NATO Security through Science Series - C:
Environmental Security

Radiation and Environmental Safety in North-West Russia

Edited by
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Springer

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This publication is supported by: The NATO Programme for Security through Science

Radiation and Environmental Safety in North-West Russia

Use of Impact Assessments and Risk Estimation

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Series C: Environmental Security

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Published in cooperation with NATO Public Diplomacy Division

Proceedings of the NATO Advanced Research Workshop on
Radiation and Environmental Safety in North-West Russia - Use of Impact
Assessments and Risk Estimation
Moscow, Russia
8–10 December 2004

A C.I.P. Catalogue record for this book is available from the Library of Congress.

ISBN-10 1-4020-4648-0 (PB)
ISBN-13 978-1-4020-4648-3 (PB)
ISBN-13 1-4020-4647-2 (HB)
ISBN-13 978-1-4020-4647-6 (HB)
ISBN-10 1-4020-4649-9 (e-book))
ISBN-13 978-1-4020-4649-0 (e-book)

Published by Springer,
P.O. Box 17, 3300 AA Dordrecht, The Netherlands.

www.springer.com

Printed on acid-free paper

Printed in the Netherlands.

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Preface

The NATO Advanced Research Workshop on *"Radiation and Environmental Safety in North-West Russia — Use of Impact Assessments and Risk Estimation*" was held in Moscow, Russia on December 8 - 10, 2004. The workshop was sponsored by the NATO Science Committee and Norwegian Radiation Protection Authority (NRPA) and organised jointly by Rostechnadzor and NRPA.

The objective of this workshop was to examine how scientific research and environmental studies, including the effects and distribution of radiation and radionuclides, can contribute to development of practical standards for protection of the environment and human health. The intention was to support operators and regulators involved in radioactive waste management projects in Northwest Russia.

The workshop attracted wide participation from relevant Russian and western organizations. International expertise from several related fields went together to produce a thorough understanding of the present status and how to develop the use of overall risk assessments and environmental impact assessments to ensure a sound use of resources when carrying out the tremendous work that must be carried out to clean up the cold war legacy. Important conclusions and recommendations have been produced and set out in the main report, providing a good basis for further development.

Such development should note that safety and environmental performance can be addressed at three levels:

a) Compliance-focused;

b) Beyond compliance, towards best practice; and

c) Continuous improvement.

The aim is to progress from a) to b) and eventually reach c). The levels refer both to operators' performance and regulators' and other stakeholders' expectations.

Fundamentally, compliance cannot be achieved without the application of environmental impact assessment and risk assessment – to judge whether protection objectives have been met. Major progress has been made towards developing common methodologies, although there are still improvements to be made, including a common understanding of objectives and interpretation of results. In addition, improved assessment capabilities are required to help distinguish multiply characterised options within a process of options assessment. In turn, this has to rely on broader holistic understanding of the issues as well as wide stakeholder involvement.

From the viewpoint of the proponents of any new development, the preparation of an environmental statement in parallel with project design provides a useful framework within which environmental considerations and design development can interact. Environmental analysis may indicate ways in which the project can be modified to avoid possible adverse effects, for example through considering more environmentally friendly alternatives. Taking these steps is likely to make the formal regulatory and planning approval stages run more smoothly.

The historical situation has resulted in that some sites in NW Russia fall short of compliance with environmental and long-term safety issues. Short term increases in risks may have to be accepted in order to eliminate long term risks. There is a concern that inflexible attitudes to compliance on health and short-term safety issues might hinder measures needed to achieve sustainable long term compliance.

While reiterating that compliance is the first, essential target, we should look beyond compliance, towards best practice. Too much focus on compliance can lead operators and regulators to take insufficient account of the wider picture. Furthermore, operators and regulators need to take a holistic view, balancing:

- Risks to health, environment and safety (workers and public);
- Short term and long term risks;
- Radiological and non-radiological risks;

- Major accidents (both preventing them and mitigating effects if they occur), and small incidents and normal situations.

Since these different risks are subject to different laws and regulations, supervised by different regulators, there must be effective co-operation between regulatory authorities. This presents a major challenge. Science and research must support the better assessment of risks, so as to allow better informed decision making. At the same time, improved procedures for efficient interfacing among the different authorities are required.

The workshop has demonstrated that continuing support of the international community in meeting this challenge is very much to be encouraged.

1. INTRODUCTION

REDUCING RISKS FROM THE NUCLEAR LEGACY

The nuclear legacy arising from the cold war includes a large number of obsolete nuclear weapons, nuclear powered vessels, and related bases and support facilities. Significant examples are located in North West Russia, on the Kola Peninsula and around the White Sea. At a number of these sites, there are installations in severe need of maintenance and/or rehabilitation as well as vessels and facilities which require decommissioning.

The primary objective of this workshop was to examine how scientific research and environmental studies, including effects and distribution of radiation and radionuclides, can contribute to development of practical standards for protection of the environment and human health. The output was intended to be useful to operators and regulators involved in radioactive waste management projects in Northwest Russia. Secondary objectives included the exchange of information on the application of risk assessment methods as applied to these projects, including the regulatory process applied to these projects.

During the work to improve the situation in North West Russia, large amounts of radioactive waste and spent nuclear fuel have to be handled safely and after the dismantling, those parts have to be disposed of properly. All of these steps may cause harm to the health of workers, the environment and the general population. Alternative options for improving the situation will involve different types of risk in different places and on different timeframes. Regulatory supervision of the development and implementation of specific projects is vital for the assurance of safety, and to achieve a balanced risk management process. Regulatory requirements are a vital input to the design of projects and early involvement of regulatory bodies will promote efficiency.

P. Strand et al. (eds.), Radiation and Environmental Safety in North-West Russia, 3–4.

Holistic View of Risk Assessments

Over recent years, a number of projects have been carried out to reduce the risk of accidents at the various nuclear sites in Russia. These projects have been backed by a number of countries, NGOs and establishments. Some of these projects have been completed successfully, whereas for others, the outcome has been more doubtful. But even for the apparently successful projects, there have often been raised questions if those projects were done in a most cost-efficient and secure manner and if the right prioritization of projects had been identified.

To support process of identifying of the optimal decisions on these issues, overall risk assessments have to be carried out. The estimation of risks is a convenient way of identifying those activities deserving priority consideration. However, risk reduction measures can never eliminate the risk associated with solving any given problem. Any option can only reduce the risks rather than remove it entirely. A balanced process is needed in evaluation of the risk profiles of the available options.

Environmental Impact Assessment

One of the important tools in risk assessment is Environmental Impact Assessment (EIA). EIAs enable environmental factors to be given due weight, along with economic or social factors, when applications for new developments, works, etc, are being considered.

For any major new development, an environmental statement developed in parallel with the project design provides a useful framework within which environmental considerations can be taken into account. Such analysis may indicate ways in which the project can be modified to minimise adverse effects. Taking these steps is likely to make the formal regulatory and planning approval stages run more smoothly.

This workshop was set up to get an overview of the Russian and international state of the art related to these issues. International expertise from several related fields has been brought together to achieve an understanding of risk assessment and environmental impact assessment methods. Focus has been given to the current status, development and application of these techniques. These techniques will support a proper process and the sound use of resources. The output will benefit the tremendous work that must be carried out to clean up the cold war legacy.

MAIN ACTIVITIES OF THE FEDERAL ENVIRONMENTAL, INDUSTRIAL AND NUCLEAR SUPERVISION SERVICE ON RADIATION AND ECOLOGICAL SAFETY ASSURANCE

A. MALYSHEV

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Functioning of the system for State Ecological Control (SEC) over the work of practically all the units performing economical activity, including radiation-hazardous facilities and enterprises, presents one of the basic directions of activity on radio-ecological safety assurance on the territory of the Russian Federation. Basic purposes and objectives of State ecological control over radiation-hazardous enterprises are stipulated by the Russian Federation legislation and regulatory legal statements in the sphere of environmental protection.

The Federal Environmental, Industrial and Nuclear Supervision Service, the organization which, at present, has taken over the functions of environmental protection, within the limits of the competence thereof carries out the realization of the policy on nature protection and state regulation of ecological safety as regards the enterprises and facilities of nuclear-industrial system by means of implementation of state ecological expertise, state ecological control and licensing.

In carrying out the SEC over the enterprises under the authority of Minatom /Ministry of Atomic Energy/ of Russia, state inspectors on environmental protection encounter one prime problem, and namely, usual negligence in realization of the nature protection measures that would require considerable material resources. In the context of deficient budget financing of enterprises the priorities in financing are given to implementation of the industrial programs at the sacrifice of nature protection ones. First of all, the reason of the above lies in the weakness of state mechanisms for insurance of ecologically hazardous activity, lack of the mechanism that would allow to attribute the nature protection costs to the products' cost price and promotion of the amortization accumulation funds with the prin-

P. Strand et al. (eds.), Radiation and Environmental Safety in North-West Russia, 5–7.

cipal objective to finance the work on decommissioning of nuclear- and radiation-hazardous facilities and rehabilitation of contaminated territories.

All the above mentioned is the topic for a joint work of the concerned Ministries and Agencies in preparation of the new bills.

Approval of the Federal Law 'On the Special Ecological Programs on Rehabilitation of Contaminated Sites of the Territories" gives a real possibility for additional allocations from foreign trade operations - with irradiated fuel assemblies (IFA) of nuclear reactors of foreign make, in order to cover the works related to rehabilitation of contaminated territories.

Organization of State Ecological Expertise (SEE) of pre-design and design materials, including radiation-hazardous facilities, is also an important function of the Service and its regional authorities. As this takes place, in most cases the state ecological expertise of such types of facilities is made at the federal level.

Whereas the condition of work on organization of SEE of the enterprises of Minatom of Russia that are subject to expertise, is quite satisfactory (the cases of declining the materials and negative SEE expert commissions' conclusions on submitted materials are extremely rare), a tendency was recently noted for qualitative deterioration of design materials, submission of incomplete set of materials and, as a result, delay in the terms for the start of expert commission's work, and in a number of cases –increase of the terms for SEE implementation caused by the need to address to additional materials.

For realization of the requirements of the Federal Law 'On the Environment Protection", a large scope of work on elaboration and approval of a large number of regulatory legal statements aimed at the following is to be fulfilled in the future:

- development of the regulatory legal documents on establishment of environment quality norms, norms of admissible discharges and emissions limits of radioactive substances into the environment, that would be in full compliance with up-to-date requirements of radiation safety and legislation of the Russian Federation;
- development and introduction of the norms of admissible level of radiation impact on the environment in production and use of nuclear energy, transport, reprocessing, storage and disposal /burial/ of radioactive waste and materials;
- development of the regulatory legal statements determining the status of contaminated territories, including polluted water areas,

depths of the earth (the sites for use of nuclear explosive technology should be highlighted as a separate problem), forests;

- development and introduction of the procedures for mandatory ecological certification and ecological audit as applied to radiation-hazardous enterprises;
- development of the regulatory documents on assessment of and compensation for the damage caused to the environment as a result of radioactive contamination;
- development of the ecological requirements specifying the structure of pre-design and design materials on substantiation of ecological safety at all the stages of realization of the projects on irradiated nuclear fuel reprocessing and radioactive waste management (transport, loading-unloading operations, reprocessing, storage, waste recovery), based on the norms of admissible level of radiation impact on the environment;
- development of an information system providing data on the condition of radiation and ecological safety in the operating organizations carrying out activity in the sphere of nuclear energy use, and the radiation situation at the adjacent territories, to the public, organs of the state authority of the Russian Federation, organs of the state authority of the Russian Federation Subjects and local governments;
- participation in the realization of international projects in the sphere of radiation-ecological safety and protection of the environment from ionizing radiation sources impact, that are implemented within the frameworks of IAEA's, ICRP's, UNO SCEAR's, WHO's, European Union's, IS&TC's programs, etc.

In conclusion I would like to wish a successful work to the participants of the workshop. We hope that fruitful exchange of opinions will help the Service in solution of the tasks mentioned above. We are looking forward to a closer co-operation in the issues related to the development of norms between Russian and international organizations. In its turn the Federal Environmental, Industrial and Nuclear Supervision Service is ready to take part in such co-operation.

2. SESSION I: APPLICATION OF INTERNATIONAL TREATIES AND RECOMMENDATIONS

Co-chairmen:

MIKHAIL BALONOV

IAEA, Moscow, RUSSIA

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ENVIRONMENTAL IMPACT ASSESSMENT IN A TRANSBOUNDARY CONTEXT

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1. Abstract

EIA is a widely recognised as a useful tool for planning an activity, as well as a systematic review of possible impacts of that activity and how to avoid the significant adverse impacts.

In international environmental law, transboundary issues related to environmental impact assessment are treated in several contexts, such as the UN/ECE Convention on Environmental Impact Assessment in a Transboundary Context (the Espoo Convention) and the EU directives 85/337 (on environmental assessment of projects) and 2001/42 (on environmental assessment of certain plans and programmes), as well as in the guidelines of the European development bank (EBRD) and the World Bank.

The Espoo Convention:

The Convention on Environmental Impact Assessment (EIA) in a Transboundary Context stipulates the obligations of Parties to assess the environmental impact of certain activities at an early stage of planning an activity. It also lays down the general obligation of States to notify and consult each other on all major projects under consideration that are likely to have a significant adverse environmental impact across national boundaries.

P. Strand et al. (eds.), Radiation and Environmental Safety in North-West Russia, 11–17.

The EIA Convention (or 'Espoo Convention') was adopted at Espoo (Finland) in 1991

The Convention entered into force on 10 September 1997.

What does the convention seek to achieve?

To give other Parties the possibility to know about, have information on, participate in and influence the planning of and decision on large-scale projects with potentially adverse effects

To give the public in the affected Party a possibility to get information about the project and let their views be known

Therefore:

Parties shall take all appropriate and effective measures to prevent, reduce and control significant adverse environmental impacts from proposed activities (ref. Article 2.1)

What are the main instruments of the convention?

Notification early in the planning process

Information_about the proposed activity and the possible adverse impacts

Possibility to comment on the proposed activity

Consultation about the project, including alternatives, mitigating measures and monitoring

Information about the outcome and how the views of the affected Party have been taken into account

2. General provisions

Each Party shall take the necessary legal, administrative or other measures to implement the provisions of this Convention, including, with respect to proposed activities listed in Appendix I that are likely to cause significant adverse transboundary impact, the establishment of an EIA procedure that permits public participation and preparation of the EIA documentation described in Appendix II. (Article 2.2)

2.1. ACTIVITIES COVERED BY THE CONVENTION

- Crude oil refineries, installations for gasification & liquefaction of coal/shale
- Large thermal power stations, nuclear power stations, other nuclear reactors
- Installations for production/enrichment of nuclear fuels, reprocessing of irradiated nuclear fuels or storage, disposal, processing of radioactive waste
- Major installations for smelting cast-iron, steel & production of non-ferrous metals
- Installations for the extraction, processing & transformation of asbestos
- Integrated chemical installations
- Construction of motorways, express roads, long-distance railway lines, large airports
- Large-diameter oil and gas pipelines
- Trading ports, large inland waterways & ports for inland-waterway traffic
- Installations for incineration/chemical treatment/landfill of toxic & dangerous wastes
- Large dams and reservoirs
- Major groundwater abstraction activities
- Large-scale pulp and paper manufacturing
- Major mining, on-site extraction & processing of metal ores/coal
- Offshore hydrocarbon production
- Major storage facilities for petroleum, petrochemical & chemical products
- Deforestation of large areas (Appendix I, abbreviated)

2.1.1.Notification: timing

For a proposed activity listed in Appendix I that is likely to cause a significant adverse transboundary impact, the Party of origin shall, for the purposes of ensuring adequate and effective consultations under Article 5, notify any Party which it considers may be an affected Party as early as possible and no later than when informing its own public about that proposed activity. (Article 3.1)

2.1.2. Notification: content

The notification shall include information of the proposed activity, including information about its possible transboundary effects; the nature of the proposed decision; and an indication of a reasonable time within which response is required (ref Article 3.2)

The notification may also include relevant information regarding the environmental impact assessment procedure, including an indication of the time schedule for transmittal of comments. (Ref. Article 3.5)

2.1.3. Notification: response from affected Party

The affected Party shall respond to the Party of origin within the time specified in the notification, acknowledging receipt of the notification, and shall indicate whether it intends to participate in the EIA procedure. (Article 3.3)

2.1.4. Notification: transmittal of information

An affected Party shall, at the request of the Party of origin, provide the latter with reasonably obtainable information relating to the potentially affected environment under the jurisdiction of the affected Party, where such information is necessary for the preparation of the EIA documentation. The information shall be furnished promptly and, as appropriate, through a joint body where one exists. (Art. 3.6)

2.1.5. Notification: public participation

The concerned Parties shall ensure that the public of the affected Party in the areas likely to be affected be informed of, and be provided with possibilities for making comments or objections on, the proposed activity, and for the transmittal of these comments or objections to the competent authority of the Party of origin, either directly to this authority or, where appropriate, through the Party of origin. (Article 3.8)

2.2. CONTENT OF THE EIA DOCUMENTATION

- Information to be included in the EIA documentation shall, as a minimum, contain, in accordance with Article 4:
- A description of the proposed activity and its purpose;
- A description, where appropriate, of reasonable alternatives to the proposed activity and also the no-action alternative;
- A description of the environment likely to be significantly affected by the proposed activity and its alternatives;
- A description of the potential environmental impact of the proposed activity and its alternatives and an estimation of its significance;
- A description of mitigation measures to keep adverse environmental impact to a minimum;
- An explicit indication of predictive methods and underlying assumptions as well as the relevant environmental data used;
- An identification of gaps in knowledge and uncertainties encountered in compiling the required information;
- Where appropriate, an outline for monitoring and management programmes and any plans for post-project analysis; and
- A non-technical summary including a visual presentation as appropriate (maps, graphs, etc.).

(Appendix II, abbreviated)

2.3. DISTRIBUTION OF EIA DOCUMENTATION

The Party of origin shall furnish the affected Party, as appropriate through a joint body where one exists, with the EIA documentation. The concerned Parties shall arrange for distribution of the documentation to the authorities and the public of the affected Party in the areas likely to be affected and for the submission of comments to the competent authority of the Party of origin, either directly to this authority or, where appropriate, through the Party of origin within a reasonable time before the final decision is taken on the proposed activity (Article 4.2)

2.4. CONSULTATION BETWEEN PARTIES

The Party of origin shall, after completion of the EIA documentation, without undue delay enter into consultations with the affected Party concerning, inter alia, the potential transboundary impact of the proposed activity and measures to reduce or eliminate its impact. Consultations may relate to possible alternatives to the proposed activity, including the no-action alternative and possible measures to mitigate significant adverse transboundary impact and to monitor the effects of such measures at the expense of the Party of origin; other forms of possible mutual assistance in reducing any significant adverse transboundary impact of the proposed activity; and any other appropriate matters relating to the proposed activity.

The Parties shall agree, at the commencement of such consultations, on a reasonable time frame for the duration of the consultation period. Any such consultations may be conducted through an appropriate joint body, where one exists. (Article 5)

3. Final Decision

The Parties shall ensure that, in the final decision on the proposed activity, due account is taken of the outcome of the EIA, including the EIA documentation, as well as the comments thereon received pursuant to Article 3, paragraph 8 and Article 4, paragraph 2, and the outcome of the consultations as referred to in Article 5. (Article 6.1)

3.1. TRANSMITTAL OF FINAL DECISION

The Party of origin shall provide to the affected Party the final decision on the proposed activity along with the reasons and considerations on which it was based. (Article 6.2)

3.2. POST-PROJECT ANALYSIS

Objectives of the post-project analysis include monitoring compliance with the conditions as set out in the authorization or approval of the activity and the effectiveness of mitigation measures; review of an impact for proper management and in order to cope with uncertainties, and verification of past predictions in order to transfer experience to future activities of the same type. (Appendix V, cfr. Article 7)

COOPERATION BETWEEN RESPONSIBLE AUTHORITIES, IDENTIFICATION OF PROTECTION OBJECTIVES, CLARIFICATION OF RISKS AND RECOMMENDATIONS TO THE REGULATORY PROCESS FOR NUCLEAR PROJECTS WITHIN THE RUSSIAN FEDERATION

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1. Introduction

Norway has been involved in nuclear safety projects in north-western Russia since 1995 through the Norwegian Plan of Action. All the projects are carried out within the Russian Federation regulatory framework, while taking due account of international guidance and recommendations as well as good practice in other countries.

Within the Plan of Action, Norwegian Radiation Protection Authority has established good cooperation with different Russian regulatory authorities as Regulatory Support Project with focus on regulatory aspects in connection with planning and accomplishing industry projects founded by Norway.

At present, dismantlement of multi-purpose nuclear submarines, rehabilitation of Andreyeva Bay and replacement of strontium radio-thermal generators (RTGs) in Russian lighthouses are the top priorities within Norwegian Plan of Action.

P. Strand et al. (eds.), Radiation and Environmental Safety in North-West Russia, 19–26.

2. Regulatory Support Project

The major goal of the Regulatory Support Project is to support Russian regulatory bodies when developing guidelines and requirements for planning, licensing and implementation of the industry projects. Another goal is that related industrial projects in Northwest Russia are managed in such a way as to efficiently secure an acceptable level of protection of human health and the environment, consistent with Russian Federation Law and with best international guidance and practice, as applicable within the Russian Federation.

The Regulatory Support Project involves the Nuclear, Industrial and Technological Regulatory Authority (NIERA) and Federal Authority Medbioextreme. NIERA is responsible for nuclear safety regulation and the nuclear safety assessment for non-defence related issues. In addition Environmental Impact Assessment and environmental protection related to radioactivity have been also be allocated as NIERA`s responsibilities. Medbioextreme regulates human health protection (workers and the public). In addition Medbioextreme regulates environmental aspects but only when it is of relevance to human radiation doses e.g. through the food chain pathways. Medbioextreme has responsibilities for regulating activities at the Andreèva Bay. Nuclear safety and safety assessment of defence-related issues are regulated by Ministry of Defence and Federal Atomic Energy Agency.

As can be seen, many of the tasks covered by the regulatory bodies overlap and therefore dialogue between these bodies is very important.

It is of interest to ensure that the regulatory system on nuclear safety and environmental protection in Russia is comprehensive and coherent. Given the wide range of protection issues, affecting different environments over different timescales, it can be difficult to manage all aspects without gaps and without unnecessary duplication of effort. Especially in implementing the licensing process and inspection programme it is very important to have good co-operation between different implementing bodies and authorities in Russia.

In Russia, as well as in other countries, there is a lack experience in much of the work necessary to improve the health, safety and environmental situation at Russian nuclear sites like Andreeva Bay. This applies both to the necessary practical measures and to the regulatory process related to those measures. To avoid delays in the licensing processes which should precede formal approval of new measures, there is a need to clarify who are the responsible authorities, what are their responsibilities, and what are their requirements in the approval process. This requires a thorough investigation of existing legislation and identification of the need for new regulations and guidelines. Co-operation with international experts in this work is helping to promote an approach to international standards where this is considered desirable or necessary. The involvement and participation of experts from the International Atomic Energy Agency (IAEA) is therefore much welcomed. To some extent, there is also a need to strengthen Russian regulatory authorities in this field, to ensure that they have the necessary powers to regulate activities according to Russian legislation.

The Regulatory Support Project co-operation has been focusing especially on development of regulatory documents that clarify the requirements for licensing of activities/measures and description/guidance related to the process of Environmental Impact Assessments. At present, both NIERA and the Federal Authority Medbioextreme are involved in regulatory co-operation related to planned activities and measures at Andreeva Bay. For both sites, existing regulatory framework has been examined and necessary additional regulatory documents have been identified and will be developed.

Special focus has been placed on the regulatory problems connected to the activities at the Andreeva Bay and decommissioning of RTGs.

2.1. REMEDIATION OF ADREEVA BAY

The responsible regulatory authority for the activities at Andreeva is Medbioextreme. The overall objective is to support application of relevant norms and standards, within the scope of Medbioextreme regulatory responsibilities, for SevRAO sites and related capabilities for radiological risk assessment. The combined scope of all projects set up within NRPA/Medbioextreme collaborations intended to include all aspects of human radiological risks: on-site and off-site, workers and public, human and environmental health protection; routine and abnormal situations and emergencies; facility operation, decommissioning and rehabilitation, and short-term and long-term time frames. The scope of this project will be focused on protection of the public off-site in routine and abnormal situations during operation, decommissioning and rehabilitation, and after delicensing of the site.

The regulatory requirements should preferably be in place before industrial projects start, since they are part of the industrial project specification. However, these requirements should not be so prescriptive as to unnecessarily constrain the identification of safe and practical options. Regulatory development needs to allow for and match the industrial project development, in stages.

Priority topics are being studied specifically to support the effective and efficient regulation of the priority industrial projects identified by SevRAO. In particular, it is understood that rules and norms exist for normal operations at nuclear facilities. However, because of past practice and changes in circumstances, some sites, or parts of sites, which are now the responsibility of SevRAO, are in a condition such that they do not fall within normal regulatory conditions. There is a need for corrective actions to return the facilities to normal conditions. It is therefore necessary to define how radiation protection regulations can be applied to these abnormal situations.

2.1.1. Protection of workers

Medbioextreme in cooperation with different Russian institutes recognises the necessity for development of regulatory guidance for improving radiological protection in abnormal situations, based on the application of radiological risk assessment.

The objective here is to develop regulatory guidance for working safely in abnormal conditions based on the application of risk assessment methods. The focus is on protection measures for workers.

Four Tasks are planned:

1. Analysis of the design approach from main technological operations with radioactive waste and spent nuclear fuel, and related dose estimation.
2. Methodological guidance for radiation dose monitoring and development of common sanitary rules for workers.
3. Analysis of emergency situations and radiation dose consequences.
4. Development of sanitary rules for nuclear protection of industrial activities related to SNF handling.

2.1.2. Protection of Public

Similar to protection of workers, Medbioextreme in cooperation with different Russian institutes recognise necessity for development of criteria and guidance for rehabilitation of radioactively contaminated land and delicensing of nuclear facilities.

he focus here is on protection measures for members of the public during operations to improve the radiation situation at the sites and with respect to release of sites for other uses.

Two Main Tasks are planned:

1. Development of understanding of current radiation situation in the environment of the Shore Technical Bases (STBs) Andreeva Bay and Gremikha village.

2. Development of radiation hygiene criteria and norms for STBs.

2.1.3. Medical Emergency Preparedness and Response

The focus here is on improving capabilities to respond to medical and radiological aspects of emergency preparedness and response at SevRAO facilities, which may arise as a result of future activities at these sites. This includes provision of regulatory advice as well as planning of radiological and medical emergencies management.

