the location of monitoring points in the SAs of either STB.

– It is not clear where background monitoring points are located, or indeed whether they exist at all.

– Information on soil characteristics is absent. This complicates the calculation of contamination density (Bq/m^2 – which is more important from the point of radiation hygiene than assessment of activity concentration (Bq/kg)). The types of vegetation are also not identified (moss, lichen, grass, etc.).

– There are no data on content of radionuclides in local food products (venison, sea fish and freshwater fish, mushrooms and berries). These data are especially important in respect of the environmental behaviour of ^{137}Cs, ^{210}Pb and ^{210}Po, for which high levels of migration in the foodchains soil–lichen–venison-human and soil–vegetation–food products–human are observed in the northern areas, especially in Murmansk region [Troirtskaya M.N. et al., 1971; Moiseev A.A. et al., 1975]. The primary contamination mechanism for lichen is from pollutants in the air. However, as a secondary source, contaminated soil cannot be excluded. The investigation of these issues in areas affected by the STBs is of interest, but data are currently practically absent.

– For the available data, the methods of analysis, sensitivity of the method and mass of the sample taken for the analyses are not identified. The absence of these details in some cases raises doubts about the validity of the data obtained. These doubts relate to, for example, results for radionuclide concentrations in the water (levels for sea and fresh water should not be equal), and some measurements of concentrations in water and forest berries, for which the average and maximum values should not be the same.

3 There is no picture of the dynamics of the radiation condition of the environment around the STB sites, as monitoring only started at the end of the 1990s.

4 It is necessary to conduct additional studies of the radiation-hygienic situation for the surveillance area around the whole perimeter of each site, not only along the coastlines. Data are especially needed for the inhabited areas of Gremikha village and Ostrovnoy.

In view of the circumstances described above, it is necessary to improve FMBA's supervision system for the control and monitoring of the radiation situation in and around the STBs at Andreeva Bay and Gremikha village, as discussed in the next section.

2.2.4 Recommendations on improvement of FMBA regulatory supervision in STB areas at Andreeva Bay and Gremikha village taking into account existing threats

Recommendations are given below for further conduct of the study with the purpose of developing criteria and standards for rehabilitation as a contribution towards improving regulatory supervision by FMBA of the STBs at Andreeva Bay and Gremikha village.

Normative activities

The main objective of Project 2 is the development of criteria and standards for STB rehabilitation. According to the concept of ecological rehabilitation of STBs of the North region of Russia [Minatom, 2004], further use of the STBs at Andreeva Bay and Gremikha village for receiving SNF and RAW from Navy vessels in operation is not anticipated. Rehabilitation of STB buildings, constructions and territories must be conducted to reach a state that will exclude any significant potential hazard associated with radioactive contamination of the soil, water and air. The role of FMBA is in the control and supervision of the rehabilitation work. Ecological rehabilitation of STB must be conducted in two stages:

- In the first stage, complex engineering-radiation examinations have to be conducted. Restoration work (of buildings) has to be carried out on those parts of the STB infrastructure that are necessary for provision of nuclear, radiation and ecological safety of the environment and personnel during the preparation and carrying out of the rehabilitation work, as well as where work to improve the management of existing SNF and RAW is to be conducted. Detailed specifications need to be developed of the tasks to be carried out, including the technical-economical justification of STB rehabilitation as a whole and of separate elements of infrastructure improvement;
- The second stage will be the realisation of the STB rehabilitation tasks, taking into account the results of technical-economical justification.

The main objective is the development of hygienic standards for radiation safety for the implementation of rehabilitation works at the STBs. This is necessary because of the absence of standards specifying acceptable residual levels of radioactive contamination. Thus it is necessary to develop radiation-hygienic rules and limits that, if met, will:

- Provide radiation safety of STB personnel and of the population living in the STB area;
- Prevent radioactive contamination of the environment; and
- Provide the necessary level of control regarding the radiation/ecological situation during rehabilitation work and management of radioactive wastes.

It should be noted that at present there are no standard levels of contamination developed to ensure ecological safety of the environment. The standard approach to radioecological safety is to ensure protection of humans. ICRP has postulated that, if humans are adequately protected by radiological standards, then other biota are also adequately protected.

Rehabilitation of STB buildings, constructions and territories can be implemented in accordance with the following concepts:

- renovation – normalisation of the radiation situation at the facility providing for further work on the site;
- conservation – continued storage of RAW under supervision; or
- liquidation – removing all RAW from the territory.

Radiation-hygienic standards should be developed for acceptable gamma-dose rate, surface beta contamination of external surfaces, specific activity of radionuclides in soil, and activity concentrations in groundwater and in air.

The basis for all normative activity on rehabilitation is the establishment of “dose quotas” with the purposes of preventing excessive exposure of the population in areas around the STB, and also of reference levels, meaning radiation parameters that can be measured as a means of radiation control and monitoring.

Monitoring and control

Monitoring of the radiation situation should include gamma-spectrum measurements in the current locations of contaminated equipment, in working areas, and in areas of identified local contamination, as well as measurements of environmental samples and local food products.

On the basis of the analyses conducted to date, described above, it can be seen that the maximum values of ^{137}Cs and ^{90}Sr contamination at the STB in Andreeva Bay are observed in media at the following sites:

- water in the brook;
- the road on the STB hill;
- bottom sediments in the bay; and
- bottom sediments in the brook mouth.

When planning for further sampling it is expedient to concentrate on the places identified above, which have been observed for several years. It is necessary to define the content of ^{137}Cs, ^{90}Sr, ^{60}Co and ^{40}K in these samples.

An analysis of the data[NRPA, 2004] supports the selection of these points for continued monitoring. The research in Project 2 should aim to identify other areas of local radioactive pollution. Notwithstanding this, for analysis of the dynamics of radionuclide behaviour it is useful to continue monitoring the already fixed points. Unfortunately, gamma spectra measured to date with open scintillation detectors, and presented by NRPA [2004], are not very informative (see Figure 3) due to the low spectrometer resolution.

It is planned to conduct similar measurements with a semiconductor spectrometer. It can be seen from presented spectra that the peak characteristic photon energy of ^{137}Cs (662 keV) is at the background of Compton scattering of other radionuclides apparently ^{60}Co and ^{40}K. It is almost impossible to analyze spectra of energy lower than 500 keV, so detection of ^{241}Am, the characteristic photon energy of which is 59,6 keV, with the given spectrometer is impossible.

Besides measurements of the radionuclides mentioned above it is necessary to conduct measurements of ^{241}Am, to use as a guide when taking samples to check for plutonium contamination. Monitoring of plutonium and americium concentrations in the environment will allow more comprehensive assessment of the radiation situation and so contribute to developing more confident recommendations for rehabilitation.

In order to assess the radiation risk due to the STBs it is necessary to have data not only about the radiation situation in working areas and control zones (gamma dose rates, concentration and dispersion of radioactive aerosols, levels of surface contamination), but also about individual doses to the controlled population groups living directly adjacent to STB territories. The population also includes personnel working in the zone of free access, i.e not classified radiation workers. Data on individual doses and dose rates, defined for given time intervals, allow assessment of annual effective and collective doses taking into account the habits of the population.

Information at our disposal [CSSES–120, 2003; 2004] includes data on gamma dose rates in different areas of the STB industrial site. Similar data for off-site areas are rather limited: generalised minimum, average and maximum values of dose within areas of the site are given, but these do not allow assessment of the radiation situation in the adjacent territory in an objective way. The dose rate data are used to calculate collective dose estimates, but measured data for individual doses are absent. In work published by NIKIET [2004a] there is only a calculated estimate, of the individual dose to a member of the public due to the industrial activity BTB, of 1 μSv/year.

For assessment of external exposure, highly sensitive individual TLDs with a low limit of detection (≤ 10^{-5} Sv) should be used. Dosimeters should be distributed to the population groups to be monitored (5 groups, each of 10–20 individuals), and worn continuously for 2-3 months. In places where people are likely to spend most time (30-40 locations), taking into account preliminary measurement of dose rates, similar dosimeters should be placed to measure the dose for 100% occupancy over the given time interval. The data obtained will be used to construct dose contours indicating dose rates by area in accordance with existing calculation models.

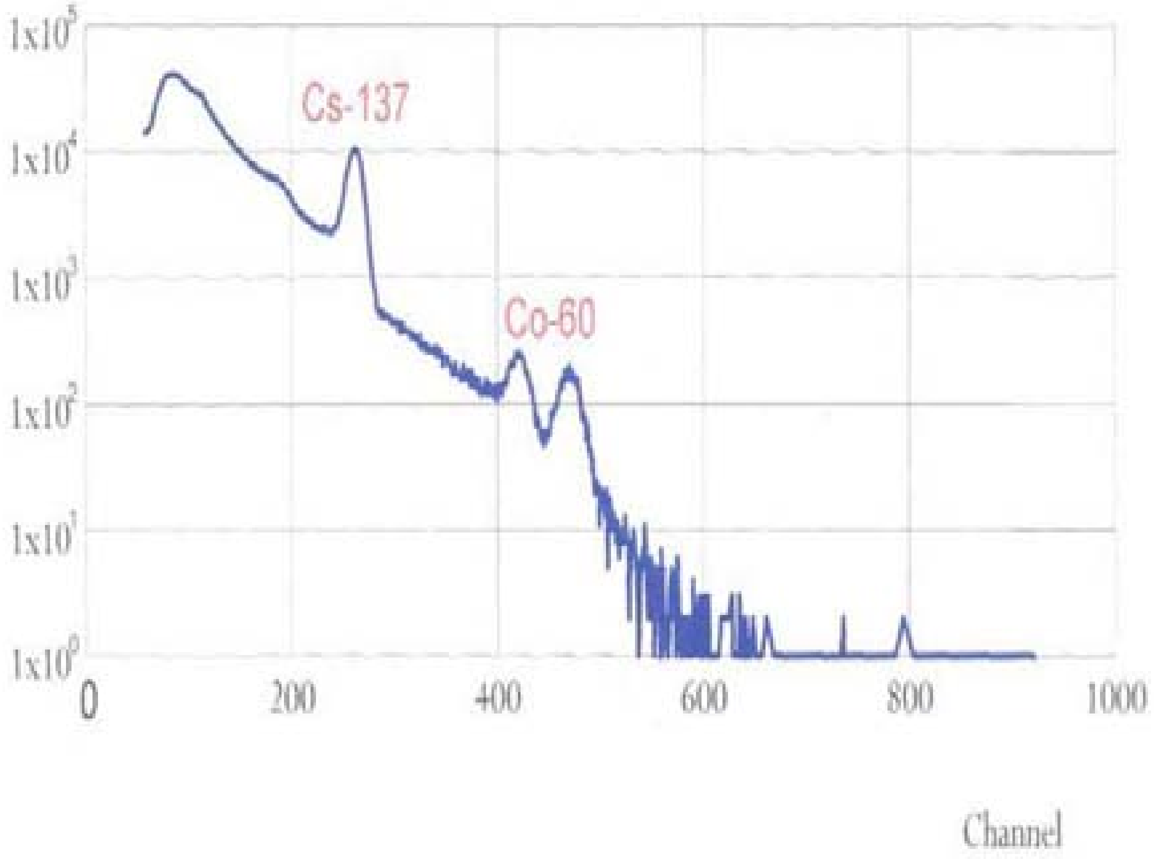

Figure 3. *Spectrum of gamma-exposure in STB plac.*

For assessment of doses from internal exposure, the following is necessary:

- to study the dietary habits of the population (i.e. consumption of different food products, kg/year), using data from studies of family budgets conducted by RF Goskomstat in the Murmansk Region;
- to study radioactivity (content of ^{137}Cs, ^{90}Sr and other man-caused radionuclides, including ^{60}Co) in seven groups of food products consumed by the population living in the SAs of the two STBs: milk and milk products; meat and meat products; bread; fish; vegetables; potatoes; and wild foods (wild mushrooms and berries). The contribution of locally obtained foods to internal doses will be taken into account;
- on the basis of calculated doses of internal exposure, to identify the “critical group” for internal exposure and the “critical” food products, i.e. those giving the highest effective dose from internal exposure.

Migration of radionuclides

The radiation situation in the territory adjacent to the STB industrial sites in Andreeva Bay and in Gremikha village is affected by: the activity on the site and in the environment; the reliability of measures to contain the sources of the activity; and the characteristics of the pathways by which radioactive substances can migrate through air and water. There are severely contaminated parts of the STB industrial sites in which dose rates reach 1-10 mSv/h, and radioactivity in soil reaches 10^4-10^7 Bq/kg, considerably above the background of the given region. Thus the STBs are sources of radiation and radio-ecological hazard.

There is published research confirming the migration of radionuclides from contamination centres. As a result almost all the territory of the coastal line near the STB at Andreeva Bay is contaminated by ^{137}Cs, at concentrations ten times higher than background level for this area. Concentrations of ^{137}Cs in bottom sediments exceed background values up to 20-30 m from the water's edge. In some samples of the east coast ^{60}Co was found, and at some points ^{90}Sr was founds at concentrations around 60 Bq/kg. In the sea water only ^{137}Cs, with average concentration 6 ± 2 Bq/m^3 , was found [Kurchatovsky Institute, 1997; Strategic master-plan, 2004].

According to presented data, ^{137}Cs, ^{90}Sr, ^{60}Co are found in the environment around Gremikha STB. However it is necessary to note that, during long-term storage of SNF, certain conditions may arise which may cause partial depressurisation of SHGC and failure of the protecting barriers of storages, resulting in the possible off-site release of other radionuclides. Plutonium presents a special potential hazard for the environment. Although plutonium migrates much more slowly than other radionuclides, such as ^{14}C and ^{3}H, its possible migration into the environment should be considered as part of the study of the long-term evolution of the site.

Distribution of radionuclides in the environment outside the STB depends on man-made and natural conditions as well as the physical characteristics of the radioactive substances in contaminating sources.

A lot of attention is paid to the behaviour of radionuclides in different water systems including the northern seas. The general patterns of radionuclide distribution in the water column and bottom sediments have been determined.

The behaviour of radionuclides and their distribution in aquatic systems depends on a number of factors, including the chemical composition of the environmental media, the presence and condition of natural isotopes and chemical analogues of the contaminating radionuclides, and the presence of natural and man-made organic substances, especially chelates.

Transformation processes due to factors such as redox conditions and pH might affect the migration and time dependent behaviour of elements with different valence states (e.g. cobalt, plutonium). Apart from the flow of the water itself, the distribution of radioactive substances with water flow is influenced by the sorption capacity of dredges, soil, and silt bottom sediments.

The migration of radionuclides depends mainly on the hydro-geological and hydrological conditions of the area. Hydrological parameters can be deduced from studying the migration of tritium, which is almost unabsorbed [Gromov V.V. et al., 1985; Henson W.S., 1985; Konoplev A.V. et al., 2000; AMAP, 2002; Sokolik G.A. et al., 2003; Stepanets O.V. et al., 2003].

Prediction of radionuclide migration is a basic part of the safety assessment for contaminated areas to support the development of rehabilitation measures and corresponding normative documentation. Such assessments must be conducted taking into account the specific man-made and natural conditions of the studied area.

Assessment of doses to the public

The population living in the surveillance area (SA) of radiation facilities is exposed to radiation from:

- cosmic rays;
- natural radionuclides in soil, air, construction materials, food products and drinking water;
- global fallout from atmospheric tests of nuclear weapons;
- man-made radionuclides released to the environment from normal operation of the facilities;
- man-made radionuclides released to the environment as a result of radiation emergencies; and
- medical procedures.

To calculate effective doses of the population due to all exposure sources, distinguishing the contribution of man-made exposure, a number of basic parameters presented in Table 9 should be used.

The Russian basic regulations for radiation safety in the normal operation of radiation facilities (NRB-99), require the following of three principles: dose limitation, justification, and optimisation.