Four Tasks are planned:

1. Analysis of current status of emergency regulation and medical sanitary provision for emergency response at SevRAO enterprises

2. Development of regulatory document on ‘Emergency Planning and Response’

3. Development of guidance documents on the application of the regulations.

4. Education and Training

2.2. DECOMMISSIONING OF RTG'S

NIERA has recognised that there is a need for upgrading the regulatory framework for the safe decommissioning and disposal of the RTGs, taking account of the magnitude of the problem and the high hazard associated with the RTGs, the upcoming work on their decommissioning and disposal as well as the lack of experience in this area. NIERA has therefore proposed to start a regulatory project that would be carried out in parallel with the ongoing industrial project.

The aim of the project is to upgrade the existing regulatory framework of the Russian Federation for the safe decommissioning and disposal of RTGs, with a focus on the following priority areas:

1. regulatory requirements and regulations,
2. licensing and authorisations,
3. supervision over the radiological safety, and
4. emergency preparedness.

Other areas such as preparation and certification of the personnel and information of the public may also be considered, but will not be addressed within this cooperation.

3. Project Coordination

Project managers are identified for each project and project plans are developed in each case. These project teams include western TSO participation, allowing scope for contributions from western experience, international guidance and external technical review.

The work of all mentioned projects is being coordinated within a common schedule. Each project is initially planned to last two years, with the first year devoted to technical development within the project teams and the second year devoted to discussion and review with outside bodies.

Further regulatory support work is anticipated, to be based on the progress made at the sites in the coming two years.

4. Conclusions

For Andreeva Bay projects in particular, consideration needs to be given to the need for an overall safety case which demonstrates to regulators and others that an appropriate balance is achieved between the need to take action to manage the spent fuel safely in the long term; the short term increase in risks associated with different operations; and the interests of all parties in ensuring that an appropriate allocation of resources is made to protect human health, of both public and workers, now and in the future, and also to protect the environment. NRPA looks for continued and improving cooperation with all involved parties, including organisations within the Russian Federation and other countries, as well as international organisations, especially the IAEA and NATO.

It is an important issue that, in some regulatory frameworks, regulatory guidance is provided by regulators setting out advice on how an operator may expect to meet the precise laws and regulations. This guidance can be useful to operators in developing their licence application because it sets out potentially relevant lines of reasoning by which compliance may be demonstrated. However, operators may also offer alternative strategies which, subject to regulatory review, still demonstrate compliance with the regulations. This approach allows and promotes all relevant experience to be brought to the table for consideration, while retaining a clear set of separate and transparent responsibilities. It also promotes an effective solution to difficult problems which not yet been 100% characterised. Early prescription can be useful top guide the way forward, but can be unhelpful when many of the issues have still to be resolved and better understood. Delay in provision of advice until everything is clear could lead to reduced safety in the interim period.

It has to be admitted that a generally more prescriptive approach appears to adopted in the USA and the Russian Federation, compared with Nordic countries. A more prescriptive approach has the advantage of legal and technical clarity, but it may result in too early definition of regulatory requirements and hence less than optimal spending of limited resources while still not necessarily managing safety in the way intended.

The NRPA looks forward to continuing collaboration with RF regulatory authorities and other organisations. Apart from the delivery of good results from the projects outlined above, a continuing good understanding of the priorities within the operator organisations is vital. The intention therefore is to follow all the industrial project developments, as regards strategic objectives and planning, to ensure that future regulatory support work most readily meets regulatory demands on radiation protection supervision.

RESPONSIBILITIES OF FEDERAL MEDICAL BIOLOGICAL AGENCY ON ENSURING OF RADIATION SAFETY IN THE NORTH-WEST REGION OF THE RUSSIAN FEDERATION

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1. Abstract

Federal Medical-Biological Agency is an executive authority which carries out functions of control and supervision in the field of sanitary-and-epidemiologic well-being of workers of separate industries with especially dangerous working conditions and the population of separate territories, including the closed administrative-territorial formations, municipal formations in which nuclear power plants are located.

The structure of agency includes 83 medical sanitary units (MSU), 9 clinical hospitals(CH), 63 centers of state sanitary epidemiological supervision (CSSES), 15 scientific research institutes (SRI) in which more than 11 thousand doctors, about 23 thousand average medical personnel, 1,5 thousand scientific employees work. At present three projects are implemented jointly with NRPA on ensuring of radiation safety at operations at Sev RAO. They cover radiation safety issues during operations, rehabilitation and emergency preparedness on and off site of SevRAO.

The report presents brief information about Federal Medical-Biological Agency, its structure and primary responsibilities regarding ensuring sanitary-epidemiological safety in North-West region of the Russian Federation and its cooperation with Norwegian Radiation Protection Authority.

P. Strand et al. (eds.), Radiation and Environmental Safety in North-West Russia, 27–31.

According to the decree of the President of the Russian Federation from October, 11 2004 1304 “About Federal Medical-Biological Agency” FMBA was established on the basis of abolished Federal Department of Medical –Biological and Extreme Problems at the RF Ministry of Health.

In development of the named Decree by the Decision of the Government of the Russian Federation from December, 15, 2004 789 « Questions of Federal Medical-Biological Agency » was issued and the Provision of Federal Medical-Biological Agency is under the process of coordination in the RF Government.

The Agency is established with the purpose of development of system of specialized sanitary-and-epidemiological supervision and medical sanitary maintenance of workers of the organizations of separate industries with especially dangerous working conditions. The Agency is a executive authority which carries out functions of control and supervision in the field of sanitary-and-epidemiologic well-being of workers of separate industries with especially dangerous working conditions (including at preparation and performance of space flights on space piloted programs, implementation of diving works) and the population of separate territories, including the closed administrative-territorial formations, municipal formations in which nuclear power plants are located, a complex "Baikonur" and Baikonur city, and functions on rendering the state services and management of the state property in the field of medical sanitary maintenance of workers of the served organizations and the population of served territories, including rendering of the medical and medical-social help, granting of services in the field of sanatorium treatment, the organization of forensic, judicial - psychiatric examinations, a donor service of blood, human organ and tissue transplantation.

It is necessary to note, that before administrative reform declared in 2004 and corresponding decrees of the RF President, Federal Department “Medbioextrem” carried out only separate functions of the executive authority.

After the President’s decree the FMBA status has increased. The agency is included into 5 executive authorities subordinated to the RF Ministry of Health and Social Development. FMBA will continue to improve its work on maintenance and regulation of radiation safety of use of nuclear power in North-West region of the Russian Federation.

At present the agency is a uniform complex that includes treatment-and-prophylactic, sanitary-and-hygienic, research, educational, pharmaceutical establishments, located in 33 subjects of the Russian Federation.

The structure of agency includes 83 medical sanitary units (MSU), 9 clinical hospitals(CH), 63 centers of state sanitary epidemiological supervision (CSSES), 15 scientific research institutes (SRI) in which more than 11 thousand doctors, about 23 thousand average medical personnel, 1,5 thousand scientific employees work.

Activity of this big collective of scientists, doctors and engineers is dedicated first of all to perfection of medical sanitary maintenance of the attached contingents, the number of which now makes 2,3 million person, including 143,7 thousand people who have contact with dangerous factors and work in hazard working conditions.

The Agency responsibilities cover:

- enterprises of nuclear-fuel cycle; nuclear power plants, research reactors; enterprises for NS decommissioning and etc.
- objects of chemical weapon storage and destruction; biotechnologies;
- objects of performance of piloted space flights;
- enterprises with works connected with rocket fuel components;
- and special state sanitary-and-epidemiologic supervision is carried out at these facilities accordingly.

2. In the North-West Region

1. Nuclear facilities are located in 4 of 11 subjects of North-West administrative district. These are two acting nuclear power plants (Leningrad, Kola). Four organizations represent FMBA in the given region:
2. CSSES and MSU # 38,118;
3. MSU #122 and CSSES #122 attend SRI and industrial nuclear enterprises in Saint Petersburg;
4. MSU #120 and CSSES #122 with branches in Murmansk and Snezshnogorsk attend Northern fleet area, Murmansk Sea Steam Navigation, Shipbuilding Company "Nerpa" in Snezshnogorsk, SevRAO;

5. CMSU # 58 and CSSES#58 attend facilities for nuclear submarines decommissioning of FSUE "Zvezdochka" and "Sevmashpredpreyatie" (Archangelsk region, Severodvinsk).

Institute of Biophysics in Moscow and SRI of Industrial and Marine Medicine in Saint Petersburg are charged with scientific - hygienic support of works on medical sanitary maintenance of the personnel in all mentioned enterprises.

A positive experience of cooperation with Norwegian Radiation Protection Authority contributes a lot to the development of works on radiation safety in the North-West region.

Besides Scientific Technical Center for Radiation Chemical Hygiene carried out separate pieces of work, including those in the framework of cooperation between the Norwegian Radiation Protection Authority (NRPA) in the field of radiation safety regulation in Andreeva Bay in 2003-2004.

Two projects were implemented.

- Project 1: Scenario and Analyses of Large-scale Emergencies with Possible Releases of Radioactive Substances On and Off Sites of “SevRAO” in Andreeva Bay
- Project 2: Provision of Nuclear and Radiation Safety at Operations at “SevRAO” in Andreeva Bay

At present Institute of Biophysics continues cooperation with NRPA:

- Project 1: Development of Regulatory Guidance for Improving Radiological Protection in Abnormal Situations, based on the Application of Radiological Risk Assessment
- Project 2: Development of Criteria and Guidance for Rehabilitation of Radioactively Contaminated Land and De-licensing of Nuclear Facilities
- Project 3: Improvement of Medical and Radiological Aspects of Emergency Preparedness and Response at “SevRAO” Facilities

The medical sanitary safety ensuring at especially dangerous facilities includes regulating-legal maintenance of activity of subordinated establishments. In this respect Institute of Biophysics and SRI IMM provide FMBA with invaluable assistance.

Only in 2003, 2004 these institutes developed and the RF chief medical officer approved over 20 sanitary-and-epidemiologic norms and rules, over

80 hygienic specifications in the field of radiation safety at use of nuclear power, chemical safety at chemical weapon destruction, rocket fuel components and etc. All of the documents have the status of regulating-legal certificates (acts) and were registered by the RF Ministry of Justice.

Among them there are such documents as sanitary rules for designing and operation of the nuclear power plants, hygienic requirements to designing and operation of nuclear reactors of research assignment, maintenance of radiation safety the Russian Federation ports at call and parking of nuclear vessels, vessels of nuclear-technology service and floating power units of nuclear thermal power plants in them, maintenance of radiation safety at designing, construction, operation and taking out of exploitation of nuclear thermal power stations of low power on the basis of the floating power block and many other things.

I hope that with the support of our foreign partners we will be able to develop high quality documents regarding planning and implementation of nuclear projects in North-West region of the Russian Federation

ROSATOM EXPERIENCE IN ARRANGEMENT OF WORKS ON REHABILITATION OF RADIATION-HAZARDOUS FACILITIES

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1. History of the Issue

In 2000 according to the Russian Federation Government's Decree a number of radiation-hazardous facilities located in the Northern Region and the Far East were placed from the Defense Ministry under the authority of Minatom of Russia /the Ministry of Atomic Energy/. Two enterprises with location in the mentioned regions were established to manage the above facilities.

The temporary storage site of the Northern Region located in the Andreeva Bay constituted an especial ecological hazard for the environment. The Cold War had left its heavy heritage of tens thousand tons of radioactive waste. Problems accumulated for this period were so huge that the solution thereof only by Minatom of Russia would have required several decades.

Having impartially assessed the real situation, exactly in the first year Minatom of Russia defined 4 main directions for the work, as follows: development of a necessary infrastructure for the ensuring of safe labor conditions for SevRAO staff; creation of conditions for spent nuclear fuel management; creation of conditions for radioactive waste management; preparation for rehabilitation of a distressed building of the former spent nuclear fuel storage.

P. Strand et al. (eds.), Radiation and Environmental Safety in North-West Russia, 33–39.

Just the above directions were brought forward at the workshop for international experts in Idaho Falls in 2001, where the Russian delegation succeeded in drawing the participants' attention to the existing problems.

The workshop results became a basis for the next IAEA CEG meeting in May 2002. By that time the experts of donor-countries had time to consider the results of the workshop in Idaho Falls, and at the meeting the proposals on technical assistance challenges were made.

Thus, the following agreements were achieved:

1. The Government of the Kingdom of Norway has undertaken rendering assistance in development of an infrastructure required for safety ensuring.
2. The Government of the United Kingdom has undertaken rendering assistance in spent nuclear fuel removal.
3. The Government of the Kingdom of Sweden has undertaken rendering assistance in radioactive waste management.

Just these directions of international co-operation have been realizing in practice from that time.

Progress in Realization of International Co-operation Directions for the Past Years.

The realization could be started only in case of availability of definite planning studies. As such a plan, the lay-out diagram of the facilities required for functioning of the temporary storage site in the Andreeva Bay, was suggested for reviewing.

Basic facilities that should be built or redesigned were shown in the diagram. The total term for work performance was calculated as equal to five years. Certainly, this term failed, but it may be accepted as a checkpoint for creation of a complex of buildings.

Absence of an all-round approach in reality led to the state, when the works were independently performed by the participants of the international co-operation in the above-mentioned directions.

The following organizations of the donor-countries are taking part in the international co-operation:

- On behalf of the Kingdom of Norway the contracts were concluded with the Finnmark Province Board and the Norwegian Radiation Protection Authority;

- On behalf of the United Kingdom all the contracts were concluded with the RVE NUKEM;
- On behalf of the Kingdom of Sweden the contracts were concluded with the Swedish International Project.

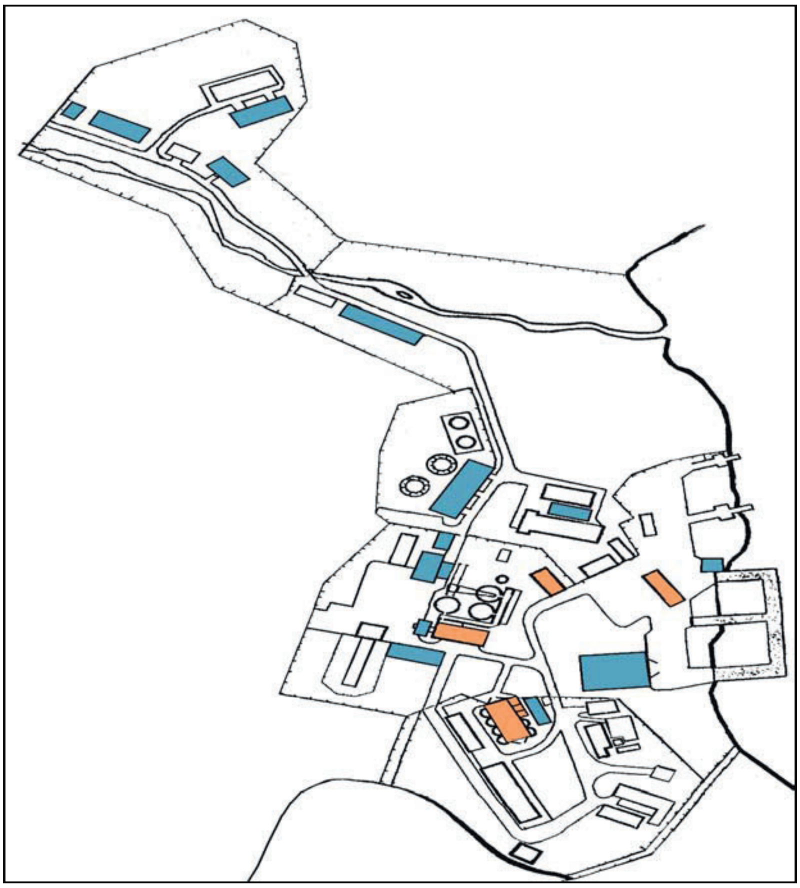

Fig. 1. Facilities required for functioning of the temporary storage site in the Andreeva Bay.

For the period since 2001 till the present time the following have been accomplished within the frameworks of co-operation with the Kingdom of Norway:

- Construction of the building, where offices and amenity rooms are located;

- Construction of the changing room for staff;
- Construction of the guard house;
- Construction of the buildings for entry control points;
- Repair of 15 kilometres of the access road to the administrative territory;
- Redesign of the main water-pipeline of water supply system;
- Survey of radiation state of the engineering territory;
- Topographical and geological surveys.

At the same time under the contracts with RVE NUKEM the following have been fulfilled:

- Training of the participants of team-work to the requirements for preparation of design proposals and the management skills for the projects;
- Manufacture, delivery as a complete set and installation of two disinfestations posts;
- Making and installation of the bay for decontamination near the spent nuclear fuel storages;
- Installation of the temporary shelter above the spent nuclear fuel storage No. 3A;
- Selection of an option for spent nuclear fuel management in the Andreeva Bay;
- Elaboration of the Declaration on Intention to create an infrastructure for spent nuclear fuel management;
- Delivery of the radiobiological laboratory as a complete set and approval thereof for operation;
- Providing staff with individual protection means and radiation monitoring devices;
- Examination of the distressed building of the former spent nuclear fuel storage;
- Training of staff to the issues on radiation safety ensuring.

The funds allocated by the Kingdom of Sweden have been spent for the following:

- Implementation of the feasibility study for ensuring management of solid radioactive waste;
- Implementation of a feasibility study for ensuring management of liquid radioactive waste;
- Construction of the separate physical protection components;
- Development of the project on public relations.

Owing to the Russian funds the urgent ecological problems have been solved at the territory of the Andreeva Bay for the period since 2001 till the present time. They concerned the improvement of upkeep conditions for radioactive waste located on the open sites. Thus, near 3,500 tons of radioactive waste were reprocessed, near 2,200 tons, mainly, of metallic radioactive waste were sorted and disposed for storage in temporary packages. The above allowed considerably to improve working conditions at the engineering territory, to ensure realization of a part of the international projects connected with the construction of decontamination bay and shelter above the spent nuclear fuel storage No. 3A. Without a preliminary preparation the realization of these international projects would have been impossible.

The mentioned list shows that a large volume of work has been performed. At the same time it is obvious that till nowadays we have no facilities for the work on spent nuclear fuel removal and conditioning of radioactive waste.

For the years of team-work the participants of the international co-operation in the Andreeva Bay have developed good business relations and improved mutual understanding, which allow to combine efforts of the foreign investors for solution of more complicated tasks. Thus, in 2004 a document, namely, Declaration on Intention to create an infrastructure for preparation of spent nuclear fuel for its shipment to the Production Association “Mayak” for reprocessing, was elaborated. The further work in this direction is connected with development of a Substantiation of Investments. Since the works with spent nuclear fuel deal with production of radioactive waste, under the offer of the Russian Party the representatives of the United Kingdom and the Kingdom of Sweden combined their efforts for development of a unified document. The document is called “Substantiation of Investments for the Creation of an Infrastructure for Management of Spent Nuclear Fuel and Radioactive Waste”. At present an active preparation of suggestions, which will allow to conclude a trilateral contract between Russia, the United Kingdom and the Kingdom of Sweden, is in progress. Implementation of this contract is planned in 2005. There are intentions to involve about 10 Russian institutes and design organizations in the work under the above contract.

As a result of the project realization an opportunity arises to get a document, which allows to carry out designing and construction of the facilities shown in the Diagram.

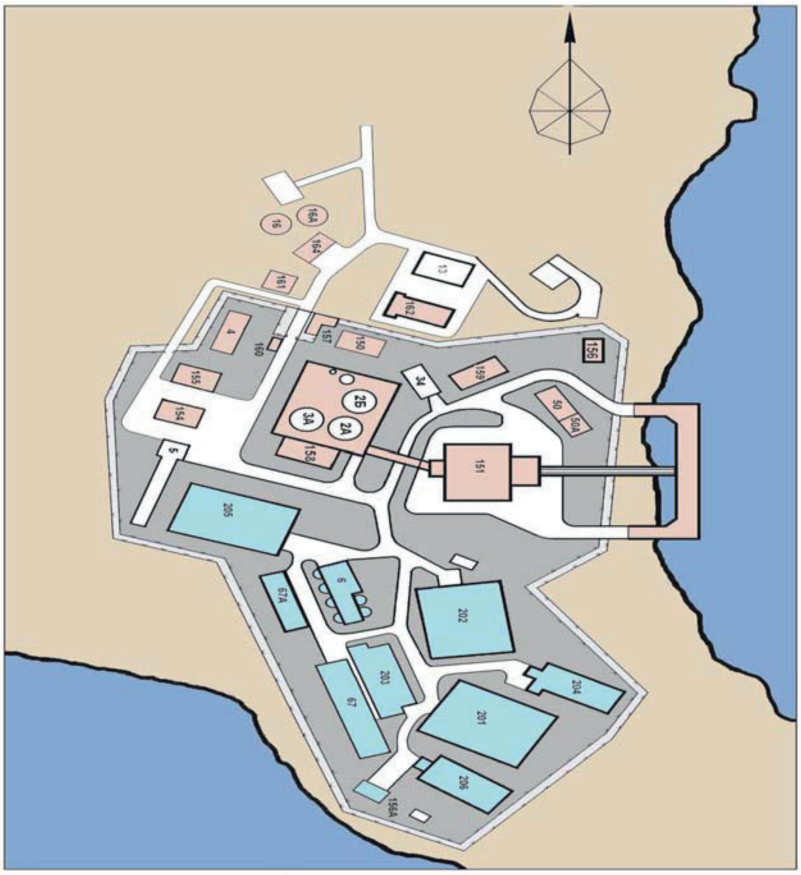

Fig. 2. Designing and construction of the facilities.

2. Perspective Co-operation

Taking due account of the complication of the tasks being solved and a sufficient large number of the participants of this work, in accordance with the IAEA Contact-Expert Group’s decision in November 2004, a Coordination Group was established for the works in the Andreeva Bay. The Group's objective is to manage the projects that are financed by foreign investors, and to carry out planning of the further works. The Group is led by Mr. Victor Akhunov, the Head of Rosatom Department on Decommissioning the Nuclear- and Radiation-Hazardous Facilities.

Having made a thorough analysis of all the volume of forthcoming works, the Group prepared a three-year work plan, which we are going to offer for the joint international co-operation. The implementation of this plan will allow to realize the designated measures in the shortest period and to start practical works with spent nuclear fuel and radioactive waste. Comparison of two presented diagrams shows that the Russian Party does not change the first intention and concentrates the efforts on the directions suggested in 2001, namely, as follows: spent nuclear fuel management, radioactive waste management, rehabilitation of Building No. 5, and creation of an infrastructure for works ensuring.

Along with the international co-operation the realization of the given plan will require serious work executing also by the Russian organizations, including the regulatory authorities. The projects that are being developed will demand obtaining experts' conclusions on their ecological and technical safety. That is why success will be likely only, if such an interaction is arranged at the earliest stages of development of the projects. Under the above condition the prepared design documents will fully comply with the Russian legislation requirements. Rosatom hopes for the understanding of complication of the problems in the Andreeva Bay by the Russian regulatory authorities and for their assistance in solution thereof.

SESSION I: SUMMARY AND CONCLUSIONS

1. Summary

Five reports, both of generic nature and containing practical results of environmental remediation performed at the Kola Peninsula, were presented at the introductory session of the Workshop.

In the first report entitled ‘Policy and systems for implementation of nuclear projects within the Northwest Russia’ Mr. V. Akhunov, Rosatom, presented wide overview of current activities aiming to resolve critical issues associated with location of numerous nuclear installations as well as spent nuclear fuel (SNF) and radioactive waste (RAW) storage facilities at the Kola Peninsula. These include Russian nuclear Navy and civilian (icebreaker) fleet, coastal naval and civilian bases, RAW processing facilities, etc. Long-term efforts of Rosatom enterprises substantially enforced by foreign counterparts from a number of European countries (Norway, UK, Sweden, France and others) as well as Canada and USA have led to gradual reduction of the number of dangerous facilities and improvement of radiation conditions. There is considerable progress in decommissioning of nuclear submarines, treatment of SNF and RAW, remediation of areas with radioactive residues such as Andreeva Bay.

Ms. I. Swensen from the Norwegian Ministry of Environment presented international treaties and recommendations on environmental protection and specifically focused on Convention on Environmental Impact Assessment in a Transboundary Context (Espoo, 1991). The Espoo Convention, in force since 1997, sets out the obligations of Parties to assess the environmental impact of certain activities at an early stage of planning. It also lays down the general obligation of States to notify and consult each other on all major projects under consideration that are likely to have a significant adverse environmental impact across borders. The Espoo Convention’s conditions would be quite applicable to Kola radiation situation if Russia was its Party.

P. Strand et al. (eds.), Radiation and Environmental Safety in North-West Russia, 41–43.

Ms. M. Sneve, NRPA, Norway, described present level of international cooperation between Russian and Norwegian regulatory authorities responsible for human health and environment protection in process of decommissioning of nuclear installations, safe management of SNF and RAW and remediation of radio contaminated land at the Kola Peninsula. As potential radiation impact, if not properly regulated, could have adverse effects both on humans and biota, the Regulatory Support Project is of major importance. It helps to identify protection objectives, clarify risks and develop recommendations to the regulatory process for nuclear projects within the Russian Federation.

The next paper was given by Mr. Yu. Grigoriev, Rosatom, who demonstrated considerable progress in remediation of Andreeva Bay facilities. Some years ago the SNF and RAW storage facilities located at the Andreeva Bay territory were in unsafe conditions that caused a lot of concern in local population and Norwegian public (Andreeva Bay is located just few tens kilometers from the Russian-Norwegian border). Russian-Norwegian cooperation in remediation of both SNF and RAW storage facilities and radio contaminated land started few years ago and already resulted in substantial improvement of local radiation conditions. New sanitary inspection facilities needed for occupational work with radiation sources have been constructed and put in operation, SNF and RAW storage facilities modernized, plots contaminated with radio nuclides partially remediated. It is planned that by 2007 remediation of the Andreeva Bay territory and facilities will be completed, and this place will be of no more concern as a regional source of environmental radioactive contamination.

V. Romanov, Medbioextreme, Russia, introduced his institution as the Federal Medical and Biological Agency at the Russian Ministry of Health. Medbioextreme is responsible for health of both workers and general public as well as for environmental protection at s.c. special enterprises and in adjacent areas. These enterprises comprise nuclear fuel cycle facilities, space industry, etc. Medbioextreme provides for safe conditions of work and life at the Kola Peninsula with the help of its research institutes and medical divisions by establishing of safety standards and provision for their application.

2. Conclusions

1. Mitigation of post-Cold War consequences in terms of potentially dangerous nuclear facilities, materials and contaminated land at the Kola

Peninsula, North-West Russia, is an important Russian national and international nuclear safety and security problem.