The requirement for application of the principle of optimisation relates to all exposure categories: exposure of personnel, exposure of the public and medical exposure. Optimisation of protection has to be carried out for all levels of doses, except that the requirements of NRB-99 are not applied to sources of radiations creating individual dose no more 10 μSv/year.

The principles of justification and optimisation of protection have to be followed on a site-specific basis in territories with residual levels of radioactive substances which remain following the discontinuance of a regulated activity, or following past human activities including emergencies..

A practical check of specific protective measures for their correspondence to the justification principle is carried out by the way of comparison of benefit, harm and cost:

$$X - (У_1 + У_2) > 0$$

where X is the benefit from application of protective measure, particularly the reduction in exposure resulting from the protection measure;

$У_1$ is the costs for conducting the protective measure;

$У_2$ is the harm to people and the environment due to absence of any protective measure.

Where there are a number of alternative methods of achieving a net benefit, the protective measure should be the one that maximises this difference (observance of principle of optimisation).

Optimisation studies will be conducted taking account of international and national recommendations [IAEA, 1990, 2002; ICRP, 1983, 1989; CEC, ALARA, 1991; J.Lochard et al., 1996; C. Lefaure, 1998; NRB-99; MR 30-1490, 2001].

When conducting optimisation the following basic factors are considered:

- radiological (preventing individual and collective doses, consequences for the environment); and
- economical (cost of conducting protective measures).

If necessary additional factors can be considered, such as the expected decrease in anxiety caused by the given situation; the increase in confidence that will be provided by protective measure and the social costs, harm and disruption that can be caused by the application of the protective measures.

Table 9. *Basic parameters for dose assessment*

Source of exposure	Pathway of exposure	Basic parameters	Significant radionuclides
Space irradiation [UNSCEAR, 2000]	directly ionizing irradiation	height above sea level	
	Indirectly ionizing (neutron) irradiation	height above sea level	
	cosmogenic radionuclides (^{14}C etc.)	accepted equal 0,012 mSv/year	
Radionuclides of global origin [RF Ministry of Health, 1999; UNSCEAR, 2000]	external exposure	Density of contamination (distribution by the profile)	^{137}Cs
	internal exposure	Specific activity in food products of local production, mushrooms and venison	^{137}Cs, ^{90}Sr
Man-made radionuclides [RF Ministry of Health, 1999; UNSCEAR, 2000; Methodic Guidance, 2003]	External exposure from radionuclides in the air	Volume concentration of radionuclides in ground level air	^{60}Co, ^{106}Ru, ^{137}Cs, ^{134}Cs, ^{144}Ce
	External exposure from fallout	Density of contamination (distribution by profile of the ground)	^{60}Co, ^{106}Ru, ^{137}Cs, ^{134}Cs, ^{144}Ce
	Internal exposure from inhalation	Volume concentration of radionuclides in ground level air	^{239,240}Pu, ^{238}Pu, ^{241}Am, ^{144}Ce, ^{244}Cm, ^{60}Co, ^{106}Ru, ^{137}Cs, ^{134}Cs,
	Internal exposure from ingestion	Specific activity in food products of local production, mushrooms, venison, wild berries, drinking water	^{60}Co, ^{106}Ru, ^{137}Cs, ^{134}Cs, ^{90}Sr
Natural radionuclides [Methodic, 1999; RF Ministry of Health, 1999; UNSCEAR, 2000; Methodic Guidance, 2003]	External exposure from radionuclides in soil	Specific activity in soil, dose rate outdoor	^{40}K, ^{238}U series, ^{232}Th series
	External exposure from radionuclides in construction materials	Dose rate indoors, specific activity of radionuclides in construction materials	^{40}K, ^{238}U series, ^{232}Th series
	Internal exposure from inhalation of dust	Specific activity of radionuclides in upper soil layer	^{238}U series, ^{232}Th series
	Internal exposure from inhalation of radon progeny	Average annual equivalent equilibrium volume activity of radon isotopes in the air indoor	Daughter radionuclides of ^{222}Rn
	Internal exposure from ingestion of food products	Specific activity in food products of local production, mushrooms, venison, fish, drinking water	^{234}U, ^{238}U, ^{226}Ra, ^{228}Ra, ^{210}Pb, ^{210}Po
Medical exposure [RF Ministry of Health, 1999]	External	Type of examination, type of equipment	
	Internal	Type of examination, activity of radionuclides administered	

2.3 Emergency Preparedness and Response Aspects

2.3.1 Consideration of objects

The highest priority sources and activites related to spent nuclear fuel (SNF) and radioactive waste management at the STB sites have been identified, in the context of the general issue of decommissioning of nuclear powered vessels (Strategic master-plan 2004). Peculiarities of the conditions at those sites, as compared to good practice for radioactive waste management, are as follows:

- there are important uncertainties concerning the radioactive materials located at the above sites. According to available information [Strategic master-plan 2004], at the Andreeva Bay site there are 17,600 m^3 of solid radioactive wastes of total activity of 660 TBq and about 3,040 m^3 of liquid radioactive wastes of total activity of 4,5 TBq. With regard to the Gremikha site an estimate of total activity of solid radioactive wastes is 37 TBq, although this is subject to much greater uncertainty;
- absence of technological decisions, in the form of project specifications and estimated documentation, which would set out and justify a complete list of all activities to be carried out at the site;
- improper conditions of storage of SNF in temporary dry storage (e.g. at Andreeva Bay, BDS 2B, 3A) and abnormal radiological conditions (e.g. in Building 5), characterised by large variations in dose rates and increased migration of radionuclides with surface and underground waters beyond the sites. Measured dose rates on-site reach 1-10 mSv/h.

This is a preliminary analysis of threats and risks as a result of potential radiation accidents and abnormal situations at the SevRAO sites and mitigation of their consequences. Some attention has been paid to a general discussion of applicability of the radiological protection system to specific conditions of SevRAO [Strategic master-plan 2004].

2.3.2 A list of problems

Practice, intervention, existing situation

The ICRP recommendations and the IAEA safety standards suggest considering radioactive waste management as a part of the practice that generated the waste [ICRP 1992, ICRP 1998, IAEA 1996, IAEA 2005a, IAEA 2005b, IAEA 2005c]. As a rule, similar approaches are used in current Russian regulations and recommendations.

However, specific conditions at the sites of Andreeva Bay and Gremikha village allow us to indicate at least two objections to approaching radiation protection only in the framework of practices:

- the conditions and technologies of SNF and radioactive waste management at the time when the bases were first established and operated did not meet the current requirements of good practice. The evidence for this is the current nuclear and radiation conditions of the SevRAO sites;
- the terms “practice” and “intervention” were introduced in 1990 in the ICRP Recommendations [ICRP 1992] and were adopted in the International; Basic Safety Standards [IAEA 1996] in 1996, and in Russia in the standards of radiation safety [NRB 1999] in 1999. One can suppose that new ICRP Recommendations will be adopted in the near future within the Russian Federation. If these Recommendations take the expected form, the separation of all situations of exposure to the population into practice and intervention will be replaced by three exposure situations:

practice, existing, and emergency. Taking into account the long-term nature of the work needed at the SevRAO objects, it seems reasonable to reflect current trends in the system of radiological protection in the regulations and recommendations.

Planned activities at the SevRAO site at Andreeva Bay include:

- management of solid and liquid radioactive wastes. This activity can reasonably be considered as part of the practice.
- management of SNF, including that which has been kept in improper conditions, creating abnormal radiation situations. This activity is worth considering as part of the practice, but as a special radiation situation associated with increased requirements for radiation safety of personnel.
- rehabilitation of the site and, probably, adjacent territories to reduce existing and potential exposure due to contamination on- and off-site.
- preparation for an emergency, which should provide means both for emergency response and to take corrective actions, depending upon the character and scale of events.

Actual and potential exposures

Potential exposure is defined in the Russian standards of radiation safety [NRB-99 1999] as "exposure that might be caused as a result of a radiation accident". However, the Russian regulatory documents do not introduce limits with respect to potential exposure. In the case of abnormal situations, one cannot exclude the possibility of exposure to the personnel in excess of regulatory limits and/or administrative levels. Though such actual exposures are not related to "radiation accident" (because there is no loss of source control), they require special investigation, and a response that is similar to emergency response.

Thus, clarification of a border line between abnormal and emergency needs to be provided by a regulatory body. It is expected that there will be interaction between projects 1 and 3 on this issue.

Classification of radiation accidents

The International Nuclear Event Scale (INES) [IAEA, 2001] is a good basis for provision of information to the population and the media about a radiation accident. However, some adaptation of this scale with respect to the SevRAO conditions would be needed to accounting for the following aspects:

- *To clarify the requirements on assessment of the hazard of radionuclides for the INES levels 5-7.* Calculation of doses off-site are carried out on the basis of the projected doses from inhalation and external exposure from the radioactive cloud and fallout deposited on the ground (integrated over 50 years). Probability of such accidents is small. For levels of 3 and 4, it is required to account for all the exposure routes, including ingestion, which has specific features (insufficiently studied) in the conditions of polar regions. *Special difficulties might arise in estimation of doses in the case of uncontrolled prolonged off-site release of radionuclides with surface and ground waters;*
- *To determine more specifically the criteria for presentation of official information on the radiation accident to the IAEA and the neighbouring countries.* At present only events classified as level 2 and higher, as well as the events of international interest, are to be reported. The latter criterion does not have any numerical definition, and will need to be considered by Russian and Norwegian specialists.

However. INES is designed as an information tool, not as an operational tool for emergency preparedness or response. The more important issue is therefore to have a system that is useful for emergency preparedness and response at the SevRAO facilities, not to fit it with INES.

2.3.3 Risks of medical consequences

As a rule, the estimates of projected radiation doses (or loss of years of life and annual death risk for an individual) are calculated assuming that no countermeasures, medical or otherwise, are carried out [Strategic master-plan 2004].

In order to minimise possible risks, it is necessary to identify the main risks to be taken into account in emergency planning, as well as possible modifying factors affecting the risks from technical and medical countermeasures that might be taken.

Risks of deterministic effects of exposure

This depends upon a number of factors including: the designed safety of the technology; adequacy of systems of control of individual doses to the personnel in emergency situations; the radiological conditions at the facility; and the level of preparedness of the system of medical response.

In the given context it is necessary to assess the possible systems of emergency response (including non-medical) aimed at decreasing the risks of deterministic effects for personnel involved in an accident.

The basic components of emergency response are determined by the following actions, including those of medical orientation:

- information (notification of the people in the zone of an accident; notification of possible means of rescue and determination of the degree of danger);
- evacuation (organisation of evacuation of the personnel from the zones of accidental exposure; and of victims of overexposure, taking account of the actual radiation situation);
- protection (use of the nearest shelters, use of individual protective equipment);
- sanitary-hygienic (removal of contaminated clothes, treatment of contaminated skin surfaces, mucous, hair);
- treatment (administration of drugs from the first-aid set, prescription of preventive treatment to medical staff, prescription of early ethiotropic or pathogenetic treatment in the case of acute radiation diseases).

A radiation accident may take the form of a release of a source of ionizing radiation beyond the framework established by the technology and conditions of operation. In such a case, a number of people can be affected by the accidental situation and the above listed actions are applied, as appropriate, to that group. A small risk of severe deterministic effects in a whole group is predicted.

Alternatively, a radiation accident may take the form of a non-authorised (casual or deliberate) contact of the person with factors or conditions resulting in overexposure of individuals, without any obvious failure in equipment or safety systems. In such a situation, there are more likely to be single cases of overexposure, with a high risk of development of severe deterministic effects. Emergency response actions are likely to be applied after the overexposure and/or when radiation injuries can be observed.

The peculiarities of operational conditions at the SevRAO STBs are as follows: (1) a possibility of uncontrollable irradiation of individual workers with a high risk of development of severe deterministic effects; and (2) a much smaller probability of irradiation of groups of personnel at clinically significant doses with a minimal risk of *development of severe radiation injuries. Severe deterministic effects off-site among members of the public, including the population of the CATF, are not expected.*

An additional risk of developing radiation injuries under the scenario of "non-authorised access of a person or violation of safety regulations" is through an initial intention by the exposed person to conceal the overexposure. Since there is also a time delay between accidental irradiation of an individual and the beginning of clinical manifestation of radiation injuries, there could be a longer than expected delay before confirmation of the irradiation. In such a situation important components of emergency response, such as information, evacuation, and protective actions, might substantially lose their efficiency. At the same time the role of medical emergency response increases, in view of the high risk of development of severe radiation injuries. Experience of medical treatment of exposed people and use of up-to-date technologies for treatment of patients are very important.

Under the above prognosis the specialists of FMBA and invited experts can provide substantial help to medical sanitary units (MSUs) and the centres of State Committee of Sanitary and Epidemiological Supervision (CSSESs).

Risks of occurrence of late consequences

Reduction of the long-term stochastic risks of accidental radiation exposures will not be the main focus of the current project. Implementation of the emergency response actions focusing on short-term effects may nevertheless also result in reduction of the long-term stochastic risks of exposure.

Risks of non-radiation accidents

For any process including transport and handling of SNF and RAW there is always a risk of industrial accidents such as collisions, poisonings and fires. It is possible to reduce these risks by improving the working conditions and provision of working safety by applying modern remote handling technologies.

In the case of radiation accident, improved emergency response (up-to-date protocols of urgent medical aid; screening; sanitary treatment; evacuation; immobilisation and transportation of injured people; etc) will also result in a decrease of the risk of injuries due to conventional accidents during the emergency response.

An increase in risks due to disadvantages of urgent medical aid

Paradoxically, deterioration or improvement in the quality and availability of medical aid might not influence the risks for the SevRAO personnel, because of the small number of staff and priorities in urgent medical aid for the staff. *The capabilities necessary for an on-site (pre-hospital) medical response (a primary part of medical aid) to be able to handle individual traumas among a small number of the SevRAO personnel are also sufficient to provide the same function in a full scale accident.* In addition, the existing practice in the Russian Federation of forming brigades of first aid medical personnel, and its priority financing, make this kind of medical aid for the SevRAO personnel accessible and sufficient. Also, problems have arisen in recent years in the organisation and maintenance of hi-tech specialised treatment, especially in neurosurgery, toxicology, and burn-trauma treatment. As a rule, modern medical technologies of these types are accessible only at large centres of science and regional hospitals.

Decrease in risks related to realisation of urgent medical aids

Groups and services attached to the FMBA and involved in the mitigation of the medical-sanitary consequences of radiation accidents are the basis of the specialised service of emergency medical aids (SSEMA). They are responsible for implementing measures aimed at protection of human health, to provide medical assistance to the staff and members of the public involved in an accident.

The effectiveness of such actions can be estimated in terms of “prevented risk” (similar to the measurement of the effectiveness of other countermeasures such as stable iodine on the basis of “averted dose”). This effectiveness is determined, to a certain degree, by the level of professional preparedness of emergency groups and services of SSEMA for medical treatment of injured and other affected persons in the complex, hazardous, and frequently unpredictable conditions of radiation accidents.

The tasks relate to

- maintenance of preparedness of the emergency groups and services of SSEMA;
- planning of medical and material support;
- maintenance of an appropriate level of training of the leaders and members of services ;

and

- operational management of work to mitigate the consequences of radiation accidents, to select the priorities and directions of development of the SSEMA system, so as to decrease the risks for personnel and the public.