2. During recent years, long-term efforts of Rosatom enterprises substantially enforced by foreign counterparts from a number of European countries as well as Canada and USA have led to gradual reduction of the number of dangerous facilities and improvement of radiation conditions. There is considerable progress in decommissioning of nuclear submarines, treatment of SNF and RAW, remediation of areas with radioactive residues such as Andreeva Bay.
3. From the discussions held during the Workshop it follows that appropriate contemporary radiological criteria and safety standards relevant to land remediation and environmental protection should be developed in order to promote further work at the Kola Peninsula.
4. Nuclear-related projects being implemented at the Kola Peninsula represent a unique example of intensive and successful international collaboration in the field of nuclear, waste and radiation safety for the public, environment and occupational workers. This international collaboration should be based on internationally agreed radiological criteria and safety standards and should provide for their application. The IAEA is prepared to assist the participants of the Kola nuclear-related projects in justification of relevant criteria and standards as well as in environmental impact assessment.
5. Safety requirements and national responsibilities for safe management of both SNF and RAW are covered by the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management, in force since 2001. International acceptance of and support for the Kola nuclear-related projects and other similar activities in Russia could be further improved when Russia becomes a Party of this important international convention.

3. SESSION II: ENVIRONMENTAL, HEALTH AND SAFETY RISKS

Co-chairmen:

A. JUBIER
Program director, NATO

C. BERGMAN

SIP, SWEDEN

AMAP. AN INTERNATIONAL COOPERATION WITH FOCUS ON THE NORHERN ENVIRONMENTS

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1. Abstract

The Arctic Monitoring and Assessment Programme (AMAP) was initiated by the ministers within the Arctic Council to monitor radioactivity and other pollutants and assess their possible consequences in the Arctic. AMAP has so far produced two assessment reports, published in 1997 and 2002, respectively. In the future, there is not seen a need for such frequent updates of the assessments and there are ongoing discussion for the future use of the unique knowledge base that has been build up during the AMAP work.

Key words: AMAP Arctic Council radioactivity monitoring assessment EIA

2. Background

In 1991, the ministers of the Arctic countries decided to initiate the Arctic Monitoring and Assessment Programme (AMAP) (AMAP 2002)under the Arctic Environmental Protection Strategy to

P. Strand et al. (eds.), Radiation and Environmental Safety in North-West Russia, 47–50.

- Produce comprehensive integrated assessment reports on the status and trends of the conditions of the Arctic ecosystem
- Identify possible causes for the changing conditions
- Detect emerging problems, their possible causes and the potential risk to Arctic ecosystems including indigenous peoples an the other Arctic residents
- Recommend actions required to reduce risks to Arctic ecosystems

To achieve these goals, AMAP has set up an assessment strategy, monitoring and QA/QC programmes. To help in preparing the data for the assessments, five thematic data centers have been set up. Four of them are collecting data on freshwater, marine, terrestrial and atmospheric environments, whereas the fifth is collecting data on environmental concentrations as well as sources for radioactivity to the Arctic environment.

The data to be used in the assessments are collected through the national implementation plans and special projects initiated by AMAP or other parties. The eight Arctic countries and organizations representing indigenous peoples in the Arctic are permanent participants in AMAP. In addition, some non-arctic European countries and NGOs are observers in AMAP.

3. Assessments

Within the AMAP, two overall assessments have been carried out. They have been covering several pollutants such as persistent organic pollutants, heavy metals and radioactivity, as well as general issues including human health and changing pathways. The first assessment was concluded in 1997 (AMAP 1997) with a supplementary work on the scientific basis for the assessment published in 1998 (AMAP 1998). The second assessment was concluded in 2002, with a series of supplementary works on the scientific background published the following years. For radioactivity, the scientific report was published in 2004 (AMAP 2004).

3.1. FIRST ASSESSMENT

The first assessment was to a large degree compiling information on the levels of radioactive contamination from the beginning of the nuclear age, studying doses to populations, vulnerable groups and areas, global and local sources of contamination, as well as sources with a potential for future contamination of the Arctic.

Some of the conclusions from that assessment are that

- The arctic populations and ecosystems are more vulnerable to radioactive contaminations than at more temperate areas.
- The main sources for large scale radioactive contamination of the arctic are the atmospheric nuclear tests in the 50'ies and 60'ies, releases from the Sellafield reprocessing plant in the UK especially in the early 70'ies and fallout from the Chernobyl accident in 1986. Thus, the levels of radioactive contamination in the Arctic are generally decreasing.
- At some location, e.g. near some locations where nuclear explosions have been used for engineering purposes, specific sources have caused local contamination.
- The greatest radiological treats in the Arctic areas are connected to the potential of accidents at nuclear sites, such as nuclear power plants or at sites where nuclear powered vessels are being managed.

3.2. SECOND ASSESSMENT

In the second assessment, (AMAP 2002, AMAP 2004) the findings in the first assessment where followed up on. Except for the loss of the later recovered submarine Kursk in the Barents Sea, no new real or potential sources of radioactive contamination were brought to the groups attention. But new information had been made available on a number of sources, both due to former classified information being made open and due to changes at the sites.

To follow up changes caused by the many projects to enhance the safety at nuclear installation, especially in North-West Russia, the assessment was going through and evaluating nuclear safety initiatives. A conclusion of this analysis was that it is important to prioritize correctly between the possible actions and that environmental impact assessments (EIAs) should be use to prioritize the actions.

Another new topic in the 2nd assessment was the protection of flora and fauna from radiation. Traditionally, radiation protection has been based on the assumption that if man is protected, then the environment is also protected. The inadequacies in this assumption have the last years been broadly recognized, and it is now a number of ongoing projects to assess the environmental consequences of radiation (Brown, Thørring, Hosseini, 2003). AMAP has taken a role to do a work on this issue from an Arctic perspective.

4. Future Work

Over a number of years, an unique knowledge base and cooperation has been build up in the AMAP expert group for radioactivity. Presently, as long as no new sources comes into play, the contamination levels keeps on descending, but anyhow, monitoring programs should be kept running, both to increase our knowledge of long term behavior of radioactive contamination, and in case of new accidents, to have a well prepared monitoring system, and a good knowledge of the existing contamination levels.

AMAP's assessments should on a routine basis be updated to incorporate new knowledge and changes in the relevant risk sites. In addition to these updates, overall risk and impact assessments should be done. These are further to be used as tools for prioritizing future actions to decrease risks. An important part of these assessments are EIAs, AMAP should work to ensure that EIAs are been employed and that there is a common understanding throughout the Arctic to how to do and interpret an EIA.

The ongoing work on protection of the environment and vulnerability analysis should continue, as AMAP has already built up a considerable knowledge base on these issues.

References

1. AMAP 1997, AMAP Working Group, *Arctic Pollution Issues: A State of the Arctic Environment Report*, AMAP Oslo, ISBN 82-7655-060-6
2. AMAP 1998, AMAP Assessment Report,: *Arctic Pollution Issues, Arctic Monitoring and Assessment Programme*, (AMAP), Oslo Norway . xii+859 pp. ISBN 82-7655-061-4
3. AMAP 2002, AMAP Working Group, *Arctic Pollution 2002*, AMAP, Oslo. ISBN 82-7971-015-9
4. AMAP 2004. AMAP Assessment 2002: *Radioactivity in the Arctic. Arctic Monitoring and Assessment Programme* (AMAP), Oslo, Norway. Xi+100 pp. ISBN 82-7971-017-5
5. Brown J.E., Thørring H. and Hosseini A. (2003), *The "EPIC" Impact Assessment Framework – A Deliverable Report for EU Funded Project ICA2-CT-2000-10032* (NRPA, Østerås, 2003) pp. 175.

RISK MANAGEMENT IN THE STORAGE AND CONDITIONING OF SPENT NUCLEAR FUEL AT ANDREEVA BAY

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1. Abstract

Andreeva Bay was the main coastal technical base (CTB) of the Russian Navy's Northern Fleet for refuelling its nuclear submarines and the interim storage of their spent fuel and associated solid and liquid radioactive wastes (SRW and LRW). It is located in the north-west of the Kola Peninsula on the western shore of Zapadnaya Litsa Bay approximately 100 km north-west of Murmansk. On the site there are 21220 spent fuel assemblies (SFA) in 3030 canisters stored in three 'temporary, dry" storage tanks. Some 10% of the fuel is believed to be significantly damaged. There are also 60 SFA stored in obsolete, Type 6 casks. The original, damaged spent fuel pool storage facility, Building 5, contains active sludges, is contaminated and has high radiation levels within and outside.

The United Kingdom Government has undertaken to fund necessary activities to improve the management of SNF at Andreeva Bay. This will involve the recovery, repackaging and safe, secure storage of the SNF currently stored at site. The project is complex with uncertainties over the environmental state of the site and the stored spent fuel, the developing

P. Strand et al. (eds.), Radiation and Environmental Safety in North-West Russia, 51–84.

regulatory state, the availability and timing of funding, etc., and complex interactions between several Russian organisations and western partners with diverse responsibilities and interests. As a consequence the UK has taken a total risk management to ensure that the project is completed safely and securely to time, cost and quality with the minimum adverse effect on the environment. In it the project/programme risks are identified, prioritised and managed together with the environmental and safety risks.

An Options study has been undertaken to determine optimum strategy for the SNF management. A preliminary screening of the options has been undertaken and selection criteria have been developed. Eight detailed options for fuel removal, repacking and transport were evaluated. Two options were selected for comprehensive analysis. These will be assessed to the preliminary design level, according to the Russian OBIN approach.

Details of this total approach are given. In addition, a series of interim measures are described, which have been undertaken to improve the radiological, etc, safety on the site and enable necessary characterisation, etc, studies to continue.

2. Introduction

Andreeva Bay was the main coastal technical base (CTB) of the Russian Navy's Northern Fleet for refuelling its nuclear submarines and the interim storage of their spent fuel and associated solid and liquid radioactive wastes (SRW and LRW). The site is located in the north-west of the Kola Peninsula on the coastal strip of the Barents Sea in Motovsky Gulf on the western shore of Zapadnaya Litsa Bay. It is approximately 300 miles north of the Arctic Circle and 100 km north-west of the port of Murmansk.

The key features of the site are:

- It was established in 1961 for the refuelling of nuclear-powered submarines (NS) and icebreakers. It is within a "closed" area, but no longer operational and has been transferred to the civilian control of Rosatom;
- It was used for interim storage of spent nuclear fuel (SNF) from first and second generation submarines and the associated solid and liquid radioactive wastes;
- Originally the SNF was stored in cooling ponds in Building 5. In 1982 a major leak occurred in that facility. The rate of leakage of

radioactively contaminated water from the pond became excessive. Three unused, 1000 m^3, liquid effluent tanks were converted quickly into “dry” storage units (DSU) by inserting metal tubes for fuel storage and filling of the interspaces with concrete;

- 21,220 spent fuel assemblies (SFA) in 3030 canisters were transferred into the three “dry” storage tanks. About 10% of these SFAs are believed to be significantly damaged;
- There are also a few type 6 casks, containing a total of 60 SFA. These are stored on top of Tanks 2A and 2B under their covers;
- The former SNF pond storage facility remains highly contaminated and has high radiation fields in some areas;
- Very large inventories of solid radioactive waste are remain on the site; and
- Large parts of the site are contaminated above the levels requiring remedial action, as stipulated by Russian legislation.

3. The Involvement and Objectives of the United Kingdom

UK involvement with the problems of Andreeva Bay began in March 1999 with a pledge of £5M assistance to tackle the problem of decommissioning redundant nuclear submarines. This allocation was later merged into the UK's Programme of Assistance on the Nuclear Legacy in Former Soviet Union (FSU) countries. As a result the UK has undertaken to fund necessary activities to improve the management of SNF at Andreeva Bay. The programme is managed within the UK Government by its Department of Trade and Industry (DTI).

The main UK objectives are to facilitate Russian efforts, through practical projects:

- To help Russia implement a “cradle to grave” approach to making ***spent nuclear fuel*** from submarines ***safe and secure***. It is hoped that this can be done as quickly as possible in order to substantially reduce the threat of a serious nuclear incident, whilst ensuring value for money and proper use of funding.

- To put in place a structure and process by which projects receiving DTI FSU funding can be successfully implemented by Russia, monitored and controlled.
- To promote the establishment by Russia of plans for the long-term management of their existing nuclear liabilities.
- To promote knowledge transfer and education in project management tools, including all aspects of risk management, and best practice in the management of radioactive wastes, safety and environmental impacts.
- To demonstrate commitment by the UK Government to improving the safety and security of the nuclear legacy within NW Russia.

The UK is working closely with other donor countries providing the practical means to help Russia meet their targets for the complete dismantling of their decommissioned NS fleet and the safe storage of SNF stocks by 2010.

4. Background to the Site and its Problems

An aerial photograph of the site is shown in Figure 1. The site is ~20 hectares in area. It can be reached by ship or for limited loads by road. The relief of the area is low, mountainous and strongly opened out. At the site the buildings vary between one and three storeys. They are of an industrial construction and were built for certain specific operations. The nearest settlements are:

- Nerpichye (1.8 km)
- Bolshaya Lopatka (2.4 km)
- The closed settlements of Zaozersk (8 km to east) and Vidyaevo (45 km to east)
- Pechenga railway station (60 km to the west)

Fig. 1. An aerial View of the Andreeva Bay CTB

The climate in the region is maritime polar with long winters (November to April), which limit outdoor operations, and short summers. The average annual temperature is only 0.3°C and 11.3°C for the warmest month. The average annual precipitation is 603 mm, being a mixture of rain and snow. Precipitation occurs on average 198 days every year.

The layout of the site is detailed in Figure 2.

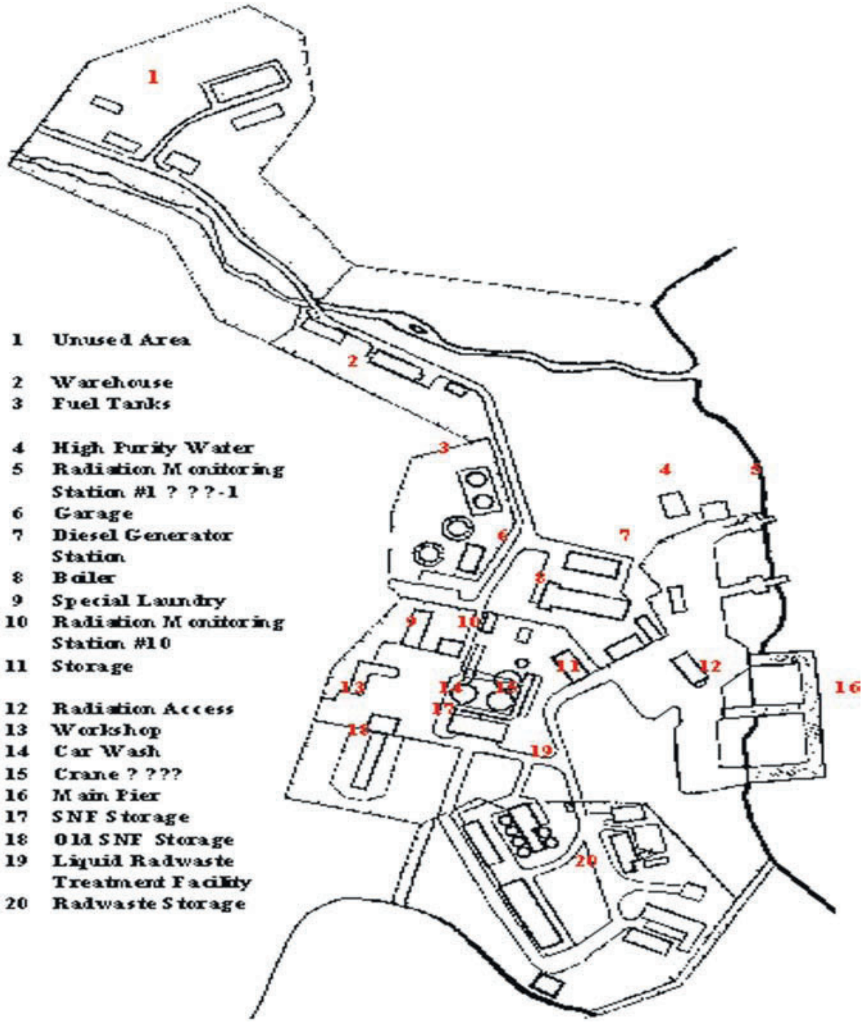

Fig. 2. A Plan of the main Facilities within the Andreeva Bay Coastal Technical Base

The main site facilities include:

- A stationary type PMK-67 pier;
- SNF storage facility – three half-buried tanks, converted into dry storage units for spent fuel assemblies (SFA): DSU 1 (structure 3A), DSU 2 (structure 2A) and DSU 3 (structure 2B). These are shown in Figure 3;
- An open pad for storage of casks with SNF;
- A pool-type SNF storage facility – Building 5, shut down, but not decommissioned;
- LRW storage facility – Tanks 2C and 2D;
- LRW treatment building – Building 1;
- A storage facility for high-level concentrates of treated LRW – Building 6;

Structures 7, 7A, 7B, 7C, 7D, 7E, 67, 67A, “montejus” pad – for SRW storage.

The infrastructure at the site is generally in a very poor state. The auxiliary buildings and facilities, e.g. boiler house, diesel power station, fire-station, tanks for residual fuel oil, etc, are mostly inoperable and beyond repair. Others, such as the vehicle washing facility, workshops and telephone exchange, have already been demolished. Before any projects can be implemented to take care of the SNF and RW, the general infrastructure, i.e. roads, electricity supply, water supply, sewers, buildings for personnel, etc, and safety infrastructure, e.g. fences, radiation control, personnel dosimetry, physical protection, need to be re-established.

The protective barriers of the SNF and SRW storage facilities have degraded over time. This has resulted in some leakage of radionuclides into the soil and contamination of the structures. This requires remedial action.

Removal of the SNF from their stores and subsequent decontamination and controlled demolition will take many years to complete. The high dose levels near and at the storage tanks restrict personnel access.

Fig. 3. A View of the DSUs 2A, 2B and 3A

The SFA were generated from several classes of the first two generations of Russian nuclear submarines. The number of fuel assemblies in store from first generation submarines is relatively small. The operational service of these submarines was terminated, when the activity in their reactor coolant due to fuel leakage had reached the maximum permissible limit. The majority of the stored spent fuel assemblies came from the first cores of the second-generation submarines. These were also removed from service, when their reactor coolant activity had reached the maximum permissible level.

Water has entered into the interspaces in the DSUs. The origin of the water is uncertain. It is most likely from infiltration from above, but might be from groundwater ingress. If the latter is the case, this implies loss of tank containment. The water is becoming increasingly active. Tank 3A is particularly corroded with a higher potential for loss of containment and activity release. For this reason it is considered as a higher risk area.

Building 5 contains active sludges and the majority of the building is contaminated. Radiation levels within and outside of Building 5 are high and will limit the remediation activities that can be completed on this building. Measuring equipment mounted on the outside wall near to the leak indicated radiation levels of 15 mGy/h. It was considered that contaminated water from the building might still be leaking into the nearby watercourse. The main issue is the stability of the building. On-site observations suggest that the building may not be very stable. Its collapse could result in the mobilisation of the sludge, ~10 Te and a possible active dust release. Both could contaminate the local area.

Activity levels of 150 MBq/L have been recorded at the bottom of the pond. Some 3000 m^3 of the water with an activity of 110 TBq leaked out of the pond. In August 1982, the lower parts of the walls and floor of the pool were covered with approximately 600 m^3 of concrete. Measurements made in 1995 showed that the brook running from Building 5 was contaminated, as was a total area of 1300 m^2. The sea has also been contamination via pond water moving through the natural watercourse. This is illustrated by high contents of radionuclides (caesium-137, cobalt-60, plutonium-239, 240) in the bottom sediments.

The SRW on-site is contained within steel drums and containers. The majority of the waste is operational equipment and PPE. Radiation measurements undertaken with the assistance of Norway indicate that contamination is already spreading. It is thought that some of the drums contain ion exchange resins and some may be leaking. As the contamination is mobile, SRW was given a high risk rating.

The LRW tanks are within the basement of Building 6. The tank contents are seeping into the ground, and into the building itself. It is not thought that the tanks are bunded. The possibility of LRW spreading is high and was therefore given a high risk rating.

5. SNF Transport and Handling

The transportation of SNF into or out of Andreeva Bay is a difficult process, complicated by the lack of a railway to the site. The road from Murmansk to Andreeva Bay does not meet safety requirements and cannot realistically be used for the transportation of SNF. Consequently, SNF has been shipped in and out by sea. There is one stationary quay and two floating piers at present, all of which are in a poor condition.

KMP-40 class port crane can be used for loading and unloading SNF from the concrete tanks and the containers placed on the outdoor storage pad. It has an arm length of 30 m and a payload capacity of 40 Te. The crane is in working condition but it is uncertain whether it meets safety requirements.

The 40 Te cranes cannot accommodate loads greater than 35 Te and hence cannot be used for 40-tonne containers. Their use is also restricted by the weather conditions. They cannot be used above wind speeds of 18 m/s, which is typical for the area throughout winter.

The road from the tanks 2A, 2B and 3A to the pier is not safe and needs rebuilding. In particular, there is a steep turn on the way to the pier (at about 25 degrees). The BeLAZ-540 truck used to transport fuel on-site has a high centre of gravity. This compromises its stability and hence fails to meet safety requirements.

6. The Radiological Situation at Andreeva Bay

In general, the level of radioactivity on 60-70% of the engineering site is within permitted limits in respect of both external irradiation and radioactive contamination. The remaining 30% has high levels of activity, which inhibits the safe remediation. The affected areas are shown in Figure 4.

At the start of the project there was a basic lack of hygiene and decontamination units for personnel, clothing and equipment, etc. Dosimetry equipment, automated control, observation and notification systems were generally unavailable. The radiological situation in the SNF storage area is poor and dangerous in some areas. The highest radiation levels reach 3 mSv/h above tank 2A. The radiation levels in the transport corridor of Building 5 are very high. Exposure to this area would result in personnel receiving unsafe doses. Gamma-dose rates in some areas of the outer wall reach 5-10 μSv/h.

At the storage pad for SRW the radiation conditions are also unsatisfactory. A maximum equivalent dose rate of up to 3-4 mSv/h has been recorded in facility No. 7. There are high levels of radioactive contamination, particularly inside Building 5, on the storage pad for SRW and in areas near to the brook by Building 5, where the maximum equivalent dose reaches 1 mSv/h.

Fig. 4. Gamma radiation at 0.1m height

The SNF assemblies have not been inspected since 1995. Removal of the SNF from their stores and subsequent decontamination and controlled demolition will take many years to complete. Due to the high dose levels near and at the storage tanks personnel access will be limited.

Radiation safety has mainly been provided mostly by administrative measures. Physical protection at the storage site does not comply with current requirements and requires updating. Engineering systems for radiation safety need to be replaced. There were no radiation detectors for personnel entering the SRW storage pads and RW storage sites (old and new). Personnel working in controlled areas, where they have to work with SNF and RW, are restricted by the high radiation doses.

7. Key Issues for safe, secure SNF Management

Figure 5 summarises the key issues on the site in respect of the safe management of the stored SNF. For the SNF recovery, three categories of fuel have been identified. The first is intact fuel, which can potentially be removed and handled without major difficulties. The second is fuel, which is damaged, whether by corrosion, degradation, accident, etc. Hence it may or may not be intact and may require special equipment and techniques to recover and repackage it. Damaged or not these fuels are judged reprocessable, which is Russia's preferred, indeed currently required, long-term management strategy for such fuel. However, there will potentially be fuel, which cannot be reprocessed in current plant and because of its limited quantity may not warrant the development of new processes and plant to treat it. This fuel is judged to be non-reprocessable.

The major issues associated with SNF recovery relate to:

1) the current state of the fuel and the methods for recovering it from the DSUs and ultimately transporting it off-site:
2) the site infrastructure needed to support these operations;
3) the waste management infrastructure necessary to deal with the waste arisings associated with the construction/renovation of facilities to recover the spent fuel and generated during the actual fuel recovery and repackaging operations;
4) the safety systems and support needed to ensure that the SNF recovery and transportation is effected safely and all exposures are ALARA;

5) the regulatory oversight and procedures used to ensure that the work is carried out safely and in accordance with all relevant regulations;

6) the management of the DSUs prior to, during and post recovery of the fuel;

7) issues of existing and potential radionuclide leakage to the ground, surface and groundwaters and the air; from the DSUs and areas proposed for the new facilities; and

8) the immediate and long-term management of Building 5, the former pool SNF storage facility.

8. The Total Risk Management Approach

The project is complex with uncertainties over the environmental state of the site and the stored spent fuel, an uncertain and developing regulatory state, complex interactions with the involvement of several Russian organisations and western partners with diverse responsibilities and interests, and uncertainties on the availability and timing of funding, etc.

As a consequence the UK has taken a total risk management approach to ensuring the safe, secure and effective delivery of the project for the recovery and containment of the SNF. In this approach the project/programme risks are managed in parallel and together with the environmental and safety risks. This has involved:

1) identification of risks;

2) analysis and assessment of the risks, e.g. as in an environmental impact assessment or safety assessment;

3) identification of techniques for managing the risks, where needed;

4) implementation of the risk management measures;

5) monitoring the effectiveness of the measures; and

6) reviewing, feedback and modification of the risk reduction strategy, as needed.