The main factors that influence the stability of functioning of the system and its effectiveness in reducing (averting) undesirable consequences (risks) for the health of personnel and the public, are as follows:

- clear allocation and understanding of responsibilities among all organisations involved;
- preparation of a complete set of consistent normative, methodical, technological and instructive documents, which are in compliance with existing legal rules and procedures;
- availability of necessary specialists among the personnel of SSEMA;
- a developed system of traditional forms of training of the medical personnel, including checking of their preparedness based on results of special exams;
- preparedness of the system of departmental requirements, specifications and standards related to the application of medical technologies under conditions of mitigation of the consequences of radiation accidents, including the means of operational communication;
- supply of individual protective equipment for radiation accidents, including the protection of medical staff providing medical aid to the victims;
- development of automated techniques to estimate medical-sanitary conditions at the locations of radiation accidents and to predict the consequences of the accidents for personnel and the public, as well as the means to predict undesirable consequences (risks) of planned preventive measures, including administration of prophylactic pharmaceuticals (particularly iodine) to personnel or the public;
- presence of proven technological regulations for the provision of rescue work by special services at the site of an accident;
- presence of a real system of planning of protective actions for the population;
- a developed system for the organisation, maintenance and implementation of training and exercises to study the actions to be applied in the event of a radiation accident, and techniques to assess preparedness, accounting for the contribution of the main factors influencing preparedness, as well as the basic risks for personnel and the public.

The first six factors are traditional, and are part of the usual organisational actions. The other factors correspond to the principles of emergency medical response of the WHO and IAEA (IAEA, 1996), which emphasise the importance of anticipatory planning of medical-interventions. This requires a combination of prediction of the probable development of medical-sanitary conditions in the event of a radiation accident and estimation of the realistic capabilities of groups and services of SSEMA to provide medical care to affected people.

A number of simple examples are detailed below to illustrate these factors.

On the one hand, operational planning is aimed at efficient use of available resources under severe time and cost pressures. On the other hand, it is aimed at decreasing risks (extent and severity of radiation injuries, irradiation of people). As an illustration, one can consider well known radiological data: after ingestion, about 35-50% of incorporated strontium leaves the intestines within 1-3 hours and is deposited in bones; iodine prophylaxis is effective only during the very first hours, and after 5-6 hours its efficiency decreases by 50%.

The preliminary analysis of the problems emphasises the importance of planned actions within the framework of the present work (see Table 10).

Table 10. *The main actions necessary to justify and develop the system of planning of medical-sanitary provision in an emergency situation.*

Subject	Status	Actions to be done
Officially adopted list of design basis and beyond design basis accidents related to technological operations of radioactive waste management and its transportation	Data on conducted studies and developments are available	Agreement and approval of the list of emergency situations
Assessment of medical-sanitary consequences of design basis and beyond design basis accidents	No data	Assessment of possible medical consequences related to the staff of the SevRAO site
Categorisation of potential radiation hazard of SevRAO according to the main sanitary rules of the radioactive waste management (OSPORB-99)	Preliminary opinion is available	Further justification, which is the basis for the development of the plan to protect population
Presence of the necessary documents on emergency preparedness and response at the enterprise, MSU, and CSSES of FMBA	Preliminary data are available	Conclusions and recommendations will be made based on the results of inspection
Preparation of the personnel of MSU and CSSES of FMBA to work in an emergency situation	The data are absent	Conclusions and recommendations will be made based on the results of inspection
Presence of the plan of interaction of MSU and CSSES of FMBA with territorial and departmental bodies of CSSESs and medical institutions	Preliminary data are available	Conclusions and recommendations will be made based on analysis of adequacy of the available system of emergency preparedness and response and the characteristics of regional medical institutions

3 Conclusions

3.1 Radiological threats

The main radiation dangerous objects at the SevRAO STBs for the environment, public and workers can be summarised as follows.

In Andreeva Bay:

- The Block Dry Storage used for storage of SNF in containers;
- Building 5, a former SNF store, and the brook flowing behind Building 5 and apparently going under the building;
- LRW storage in regular and irregular places of storage, the tanks in constructions 6 and 7, and in the basement of Building 6 SRW storage areas;
- Construction 67A (SRW storage);
- Construction 67, in which containers of SRW are stored;
- Constructions 7 and 7A , which are buildings for SRW storage; and
- Other sites for SRW storage.

In Gremikha village::

- SHGC (spent fuel) storage;
- SEP (cores from liquid-metal-cooled reactors) storage (Building 1B);
- 11 areas of LRW storage;
- SRW storage site;
- Temporary SRW storage site;
- PEK-50 for LRW storage; and
- Pumping facility for receiving and distribution of LRW.

In addition, there is radioactive contamination on and around the sites. Taking account of the objects and contamination, the main radiological threats can be summarised as follows (in approximate order of priority):

1. At both STB industrial sites there are storage areas containing highly active materials and severely contaminated parts of the territory. Dose rates in parts of the sites exceed 1 mSv/h.
2. The territory and area of water of the coastal strip of STB Andreeva Bay is contaminated by ^{90}Sr, ^{137}Cs and ^{60}Co. The ratio of ^{90}Sr to ^{137}Cs fluctuates widely, indicating the presence of centres of local radioactive contamination with different activity levels. Abnormal contamination of ^{137}Cs in the ground is registered in the area of berth (to 4000 Bq/kg), in the low land between the SNF and SRW storage and the junkyard (up to $2x10^4$ Bq/kg), and at Building 5 along the brook (up to 10^6 Bq/kg). Concentrations of ^{90}Sr in the ground vary from <20 to 7500 Bq/kg. The content of ^{60}Co in the soil of the coastal zone was 13 – 152 Bq/kg. In samples of soil taken in Zaozersk, concentrations of ^{137}Cs and ^{90}Sr were not higher than 50 Bq/kg, much lower than on the industrial site, and decrease with distance from the site. The local concentration of ^{137}Cs in soil in Gremikha village reaches 2400 Bq/kg in one place.

3. The concentration of ^{137}Cs in bottom sediments of the coastal strip in the STB areas of Andreeva Bay varies from <20 to 600 Bq/kg depending on distance from the mouth of the brook. The content of ^{137}Cs in the brook water also varies from less than 20 Bq/l to 500 Bq/l near Building 5. Contamination of seaweeds and periphyton in the area of vessel anchorage is more than a factor of ten higher than in seaweeds collected in the SSZ (>2500-4600 Bq/kg compared to 200 – 250 Bq/kg). Contamination of bottom sediments differs only by three times (600 Bq/kg in comparison with 200 Bq/kg). This shows accumulation of man-made radionuclides in water organisms. Levels of specific total beta activity in seeds in the Gremikha STB area of water are >200–430 Bq/kg. In seaweeds at Gremikha, the concentration of ^{137}Cs is more than 1500 Bq/kg.
4. Average annual concentration of ^{90}Sr and ^{137}Cs in the atmosphere of the SSZ and SA are <0,03–0,7 and <0,22–0,7 Bq/m^3 respectively. These values are ten times lower than acceptable levels (2,7 Bq/m^3 for ^{90}Sr and 27 Bq/m^3 for ^{137}Cs). But these values are much higher than background levels of ^{90}Sr and ^{137}Cs in the atmosphere of the Murmansk region (1,0-18,0) μBq/m^3.
5. Activity concentrations of ^{137}Cs in the sea water in Andreeva Bay, 20 m from the shore, are in the range 5–7 Bq/m^3 whereas background for the given area is ~10 Bq/m^3. Nevertheless traces of radioactive contamination of sea water in the area of berths in Andreeva Bay are noted. Higher concentrations of ^{137}Cs in the sea water – up to 20 Bq/ m^3 – are found in Gremikha STB area of water than in the open sea.
6. Realistic assessment of public radiation doses on the basis of available data is difficult, because many parameters of radiation-hygienic situation have not researched yet. In particular, reliable data on of the level of radionuclides in drinking water and foods (including venison, fish, and wild plants) are absent.
7. There is little data on the existence of radionuclides in soils and their migration in the environment of Andreeva Bay and Gremikha.

3.2 Actions to reduce the threats

As indicated above, the Andreeva Bay and Gremikha village (STB) sites comprise a range of radioactive sources, including spent nuclear fuel, liquid and solid radioactive wastes, and areas of environmental contamination. Given the very high dose rates existing, it is important to prioritise and schedule actions to control these sources in order to ensure that the hazards are minimised appropriately. There would be significant advantage in removing spent nuclear fuel as the first priority as outlined below.

The current very high dose rates on-site mean that, under present conditions, any on-site operations carry a significant health risk. The very high dose rates are thought to be largely attributable to the spent nuclear fuel (SNF) and high level radioactive wastes (RAW), e.g. SNF in dry storage areas 2A, 2B and 3A at Andreeva. The present storage conditions for these materials are unstable and liable to deterioration, such that these conditions also constitute a significant and increasing accident risk. Thus, while the removal of SNF would entail a significant increase in occupational doses, and a temporary increase in the probability of an accident occurring while the SNF is removed, it is envisaged that, in the long-term, the removal of SNF would result in a significant reduction in both the on-site dose rates and the risk of serious accidents. This would allow other on-site operations to be conducted more safely (and hopefully within the normal regulatory regime).

A programme of work to remove the SNF from the dry storage cells at Andreeva Bay promptly has been proposed, but would require special regulations for working in abnormal conditions on-site. An alternative programme of work, involving infrastructure improvements on-site so that work can be carried out within existing regulations for normal conditions, has also been formulated, but the infrastructure improvements would require several years' work before removal of the SNF could begin (allowing the possibility of further deterioration). The aim is to find the optimum solution whereby the SNF can be removed as soon as possible, without breaching fundamental safety norms.

It is also clear that more information is required to fully characterise the condition of other wastes and sources of contamination on-site. Once the SNF has been removed the improved dose-rate conditions should make it possible to determine the condition, risks and dose rates implied by the other waste streams more effectively. On the basis of this information, priorities for further clean up and waste treatment actions may then be identified. It may then be possible to carry out those activities under regulations for normal conditions.

There is no information to suggest that off-site contamination levels require urgent action. However, there is little information about radiological conditions off-site, and a number of specific data gaps have been identified related to the levels and movement of radionuclides in the environment. Although this is of lower priority than the removal of SNF, it would be possible to gather off-site information at the same time to inform the development of regulatory criteria for long-term planning for rehabilitation and site de-licensing.

3.3 Provisional regulatory activities

In order to undertake any programme of work to mitigate the threat posed by SNF on the sites that can be agreed between operator and regulator, assessment of the following factors will be required:

1. The current situation before undertaking SNF removal work:
    a. Dose rates, worker and public doses under current conditions;
    b. The risk to workers and the public from accidents (before any action);
    c. The likely development of the situation (including changes in the dose rates and accident risks) if no action were taken.
2. The risks of undertaking SNF removal work:
    a. Detailed identification of work procedures;
    b. Doses and accident risks implied by different procedures, taking account of:
        I. The detailed characterisation of dose rates, from 1.a. above;
        II. Different timescale strategies;
        III. Other options for reducing doses and risks as appropriate (e.g. personal protective equipment);
    c. Identification of appropriate procedures to reduce the probability and/or impact of potential accidents:
        I. Priorities for emergency planning and response capabilities are likely to depend upon the strategy adopted on-site (the focus on medical treatment of workers is partly a result of the greater likelihood that SNF removal will be dealt with first and that the most likely accidents are therefore those affecting a few workers rather than causing environmental contamination).
3. The future situation:
    a. Residual doses and risks following different remedial action strategies.

Supporting this work, regulations and procedures for workers on-site need to be developed that can be applied to abnormal situations while remaining within the existing legal norms.

In parallel, activities can be undertaken preparatory to future decision making on the decommissioning and eventual de-licensing of the sites and any necessary cleanup in the surrounding areas. The main preparatory activities would aim to:

1. Obtain better information on radiological conditions off-site, and how these are changing due to conditions on-site (this information can also be an input to defining the current situation in point 1.a. above); and
2. Develope regulatory criteria and guidance for the cleanup of contaminated areas and delicensing of the sites.

These aspects are outlined in more detail below.

Characterisation of current situation

1. Currently, detailed plans of the operations to improve management of SNF and RAW at the SevRAO facility at Andreeva Bay are in the initial stages of design. They will be designed on the basis of requirements of OSPORB-99 and NRB-99, which do not take full account of the conditions at SevRAO sites. It therefore seems desirable for the regulatory bodies, and particularly of the Institute of Biophysics, to participate in the assessment of proposed project decisions.
2. In order to assess radiation risk due to the existence and industrial activities of the STBs it is necessary to have data not only about radiation situation in working areas and in the control zones (gamma dose rate, concentration and dispersion of radioactive aerosols, levels of surface contamination), but also about individual exposure of the controlled population groups directly adjacent to STB territories. Data on individual doses and dose rates in specific areas, defined for given time intervals, allow assessment of annual effective and collective doses, taking into account the habits of population.

Actions necessary to undertake SNF Removal

3. Analysis of proposed project decisions will be based both on the assessment of parameters defining the radiation situation during SNF management operations and on the set of normative-methodical documents developed within the Project 1,: including
   - Classification of radiation-hazardous technological operations and the range of measures to ensure radiation safety during their performance
   - Recommendations on the use of personnel protective equipment in real SevRAO conditions;
   - Recommendations on the application of collective protection means for the workforce in real SevRAO conditions;
   - Development of Guidance “Sanitary rules of radiation safety for the operation at SevRAO facilities” and realisation, as a result, of regulatory functions in the field of radiation safety.
4. Final Guidance has to address the following tasks to provide for the selection of optimal project decisions:
   - Radiation safety of SevRAO personnel during operation in the most radiation-hazardous conditions where SNF removal from the storage cells has to be conducted, as well as the draining of water from SNF containers and their transportation to the point of re-packaging;

- Radiation safety of SevRAO personnel in the abnormal and/or emergency situations which could arise during SNF removal from the storage cells, draining water from containers and their transportation to the point of re-packaging.

Identification of accident risks and emergency preparedness

5. At the present stage of development of the system of emergency preparedness and medical-sanitary provision at the SevRAO site, one of the first actions is the initialisation of procedures aimed at obtaining an officially authorised list of possible emergency situations at different stages of SNF/RAW management (including transportation). This can then be used to prepare a list of categorised objects related to their potential emergency hazard, according to the requirements of normative documents. In turn, assignment of objects to categories will determine the necessary level of planning of protective and medical actions with respect to both the personnel and the population. The above procedure is likely to be iterative, as the category of an object could be changed due to improvement of technology, conditions of storage or removal of RAW. At present, for Project 3 it is conservatively assumed, that SevRAO sites will be considered objects of the first (highest) category of potential emergency hazard according to requirements of MSRRWM-99.
6. As a result of the analysis of possible emergency situations, the pathways and factors affecting emergency exposure of personnel, it is planned to consider two variants of a possible structure of casualties (numbers of involved and injured people, and the degree of injuries). The first variant of the estimates will be based on the formal data received from SevRAO, available within the framework of existing plan of emergency preparedness and response. The second variant of estimates will be obtained using a special expert-analytical technique. Comparison of those estimates will allow the optimisation of medical provisions, to be capable of rendering the necessary medical aid, and of the documents regulating the work of medical personnel.
7. The preliminary analysis has shown that even in the worst case of emergency situations at the SevRAO site the population is unlikely to be exposed at a clinically significant level of dose. At the same time it is necessary to estimate the adequacy of the territorial medical service at providing emergency response related to the public during intervention (evacuation, shelter, restrictive actions in the contaminated areas). It is planned to analyse available plans, including plans on interaction between MSU-120 and territorial medical institutions.

Development of rehabilitation criteria and an understanding of the off-site conditions

8. For the most part, work on radiation-hygienic control of the environment of the STBs in Andreeva Bay and Gremikha village have been conducted on the territory of the industrial site and in the SSZ. The radiation situation on the industrial sites is relatively clear, whereas the situation in the surveillance area (SA) off-site requires additional examination, especially on land. Information on the radiation situation in the SA are extremely scarce or absent. There is no picture of the dynamics of the radiation situation of the environment outside the STB, as monitoring of the radiation situation started in the late 1990s. It is necessary to conduct additional studies of the radiation-hygienic situation in the surveillance area around the whole perimeter of the STB, not only along the coast line, and especially in the inhabited areas of Gremikha village and Ostrovnoy.
9. Predication of radionuclide migration is a basic part of safety assessment of the contaminated areas and must be conducted taking account of the specific man-made and natural conditions of the studied area of the region. This will allow the development of appropriate rehabilitation measures and corresponding normative documentation.