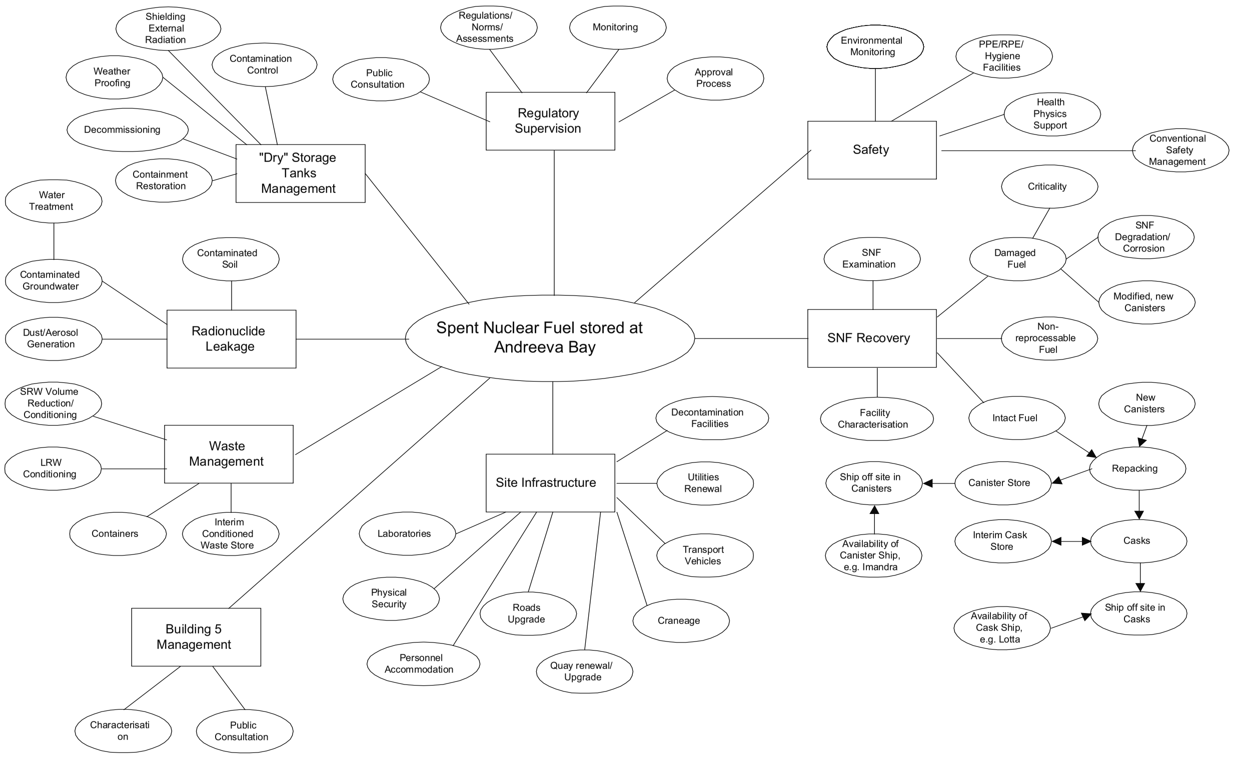

Fig. 5. Key Issues in the Management of SNF at Andreeva Bay

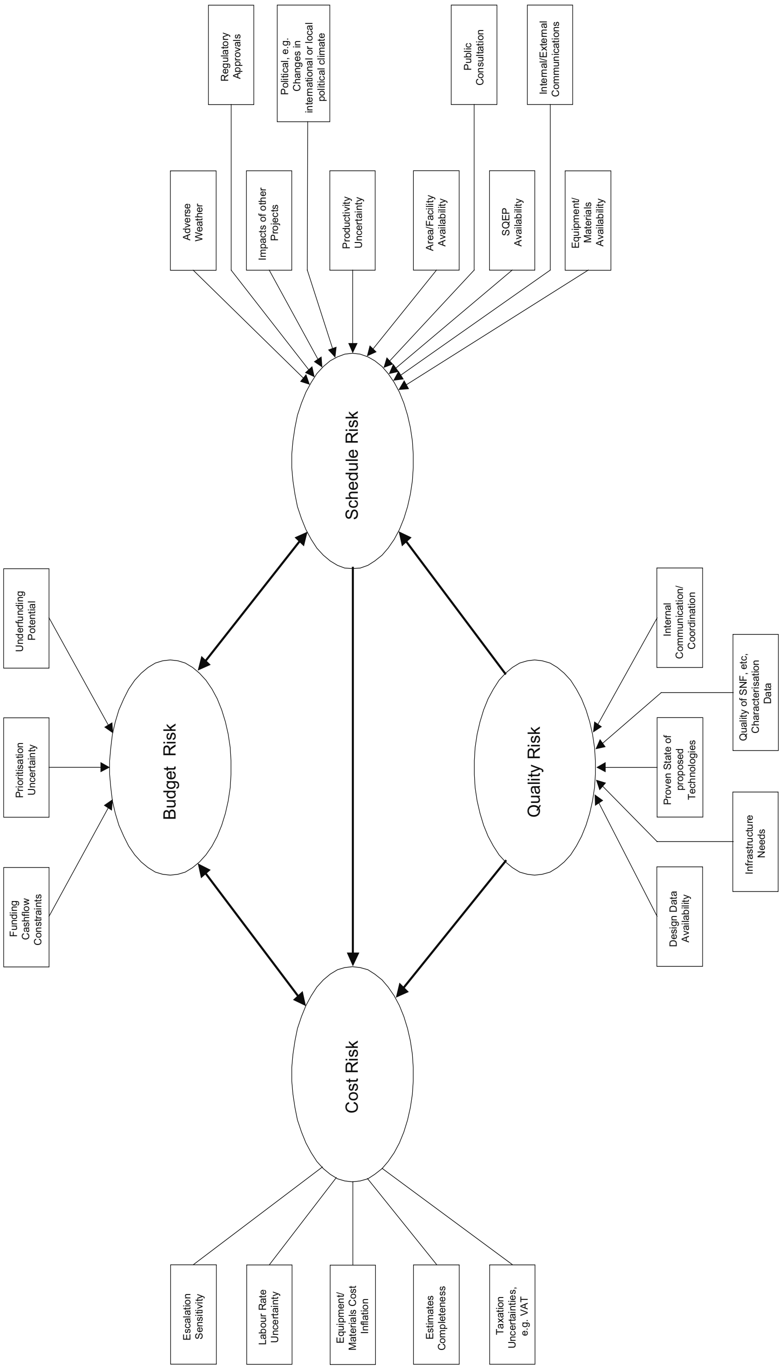

Fig. 6. Key Factors considered in the Management of Programme Risks

This has involved considering for all categories of risk, both the probability of an event occurring and the consequences when it does. This enables appropriate mitigating action to be taken, if needed. In this approach it has been necessary to consider:

a) safety both under normal operating conditions and in the event of accidents. This covers both worker and public safety and radiological and non-radiological risks;

b) risks to the environment. These include risks associated with the consumption of materials, generation of wastes, discharges, voluntary or otherwise, to air, water and soil. It considers radiological and non-radiological, chemical, toxic and hazardous releases under normal and accident conditions;

c) risks to the performance of the project, i.e. project/programme risks. These are the risks to the successful completion of the project in meeting its objectives, e.g. time, cost and performance. They include financial, commercial, human resource, quality and technical risks. They also include political and security risks, changes in the outlook and drivers of donors or implementers may influence the successful completion of the project.

The risk management process is iterative, developing and on-going. In undertaking the initial assessment risks were identified under the following categories:

1) commercial;
2) contractual;
3) resourcing;
4) technical;
5) safety;
6) environmental; and
7) political.

Threats were identified, which adversely affected performance of the project. They were assigned a probability factor, PF, which was the probability that the threatened event will occur during the course of the programme. These were rated on a scale from 1 to 5, ranging from improbable to almost certain and with probabilities of <10% through to

>80%. They were also assigned an impact factor on a scale of 1 to 4, ranging from insignificant to a major deficiency in meeting the specification, etc. This factor assessed the impact of the threatened event upon occurrence upon technical performance, cost, etc.

The product of PF and each impact factor (cost, programme and performance) gave the risk factor. Risk factors of 1-2 were assessed as insignificant, 3-4 as low, 5 to 9 as medium and 10-20 were high risks. The risks were then listed in a Risk Register in decreasing order of rating for mitigation, i.e. most serious risks at the top. This register gave the priority order for devising risk avoidance, mitigation and contingency measures.

From the outset a major effort has been made to identify and prioritise all of the factors and threats, which could affect the successful delivery of the project.

For the programme risk four main types of risk were identified. They are summarized in Figure 6.

1) cost risk;
2) budget risk;
3) quality risk; and
4) schedule risk.

The cost risk considered the basis for the initial cost estimate in terms of its completeness, its sensitivity to escalation with labour, materials, equipment, etc, inflation and other uncertainties, such as obtaining full exemption from Value added tax (VAT). The budget risk considered cash flow, priorities and constraints. The quality risk included information, design, procedures and workmanship, which could all affect the quality of the delivered solution. These included the quality of the existing characterisation data on the SNF, state of current facilities, contamination, etc, availability of adequate design codes, etc, the proven state of the proposed technical solutions, the availability of necessary infrastructure and the effectiveness of communications and coordination between the various organisations, e.g. Rosatom, SevRAO, the various Russian subcontractors, the regulatory bodies and the different donors, involved in delivering the solution. The last component is Schedule risk. This considered all of the factors, which could affect the delivery of the selected management option within an acceptable timescale. These ranged from the impact of extended adverse weather, the availability at the appropriate time of the necessary facilities, equipment, suitably qualified staff, etc, regulatory approvals, public consultation, dependencies upon/interactions with other projects, such as the refurbishment/construction of new radwaste treatment and storage facilities. Finally, there are the uncertainties over changes in priorities in the political climate locally, nationally and internationally.

The strategy has been to endeavour to control the components of these risks, wherever possible, and to have mitigation measures and contingency plans for the remainder. A few risks, such as changes in donor priorities for funding, could have very major impacts on the project with little scope for mitigation. For many of the others practical measures can and have been devised.

9. Uncertainties and Risks in Regulation

A key factor in the programme risk was the developing regulatory system and regulations. Russia has a complex system of regulatory bodies and norms. However, they have not been developed to deal with the needs to recover situations on existing contaminated, dilapidated sites.

The regulatory system is being developed and improved for this situation with Norwegian assistance. However, its current state and the compatibility of the timescale for its change compared to the project timescales do pose significant risks to the project and programme. Particular uncertainties of concern are:

- Regulatory hierarchy, coordination and agreement between regulators on respective areas of responsibility and interfaces at local, regional and national and military and civilian levels. Concept of Lead Regulator. Concept/position of “Statutory Consultees”. Levels of approvals and time impact.
- Timing of regulatory inputs and roles in process selection, etc.
- Accepted standard assessment tools, e.g. approved models, methodologies, codes, default parameters, standard scenarios, etc.
- Future of wastes from site remediation e.g. contaminated soils, etc, and decommissioning. Absence of waste disposal facilities, waste acceptance criteria, etc. Hence uncertainty for any waste conditioning, etc. Acceptability and implications of on-site disposal.
- Final state of site and the remediation criteria. Acceptability of natural attenuation, subject to acceptable on-site safety, as potential management strategy.

- Treatment of site state by regulators as an "Emergency Situation", i.e. ICRP "Intervention" condition rather than as a "Practice". UK judgement would be "Practice". Differences in judgement criteria.
- Interpretation of ALARA/ALARP for optimisation of operational and environmental exposures and impacts and behaviour towards de minimus exposures, etc.
- Concepts of Best Practicable Environmental Option (BPEO), Best Practicable Means (BPM), etc, for deciding on management strategies. Role in EIA process. Methods for deciding balances between gaseous and liquid discharges and solid and liquid waste arisings.
- Basis for Discharge and Acceptable Residual Contamination Limits. Potential use of "Case by Case" basis with modelling. Interpretation of international treaty obligations, e.g. OSPAR.
- Bases for judgements on balances between risks, exposures, and impacts today and in future.

10. Initial Scoping Assessment of Threats and Risks

As an initial step the source terms at Andreeva Bay were considered. The approximate inventory was established.

Table 1. Source Terms Inventory

Stream	Activity	Comments
Tanks 2A, 2B and 3A	10^{16} Bq	21220 SFA
Casks (in the Tanks 2A and 2B enclosures)		60 SFA
Building 5	10^{13} Bq	110 TBq, likely mostly ^{137}Cs has leaked into the soil and some has migrated 500 –600 m to sea.
SRW	10^{13} Bq	
LRW	2 x 10^{12} Bq	
Contaminated territory		

The source terms were then ranked in terms of stability of containment, i.e. how likely could material be released from the various containments. They were ranked in terms of natural evolution and incident. "Natural Evolution" considered the threat posed from leaving the waste / fuel in its current containment without intervention. Incident considered terrorist or onsite operation activities.

Table 2. Source Threats

Sources	Natural Evolution	Incident
SNF Tanks 2A and 2B	Medium	Low/Medium
SNF Tank 3A	High	Low/Medium
SNF Casks	Low	
Building 5	Low / Medium	Medium/High
SRW	High	
LRW	High	
Contaminated Territory	Low	

10.1. KEY TECHNICAL UNCERTAINTIES

- State of DSTs and SNF stored within them. Nature, location, rate and source of any water ingress, etc.
- Quantity and extent of damaged SNF and ease of recoverability from DSTs.
- State of contamination of ground, subsurface geology and groundwater around DSTs and Building 5 with rates of radionuclide migration there from, etc.
- Corrosion behaviour of SNF under current DST storage conditions.
- Potential for criticality incidents within DSTs with possible conditions, magnitude, etc,
- Evolution of on-site contamination with time in presence and absence of remedial action.
- Practicability of reprocessing damaged SNF at Mayak in short and long-term.

10.2. INCIDENT THREATS

Incidents could occur through several mechanisms, whether natural, accidents or from deliberate activities (unpredictable events). The key threats include:

- Seismic resulting in building collapse
- Fire
- Sabotage, missiles
- Air crash
- Weather extremes – flood, wind, cold, lightening strike
- Vehicle / Crane crash
- Building collapse
- Theft

11. Safety Risk Management

Fundamental to the effective delivery of the project has also been the requirement that it should be executed safely at every stage with measures being implemented to minimize all significant risks to the health of the workforce and the public. To achieve this has required a focus on several key areas: radiological safety, safety in respect of non-radiological hazardous materials, i.e. chemical hazards, biohazards and other hazards, e.g. asbestos-nature, explosion and combustion risks, etc. It also requires attention to conventional industrial safety, regulatory requirements and supervision, procedures, emergency response capabilities and training. These aspects and their interactions are summarized in Figure 7.

The radiological safety required consideration of the existing state of radioactive contamination on surfaces, structures, surface waters, the underlying geology and groundwater on the site and the sediments along the immediate sea shore. It also required consideration of the potential for criticality incidents and the potential for the leakage of further radioactivity.

Factors addressed in improving radiological safety were radiation monitoring arrangements and equipment, personal and respiratory protective equipment, personnel and equipment decontamination facilities, personnel hygiene units, dosimetry and laboratory services, etc. There was also a need for an adequate emergency response capability in terms of medical and rescue support, fire fighting services, incident planning, control and liaison with external services, etc. All of these needed to be supported by appropriate staff training and procedures at the individual and group level.

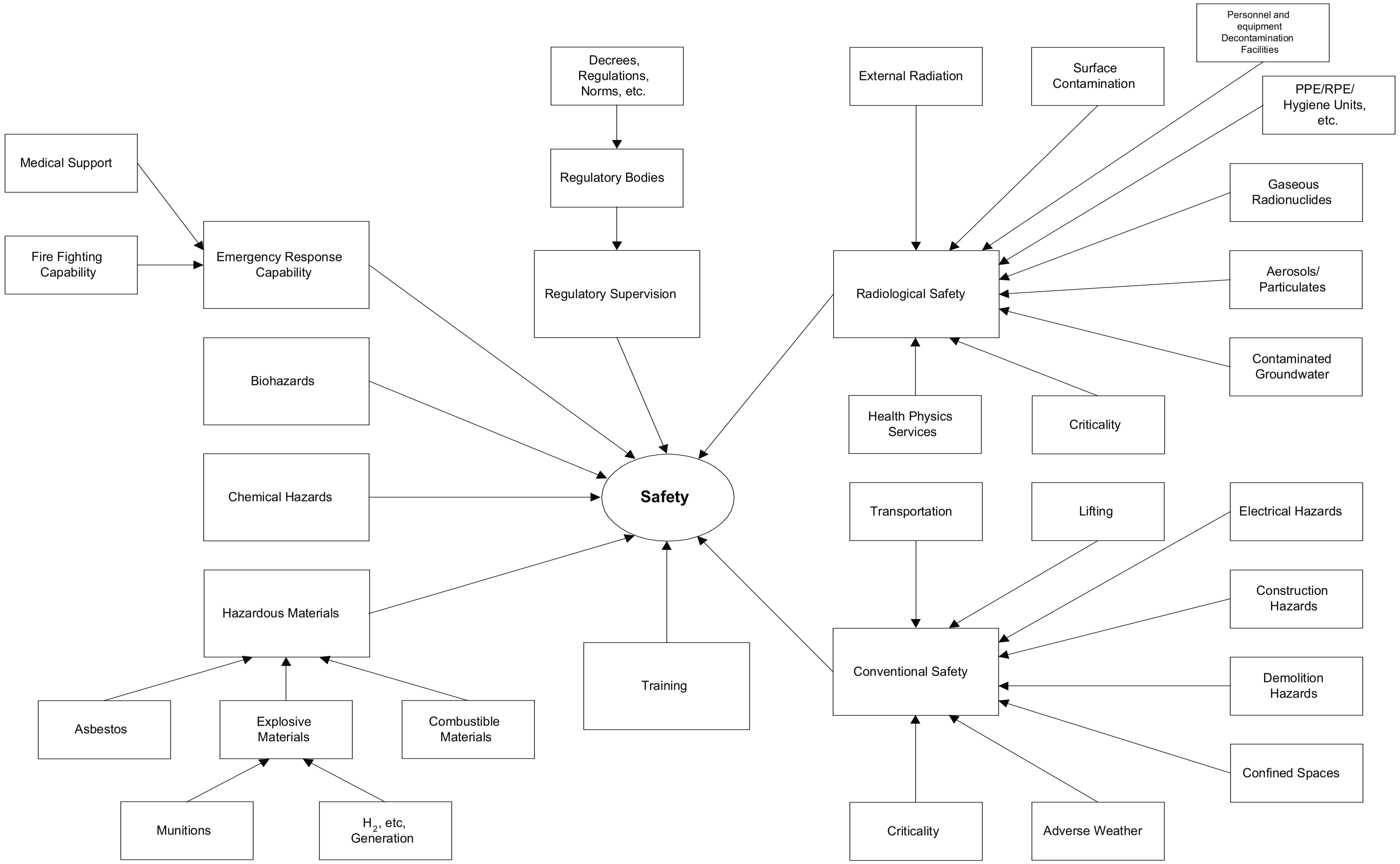

Fig. 7. Key Factors considered in the Management of Operational Safety

12. Approach to selecting the optimum Management Option for the SNF

In selecting the preferred option for the recovery, repackaging and interim storage of the spent fuel, a number of factors influence the decision. The approach adopted has been to determine a best practicable environmental option (BPEO), but subject to the constraints imposed by the existing site, structures, likely available facilities and acceptable endpoints. The key factors in addition to programme and acceptability are summarised in Figure 8. These are health and safety, environmental impacts, operational feasibility and requirements and socio-economic factors. Health and safety included consideration of exposures of operators to radiological and other hazardous substances, risks of accidents with each option and the degree of hazard reduction provided. The acceptability considered compatibility with Russian national policy on SNF management, potential public, local, regional and international political acceptability, particular donor sensitivities, and the security of the SNF, particularly in respect of potential misappropriation and non-proliferation. The assessment of potential environmental impacts considered releases to air, water and ground, public exposures, ecosystem impacts, waste management, international treaty obligations, e.g. OSPAR, and potential for commercial damage caused by releases, e.g. to fish stocks. Operational feasibility includes assessment of the technical feasibility and timescale with availability of SRW and LRW conditioning and storage facilities, the necessary infrastructure, both on site, locally and regionally, etc. The socio-economic assessment includes assessment of capital, commissioning, operational and decommissioning costs, resource usage and the wider economic impact of the works, e.g. creation and maintenance of local jobs, skills and local communities, etc.

13. Creation of Safe Working Conditions for Personnel

The Andreeva Bay CTB is currently in a very poor state of repair with several buildings in a hazardous, physical condition and with areas of unconstrained radioactive contamination. To rectify these problems and plan and develop the SNF management programme further, there has been a need to characterise the nature and extent of the existing radiological contamination on the site, the structural state of the buildings and other facilities, such as the pier and crane. To achieve this, there has been an urgent need for immediate safety improvements to enable the work to continue.

An important part of the immediate safety improvements is to ensure that personnel at Andreeva Bay have safe working conditions. These did not exist over much of the site.

The DSUs for SNF and RW storage facilities do not have all of the necessary equipment or infrastructure to ensure nuclear, radiation, service and ecological safety, whilst meeting sanitary and health requirements. The services were laid in the 1960s, and have not been refurbished since.

The following activities were required to ensure safe working conditions over the site:

- restoration of the water supply system and the laying of local water supply pipes;
- restoration of the electrical power supply system and construction of new electrical power facilities to ensure operation of facilities being restored and of new facilities;
- construction of decontamination centres, locker rooms;
- equipment of the radiobiological laboratory with special equipment and devices;
- upgrading of the radiochemical laboratory; the laying of two lines of wastewater disposal system with water-treating facilities;
- reconditioning of the cranes in the RW storage facilities;
- repairing of the KPM-40 crane rails;
- improving the access railways and roads to the enterprise (15 km) and local railways and roadways, including access ones leading to the pier.

Completion of the above activities will provide a sufficient infrastructure base to enable site works to begin.

13.1. OBJECTIVES FOR IMPROVING THE EXISTING GENERAL SITE SAFETY

A safety upgrade programme has been started with the following objectives:

- Improve the current standard of operational radiological protection at the site, including monitoring and decontamination facilities;
- Ensure safe working conditions that comply with the legislative requirements and radiological safety standards (NRB-99, OSPORB-99);
- Development of a radiation and safety management system;
- Improve containment of DSTs and particularly of DST 3A; and
- Monitor existing and developing state of DSTs, SNF and contamination, including potential criticalities.

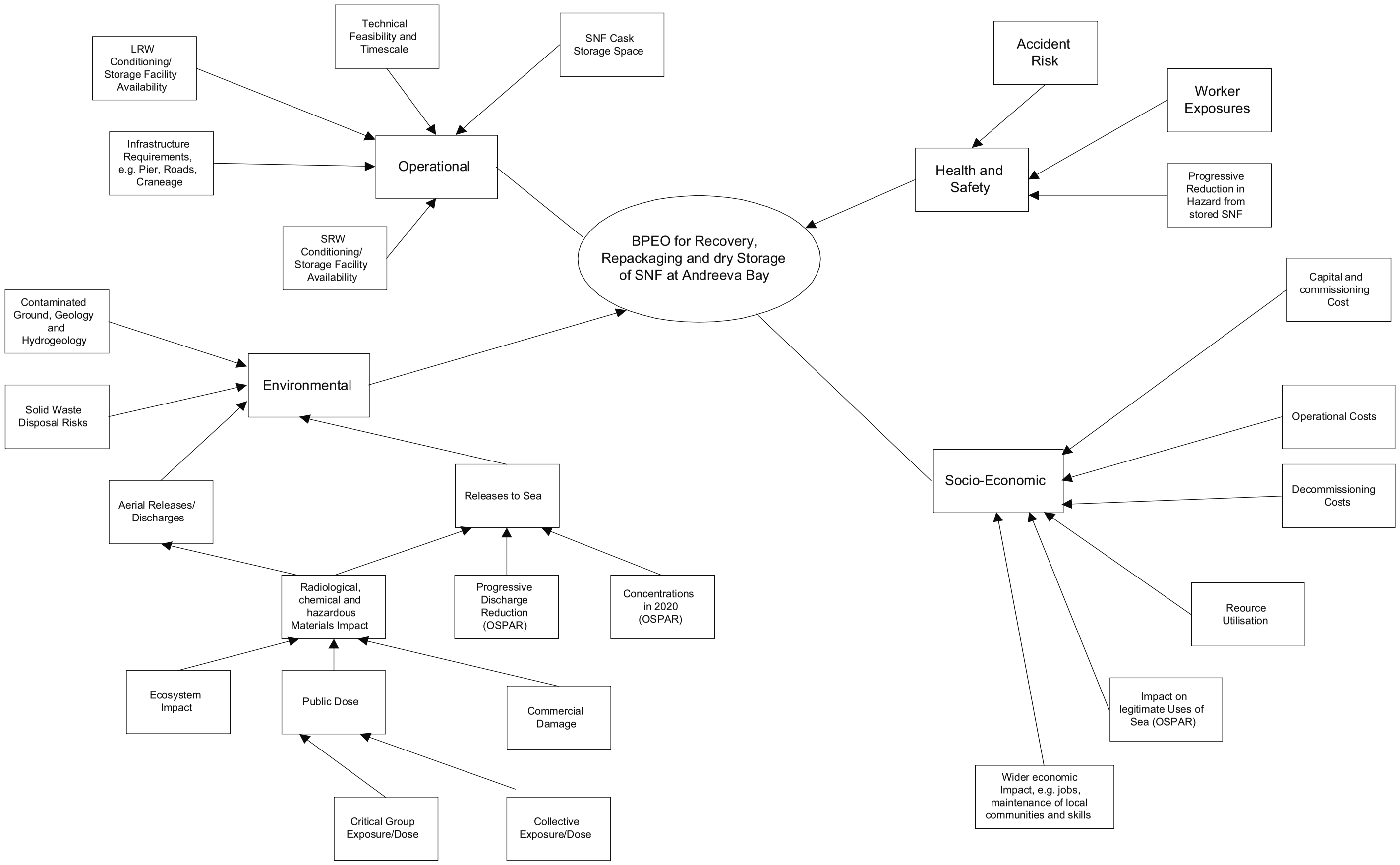

Fig. 8. Key Factors considered in the Selection of the BPEO for SNF Recovery, Repackaging and Storage

13.2. UPGRADING OF RADIOLOGICAL PROTECTION ON SITE

In respect of the radiological protection on the site the upgrade programme has included:

- Provision of dosimetry, laboratory, medical and personal protective equipment;
- Mobile hygiene units (sanitary passes) for 10 persons have been installed in the SNF area and near Building 5. Figure 9 shows the unit installed in the SNF area;
- A vehicle decontamination pad is being built near the SNF area. Figure 10 shows the unit in the final stages of construction;
- An active ventilation system is being installed in the main building of the Norwegian village to enable use of the laboratory facilities there;
- Materials/equipment for secondary SRW and LRW management are being purchased; and
- An engineering survey of Building 50 to evaluate whether it is capable of long term use (with renovation) as a radiation protection control station.

Fig. 9. A View of one of the two new, portable Personnel Hygiene Units

Fig. 10. A View of the partially completed, new Vehicle Decontamination Building

13.3. IMPROVEMENT IN EXISTING SITE SAFETY - PRACTICE

Work has been undertaken to improve the containment and working conditions around the DSUs. The objectives are:

- Improvement in the conditions of the SNF tanks both in the short term and in the long-term.
  - To protect spent nuclear fuel (SNF), and specifically Tank 3A, from rain and snow ingress;
  - To allow SNF removal from the dry storage tanks;
  - To protect the environment from release of radioactivity during SNF storage and removal operations;
  - To establish satisfactory radiation protection, hygiene and sanitary conditions for the workers, while removing SNF from the dry storage.

The DTI has funded the design, construction and installation of a permanent cover for the tank. This cover has to ensure the safety of the fuel and the preservation of the local environment. It is shown in Figure 11 after positioning in place.

13.4. SCHEME FOR IMPROVEMENT OF SNF SAFETY AND SECURITY

A scheme has been developed to generally improve SNF safety and security. It involves:

- Characterization of existing situation
    - Inside and around of Building 5
    - Construction of boreholes around the DSUs, coupled with tracer tests to determine groundwater levels, flowrates, direction, etc.
    - Infrastructure surveys
    - Norwegian characterization programme involving topographical surveys, construction of boreholes over the site to characterise the local geology, hydrogeology and any contamination at depth, etc.
- Improvement of existing site safety
    - Health Physics support
    - Temporary cover over DST 3A
    - Provision of decontamination facility
    - Upgrading laboratory facilities for environmental monitoring
- Planning for SNF recovery
    - Optioneering studies
    - Selection of preferred option
    - Preparation of OBIN, detailed design, OVOS, etc.
    - Regulatory approvals
    - Infrastructure renewal

Fig. 11. A View of the new temporary, weatherproof Cover over Tank 3A

- Recovery and repackaging of SNF
    - Construction of SNF recovery facilities
    - Construction of SNF characterisation and repacking facilities
    - Import of new containers, dual purpose casks, e.g. TUK 108/120, TK 18
    - Commissioning of constructed facilities
- Interim storage of SNF in canisters/casks
    - Construction of a canister or cask store
- Ultimate transfer of SNF off-site for reprocessing or direct disposal
    - Canister/cask transport ship

14. Options for the Management of SNF and its Facilities

As part of the project development an optioneering study has been undertaken to identify the available management options for the SNF, its former storage facility, Building 5 and the contaminated ground around the SNF storage facilities.

Table 3. Viable Options for the interim Management of the SNF

Option	Description
1	Do nothing but monitor environmental conditions and containment. Provide short-term fixes, if monitoring highlights problem with tanks or SNF
2	In-situ containment –above and below ground
3	In-situ immobilisation
4	Decommissioning, transport and storage in an on-site canister store
5	Decommissioning, transport and storage on-site in casks
6	Decommissioning, transport and storage in an off-site canister store
7	Decommissioning, transport and storage off-site in casks
8	Prompt removal using historic approach with minimum of containment

For the storage and transport options indicated above, there are several sub-options which could be implemented:

Construct a Conditioning/repackaging Centre on-site –production of acceptable forms for storage or transport for all on-site SNF. This could be based on handling fuel in canisters or casks;

- Segregation SNF to account for Mayak acceptability criteria;
- Re-package SNF into new canisters, allowing for transport to Mayak (to improve seal, and to allow processing at Mayak for damaged fuel)

15. Contaminated Soil

The following options were identified for the management of contaminated soil at Andreeva Bay:

Table 4. Viable Options for the Management of the contaminated Soil

Option	Description
1	Do nothing
2	Do nothing and monitor
3	Do nothing, monitor and characterise
4	Dig and dump/store on-site
5	Dig and treat to decontaminate
6	Clean in-situ, e.g. pump and treat
7	Contain with physical barriers, e.g. curtain walls, etc
8	Cover to prevent infiltration and associated activity spread
9	Immobilise in-situ, e.g. grouting, in-situ vitrification

16. Characterization of existing Situation

To support the option studies additional characterisation requirements have been identified and the studies are being undertaken. The work involves:

- Development of a management plan for Building 5;
- Development of a database of existing information (3-D model of Building 5);
- Preliminary survey undertaken
- Comprehensive engineering and radiation survey of the Building 5 facility. This will include:
    - ➢ Man-entry to determine condition of the main hall, roof and foundations of Building 5;
    - ➢ A preliminary investigation of the basement of Building 5;
    - ➢ A remote and possible robotic survey of the bottom and walls of the pools
- Development of a database on the existing state of the whole site, facilities and projects

- Cored boreholes constructed around DSUs with depth, groundwater, geological, contamination and engineering structural analyses;
- Tracer tests around DSTs to determine groundwater flow characteristics;
- Engineering surveys of key facilities that will or may remain to be used in the SNF and RW management programmes. This will include the pier, certain buildings, roads, infrastructure, etc.

17. Conclusions

1. The prime objective of the programme has been to develop and implement an SNF management plan for the recovery, repackaging and safe, secure storage of the SNF currently stored at the Andreeva Bay CTB site.
2. A total risk management programme has been applied to ensure that the project is completed safely and securely to time, cost and quality with the minimum adverse effect on the environment.
3. An Options study has been undertaken to determine optimum strategy for the SNF management.
4. A preliminary screening of the options has been undertaken and selection criteria have been developed.
5. Eight detailed options for fuel removal, repacking and transport were evaluated.
6. Two options have been selected for comprehensive analysis. These will be assessed to the preliminary design level, according to the Russian OBIN approach.
7. The next stages will involve:
    1) the selection of preferred option;
    2) the preparation of a comprehensive environmental impact assessment (OVOS), according to Russian procedures and compliant with western best practice; and
    3) the preparation of the detailed design of selected option.

UTILIZATION OF SPENT RADIOISOTOPE THERMOELECTRIC GENERATORS AND INSTALLATION OF SOLAR CELL TECHNOLOGY AS POWER SOURCE FOR RUSSIAN LIGHTHOUSES - FINAL REPORT

PER-EINAR FISKEBECK

Chief engineer, Finnmark County Governor, NORWAY

1. Objective

- Reduce risk of radioactive pollution of Varangerfjord and Barents Sea.
- Reduce risk of theft of radioactive material and the possibility of making dirty bombs.

2. Project

The Northern Fleets hydrographical department has with support from Norway worked on the utilization of spent strontium-containing RTGs used as power sources at lighthouses situated at the Kola Peninsula.

P. Strand et al. (eds.), Radiation and Environmental Safety in North-West Russia, 85–88.

RTG is an abbreviation for radioisotope thermoelectric generator. The active part of the generator consists of Strontium-90, a radioactive isotope with 29.1 year halftime. Described in simplicity the strontium element (RIT-90) is used as a heat source and the difference in temperature to the surroundings is utilized to create voltage over a thermoelectric element consisting of semiconductor material.

The implementation of the project can be separated into four stages:

1. Technical and physical control of the RTGs.
2. Transfer to Moscow
    a. Helicopter transport from the sites to a temporary gathering point
    b. Transfer to the Nuclear icebreaker fleet (Atomflot) site where the RTGs are loaded on custom railroad carriages and transported to Moscow.
3. Dismantlement in Moscow at the Russian National Institute for technical physics and automation research (VNIITFA). After dismantlement the radioactive heat sources (RHSs) are moved to transport containers and loaded onto train.
4. Transport to the Enterprise Mayak, Chelyabinsk Oblast and final storage.

Using the 2002 project as an example, practical work started in June as specialists from Minatom (now: Russian Federal Atomic Energy Agency) performed a technical and physical check of each RTG. The generators have a radiation shield consisting of either wolfram or depleted uranium. Defects in this shield have occurred, but up to now only in cases where depleted uranium has been used. In 2002 no generators had defects in the radiation shield and a permission from Minatom to transport the generators from Murmansk to Mayak via Moscow.

A temporary, guarded storage pad was build at the Kola bay to which all RTG were transported by helicopter or boat during the month of July. The same month they were transferred by boat to the Atomflot site and loaded onto custom railroad carriages. These carriages have a removable floor and are reinforced according to IAEA regulations.

By the end of July the RTGs arrived VNIITFA in Moscow. Upon arrival the radiation levels were assessed and the generators moved to a radioactive waste storage. After the initial control each RTG was dismantled in a hot-chamber and the RHSs removed. The sources were then transferred to technical containers on placed in transport containers complying IAEA criteria. Wolfram initially used as radiation shield was re-melted into transport containers. These transport containers have a mass of about 1500 kilos of which 700 kg is pure wolfram. The radioactive source RIT-90 weighs approximately 5 kg.

The RHS were transported in wolfram containers to the Mayak enterprise in Chelyabinsk Oblast.

Upon arrival the radioactive sources went through a surface and radiation control at Mayak plant No. 45. Then the identification numbers on the technical containers were checked and compared to the freight documentation and lists received from VNIITFA. Next the RHS were removed from the transport containers in a hot chamber and transferred to Mayak internal containers. As soon as all transport containers were emptied a Mayak representative signed for the shipment and transport containers were returned to Moscow. The internal containers were transferred to the storage at plant No. 235. There the RHSs were removed from the internal containers in another hot chamber and put into metal containers filled with liquid phosphoric sand. 3 of these metal containers constitute a storage unit. The storage units were then moved from the hot chamber to the permanent storage by means of a cylinder lowered from the roof onto the units.

3. Environmental impact assessment

Rosatom coordinates the preparation of the EIA and it is evaluated by Rostechnadzor. The Finnmark County Governor will ask the Norwegian Radiation Protection Authority to contribute with quality assurance of the assessment. The EIA must satisfy international demands to the utilization.

4. Installation of solar panels as power source in lighthouses

The Northern Fleet's hydrographical department and the Murmansk County Administration wish by the help of Norway to install solar cell technology as power source at lighthouses.

The Russians has planned all installations and carried out inspections of all lighthouses. The installation work has been set out to tender.

We have tested solar panels of Russian manufacture at two locations, Honningsvåg and Sjavor. The equipment has been supplied by the OAO Saturn factory in Krasnodar. The testing has been successful both with regard to mechanical and electrical design. The Russian equipment has functioned satisfactorily without interruption that could make installation extinguish.

A working group consisting of the Finnmark County Governor, the Norwegian Coastal Administration, Troms and Finnmark, the Northern Fleet's hydrographical department and the Murmansk County Administration is responsible for the execution of the installation and supervision of the work carried out by Russian firms.

After the projects have been concluded a final report with audited accounts will be prepared.

5. Russian procedures

The Murmansk County Administration is responsible for achieving tax exemption, which is issued by the Russian department of Finance.

All involved Russian suppliers of equipment and firms responsible for installation possess all necessary Russian licenses to carry out the project.

RESEARCH OF RADIOACTIVE CONTAMINATIONS OF THE BALTIC SEA WITHIN THE HELCOM PROGRAMS

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"Khlopin Radium Institute", St. Petersburg, RUSSIA

For the countries surrounding the Baltic Sea, the problems connected to radioactive contamination of this closed sea of the Northern Europe with its the lowest ability for self-cleaning are very urgent. For 80 millions populations from 9 countries inhabiting the Baltic coast, the questions of the Baltic ecology have paramount social and economic importance. And frequently these problems besides practical and scientific importance have the expressed social - political shadow, especially after Chernobyl NPP accident. Now the Baltic Sea concerns, alongside with the Irish Sea and the Black Sea, to the three the most “polluted” (by technogenic radioactive pollution) seas of the world.

Within the framework of the Intergovernmental Agreement of the member-states of the Helsinki Convention the wide, public and intensive international cooperation of Russia with the states of Northern and Central Europe for solution of an ecological problem, in particular, by permanent monitoring of radioactive pollution of the Baltic marine environments is developed.

The large-scale research of the Baltic Sea radioactive contamination was begun in 1970. Onboard of the research vessel “Academician VERNADSKII” specialists of the Laboratory For Radiation Monitoring of the V.G. Khlopin Radium Institute have provided survey of the southeast part of the Baltic sea, including the Gulf of Finland. The received results

P. Strand et al. (eds.), Radiation and Environmental Safety in North-West Russia, 89 –102.

have put a beginning to the annual studies by the KRI provided till the present time. During the first years these researches were carried out under the individual programs, further they were added by the international programs.

Since 1974 all scope of sampling work is provided research vessel “BOYAN”, which is sailing–motor cruiser yacht belonged to the KRI. The vessel is equipped by the necessary navigating equipment, including satellite-navigating system, communication facility and sampling devices.

Since 1975 the researches in the region have been carried out together with the experts of Poland and GDR. Soon these researches were incorporated by the Program of the Commycom.

In 1978 the Cooperation Agreement on research of radioactive pollution of the Baltic Sea was set up with Finland (Finnish Center of Radiating and Nuclear Safety). In 1979 the similar Agreement was signed with Sweden (Swedish Institute of Radiating Protection). In 1982 - 1985 the IAEA program («Study of radioactive substances in the Baltic Sea») united the researches of radioactive contamination of the Baltic Sea, which have joined all the Baltic states. The work on this program included an estimation of long-term behavior of the radio nuclides arriving to the Baltic Sea, including pathways of their penetration in human-being, and were carried out jointly by the scientists from all countries surrounding the Baltic sea, and by the experts of the International Laboratory of a Marine Radioactivity in Monaco (IAEA). In all these Programs the KRI Laboratory for Radioecological Monitoring represents national interests of our country.

The IAEA Program during 1982-1985 resulted in a Document, in which the estimation of the sources of radionuclides receipt into the Baltic Sea was made. By 1985 the accumulation of Cs-137 in the Baltic Sea was estimated: from a global source – 670 TBq, from nuclear reprocessing facilities of Western Europe (with waters of Northern Sea) – 150 TBq, from all the Baltic NPPs - 2 TBq. Thus, the work of Baltic PPS, which total capacity to 1985 made more than 17000 MWt, practically has not affected a stock of Cs-137 in the Baltic sea (“ Study of Radioactive Materials in the Baltic Sea”, TECDOC-362, IAEA, 1986).

In April 1986 the region of the Baltic Sea has undergone to radioactive pollution as a result of Chernobyl NPP accident. In April - May 1986 significant changes in a radiological mode of the Baltic region took place caused the accident. Now alongside with the Irish and Black seas, Baltic is characterized by the highest contents of radioactive substances in comparison with all other seas of Globe.

Besides Chernobyl NPP accident, the other sources of significant receipt of artificial radio nuclides in the Baltic sea are the global fallout and transport through the Danish straits of sea water polluted with the West-European facilities of reprocessing of nuclear fuel, first of all in Sellafield. In comparison with such sources, as global fallout, transport of water from Sellafield and La Haag, Chernobyl fallout, the role of releases from Nuclear power stations and research centers located in drainage area, is smallest.

In 1987 by the decision of the Helsinki Commission Working group Monitoring of Radioactive Substances was organized for collection and estimation of the data on radioactive pollution of the Baltic Sea. The group has united in its structure of the experts from the states of the region: USSR, Finland, Denmark, Sweden, Germany, GDR and Poland. Now structure of the Group includes the experts from the Russian Federation, Finland, Denmark, Sweden, Germany, Poland, Estonia, Lithuania, Latvia and IAEA. The necessity of creation of the Group was dictated by the following circumstances:

- Termination of the appropriate IAEA PROGRAM;
- Significant pollution of region caused by consequences of the Chernobyl accident;
- necessity of creation of the international system on monitoring of radioactive pollution of the most important water basin of Europe.

In accordance with a Terms of Reference Group of experts on Monitoring of Radioactive Substances in the Baltic Sea (MORS) shall:

- to inform a Commission on questions connected to monitoring and an estimation of a condition of radioactive substances in the Baltic Sea;
- to carry out compilation of the available data on radioactive dumps in the Baltic Sea and to report them annually on MORS Meetings;
- to carry out data gathering from all areas of the open sea, mainly from stations of the Baltic of monitoring program, and also from coastal areas, where it is necessary, for annual delivery of the results;
- to submit the data on radio nuclides in a database of a Commission, including marine environmental data and data on releases and discharges;

- to provide estimation of the data and risk assessment concerning radiating influence on the population living around of the Baltic sea, and besides to carry out development of the models for prediction of radiating doze loading in emergencies;
- to carry out all necessary actions on quality assurance of the analytical data.

From a beginning of work on study of radioactive pollution of the Baltic Sea within the framework of the Helsinki Convention, KRI represents interests of the RF in the Helsinki Commission on questions connected to environmental radioactive contamination of the region.

The basic task at the first stage of work of the MORS Group was the estimation of the Chernobyl accident consequences. For this purpose since spring of 1986 by HELCOM request all the member states have intensified significantly sampling programs and measurements. The experts of the USSR compiled and submitted to the HELCOM 1986 - 1988 data on water and bottom sediments contamination This work was finished in 1989 by release of the HELCOM Publication No 31: "Three-years observations of the radio nuclides levels in the Baltic sea after Chernobyl accident".

According to the Recommendations 10/3 (in the further Recommendation 18/1) MORS Group has developed constantly working system of the international monitoring of radioactive contamination of the Baltic Sea, which contains joint monitoring program for all member states, defines clearly the responsible areas and monitoring stations, the radio nuclides to be monitored and quality assurance program to be implemented in each Laboratory.

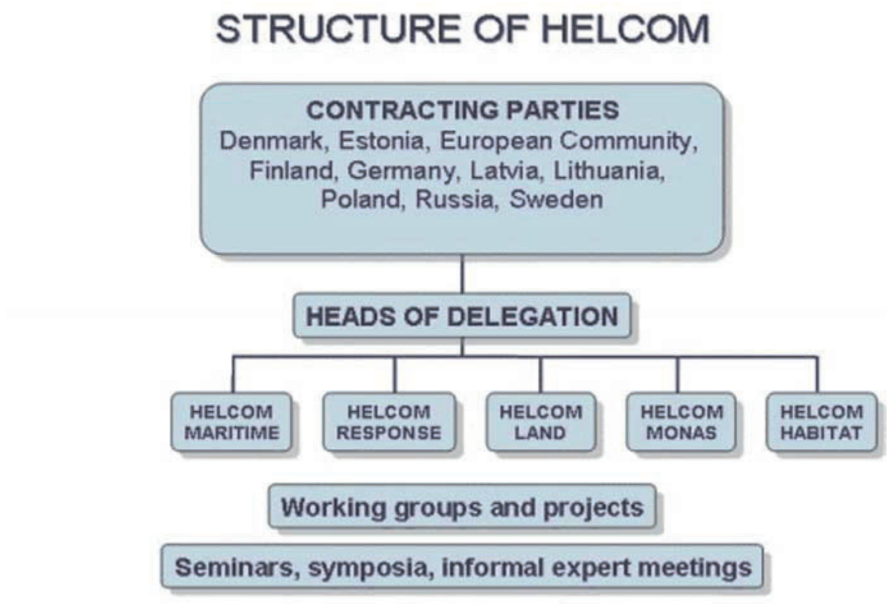

Fig. 1. Structure of HELCOM (from: http://www.helcom.fi)

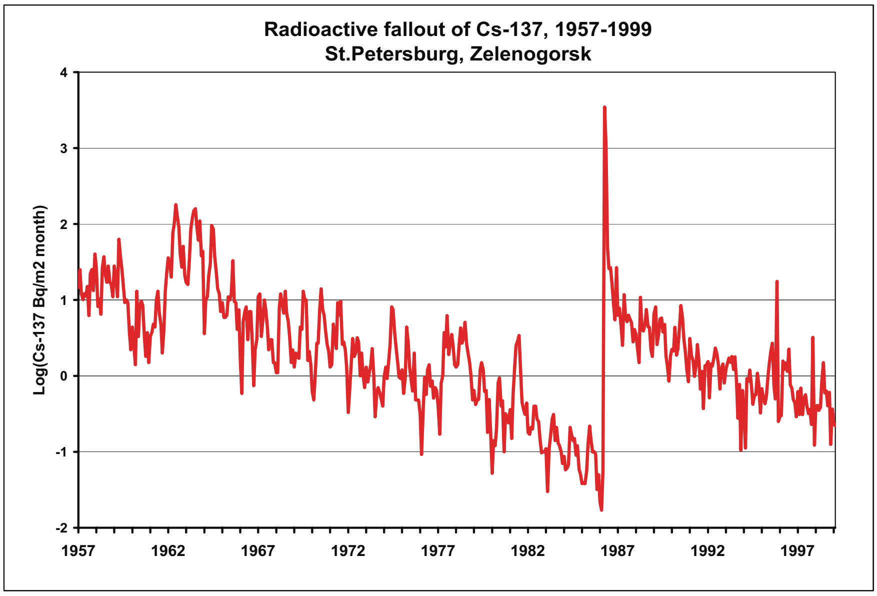

Fig.2. Radioactive fallout of Cs-137, 1957-1999.St.Petersburg, Zelenogorsk

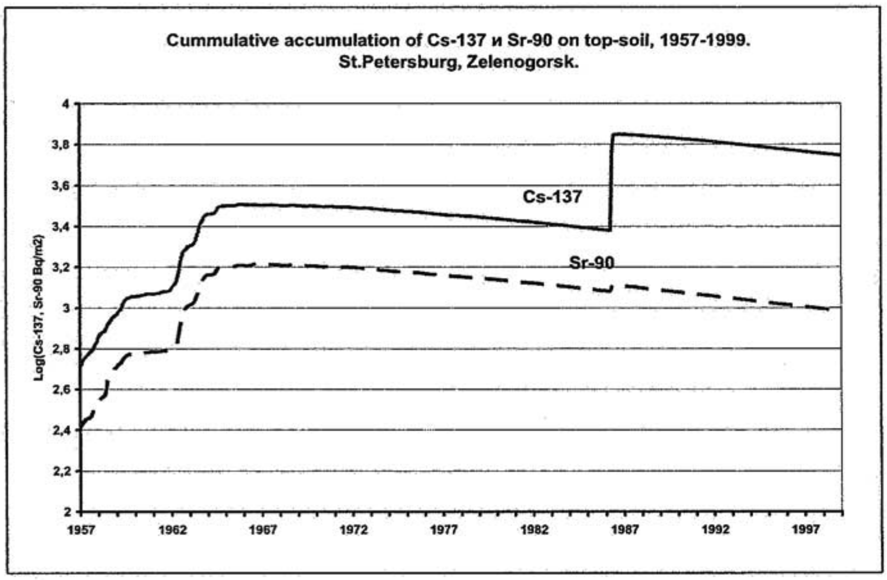

Fig. 3. Cumulative accumulation of Cs-137 и Sr-90 on top-soil, 1957-1999,St.Petersburg, Zelenogorsk

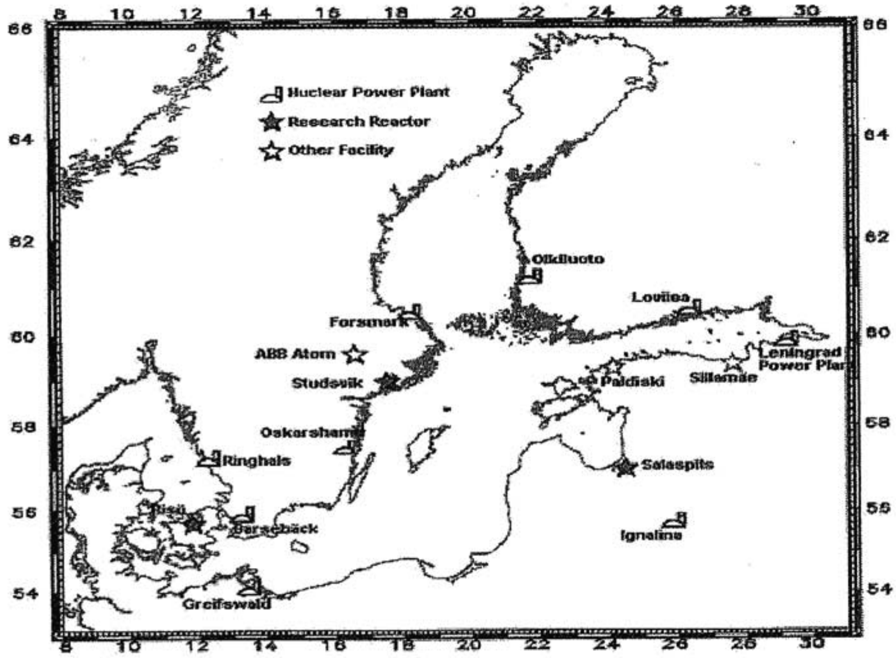

Fig. 4. Nuclear Power Plants and other nuclear facilities in the Baltic Sea area(from: http://www.helcom.fi).