10. Regulatory documents will need to be developed to provide for radiation safety of personnel and the public during and following the rehabilitation of the territory by means of development of criteria for the residual contamination of land, buildings and constructions of SevRAO facilities with radioactive substances. These criteria should related to some of the most probable options for their decommissioning (unlimited use, restricted use as an industrial facility using radioactive materials, restricted use as an industrial facility without radioactive materials, etc).
11. State sanitary-epidemiological supervision of the state of the environment off-site will require improvement of the appropriate methodical documents:

- Ensuring radiation safety control and supervision over the STB rehabilitation requires development of a special document – an order (regulation) for the conducting of control and monitoring. Guidance will be provided in this document on issues such as the required amount, frequency and type of monitoring and inspection.
- Development of criteria and hygienic norms on rehabilitation, providing social guarantees of public radiation safety at territories affected by radioactive contamination associated with the STBs;
- Setting of "dose quotas" to limit radiation exposure in the STB areas, as well as development of reference levels for measurable radiation parameters, which can be monitored during radiation control.

References

AMAP (2002). Assessment 2002 г. Radioactivity in Arctic. Arctic. Monitoring and Assessment Program (AMAP), Oslo – 2004 – p.100.

CEC (1991). ALARA: From Theory Towards Practice, Rep. EUR-13796, CEC, Luxembourg. – 1991.

CSSES of Murmansk region (2003). Radiation-hygienic passport of Murmansk region territory for 2003 // CSSES of Murmansk region. – Federal Center of state Sanitary –Epidemiological Supervision of RF. Moscow – 2004 – p.8.

CSSES–120 (2003). Annual report of Industrial-Sanitary Laboratory #1 and #2 Central State Sanitary Epidemiological Supervision – 120 (CSSES 120) for 2003 – Zaozersk Filial №1, Ostrovnoy Filial №2 by «SevRAO», CATF Snezshogorsk Murmansk region, - 2003. – p.31.

CSSES–120 (2004). Annual report of industrial-sanitary laboratory # 1 and # 2. Central State Sanitary Epidemiological Supervision – 120 (CSSES 120) for 2004 – Zaozersk Filial №1, Ostrovnoy Filial №2 by «SevRAO», CATF Snezshogorsk Murmansk region, - 2004. – p.26.

Gromov V.V. et al. (1985). Man-caused radioactivity of the World Ocean. М. Energoatomizdat. 1985 – p.172.

Henson W.S. (1985). Transuranium Elements in the Environment. Translation from English. Edited by W.S.Henson. М. Energoatomizdat, 1985, p.344.

IAEA (1990). Operational Radiation Protection: A Guide to Optimization, Safety Series No. 101, IAEA, Vienna.

IAEA (2002). Optimization of Radiation Protection in the Control of Occupational Exposure. Safety Reports Series No. 21, IAEA, Vienna, - 2002.

ICRP (1983). Cost–Benefit Analysis in the Optimisation of Radiation Protection, ICRP Publication 37, Pergamon Press, Oxford and New York. – 1983.

ICRP (1989). Optimisation and Decision-Making in Radiological Protection, Publication No. 55, Pergamon Press, Oxford and New York. – 1989.

ICRP Publication 60 1990. Recommendations of the International Commission on Radiological Protection. Annals of the ICRP Vol.21 No. 1-3, 1992.

ICRP Publication 81. Radioactive protection recommendations as applied to the disposal of long-lived solid radioactive waste. Annals of the ICRP Vol.28 No. 4, 1998.

IAEA - International Atomic Energy Agency. International basic safety standards for protection against ionizing radiation and for the safety of radiation sources, Safety Standards. Safety Series 115 Vienna, Austria. 1996

IAEA - International Atomic Energy Agency. Implementation of the remediation process for past activities and accidents. Draft Safety Guide. DS172. Vienna, Austria. 2005a.

IAEA - International Atomic Energy Agency. Release of sites from regulatory control upon termination of practices. Draft Safety Guide. DS332. Vienna, Austria. 2005b.

IAEA - International Atomic Energy Agency. Decommissioning of nuclear facilities. Draft Safety Guide. DS333. Vienna, Austria. 2005c.

IAEA - International Atomic Energy Agency. International scale of nuclear events (INEC). Guide for users. Publication 2001. IAEA-INES-2001.

Konoplev A.V. et al. (2000). Transformation of Forms of Location of ^{90}Sr and^{137}Cs in Soil and Bottom Sediments. Nuclear Energy. 2000 г., V. 88, edition. 1, p. 3.

Kurchatovsky Institute (1997). Implementation of 1 stage of works for prevention large-scale radiation contamination of Andreeva Bay. Report. Institute of Nuclear Reactors RSC «Kurchatovsky Institute». Moscow – 1997. –p. 15.

Kurchatovsky Institute (2000). Report on implementation of scientific research work «Preparation and Conduct of Works for Prevention of Largescale Radiation Contamination of Andreeva Bay (Murmasnk region)". Agreement 6/1998. Institute of Nuclear Reactors RSC «Kurchatovsky Institute». Moscow – 2000. – p.21.

Lefaure C. (1998). Monetary Values of the Person-Sievert — From Concept to Practice: The Findings of an International Survey, CEPN-R-254, Centre d'etude sur l'evaluation de la protection dans le domaine nucleaire, Paris. – 1998.

Lochard J. Et al. (1996). Lochard J, Lefaure C, Schieber C, Schneider T A (1996). Model for the determination of monetary values of the man-sievert, J. Radiol. Prot. 16.. – P. 201–204.

Machonko (2004). Radiation Situation in the Territory of Russia and Adjacent States in 2002. Yearbook. Under edition by K.P.Machonko. – Obninsk: NPO «Tayphun».

Methodic Guidance (2003). Methodic Guidance "Calculations of Doses of Population Exposure Living in Surveillance Area of the Facilities Federal Agency for Atomic Energy" (draft). Federal Department "Medbioextrem". 2003.

Methodic (1999). Methodic. Selective Examination of Inhabited Houses for Assessment of Exposure Doses of the Population. # 11-2/206-09. Approved by Deputy Chief Medical Officer of the Russian Federation S.I. Ivanov.

Methodic Recommendations (2001). Methodic Recommendations. MR 30-1490-2001. Optimization of Radiation Protection of the Personnel of RF Minatom. In manual Methodic Provision of Radiation Control at the Facility. Volume 2.– Moscow. – 2002.

Minatom (2004). Concept of Ecological Rehabilitation of Shore Technical Base of the North Region, approved by Rumyantsev A.Y. in February 2004 – Moscow, RF Minatom, FSUE NIKIET – 2004 – p.15.

Moiseev A.A. et al. (1975). Moiseev A.A., Ramzaev P.V. Cs –137 in Bioshere. M.: Atomizdat.– 1975. – p.180.

NIKIET (2004a) Report. Project: Andreeva Bay -Task 2. Technical-economical assessment (of versions) of handling spent nuclear fuel of shore technical base of Andreeva Bay of Kola Peninsula and assessment of influence on the environment. Volume 2., NIKIET after N.A. Dolezshalya. Moscow – 2004, – p.197.

NIKIET (2004b). Report. Project: Andreeva Bay -Task 2. Technical-economical assessment (of versions) of handling spent nuclear fuel of shore technical base of Andreeva Bay of Kola Peninsula and assessment of influence on the environment. Volume. 1. NIKIET after N.A. Dolezshalya. Moscow – 2004, p.182.

NRB-99 (1999). Standards of Radiation Safety. Ministry of Health of Russia. Moscow. 1999.

NRPA (2004). Andreeva Bay Radiation Protection Project. Measurements and results. NRPA, Norway. – 2004. – 84p.

Ostrovnoy Branch №2 (2001). Act of E Statement of examination of sanitary-hygienic condition of OF #2 FSUE "SevRAO"in Ostrovnoy from 23.08.2001, p.21.

Ostrovnoy Branch №2 (2004). Radiation-hygienic passport of organization FSUE “SevRAO” (OF # 2) for 2004. Branch in CATF Ostrovnoy, Murmansk region, - 2004 – p.5.

Report. Analysis of risk and the consequences of emergency situations with possible release of radioactive products on-site and off-site of SevRAO at the Andreeva Bay site. Report. 2004

RF Ministry of Health (1999). RF Ministry of Health # 239, Federal Supervision of Russia for Nuclear and Radiation Safety # 66, State Committee for Protection of the Environment # 288 from 21.06.99. Decree on Approvement of Methodic Guidance "Order of Introduction of Radiation – Hygienic Passport of Organizations and Territories".

Rosatom, undated Nuclear safety guarantee in IFA storage at FGUP SevRAO and FGUP Dal’RAO facilities. Decision № C1/5-7 section №1 of Scientific Technical Committee №5 of Rosatom

Sokolik G.A. et al. (2003). Influence of Organic Components on condition of Pu and Am in soil and soil solutions. Radiochemistry. 2003, #4. – p. 375.

Strategic master-plan (2004). Strategic Approaches to the Solution of Problems of Complex Decommissioning of the Russian Atomic Fleet Taken out Exploitation in North-West of Russia. Review prepared for preliminary consultations with the community in Murmansk, Severodvinsk and in Moscow on November 22-26, 2004, p.28.

Stepanets O.V. et al. (2003). Study of Role of Suspended Material and Soluble Organic Substances in Behavior and Migration of anthropogenic radionuclides in system river-sea. Radiochemistry. 2003, #4. – p. 382.

Troirtskaya M.N. et al. (1971). Troirtskaya M.N., Ramzaev P.V., Moiseev A.A. and et. Radioecology of landscape of Farthest North //Radioecology, V. 2. Edited by Klechkovsky V.M. M.: Atomizdat. – 1971. – p.720.

UNSCEAR (2000). Sources and Effects of Ionizing Exposure. Report of UNSCEAR 2000 with scientific annexes. Volume 1. Sources (part 1). Translation from English edited by academician of RAMS L.Ilin and prof.S.P.Yaroshenko. M., RADECON, 2002.

Vakulovsky C.M. (2003). Radiation Contamination of Water Objects in the USSR territory in 1967 – 2000. Dissertation for Scientific Degree of Doctor of Technical Science. Moscow – 2003. – p.66.

Vasiliev A.P. (2005). Workflow on decommissioning of NS and STB rehabilitation//Report at NTS 5 session #2 of Rosatom on March 9, 2005.

Contributing experts from Russia

Kochetkov O.A. *– Deputy director, chief of department, doctor of technical sciences*

Simakov A.V. *– Chief of laboratory, doctor of medical sciences*

Shandala N.K. *– Chief of laboratory, doctor of medical sciences*

Savkin M.N. *– Deputy director, chief of laboratory, doctor of technical sciences*

Abramov Yu.V. *– Senior researcher, doctor of technical sciences*

Barchukov V.G. *– Senior researcher, doctor of medical sciences*

Gimadova T.I. – *Chief of laboratory, doctor of technical sciences*

Grachev M. I. *– Chief of laboratory, doctor of medical sciences*

Klochkov V.N. *– Senior researcher, doctor of technical sciences*

Novikova N.Ya. *– Senior researcher, doctor of biological sciences*

Orlova E.I. *– Senior scientist, doctor of chemical sciences*

Rubtsov V.I. *– Chief of laboratory, doctor of technical sciences*

Sayapin N.P. *– Senior researcher, doctor of medical sciences*

Titov A.V. *– Senior sciences*

Tuteliyan O.E. – *Doctor of medical sciences*

Tsoviyanov A.G. *– Chief of laboratory, doctor of technical sciences*

Frolov G.P. *– Senior researcher, doctor of medical sciences*

Shinkarev S.I. *– Chief of laboratory, doctor of technical sciences*

Yatsenko V.N. *– Chief of laboratory, doctor of technical sciences*

Abbreviations and Acronyms

BDS – *block of dry storage*

CATF – *Closed Administrative-Territorial Formation*

CSSES - *Central State Sanitary Epidemiological Supervision*

FMBA - *Federal Medical-Biological Agency*

IAEA – *International Atomic Energy Agency*

ICRP – *International Commission on Radiological Protection*

INES – *International Nuclear Event Scale*

IFA – *irradiated fuel assembly*

ISL – *industrial-sanitary laboratory*

LRW – *liquid radioactive waste*

MIP - *means of individual protection*

MFA - *Ministry of Foreign Affairs (Norway)*

MSU – *medical sanitary unit*

NIKIET - *Research and Design Institute for Power Engineering*

NRB-99 – *Russian Federation Standards of Radiation Safety (NRB, 1999)*

NRPA – *Norwegian Radiation Protection Authority*

OSPORB-99 – *Sanitary rules for radiation safety, main sanitary rules of radioactive waste management*

PEK-50 – *a type of storage floating tank for liquid radioactive waste*

RAW – *Radioactive Waste*

RF – *Russian Federation*

RHW - *radiation-hazardous works*

SA – *surveillance area*

SEP – *spent extracted part*

SevRAO - *Northern Federal Enterprise for the Treatment of Radioactive Waste*

SHGC – *spent heat-generating construction*

***SLRW* –** *storage of liquid radioactive wastes*

***SMD* -** *scientific-methodical documents*

SNF – *spent nuclear fuel*

SRW – *solid radioactive waste*

SSEMA – *special service of emergency medical aid*

***SSZ* –** *sanitary shelter zone*

STB – *shore technical base*

STSSRW – *site of temporary storage of solid radioactive wastes*

TLD – *thermoluminescence dosimeter*

StrålevernRapport 2005:1
Virksomhetsplan 2005

StrålevernRapport 2005:2
Natural Radioactivity in Produced Water from the Norwegian Oil and Gas Industry in 2003

StrålevernRapport 2005:3
Kartlegging av historiske utslipp til Kjeller-området
og vurdering av mulige helsekonsekvenser

StrålevernRapport 2005:4
Assessment of environmental, health and safety consequences of decomissioning radioisotope thermal generators in NW Russia

StrålevernRapport 2005:5
Environmental Impact Assessments in Arctic Environments
Protection of plants and animals

StrålevernRapport 2005:6
Anbefaling for opplæring av medisinske fysikere i stråleterapi i Norge

StrålevernRapport 2005:6b
Øvingsoppgaver til Anbefaling for opplæring av medisinske fysikere i stråleterapi i Norge

StrålevernRapport 2005:7
Radionuclides in Marine and Terrestrial Mammals of Svalbard

StrålevernRapport 2005:8
Forvaltningsstrategi om magnetfelt og helse ved høyspentanlegg

StrålevernRapport 2005:9
Statens strålevern i Mammografiprogrammet
Databaseprogram for kvalitetskontrollresultater

StrålevernRapport 2005:10
Radioaktiv forurensing i sauekjøtt, ku- og geitemelk, 1988-2004

StrålevernRapport 2005:11
Tilsyn med medisinsk strålebruk ved fem Helseforetak i 2004
- etter ny forskrift om strålevern og bruk av stråling

StrålevernRapport 2005:12
Stråledose til screena kvinner i Mammografiprogrammet

StrålevernRapport 2005:13
Reprosessering og lagring av brukt reaktorbrensel i Russland
Status og alternativer

StrålevernRapport 2005:14
Norsk støtte til sikkerhetsarbeid ved russiske kjernekraftverk
Strategi for 2005 - 2007

StrålevernRapport 2005:15
Yrkeseksponering i Norge
Ioniserende stråling. Ikke-ioniserende stråling

StrålevernRapport 2005:16
Årsrapport fra persondosimetritjenesten ved Statens strålevern 2004

ISSN 0804-4910

Lobo Media 34428