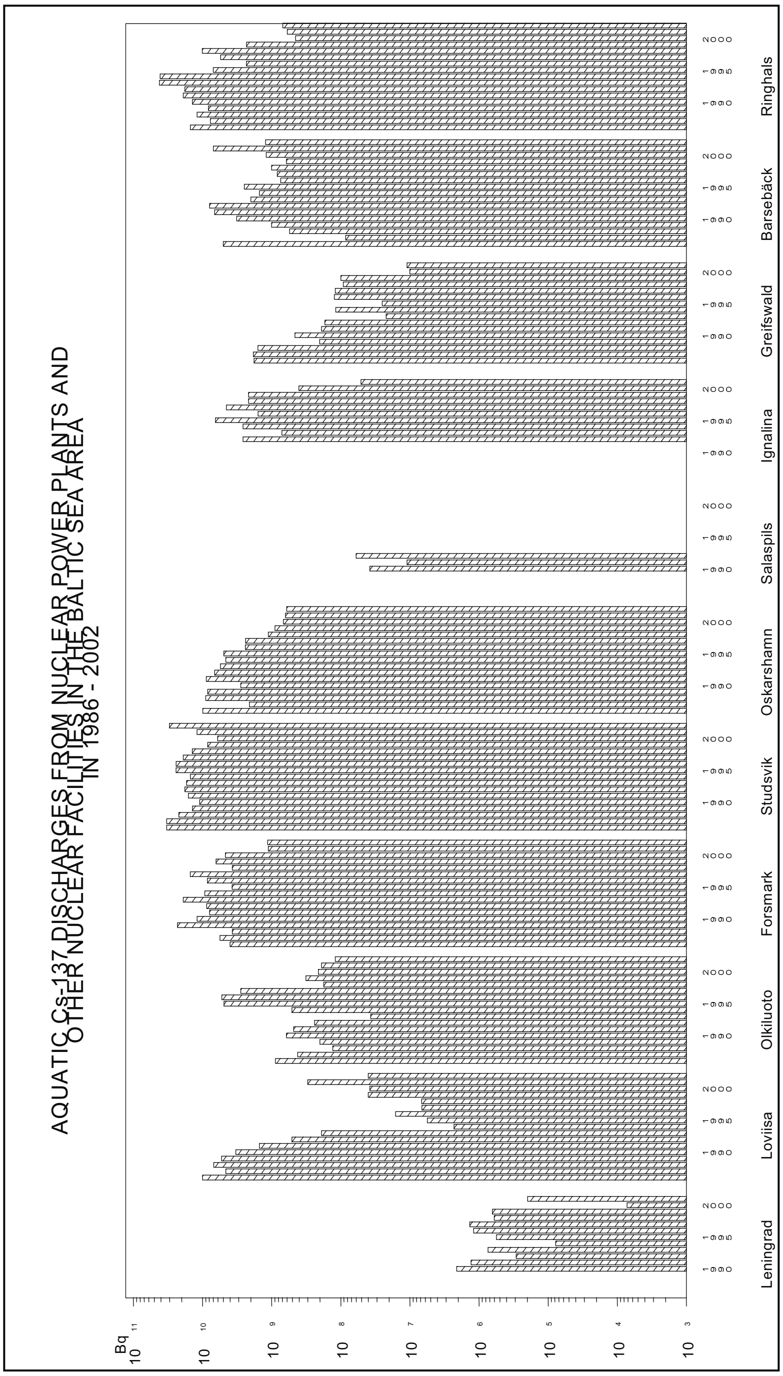

Fig. 5. Aquatic Cs-137 discharges from nuclear power plants and other nuclear facilities in the Baltic Sea area in 1986-2002

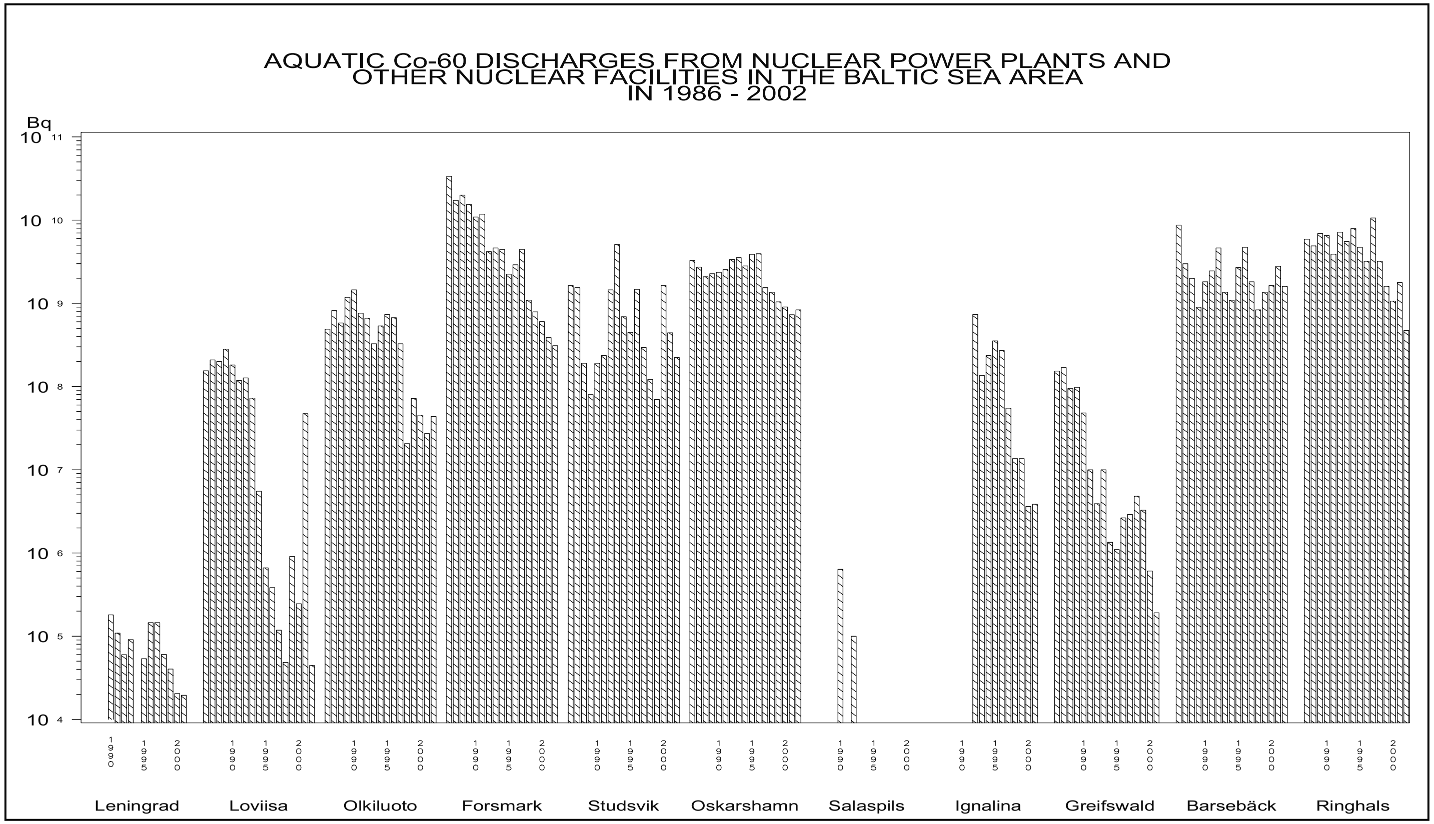

Fig. 6. Aquatic Co-60 discharges from nuclear power plants and other nuclear facilities in the Baltic Sea area in 1986-2002 (from:)

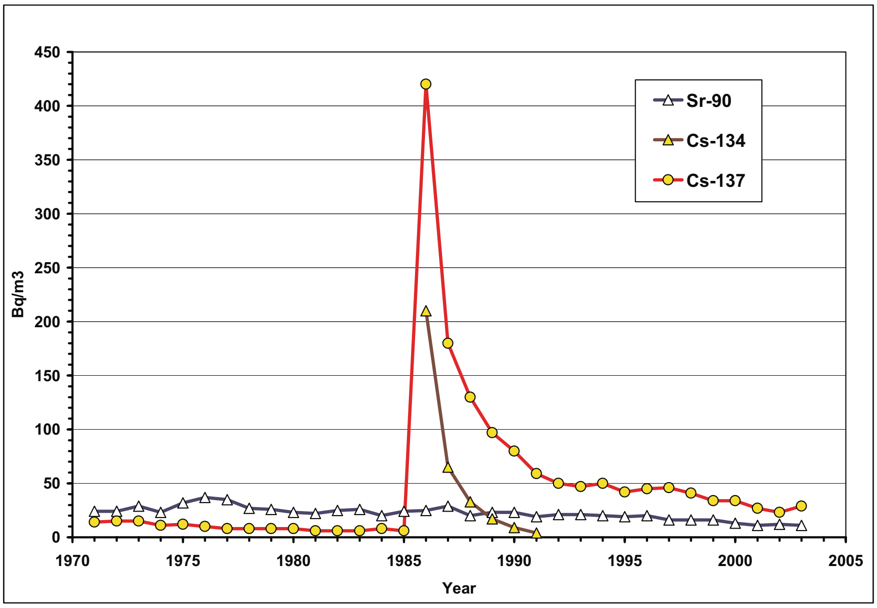

Fig. 7. Averaged values of Sr-90, Cs-134 and Cs-137 concentrations in waters of the Koporski Bay of the Gulf of Finland in 1971-2003 years

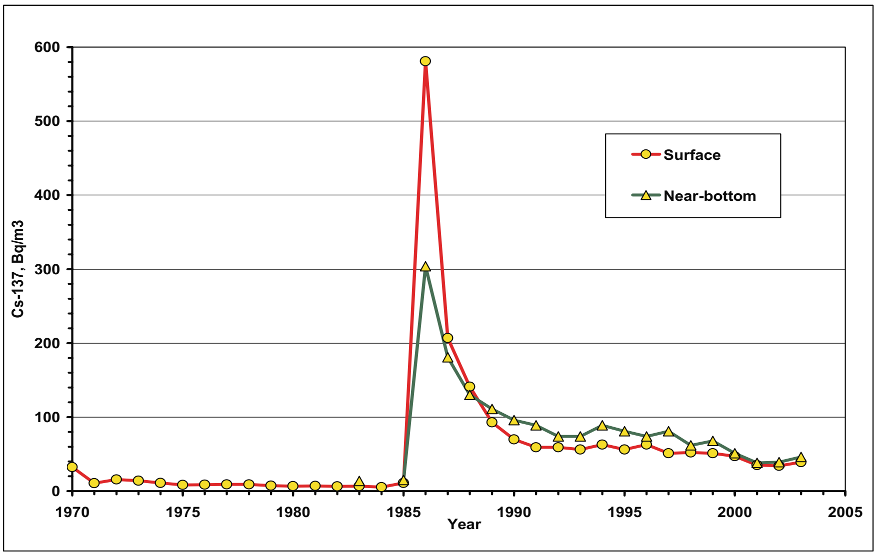

Fig. 8. Averaged values of cesium-137 concentrations in surface and near-bottom waters of the Gulf of Finland in 1970-2003 years

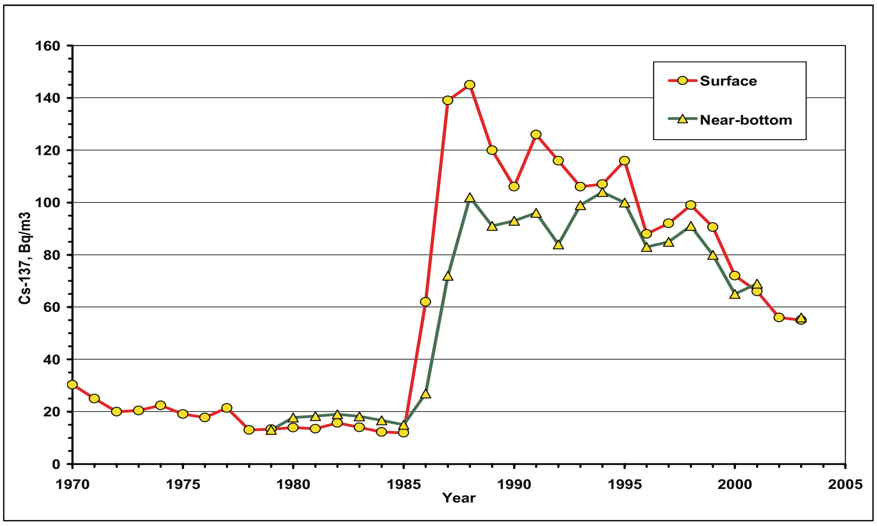

Fig. 9. Averaged Cs-137 contents in surface and near bottom waters of the Baltic Sea Proper, Eastern part in 1970-2003

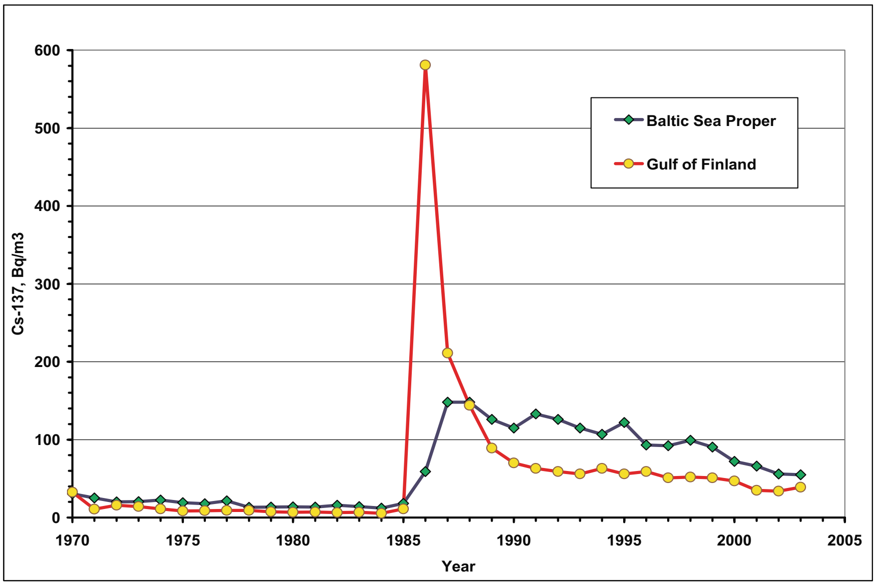

Fig. 10. Averaged values of cesium-137 concentration in surface waters of the eastern part of the Baltic Sea Proper and the Gulf of Finland in 1970-2003 years

Table 1. Nuclear Power Plants and other nuclear facilities in the Baltic Sea area

Facility	Country	Type of facility; number of units	Remarks
Greifswald	Germany	Power Plant; 5 PWR	Shut down in 1990
RISØ	Denmark	Researsh reactor	
Ringhals	Sweden	Power Plant; 3 PWR, 1 BWR	
Barsebäck	Sweden	Power Plant; 2 BWR	First reactor was shut down in 1999
Oskarshamm	Sweden	Power Plant; 3 BWR	
Forsmark	Sweden	Power Plant; 3 BWR	
Studsvik	Sweden	Researsh reactor, Waste handling facility	
Olkiluoto	Finland	Power Plant; 2 BWR	
Loviisa	Finland	Power Plant; 2 PWR	
Leningrad	Russia	Power Plant; 4 RBMK	
Salaspils	Latvia	Researsh reactor	Shut down in 1998
Ignalina	Lithuania	Power Plant; 2 RBMK	
Paldiski	Estonia	Training centre	Shut down in 1989
Sillamae	Estonia	Chemical metallurgy plant, Wastedepository	
ABB Atom	Sweden	Fuel fabrication plant	

Table 2. Input of Cs-137 to the Baltic Marine Area during the period 1950-1996 (Sven P.Nielsen in: Environment of the Baltic Sea Area 1994-1998, HELCOM)

Source	Input mode	Cs-137, TBq
Weapons fallout	Atmospheric deposition	1800
Weapons fallout	Riverine runoff	100
Chernobyl fallout	Atmospheric deposition	4400
Chernobyl fallout	Riverine runoff	300
Europian reprocessing	Hydrodynamic transport	400
Nuclear facilities	Coastal discharge	2

Table 3. Debalance water discharges from the Leningrad NPP to the Gulf of Finland

Year	Volume, thousand of m^3	Co-60		Cs-137	
		Bq/year	% from allowed	Bq/year	% from allowed
1973-1988	-	-	-	-	-
1989	4	• -activity = 4.218 +06 Bq/year			
1990	19.2	1.80 +06	0.013	2.10 +06	0.360
1991	9.61	1.20 +06	0.009	1.30 +06	0.220
1992	18.04	6.60 +05	0.005	2.90 +05	0.050
1993	3.56	1.06 +06	0.007	7.40 +05	0.125
1994	0.3	0,00	0.000	7.80 +01	0.00001
1995	5	5.90 +05	0.004	5.60 +05	0.095
1996	10	1.55 +06	0.011	1.18 +06	0.199
1997	4.99	1.60 +06	0.011	1.36 +06	0.230
1998	7.71	6.66 +05	0.005	6.03 +05	0.102
1999	10	4.44 +05	0.003	6.40 +05	0.108
2000	9	2.25 +05	0.002	7.22 +03	0.001
2001	7.24	2.15 +05	0.001	1.98 +05	0.033
2002	2.55	6.22 +04	0.002	1.66 +05	0.015
2003	10.5	4.97 +05	0.013	1.03 +06	0.094

Table 4. Air Releases From Leningrad NPP for the period 1985-2003.

Year	Nobel Radioactive Gases	Co-60 Bq/year	Sr-90 Bq/year	Cs-137 Bq/year	I-131 (gaseous + aerosol fractions)
1985	7.8 E+15	-	-	-	4.59 E+9
1986	4.70 E+15	-	-	-	2.97 E+10
1987	4.44 E+15	-	-	-	2.70 E+10
1988	3.51 E+15	-	-	-	1.35 E+10
1989	2.93 E+15	-	-	-	2.70 E+9
1990	1.62 E+15	-	-	-	8.14 E+9
1991	-	2.8 E+8	-	5.2 E+8	2.0 E+10
1992	-	6.7 E+8	3.0 E+7	2.6 E+9	8.9 E+10
1993	1.6 E+15	7.4 E+8	4.6 E+7	9.5 E+8	3.5 E+10

1994	1.79 E+15	4.1 E+8	4.1 E+8	1.9 E+9	5.0 E+10
1995		1.4 E+8	2.0 E+6	1.2 E+9	2.0 E+10
1996	1.04 E+15	7.4 E+7	3.1 E+7	1.3 E+9	2.9 E+10
1997	9.6 E+14	1.4 E+8	7.4 E+6	5.2 E+8	1.7 E+10
1998	-	1.7 E+8	1.6 E+7	7.4 E+8	1.7 E+10
1999	-	2.0 E+8	6.7 E+6	3.4 E+8	2.1 E+9
2000	-	2.2 E+8	5.2 E+6	6.2 E+8	1.7 E+10
2001	3.56 E+14	1.9 E+8	4.1 E+6	4.9 E+8	1.1 E+9
2002	4.59 E+14	1.89 E+8	-	2.02 E+8	1.06 E+9
2003	3.76 E+14	1.51 E+8	-	1.56 E+8	1.15 E+9
Allowed	3.70 E+15	2.50 E+9	-	4.0 E+9	9.30 E+10

SESSION II: SUMMARY AND CONCLUSIONS

1. Summary

Prior to the presentation Mr. Bergman, as one of the appointed co-chairmans for the session, elaborated on the different concepts of risk, their similarities and differences. There are sometimes conflicts between efforts to reduce different risks. Examples; efforts to reduce environmental impact often results in the increase of occupational exposure; efforts to carefully assess risk before taking operational actions may result in further deterioration of a situation that result in more dangerous operations. It is therefore necessary to carefully evaluate all different aspects of risk to reach a practical and sometimes pragmatic balance.

The session comprised 5 presentations:

Two presentations focused on monitoring of the environment especially monitoring of radioactive material. One programme was on the done under the Arctic Council and covered the whole Arctic Region (AMAP –Arctic Monitoring and Assessment Programme) and the other, Helcom/MORS, which was done within Helcom, went into detail on the presence of radionuclides in the Baltic Sea. Both programmes are well established and have good infrastructure to implement their respective monitoring programmes.

It was pointed out that the results of the work is of great value to plan and implement programmes to reduce risk and especially AMAP could be of value for planning and implementing remediation activities in the North West Russia. How AMAP could be used in practice for that purpose could be an issue for further discussion at the closing session.

One presentation explained the role of the regulatory authority associated with the Ministry of Defence, MoD-GAN. This organisation has authority for activities undertaken at military sites and with material originating

P. Strand et al. (eds.), Radiation and Environmental Safety in North-West Russia, 103–104.

from military activities like what is done at Andreeva Bay and Gremikha Bay.

This presentation trigged an intensive discussion on responsibilities of the different parties especially the civilian and military authorities. Although it may look clear on the paper (at least according to the presentation) the discussions demonstrated that the issue is far from clear and transparent. The need for better co-ordination between military and civilian organisations was pointed out. From the perspective of the western participants it is clear that further clarification is needed.

A very detailed presentation was made describing management of all different risks associated with the implementation of two projects at Andreeva Bay; management of the SNF at the site and assessment of the building 5. Two important problems were pointed out; lack of waste acceptance criteria and lack of criteria for the remediation (what level of remaining contamination is acceptable). Another problem emphasised by the presentation was the need for clarification f the role of the different authorities in Russia. From the discussion it was not clear that it is a proper understanding in Russia of the different roles of the operator and the authorities.

One presentation was devoted to the practical risk reduction by replacing of the RTG used as power source for light houses on remote locations along the northern coast of Russia with solar panels. The presentation was an excellent example of practical risk reduction by replacing a radiation energy source with a non-radioactive.

2. Conclusions

As a summary it can be concluded that the session gave a number of very appropriate presentations on risk and how to manage risks. A number of questions were raised mainly related to the understanding of the Russian system for regulating investment projects many of which will be further discussed during later sessions of the workshop.

4. SESSION III: RISKS AND ENVIRONMENTAL IMPACT ASSESSMENT

Co-chairmen:

A.A: ZRYANIN

FSETAS, Moscow, RUSSIA

INGVILD SWENSEN

Norwegian Radiation Protection Authority, Østerås, NORWAY

IMPLEMENTATION OF ENVIRONMENTAL IMPACT ASSESSMENT IN NS DISMANTLEMENT

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1. Introduction

The main objective of elaboration of a document on Environmental Impact Assessment (EIA) is to prepare technological processes safe for the environment and other decisions for performance of works on NS dismantlement. In the course of EIA the following tasks are fulfilled:

- Identification and analysis of possible negative impact sources for the environment, connected with technological processes for NS dismantlement;
- Prognostication and comprehensive evaluation of environmental changes that can happen as a result of impacts during NS dismantlement;
- Prognostication and prioritization of ecological consequences, as well as social, economical and other ones in connection with the above, arising out of the realization of NS dismantlement projects.

The purpose of EIA implementation is to prevent or mitigate negative impact of NS dismantlement on the environment, as well as social, economical and other consequences in connection with the above. The main criteria

P. Strand et al. (eds.), Radiation and Environmental Safety in North-West Russia, 107–134.

of environmental impact assessment of chemical and radiation factors in NS dismantlement are as follows:

- non-excess of effluents of harmful chemical substances (HCS) and radioactive substances (RS) in total beyond the specified norms of maximum permissible effluents of HCS and RS;
- non-excess of total discharges of HCS and RS with sewage waters;
- non-excess of total amounts of industrial (toxic) wastes specified by limits on waste disposal;
- safety ensuring of production activity and possible accidental situations in the process of NS dismantlement with the help of organizational measures and technical means;
- safety of population of the zone allocated for building during production activity of the enterprise carrying out NS dismantlement, in normal and emergency conditions.

As the basis for arrangement of NS dismantlement process a positioned method envisaging performance of a specific work volume on definite places – positions, was accepted. Organizational-and-technological scheme of NS dismantlement at “Zvezdochka” enterprise (see Fig. 1) was developed with due account of the most rational use of the existing productive capacities.

Below in the paper, as an example, we give information on EIA during dismantlement of the "Victor-II" class NS.

2. Radiation impact assessment

2.1 ASSESSMENT OF RADIATION IMPACT ON PERSONNEL POPULATION AND ENVIRONMENT UNDER NORMAL PROCESS OF NPS DISMANTLEMENT

The scheme of assessment of radiation impact on personnel, population and environment under normal process of NPS dismantlement is given in Figure 2.

NPS dismantlement, including spent nuclear fuel (SNF) and radioactive waste management, is followed by the following *types of radiation impact*:

- external irradiation of human body;

- internal irradiation of human body;
- radioactive contamination of environment, becoming an additional source of external and internal exposure of people.

The main *sources of radiation* during NPS dismantlement are the following:

- SNF fission products;
- activated reactor structural materials;
- radioactive fission and corrosion products accumulated on the surfaces contacting with primary loop coolant;
- radioactive fission and corrosion products, contained in steam-generating unit (SGU) loops fluids;
- radioactive waste (RW), generated during NPS dismantlement.

2.1.1 Radiation safety philosophy and criterion

To provide radiation safety during works with ionizing radiation sources under normal conditions, radiation safety philosophy *(limitation, substantiation and optimization principles*) to be fulfilled.

Russian Federation Law "On radiation safety of population" and "Radiation Safety Norms" NRB-99 states different basic dose limits for different categories of persons, exposed to radiation impact, as a *criterion of limitation principle*.

2.1.2 Determination of steam-generating unit radiation characteristics

Basic data for analysis of SGU radiation characteristics are values of equipment and SGU process fluids activity. This activity values depend essentially on nuclear power plant operation modes, first of all on NPP operating time and dwell time after operation completion.

SPENT NUCLEAR FUEL ACTIVITY

SNF radionuclide composition calculations are based on OKBM methods. The main task of calculations is to determine nuclides accumulation and reduction values during fission, irradiation and disintegration. Calculations are carried out using constants (cross sections) library, modified for propulsion reactors. Calculation of activity, accumulated in SNF, is carried out with taking into account actual modes of operation upon SGU operation results.

SGU STRUCTURAL MATERIALS ACTIVITY

After NPS decommissioning, the main sources causing radioactive contamination of reactor facility equipment are activated products of structural materials. Generation and accumulation of induced activity are related to neutron-caused activation of reactor internals, reactor vessels, as well as metal-water protection tanks and NPS pressure hull, located in immediate proximity to the reactor, during reactor operation.

Accumulated activity of reactor structural members is calculated using OKBM methods, which are based on multi-group bivariate program of radiation transfer calculation by discrete ordinates method (using computational solution of Boltzmann kinetic equation). Activity is calculated for operation mode at constant power level with respect to operation and dwell time.

For steelworks activity calculation, basic radionuclides existing within 3-1000 years dwell interval, are considered. These radionuclides form at activation of elements, contained in steels, out of which the members of reactor internals, reactor vessels, metal-water protection tanks and other equipment are manufactured.

Refer to Table 1 for the results of reactor structural materials and pressure hull activity calculations (Victor-II class submarine).

Calculations indicate that accumulated radioactivity is generally concentrated in reactor internals and reactor vessels. After reactor, central caisson and the bottom of metal-water protection tank have the greatest radioactivity, however, it forms less than 2% of total activity. Pressure hull activity forms about 0,04 % of total radioactivity. In first years after reactors shutdown, structures radioactivity, accumulated during operation, is determined by radio nuclides Fe^{55} and Co^{60}.

LOOPS FLUIDS AND SURFACE DEPOSITS ACTIVITY

Method of corrosion products activity calculation

Activity of corrosion products in primary coolant is taken in accordance with test data and results of calculations as per OKBM methodology. This methodology allows calculations for nuclear power plant loops of different design with taking into account actual mode of plant operation.

Calculation model covers the following sources of radioactive nucleuses formation:

- structural materials activation in radiation zone with their subsequent corrosion and carryover in coolant;
- corrosion products activation in coolant when it passes through areas in radiation zone.
- activation of corrosion product deposits on surfaces, located in radiation zone.

Procedure of fission products activity calculation

Radio nuclides (fission products) accumulation in primary loop equipment elements is calculated as per OKBM methodology. This methodology particularly allows calculation of fission products distribution in primary loop coolant volume – in water and on loop surfaces, filter mixture and in pressure compensation system for the following sources of fission products:

- from fuel rods surface, due to contamination of rod tubes by uranium;
- from untight fuel rods surfaces and internals.

Input data and results of calculation of primary loop radio nuclides activity

Fission and corrosion products formation and mass transfer in primary loop are calculated with taking into account design values of reactor facility and operation modes, obtained upon SGU operation data. Total amount of fission products, accumulated on equipment surfaces and in filter mixture, is determined first of all by condition of fuel rod claddings.

Refer to Table 2 for the results of calculation of fission and corrosion products activity in primary loop and filter sorbents of the latest filter bed with regard to the reactor core and Victor- II class NPS reactor energy-producing.

Results of calculation of third loop corrosion products activity

Formation and mass transfer of third loop corrosion products are calculated by the above-mentioned methods of corrosion products activity calculation.

Refer to Table 3 for the results of calculation of corrosion products activity on equipment surfaces and in third loop filter sorbents of the latest filter charge in Victor- II class NPS. Third loop coolant activity is $3{,}1\times10^5$ Bq.

2.1.3 Calculation of penetrating radiation

With water-filled reactor, the water layer over reactor core and surrounding structures is an effective protection, which completely attenuates penetrating radiation.

Design analysis and experience of SNF unloading with water-filled reactor indicate that radiation levels, which define personnel dosage, are generally determined by gamma-radiation of radioactive deposits on primary loop surfaces. Contribution of fission products, accumulated in fuel, in dosage is possible during spent fuel rods assembly loading in cask at minor dwell periods after reactor shutdown. In this connection, minimum estimated dwell time after reactor shutdown and prior to work commencement is 3 years, which result in radiation source intensity decrease due to radioactive disintegration and, therefore, this is a factor of radiation mitigation.

Refer to Table 4 for calculated values of radiation levels at SNF unloading from drained reactor of Victor-II class NPS.

Experience of II-generation NPS drained reactors confirms that radiation safety of these works is ensured. Thus, during SNF unloading at "Zvezda" shipyard, personnel individual doses amounted to an average of up to 1-2 mSv, at that, maximum value of individual dose did not exceed 4 mSv for one unloading operation.

In accordance with unloading procedure, the time period, within which reactor remains open upon SNF unloading completion (from the moment of positioning device removal up to standard cover installation), is shorter in comparison with total unloading duration. Personnel is required to be close to open reactor only within 5—10 minutes. Personnel radiation safety at this stage of works is provided by several organization measures: radiation monitoring at work sites with open unloaded reactor, exclusion of unauthorized personnel from work sites, increasing of personnel shifts quantity.

Personnel dosage due to works with open unloaded reactor will increase to an average of not exceeding 1 mSv and for entire unloading they will not exceed 2-3 mSv, that amounts to 10-15 % of A-category personnel dose limit specified by NRB-99.

2.1.4 Assessment of radiation consequences, caused by radionuclides emission into environment

Radio nuclides emission into environment at normal mode of dismantlement may occur from primary loop coolant and gas system of pressure compensation during the following operations (Table 5):

- high pressure gas bleeding;
- reactors drainage prior to defuelling;
- reactor cover removal;
- SNF unloading.

Radioactive noble gases, contained in pressure compensation system and primary coolant, are fully emitted into environment. Refer to Tables 6 and 7 for total emissions of radionuclides at SNF unloading and cutting of Victor- II class NPS outer and pressure hulls respectively.

From experience of unloading of nuclear-powered icebreaker cores radioactive aerosols emission into environment amounts to 2% — for Cs radionuclides and for other radionuclides not exceeding 1% of activity, contained in primary loop coolant.

Study of emission allowability is performed by method of radiation doses direct calculation. Calculation of radioactive emissions dissemination in atmosphere and population individual radiation doses is carried out as per OKBM methods, developed on basis of current normative documentation.

The following radiation impact ways are taken into account for population radiation doses calculation:

- external irradiation, caused by passing radioactive cloud;
- external irradiation, caused by ground contaminated with radionuclides;
- internal irradiation at radionuclides inhalation.

Radiation doses are calculated for the worst weather conditions: wind speeds and Paskwill atmospheric stability classes, which resulting in maximum doses, are selected.

Refer to Table 8 for the calculation results of individual radiation effective doses of population for Victor- II class NPS.

At normal dismantlement procedure dosages are determined by one-year radiation from ground surface, contaminated with Cs-radionuclides, which are accumulated in primary loop.

According to carried out calculations, effective annual dose, related to radionuclides emission into environment at normal dismantlement procedure, will be 3,4 μSv for population. Maximum effective dose of radiation will not exceed 1,0 μSv for Severodvinsk population at the border of sanitary-protective area (500 m from radiation emission point). Specified radiation doses are less than annual radiation dose, caused by natural radiation background.

According to the principle of sanitation requirements predominance over environmental requirements, if individual radiation standards are not exceeded, radiation safety of all natural ecological systems is thereby provided. Hence, radionuclides emission into environment at normal procedure of NPS dismantlement is allowable.

2.1.5 Study of radioactive waste management impact on environment at NPS dismantlement

The main Bldg. of RW management is to minimize radiation impact to appropriate attainable value with taking into account sanitation norms, economical and social factors. At NPS dismantlement the assigned Bldg. may be achieved by special measures.

Measures on RW management at "Zvyozdochka" are performed according to process scheme given on Fig.3, this allows meeting the following conditions:

- quantity (volume, weight) and activity (volume and specific activity) of RW, forming at NPS dismantling, to be minimal;
- radiation safety requirements to be fulfilled.

As radioactive wastes of new types for the shipyard will not form at NPS dismantlement, it may be concluded, that above-mentioned capability is provided on the assumption of the following inequalities solving at each stage of NPS dismantlement. Each inequality is made up for an individual type of radioactive waste:

$$\left\{ V_i + V_{\exists i} \le V_{ОИi} \right. \tag{1.1}$$

where V_i – volume of *i*-type RW, generated at the shipyard during NPS dismantlement, m^3;

$V_{\exists\, i}$ – volume of *i*-type RW, currently generated at the shipyard due to other types of activity during year, m^3;

$V_{ОИ\, i}$ – volume of *i*-type RW corresponding to capacity of the facilities of infrastructure for RW management at the shipyard, m^3.

With conservative approach to evaluation of RW management impact on environment, it may be assumed, that RW of the same types form prior to NPS dismantlement work commencement and during this process at "Zvyozdochka" shipyard. In this case the left part of all inequalities of the system (1.1) will be maximal.

Refer to Tables 9 and 10 for range and characteristics of RW, generated during Victor- II class NPS dismantlement.

Inequalities system solution (1.1) indicates that infrastructure production facilities for RW management suffice for implementation of the process scheme, given in Fig. 3.

2.2 ASSESSMENT OF RADIATION CONSEQUENCES IMPACT, CAUSED BY DESIGN AND WORST-CASE EMERGENCIES DURING NPS DISMANTLEMENT

2.2.1 Classification and list of potential emergencies

Emergencies, which may occur during NPS dismantlement, are divided into design-case and worst-case types depending on initial events and emergency measures. By emergency development features, design-case and worst-case emergencies are classified into nuclear and radiation types.

Nuclear emergencies includes emergencies, which result in increasing of effective factor of neutron multiplication in the reactor core. Radiation emergencies includes emergencies, which result in loss of ionizing radiation source control.

The reasons of emergencies during NPS dismantlement may be personnel errors and mechanisms failure, as well as conditions, caused by external events (flooding, fire, aircraft crash, etc.).

DESIGN-CASE EMERGINCIES

Refer to Table 11 for design-case radiation emergencies.

In case of SNF cask fall, its severe damage with emission of maximum estimated accumulated activity in the form of fission gases and iodines is postulated. Note should be taken, that used fuel composition is an effective barrier, which confine fission products, therefore this assumption is considered to be conservative. Similar scenario is taken for fuel rods assembly damage during unloading.

Fire in reactor compartment as a result of standard equipment inflammation, is highly unlikely event, as dismantled NPS equipment is safely deenergized, and power supplies are dead. Inflammation of non-standard equipment (space heaters, etc.) is more likely. Even in this case any nuclear and radiation hazardous conditions are impossible, as fire in compartment can not impact on reactor core conditions.

Fire consequences analysis assumes, that activity emission may occur as a result of evaporation of reactor water, containing long-lived fission products and remained after drainage operation. Estimated water volume will not exceed 50 l.

In terms of adopted drainage technology it is accepted that unauthorized discharge of coolant in water area occurs owing to drainage pipeline breaking, at that primary coolant discharge may be up to 0,5 tonnes at maximum estimated activity.

WORST-CASE EMERGENCIES

Excess positive reactivity may release if a single edge compensating grid is removed, that may occur only at dismounting of compensating grid drives prior to reactor core unloading in combination with unmonitored reactor filling with water. Removal of one of edge compensating grids out of reactor core, owing to its engaging with drive and with unmonitored reactor filling with water, may occur only in combination with personnel misoperations.

With multi-level protection emergency with occurrence of uncontrolled chain fission reaction on dismantled NPS may be considered to be only postulated. Refer to Table 12 for the list of worst-case emergencies, caused by external events.

In case of NPS flooding at stage of SNF storage or unloading, when primary loop is drained, and compensating grids are safely secured in bottom position reactivity variation is possible on account of reactor filling with water (as a result of primary loop seal failure), but it is evident, that in this case reactor safety is not violated, as reactor subcritical is kept owing to compensating grids submergence.

It is pertinent to note, that by the terms of reactor cores unloading NPS flooding may not occur at significant depths and is considered as a sufficiently short-term situation (not exceeding 1-2 months), with regard to obligatory measures for submarine raising. Thus corrosion and high pressure water impacts on compensating grid stopping devices are excluded.

Hence, conditions of SGU nuclear safety at postulated emergency with NPS flooding during drainage, storage with primary loop to be drained, preparation for reactor core unloading and unloading, are provided. Study of emergency radiation consequences is given below.

Aircraft crash may be represented as combined exposure of impact and subsequent fire. it is evident, that this exposure obtains its the most hazard level at SNF unloading. According to strength calculations of refuelling complex equipment, mounted on reactor cover at SNF unloading, it withstands an eventual impact and in this case no significant exposures on the reactor core occur.

Burning of spilled fuel inside the reactor is impossible because of absence of sufficient access for air. Estimated result of fire, caused by spilled fuel burning, is heating of refuelling cask with spent fuel assembly being unloaded.

2.2.2 Radiation impact on personnel and population in case of design-case and worst-case emergencies

DESIGN-CASE EMERGENCIES.

Fall of SNF cask

Radiation consequences of emergency are studied reasoning from the term, that in result of SNF cask fall, fuel composition and fuel rod tubes will be destructed and volatile fission products (Kr^{85} and I^{129}) will emit fully (100%) into atmosphere .

Carried out calculations indicate, that maximum effective radiation doses will be : 1,3 μSv - for the shipyard personnel, 0,12 μSv - for population of Severodvinsk at the border of sanitary-protective area (500 m from radioactive emission point). Specified radiation doses are significantly lower than 1 mSv – dose limit for population as per NRB-99 in case of normal operation.

Fuel rod assembly damage during unloading

Emergency may occur owing to deterioration of stress-strain properties of fuel rod assembly structural material, deterioration of fuel rod assembly configuration during operation and long-term storage, as well as personnel misoperations at unloading.

Evaluation of radiation consequences is given above. This evaluation supposes full emission of volatile fission products out of fuel rod assembly. Maximum effective dose in intermediate proximity to the cask will not exceed 1,3 μSv, which is significantly lower than dose limit as per NRB-99 in case of normal operation and will not pose hazard for the personnel and environment.

Fire in compartment during SNF unloading

Conservative approach assumes, that combustion rate such, that water (about 50 kg), remained after coolant draining, fully evaporates from reactor. Activity emission in atmosphere during coolant evaporation is caused by caesium radionuclides. Radionuclides (corrosion products Fe, Co) carryover with vapour does not exceed 1%. Vapour puffs generate a plume after emission into atmosphere. Maximum radiation is exposed to the personnel, being inside of this plume. Maximum radiation dose of personnel will be 4 μSv - per emergency.

Population radiation consequences of emergency are calculated for different categories of atmosphere stability. Maximum effective annual dose of radiation will not exceed 0,1 μSv for Severodvinsk population at the border of sanitary-protective area(500 m from radiation emission point). Specified radiation doses are significantly lower than 1 mSv – dose limit for population as per NRB-99 in case of normal operation.

Accidental discharge of primary loop coolant into water area.

Emergency may occur because of personnel errors or pipeline depressurization during reactors drainage. Maximum volume of primary coolant, which may flow out without any control, will not exceed 0,5 m^3. Maximum emission of activity in water area at unauthorized primary coolant discharge will be $1{,}73 \times 10^8$ Bq.

Primary coolant flowing out within 15 minutes into "Zvyozdochka" shipyard water area, with 12 m sea depth at unloading point and 0,5 m/s flow velocity, will extend in volume ~ $6{,}5 \times 10^4$ m^3 on account of turbulization.

Refer to Table 13 for the results of seawater activity calculations. This Table also contains values of radionuclides reference concentrations (KK_i) in bay water, which form 0,1 mSv dose for a year with the following radiation ways:

- inhalation of aerosol particles and water vapours;

- external irradiation during production activity at quay and floating facilities.

In case of simultaneous presence of several radionuclides in water, criterion for nonexceedance of 0,1 mSv dose is the following condition observance:

$$\sum \frac{A_i}{KK_i} \le 1 \tag{1.2}$$

where Ai - specific activity of i-radionuclide in water;

KKi - reference concentration of i-radionuclide in bay water.

Obtained values of water specific activity in "Zvyozdochka" shipyard bay are significantly lower than values of reference concentrations, appropriate to annual effective radiation dose of 0,1 mSv. Value $\sum \frac{A_i}{KK_i}$, being a criterion in case of simultaneous presence of several radionuclides in water , < 1.

Thus, population radiation dose will not exceed 0,1 mSv, i.e. it is lower than dose limit for population as per NRB-99 under normal operation conditions. From the preceding it may be seen that emergency discharge of primary coolant will not result in appreciable radiation and environmental consequences.

Accidental emission of gas out of high pressure gas system at pressure relief in primary coolant

Radiation consequences are assessed with assumption of full emission of volatile radionuclides activity.

According to calculations maximum annual effective dose of radiation will be $7,0\times10^{-2}$ mSv - for the shipyard personnel, and $9,0\times10^{-2}$ mSv - for Severodvinsk population at the border of

-protective area (500m from radioactive emission point). Specified radiation doses are significantly lower than 1 mSv – dose limit for population as per NRB-99 in case of normal operation.

WORST-CASE EMERGENCIES

Emergency with self-sustaining chain reaction during SNF unloading

This emergency should be considered as highly unlikely event and postulated one. Emergency dynamics and energy-release level are calculated as per OKBM methods. Maximum temperature of fuel, which is obtained at emergency, exceeds temperature threshold of commencement of fuel rod claddings depressurization. Thermal depressurization of claddings may occur for not exceeding 10% of total quantity of fuel rods in the reactor core.

Self-sustaining chain reaction is followed by atmospheric emission of both formed radionuclides owing to outburst and previously accumulated radionuclides during reactor power operation.

Energy-release integral corresponds to $2,5\times10^{18}$ disintegrations. Site radiation consequences are calculated for broad spectrum of radionuclides – for 130 fission products, which fully determine total activity during outburst. Maximum values of activity are used in calculation of emission into environment.

Total activity of main radionuclides, formed during self-sustaining chain reaction at the moment of outburst termination, will be $1,69\times10^{16}$ Bq, maximum activity after outburst - $1,82\times10^{16}$ Bq. Activity emission into environment upon radionuclides, determining radiation situation, will be $1,25\times10^{15}$ Bq.

Refer to Figure 4 for distribution of individual radiation dose rate along the axis of aerodynamic shadow.

The calculations indicate, that people radiation at inhalation of air contaminated with radionuclides and radiation cloud impact within the zone of aerodynamic shadow result in doses, which significantly exceed allowable annual dose limits for both personnel and population (50 mSv/year and 5 mSv/year respectively).

Refer to Table 14 for individual effective radiation doses. Dosage of population is determined by annual radiation, caused by ground surface, contaminated by Cs^{137} , which are accumulated during reactor operation, and inhalation radiation.

As follows from calculation results, maximum annual effective dose of Severodvinsk population radiation at the border of

-protective area (500 m from radioactive release) during emergency with self-sustaining chain reaction will be 37 mSv, which does not require population evacuation as per NRB-99.

Zone of protective measures taking is confines within ~5,0 km radius. Beyond 5,0 km zone protective measures are not required, except for temporary restriction on consumption of local foodstuff.

Refer to Table 15 for the results of Severodvinsk population radiation doses calculation for activity emission in different directions with annual wind rose taken into account.

Thus, Severodvinsk population collective dose will be maximum in the case at south wind during emergency with self-sustaining chain reaction and will amount to $5{,}7\times10^4$ person./mSv. Specified dose of radiation does not exceed annual population dose in this region, which is derived from natural radiation background.

NPS flooding at SNF unloading

According to performed analyses, being in sunk state within two months is not a sufficient condition for penetration corrosion damage of tight tubes of fuel rods and SNF activity emission into environment.

To obtain overall evaluation of radiation consequences, caused by NPS flooding at fuel unloading, it is assumed that reactor core operated up to maximum allowable conditions, i.e. fuel rod tubes became untight. Rate of fission products and actinoids activity emission out of reactor core at flooding will be $8{,}22\times10^{13}$ Bq/year.

The source, determining intake of structural material activation products, is seawater corrosion of fuel rods tubes, reactor internals and reactor vessel, as well as structures of metal-water protection tank and NPS pressure hull, located in intermediate proximity to the reactor.

Refer to Table 16 for the results of calculations of corrosion products activity emission rate at NPS flooding during SNF unloading.

According to indicated results, activity of structural materials corrosion products, emitted for two-month period of NPS sinking condition, will be $2{,}0\times10^{12}$ Bq.

During study of flooding consequences it was assumed, that emitted radionuclides are homogeneously mixed in water sheet, which cross sectional dimensions are determined by navigable depth in flooding point and NPS hull width.

Refer to Table 17 for obtained values of water specific activity in water area upon determing radionuclides. This Table also comprises reference concentration values (KK_i) of radionuclides in bay water, which form 0,1 mSv/year dose and values $\frac{A_i}{KK_i}$.

Obtained values of water specific activity in bay are lower than reference concentration values, appropriate to annual effective dose of radiation - 0,1 mSv.

Value $\sum \frac{A_i}{KK_i}$, as a criterion in case of simultaneous presence of several radionuclides in water, is less 1. Thus, annual effective dose of radiation, determined by emergency flooding of NPS, is less than dose limit for population as per NRB-99.
With given results taken into account, it may be thought, that emergency flooding of NPS during SNF unloading will not result in significant radiation and environmental consequences.

Aircraft crash on NPS during SNF unloading

Two following scenarios are to be considered:

1. aircraft crash on NPS beyond reactor compartment;
2. aircraft crash directly on reactor compartment during SNF unloading.

Aircraft crash on reactor compartment during SNF unloading may have grave radiation consequences, for the lack of structural barriers, such as outer and pressure hull of NPS and reactor cover.

It is assumed, that aircraft will crash on positioning device plate, which results in the following:

- mechanical impact on equipment and reactor elements;
- fire in reactor compartment, caused by spilled fuel burning.

Analysis of dynamic disturbances at the moment of aircraft impact indicates, that fuel rods will not collapse, which excludes fission products emission.

Thermal condition of spent fuel assembly at aviation fuel burning is studied on basis of OKBM methods. Upon calculation results maximum temperature of fuel rods in 0,5 h after fire commencement will not exceed 380 ^{0}C. Temperature will increase up to limit value of 600 ^{0}C in a few hours after emergency commencement under condition that fire will not stop in the compartment.

Thus, fire in reactor compartment, on the assumption of its localization and extinguishing within a few hours, will not result in fission products emission out of reactor core fuel. In this case emergency radiation consequences will relate to atmospheric emission of activity, contained in undrainable fuel volume of primary coolant. Effective dose of personnel radiation will not exceed 7,0 mSv. Effective dose of population radiation will not exceed 0,1 μSv, which is significantly lower than 1 mSv - dose limit for population as per NRB-99.

2.2.3 Radiation risk assessment

ASSESSMENT OF RADIATION RISK FOR SHIPYARD PERSONELL

Radiation risk is evaluated in accordance with NRB-99 principles. Radiation risk evaluation is based on results of calculations of radiation consequences, resulted from design and beyond design basis emergencies and evaluation of these emergencies occurrence probability. Refer to Tables 18 and 19 for calculation results.

The results of personnel radiation risk evaluation are lower than specified value as per NRB-99.

ASSESSMENT OF SEVERODVINSK POPULATION RADIATION RISK

Radiation risk assessment is based on results of calculations, carried out for radiation consequences, resulted from design and beyond design basis emergencies and evaluation of these emergencies occurrence probability. Refer to Table 20 for these calculation results.

Radiation risk of population under eventual emergencies during Victor-II class NPS dismantlement is significantly less than limit of individual permanent risk specified by NRB-99 for population $5{,}0\times10^{-5}$ and negligible risk level.

Among design emergencies the greatest radiation risk is assigned to emergency with cask fall from fuel rod assembly. Among beyond design basis emergencies the greatest radiation risk corresponds to emergency with NPS flooding. Radiation risk of emergency with self-sustaining chain reaction is less due to lower probability of its occurrence, which is provided by reactor and reactor core structure, as well as by additional measure — reactor drainage prior to unloading.

In whole the results of population radiation risk evaluation under eventual emergencies during Victor-II class NPS dismantlement indicate high level of these works safety.

2.2.4 Development of measures to insure nuclear and radiation safety.

Refer to Table 21 for instances of compensatory measures to insure nuclear and radiation safety.

2.2.5 Assessment of radiological impact on critical groups of population and personnel

RADIATION CONDITIONS IN SANITARY-PROTECTIVE AREA AND OBSERVATION AREA

Actual radiological impact on critical groups of population and personnel under normal production operation is evaluated upon radiation monitoring data.

Scope, type and rate of radiation monitoring in sanitary-protective and observation areas are determined and performed in accordance with "Program of environment monitoring in sanitary-protective and observation areas of enterprise".

Monitored radiation parameters are the following:

- volume activity of aerosols in ambient air;
- density of precipitation radioactive contamination;
- seawater volume activity;
- specific activity and concentration of individual radionuclides in bottom sediment of the shipyard water area;
- specific activity of soil in sanitary-protective area around Bldg.s of RW management;
- volume activity of sewage (storm and faecal), underground waters in monitoring holes;
- gamma dose rate and contamination of space surfaces, shipyard facilities equipment and crosswalks by radioactive substances.

In addition, upholding of specified authorized limits of doses for personnel and population is permanently monitored.

Radiation conditions for recent years in "Zvyozdochka" shipyard area is given in Tables 22-27, environment sampling scheme- on Figure 5.

VOLUME ACTIVITY OF AEROSOLS IN AMBIENT AIR

Ambient air aerosols sampling is performed using stationary filtering and ventilation plants, where ФПП-15 grade Petryanov filter cloth is used as a filter.

As measurements results show, value of volume activity of ambient air aerosols and concentration of individual radionuclides in ambient air aerosols are significantly lower than maximum reference levels.

ATMOSPHERIC PRECIPITATION DENSITY (TABLE 23)

Precipitation are collected in reservoirs-receivers with 0,25 m^2 collection area. Exposure period is 1 month.

According to measurement results concentration levels of long-life radionuclides in atmospheric precipitation do not exceed maximum reference level for total beta activity of atmospheric precipitation, which is equal to

$$370^* \frac{Bq}{m^2 \cdot month} \tag{1.3}$$

MONITORING OF WATER AREA CONTAMINATIONWITH RADIOACTIVE SUBSTANCES

Bottom sediment (refer to Table 24) in shipyard water area is sampled using winch and dredger according to cartograms of sampling points. Upon measurements results radionuclides concentration in bottom sediment samples at shipyard water area do not exceed reference levels.

Volume activity of seawater samples (refer to Table 25), taken at the shipyard water area averages *4,9 Bq/l for a year*. Concentrations of radionuclides Sr^{90}, Cs^{137} and Co^{60} in water samples are significantly lower than maximum reference levels of these radionuclides. Volume activity of treated waters of faecal sewerage at sewage treatment facilities discharge into the White sea water area (refer to Table 26) does not exceed reference level as well.

LEVELS OF EXTERNAL RADIATION AND CONTAMINTATION OF SHIPYARD FACILITIES AND AREA WITH RADIOACTIVE SUBSTANCES

During operations on RW management maximum values of dose rate of A-group personnel external radiation depending on operation types were within *0,05* to *1,5 mSv/h* range, and individual average annual dose was within *1,5* to *2,5 mSv* range.

Rate of external radiation dose in sanitary-protective and observation areas does not exceed reference levels. Radioactive contamination of space surfaces and equipment on shipyard area is monitored using instruments. Exceedance of reference levels, related to radioactive substances contamination in sanitary-protective and observation areas, was not revealed (refer to Table 27).

MONITORING OF PERSONNEL AND POPULATION RADIATION DOSES LIMITS

Radiological impact of ionizing radiation industrial sources on critical groups of personnel and population is evaluated on basis of the following data:

- results of external radiation dose monitoring;
- results of internal radiation dose monitoring.

The following methods are used for individual dose monitoring of external radiation:

a) individual dose monitoring - by photographic method (individual dose measuring range is from 0,5 to 20 mSv);

b) individual dose monitoring - by photoluminescent method (individual dose measuring range is from 0,25 to 5000 mSv);

Internal radiation dose is evaluated using human radiation spectrometer. Minimum measured activities, incorporated in human body, are the following:

- Co^{60} – 55,5 Bq;
- Cs^{137} – 40,7 Bq

3. Evaluation of radiation impact factors

3.1 ANALYSIS OF AMBIENT AIR QUALITY

The prime objective of polluting substances discharges calculation is the following:

- evaluation of impact of substances discharge sources from dismantlement Bldg.s and the entire shipyard, on ambient air;
- determination of additional contamination level for environment Bldg.s;
- sufficiency evaluation of measures on maximum allowable discharge norms upholding.

This document covers atmospheric emissions of hazardous chemicals, emitted during NPS cutting into major sections, standard-size scrap metal and reactor compartment unit preparation for stable storage afloat.

The main methods of hull structures cutting are the following:

a) oxyacetylene cutting – the main method of cutting. The heat, released under iron burning, causes metal surface melting and melted metal is carried away together with melted oxides;

b) plasma arc cutting – under gas-arc (plasma arc) cutting metal is melted its whole width and cut thickness, then it is removed with hign-velocity gas flow. Plasma jet temperature runs up to 10000-50000 ºC, at that the majority of chemical elements, as a part of metal composition, evaporate. Because of significant specific emissions of hazardous substances, this type of cutting is used only for structures out of non-ferrous metals and alloys (aluminium, copper and titanium alloys);

c) mechanical cutting. Guillotine cutter use allowed to improve environmental situation and to decrease total emissions of hazardous substances into atmosphere by 30%.

The most dusty operations on NPS dismantlement are the following:

- surface grinding using manual pneumatic tool – respiration zone contains particles of abrasive and machined metal, which concentration is up to 60,5 as much as maximum permissible concentration (MPC), manganous and nickel oxides concentration are - up to 1,4 and up to 8 as much as MPC respectively;

- arc-air gouging – this process causes formation of aerosol, which comprises lead (short-term maximum emissions - up to 114 as much as MPC), manganous and nickel oxides (maximum emissions - up to 12,3 and 9,8 as much as MPC respectively);
- manual electric arc welding by austenitic type electrodes, under which chromium, manganous and nickel oxides emit.
- gas cutting of red lead-coated structures is followed by lead emission, with short-term maximum concentration to 67 as much as MPC.

The following calculations are carried out for Environmental Impact Assessment development.

3.1.1 Calculation of rate of polluting substances emission, which form during thermal cutting and welding, as well as painting and drying of reactor compartment unit.

Rates of polluting substances emission under gas cutting and welding are determined by method, which is based on specific values of polluting substances emission.

Polluting substance emissions are calculated with considering metal gas cutting and welds grinding of all sites as simultaneous operations. Gas cutting and welding operations on reactor compartment unit preparation to be performed separately, therefore maximum rates of emissions are taken for calculations.

3.1.2 Calculation of rate of polluting substances emission, which form at old paint coating grinding of welds.

Welds grinding is performed manually at 0,5 m^2/h. Calculation of polluting substances emission rate is based on specific values of elements emission under old paint coating grinding of surface.

3.1.3 Calculation of volatile organic compounds rate under painting and rubberizing

Volatile organic compounds emission is calculated with taking into account data on area of surface to be painted, paint coating consumption rates, volatile elements portion and efficiency of paint coating plants

3.1.4 Calculation of hazardous substances emission rate from the site of cables processing

Cables are processed using cable chopping plant, which is equipped with exhaust ventilation system, local suction devices, air conduits, dust cleaning device and exhaust blower.

During plant operation organic dust as PVC dust emits into atmosphere. Dust cleaning device – fabric filter with 75% cleaning efficiency.

3.1.5 Calculation of hazardous (polluting) substances dispersion

Hazardous (polluting) substances dispersion is calculated using "Ecolog" software system. Refer to Fig.6 for calculation procedure.
Two types are taken for consideration at calculation of polluting substances dispersion in ambient air:

- of all shipyard emission sources;
- of all shipyard emission sources with NPS dismantlement objects taken into consideration.

Dispersion calculations are carried out at full load of the shipyard and simultaneous operation of all process equipment. Calculation are carried out on polluting substances, which form during NPS dismantlement operations. Calculations include surface background concentrations, interpolated by emission sources location, meteorologic conditions and factors, which determine conditions of polluting substances dispersion in atmosphere.

Calculation results indicate exceedance of MPC values at the border of sanitary-protective area of the shipyard for the following substances: nitrogen (IV) oxide (nitrogen dioxide), ferrous oxide (Fig.7-8).

Surface maximum concentration of ferrous oxide is 1,1 as much as MPC. Exceedance is related to contamination of surface atmosphere by emissions from blank production sources. Dispersion calculation indicates, that the main sources of ferrous oxide emission into atmosphere are "Kristall" plasma cutting machine, gas cutting and welding in hull preparation shop.

Surface maximum concentration of nitrogen oxide (IV) (nitrogen dioxide) is 1,02 as much as MPC. HP boiler emissions make greater contribution into ambient air contamination.

Calculations state, that NPS dismantlement project supposes some increase of total polluting substance emissions into atmosphere as compared to current status. The reason is that gas cutting and welding operations quantity will increase during NPS dismantlement. Total emission will not exceed allowable level and will be 50,4% of maximum allowable emission.

CONCLUSION

Implementation of NPS dismantlement projects at the Zvyozdochka shipyard will not result in exceedance of hazardous chemicals standard emissions into atmosphere and air contamination levels. Hence, environmental conditions degradation at the border of sanitary-protective area and resident area with regard to current status will not occur.

3.2 TOXIC WASTE MANAGEMENT

List of industrial waste, their physical and chemical properties, and methods of their neutralization and disposal are indicated in «Code of enterprise industrial wastes".

Implementation of NPS dismantlement project will not result in wastes increase and will not impact on shipyard environmental conditions. All types of industrial wastes, which will form in the course of this project implementation, are not new for the shipyard, as they forms at actual activity.

3.3 ANALYSIS OF WATER RELATED ACTIVITY

Refer to Table 28 for the total emission of polluting substances with Zvyozdochka shipyard sewage for 2002 year and maximum allowable discharge

3.4 CHEMICAL RISK EVALUATION

Refer to Table 29 for procedure of chemical risk evaluation, used for NPS dismantlement. This procedure comprises four main steps:

- hazard identification;
- exposure evaluation;
- evaluation of "dose-effect" relation;
- risk characteristics.

Hazard identification is inventory of discharges into environment.

Exposure evaluation is obtaining of information on actual dosages of personnel and population. Dose is a function of substance concentration, volume intake of substance, impact rate and body weight. Equation of design dose for population is obtained through general formula manipulations.

Linear non-threshold design model is taken for evaluation of "dose-effect" relation. Injury R, expressed in factor of lost years of life – expectation of lost years of life ahead, referred to time unit of a person being affected by source of risk being considered, is determined as a function of annual dose and injury, caused by hazardous chemicals dose unit. Value of individual annual lethal risk may be obtained by dividing of injury value by average lost years of life ahead.

Victor-II class NPS dismantlement will not result in significant increase of hazardous chemicals discharge volumes into shipyard water area. Shipyard water balance (water consumption and water drainage) will not shift.
Step of risk characteristics evaluation includes calculation of combined risk, which is determined as an amount of calculated values of risk for each of polluting substances taken into consideration.

Environmental Impact Assessment includes evaluation of chemical risk for personnel and population under normal conditions of NPS dismantlement. Within this study all types of hazardous chemicals, escaping during dismantlement procedures, are considered.

In addition, this study includes calculation of individual annual lethal risk *r* and expectation of lost years of healthy life ahead *R* for "Zvyozdochka" personnel and population according to procedure, given on Figure 9. Calculation results are indicated in Table 9, according to which population run the high-level chemical risk.

3.5 ECOLOGICAL MONITORING

The shipyard undertook for systematic ecological monitoring of environment impact, caused by the shipyard activity. Existing system of ecological monitoring covers all mediums: atmosphere, water and soil. Monitoring is exercised for conditions of ambient air, water area, bottom sediment, soil, quantitate and qualitative composition of polluting substance emissions into atmosphere, quantitate and qualitative composition of polluting substance discharges with sewage into water and snow precipitation in area of NPS hulls cutting.

To exercise ecological monitoring the shipyard has available specially equipped laboratory facilities with trained personnel, who regularly pass through certification. Water and air analysis laboratory staff consists of 24 persons (4 engineers and 20 laboratory technicians). Instruments are regularly verified, analysis procedures for samples of different mediums are certified according to guiding documents of Environmental Authorities and Sanitary Supervision Service.

Ambient air quality monitoring in sanitary-protective area and at production site is exercised for dust, soot, manganese compounds, sulfur and nirtogen oxides. Atmospheric emissions are monitored on emission sources. Exceedance of maximum permissible concentrations of hazardous substances were not registered in sanitary-protective area of the shipyard.

Water area is monitored in two points above and below shipyard discharge points. Increase of water area contamination is not registered.

Sewage is monitored for each discharge of production storm sewage and sewage & processing installations discharge. In addition soil and snow samples are analysed for heavy metals content in NPS dismantlement areas. Contamination increase is not registered.

The results of instrumental monitoring are analysed by the shipyard technicians and submitted to State Surveillance Authorities.

Implementation of NPS dismantlement projects will not add new sources of hazardous chemicals emission in atmosphere and discharges in shipyard water area. Therefore environmental quality at production sites will not deteriorate at this project implementation. Development of additional measures on ecological monitoring is not required. Ecological monitoring to be exercised in scope of existing inspection schedules, agreed with State Surveillance Authorities.

4. Conclusion

Based on given information, the following statements on Environmental Impact Assessment at Victor- II class NPS dismantlement may be specified.

Maximum gross radioactivity, accumulated in steam-generating plant of Victor-II class NPS, in three years of holding will be $1,4 \times 10^{16}$ Bq (per one reactor). The main portion of activity value is contributed by Spent Nuclear Fuel. SNF unloading will result in total 3 times decrease of reactor compartment activity. In this case the most radiation-dangerous radionuclides will be removed.

Radiation personnel burden caused by gamma-radiation penetrating at SNF unloading from Victor- II class NPS will not exceed 2-3 mSv, which is 10-15% of specified dose limit of A category personnel radiation. Obtained results with experience of II-generation reactors drainage indicate, that personnel radiation safety may be provided under strict adherence to schedule of operations on SNF unloading.

Effective annual dose of radiation, related to radionuclides emission into ambient air at normal dismantlement procedure, will be 3,4 μSv for “Zvyozdochka” personnel. Effective annual dose of Severodvinsk population radiation at the border of sanitary-protective area will not exceed 1,0 μSv. Specified radiation doses are less than annual radiation dose, caused by natural radiation background

Results of analysis for radiation factors indicate, that maximum annual effective dose of population radiation at design emergencies during Victor-II class NPS dismantlement will not exceed 0,1 mSv, which is significantly lower than dose limit for population specified by NRB-99 under normal operation conditions. The gravest radiation consequences correspond to postulated beyond design basis emergency with self-sustaining chain reaction as a result of edge compensating grid removal at drives dismounting and unmonitored reactor filling with water. Occurrence of this emergency is excluded by application of safety measures, operations technology and, in addition, reactor drainage prior to reactor core unloading.

According to calculations maximum annual effective dose of Severodvinsk population radiation at the border of sanitary-protective area (500 m from radioactive emission point) in case of hypothetical emergency, related to self-sustaining chain reaction occurrence. will be 37 mSv, which does not require population evacuation as per NRB-99, population radiation doses will not exceed annual population doses of radiation in this region, which is determined by natural radiation background.

According to calculations radiation risk for both "Zvyozdochka" personnel and population of Severodvinsk in case of eventual emergencies during Victor-II class NPS dismantlement is significantly less than limit of individual risk of industrial radiation for population $5{,}0\times10^{-5}$ and negligible risk level specified in NRB-99.

Implementation of this NPS dismantlement project at the "Zvyozdochka" shipyard will not result in exceedance of hazardous chemicals standard emissions into atmosphere and air contamination levels in resident area.

The project provides for additional scope of gas cutting, welding and painting works, as well as works on cables chopping. Other types of polluting substance emissions, caused by the activity, scheduled in NPS dismantlement project, are not anticipated. Hence, types and volumes of polluting substances do not vary at the shipyard. Scheduled works will not cause significant extension of gas cutting, welding and painting and cable chopping works scope, and sharp increase of hazardous chemicals emission into atmosphere.

Operations of Victor-II class NPS dismantlement areas will not actually impact on existing water balance (with regard to water consumption and water drainage) of the "Zvyozdochka" shipyard and will not result in volume change of hazardous chemicals discharge with sewage into water area. All types of industrial wastes, which will form in the course of this project implementation, are not new for the shipyard, as they form at actual activity. Forming waste will be allocated in compliance with Limitations on industrial and sanitary waste disposal.

Basing on analysis of actual data, accumulated during "Yankee", "Delta-I", "Delta-III", "Kursk" and "Victor-II" classes NPS dismantlement, selection of optimal engineering and administration solutions, it may be concluded, that the essential part of content of documents on Environmental Impact Assessment (~70%) does not depend on particular class of NPS to be dismantled but it is determined by features of engineering processes, equipment in service, radioactive and other wastes management facilities used at specific Shipyard.

It seems to be practical to develop the main part of Environmental Impact Assessment at dismantlement of any class NPS within the next few years, so that, when developing further similar documents, this standard Environmental Impact Assessment to be made specific as applied to conditions for management of wastes and process operations, adopted at the shipyard.

FIGURES AND TABLES

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Table 1. Induced activity of reactor structural materials and NPS pressure hull at 3-years dwell period

Structural member	Total activity, Bq
Reactor internals	$4{,}0\times10^{15}$
Reactor vessel	$4{,}7\times10^{14}$
Central caisson and bottom of metal-water protection tank	$7{,}3\times10^{13}$
Pressure hull	$1{,}7\times10^{12}$

Table 2. Activity of fission and corrosion products of reactor primary loop equipment at 3-year dwell period.

Equipment	Reactor	Pressurizer	Filter	Primary loop coolant
Total activity, Bq	$1{,}3\times10^{12}$	$2{,}8\times10^{10}$	$9{,}0\times10^{11}$	$2{,}9\times10^{9}$

Table 3. Activity of corrosion products in third loop equipment at 3-year dwell period.

Equipment elements	Total activity, Bq
Metal-water protection tank	$1{,}1\times10^{9}$
Third and fourth loops heat-exchangers	$3{,}1\times10^{8}$
Pipes, primary loop filters cooler	$2{,}1\times10^{8}$
Primary loop filter	$1{,}7\times10^{8}$
Total amount	$1{,}8\times10^{9}$

P. Strand et al. (eds.), Radiation and Environmental Safety in North-West Russia, 135–160.

Table 4. Radiation levels at SNF unloading from drained reactor.

Process stage	Dose rate, mSv/h	Measurement point
Unloading of RTD wells	0,4	At the distance of 0,1 mm from RTD surface
Wells and safety rods trimming	0,4	At the distance of 0,1 mm from safety rod well
Reactor cover removal, positioning device installation	2	On bottom face of reactor cover
	1	On open reactor axis at 1,5 m elevation of sliding screen top plate
Works with positioning device	0,02	At 0,5 m elevation from positioning device surface
Fuel rods assemblies unloading	<0,001	On surface of fuel cask

Table 5. Radioactive emissions at normal modes of NPS dismantlement

Dismantlement stage	Emission source
Removal operations for SNF unloading	Emission at high pressure gas bleeding
SNF unloading	Emissions at SNF unloading from reactor
Reactor compartment unit formation	Emissions at cutting of NPS outer and pressure hulls

Table 6. Total emission of radionuclides at SNF unloading from each reactor Victor-II class NPS

Radionuclide	Fore reactor, Bq	After reactor, Bq		
			personnel	population
Mn-54	3800	78000	$1,3\cdot 10^{7}$	$5,3\cdot 10^{5}$
Co-60	7700	$2,79\cdot 10^{5}$	$6,9\cdot 10^{6}$	$8,3\cdot 10^{4}$
Cs-134	2900	–	$2,9\cdot 10^{6}$	$1,5\cdot 10^{5}$
Total	14000	$3,57\cdot 10^{5}$		

Table 7. Radionuclides emission at cutting of Victor-II class NPS outer and pressure hulls

Radionuclide	Emission, Bq	Annual yield limit $_{pers.}$, Bq/year
Iron-55	1900	$5,4\cdot 10^{7}$
Ni-59	0,15	$1,5\cdot 10^{8}$
Ni-63	17	$4,5\cdot 10^{6}$
Co-60	170	$6,9\cdot 10^{6}$

Table 8. Effective dose of population radiation at normal mode of Victor- II class NPS dismantlement, mSv

Distance, km	Cloud radiation dose	Inhalation radiation dose	Surface radiation dose	Total
0,1	$5,8\times 10^{-6}$	$7,7\times 10^{-5}$	$3,3\times 10^{-3}$	$3,4\times 10^{-3}$
0,2	$4,5\times 10^{-6}$	$6,0\times 10^{-5}$	$2,6\times 10^{-3}$	$2,7\times 10^{-3}$
0,5	$1,6\times 10^{-6}$	$2,1\times 10^{-5}$	$9,0\times 10^{-4}$	$9,2\times 10^{-4}$
1	$5,4\times 10^{-7}$	$6,4\times 10^{-6}$	$2,8\times 10^{-4}$	$2,9\times 10^{-4}$
2	$1,8\times 10^{-7}$	$1,8\times 10^{-6}$	$7,9\times 10^{-5}$	$8,1\times 10^{-5}$
3	$9,2\times 10^{-8}$	$8,6\times 10^{-7}$	$3,7\times 10^{-5}$	$3,8\times 10^{-5}$

Table 9. Range and characteristics of liquid radioactive wastes (LRW), forming at Victor-II class NPS dismantlement

LRW	Volume, m^3	Genertion nature	Category	Chemical nature	Radionuclides composition
Primary loop coolant	35	Operational	Low active (β-emmitter)	Weak-salinity non-organic	H^3, C^{14}, Fe^{55}, Co^{60}, Ni^{63}, Sr^{90}, Cs^{134}, Cs^{137}
Water from metalwater protection tank	30	Operational	Low active (β - emmitter)	Weak-salinity non-organic	Co^{60}, Sr^{90}, Cs^{137}
Bioprotection tank wastewaters	32,8	Opertional	Low active (β - emmitter)	Salinity organic	S^{35}, Ca^{45}, Mn^{54}, Fe^{55}, Co^{60}, Sr^{90}, Cs^{137}
Wastewater from accessories, PPE, and reactor compartment decontamination	25	Production	Low active (β - emmitter)	Weak-salinity and salinity non-organic	Fe^{55}, Co^{60}, Ni^{63}, Sr^{90}, Cs^{134}, Cs^{137}
Laundry wastewaters	1000	Production	Low active (β - emmitter)	Organic, salinity non-organic	Co^{60}, Sr^{90}, Cs^{137}

Table 10. List of design-case radiation emergencies during NPS dismantlement

Initial events	Consequences evaluation
1 Fall of SNF cask with fuel rod assembly being loaded	Fuel rod assembly destruction with subsequent emission of activity accumulated in fission gases and iodines
2 Fuel rod assembly damage during unloading	Fuel rod assembly destruction with subsequent emission of activity, accumulated in fission gases and iodines
3 Fire in reactor compartment during SNF unloading	Activity emission at water residue evaporation in reactor
4 Accidental partial discharge of primary loop coolant (up to 0,5 tonnes) into water area	Emission of activity, accumulated in coolant, which is discharged into water area

Table 11. List of worst-case emergencies

Accidental event	Consequences evaluation
Self-sustaining chain reaction	
1. Postulated unmonitored removal of one of edge compensating grids with reactor to be filled with water.	Occurrence of self-sustaining chain reaction (outburst) with damage of a part of fuel rods and activity emission.
Accidents as a result of external events	
2.NPS flooding during SNF unloading	Activity emission out of unsealed fuel rods and owing to corrosion of reactor elements, metal-water protection tank and pressure hull.
3. Aircraft crash on NPS during fuel rod assembly unloading	Fire, superheating of spent fuel assembly being unloaded in the cask, with accumulated activity emission

Table 12. Specific activity of water in "Zvyozdochka" shipyard water area at accidental discharge of primary loop coolant.

Radionuclide	Seawater activity Bq/kg	Reference concentration at works on quay, Bq/kg	$\frac{A_i}{KK_i}$
Sr^{90}	$1,5\times10^{-5}$	$2,08\times10^{4}$	$7,2\times10^{-10}$
Cs^{137}	1,7	$6,41\times10^{4}$	$2,7\times10^{-5}$
Fe^{55}	0,42	$7,4\times10^{5}$	$5,7\times10^{-7}$
Ni^{59}	$1,3\times10^{-3}$	$1,89\times10^{6}$	$6,9\times10^{-10}$
Co^{60}	$4,5\times10^{-2}$	$7,14\times10^{3}$	$6,3\times10^{-6}$
Ni^{63}	0,14	$5,55\times10^{5}$	$2,5\times10^{-7}$

Table 13. Effective dose of population radiation at emergency with self-sustaining chain reaction, mSv

Distance, km	Cloud radiation dose	Inhalation radiation dose	Surface radiation dose	Total
0,5	1,9	9,7	26,0	37,0
1	0,54	6,9	18,0	26,0
2	0,12	3,2	8,3	12,0
3	0,051	1,8	4,7	6,5
5	0,017	0,81	2,2	3,0
10	0,0029	0,27	0,70	0,97

Table 14. Severodvinsk population doses of radiation in case of emergency with self-sustaining chain reaction at different distances and directions from emission point, person-mSv

Distance, km	Direction					
	South	South-east	East	North-east	MP	South-west
1,0-1,5				$3{,}3\times10^{3}$		
1,5-2,0				$9{,}5\times10^{3}$	$9{,}6\times10^{3}$	
2,0-2,5	$1{,}4\times10^{4}$	$8{,}6\times10^{3}$		$1{,}2\times10^{4}$	$4{,}3\times10^{3}$	
2,5-3,0	$1{,}3\times10^{4}$	$1{,}0\times10^{4}$	$6{,}3\times10^{2}$	$3{,}2\times10^{3}$		
3,0-3,5	$1{,}2\times10^{4}$	$8{,}7\times10^{3}$				
3,5-4,0	$9{,}0\times10^{3}$	$6{,}8\times10^{3}$				$1{,}1\times10^{3}$
4,0-4,5	$6{,}7\times10^{3}$	$3{,}3\times10^{3}$				
4,5-5,5	$2{,}6\times10^{3}$	$6{,}0\times10^{2}$				
Total	$5{,}7\times10^{4}$	$3{,}8\times10^{4}$	$6{,}3\times10^{2}$	$2{,}8\times10^{4}$	$1{,}4\times10^{4}$	$1{,}1\times10^{3}$

Table 15. Rate of structural materials activity emission at NPS flooding during SNF unloading, Bq/year

Source	Total
Pressure hull	$9{,}3\times10^{9}$
Caisson of metal-water protection tank	$1{,}3\times10^{9}$
Reactor vessel	$4{,}8\times10^{11}$
Reactor internals	$1{,}8\times10^{11}$
Fuel rod tubes	$1{,}3\times10^{12}$
Total	$2{,}0\times10^{12}$

Table 16. Values of tracing specific activity upon determing radionuclides in "Zvyozdochka" shipyard water area at NPS flooding during SNF unloading

Radionuclide	Trace activity, Bq/kg	Reference concentration at works on quay, Bq/kg	$\frac{A_i}{KK_i}$
Fe^{55}	0,95	$7,4\times10^{5}$	$1,3\times10^{-6}$
Sr^{90}	8,6	$1,29\times10^{4}$	$6,7\times10^{-4}$
Cs^{137}	9,3	$6,41\times10^{4}$	$1,5\times10^{-4}$
Ce^{144}	2,3	$1,07\times10^{3}$	$2,2\times10^{-3}$
Pm^{147}	4,7	$1,1\times10^{4}$	$4,3\times10^{-4}$
Pu^{241}	3,9	$1,55\times10^{3}$	$2,5\times10^{-3}$

Table 17. Radiation risk evaluation under normal conditions of NPS dismantlement.

Sources of radiation emissions.	Permanent risk coefficient, 1/Sv	Individual effective dose E_i, Sv	Individual lethal risk R_{ci}, 1/year	Annual individual damage in terms of lost years, L_{ci}, years per annum
Fuel rods assemblies unloading	$5,60\cdot10^{-2}$	$5,00\cdot10^{-12}$	$2,80\cdot10^{-13}$	$5,00\cdot10^{-12}$
Hull cutting	$5,60\cdot10^{-2}$	$5,00\cdot10^{-15}$	$2,80\cdot10^{-16}$	$5,00\cdot10^{-15}$

Table 18. Evaluation of "Zvyozdochka" personnel radiation risk under potential emergencies during Victor-II class NPS dismantlement.

Emergency scenario	Radiation dose, Sv	Emergency probability	Radiation risk
Normal dismantlement procedure	$3,4\times10^{-6}$	1	$1,9\times10^{-7}$
1 Design-case emergencies			
1.1 Fall of SNF cask.	$1,3\times10^{-6}$	$8,0\times10^{-3}$	$5,8\times10^{-10}$
1.2 Fuel rod assembly damage during unloading	$1,3\times10^{-6}$	$6,0\times10^{-3}$	$4,4\times10^{-10}$
1.3 Fire in compartment during SNF unloading	$4,0\times10^{-6}$	$1,6\times10^{-4}$	$3,6\times10^{-11}$
1.4 Accidental discharge of primary loop coolant into water area.	$<1,0\times10^{-4}$	$4,0\times10^{-6}$	$2,2\times10^{-11}$
1.5 Accidental gas emission out of HP gas system.	$7,0\times10^{-5}$	$4,0\times10^{-6}$	$1,6\times10^{-11}$
2 Worst-case emergencies			
2.1 Self-sustaining chain reaction during SNF unloading	0,2	$<1,5\times10^{-7}$	$1,6\times10^{-9}$
2.2 NPS flooding during SNF unloading	$<1,0\times10^{-4}$	$1,2\times10^{-4}$	$6,7\times10^{-10}$
2.3 Aircraft crash during SNF unloading	$1,4\times10^{-2}$	$2,0\times10^{-9}$	$1,6\times10^{-12}$

Table 19. Results of population radiation risk evaluation under potential emergencies during Victor-II class NPS dismantlement.

Emergency scenario	Radiation dose, Sv	Emergency probability	Radiation risk
Normal dismantlement procedure	$1{,}0\times10^{-6}$	1	$7{,}3\times10^{-8}$
1 Design emergency			
1.1 Fall of SNF cask.	$1{,}2\times10^{-7}$	$8{,}0\times10^{-3}$	$7{,}0\times10^{-11}$
1.2 Fuel rod assembly damage during unloading	$1{,}2\times10^{-7}$	$6{,}0\times10^{-3}$	$5{,}3\times10^{-11}$
1.3 Fire in compartment during SNF unloading	$1{,}0\times10^{-7}$	$1{,}6\times10^{-4}$	$1{,}2\times10^{-12}$
1.4 Accidental discharge of primary loop coolant into water area.	$<1{,}0\times10^{-4}$	$4{,}0\times10^{-6}$	$2{,}9\times10^{-11}$
1.5 Accidental gas emission out of HP gas system.	$9{,}0\times10^{-5}$	$4{,}0\times10^{-6}$	$2{,}6\times10^{-11}$
2 Beyond design basis emergencies			
2.1 Self-sustaining chain reaction during SNF unloading	$3{,}7\times10^{-2}$	$<1{,}5\times10^{-7}$	$4{,}1\times10^{-10}$
2.2 NPS flooding during SNF unloading	$<1{,}0\times10^{-4}$	$1{,}2\times10^{-4}$	$8{,}8\times10^{-10}$
2.3 Aircraft crash at the moment of SNF unloading	$1{,}4\times10^{-2}$	$2{,}0\times10^{-9}$	$2{,}0\times10^{-12}$

Table 20. Compensatory measures to decrease risk of nuclear and radiation emergencies

Emergencies	Measures to decrease emergencies risk
Self-sustaining reaction	Reactor drainage, moisture-free storage and unloading
Emergencies, related to lifting operations at SNF management	Improvement of operational reliability of hoisting appliance elements and unloading schemes
Emergencies, related to NPS flooding during storage and transportation.	Flooding of main ballast tanks with spumed polystyrene, use of pontoons and floating docks
Emergencies, related to reactor compartment units flooding during transportation and storage in PVC	Observance of instructions on towing, construction of surface storage facility for reactor compartment, dock repair of reactor compartment, buoyancy tanks filling with polystyrene.
Emergencies, occurred during transportation, processing and storage of solid and liquid radioactive wastes	Use of mobile modular plant for SRW and LRW treatment directly at RW generation place, improvement of existing system of RW management.
Emission waste sorbents used in activity filter	Denied sorbents unloading, storage in reactor compartment unit
Emergencies with fire	Removal of combustible materials, serviceability of fire-extinguishing systems, access restriction

Table 21. Aerosols radioactivity

Year	Average annual activity, Bq/m^3 x 10^{-5}					
	Sampling point					
	Bldg. 159	Quay 150	Quay 101	Quay 9	Transformer substation-31	Town
	Σ_β	Σ_β	Σ_β	Σ_β	Σ_β	Σ_β
1999	----	52.0	54.5	46.0	≤ 60.2	36.5
2000	----	37,3	≤ 39,8	35,3	35,1	22,8
2001	----	42,3	46,2	34,3	36,0	31,2
2002	16,85	30.87	47.72	30,85	39,65	22,5
2003	24,1	33,3	26,7	27,5	32,3	25,3
Refeence levels	5000	5000	5000	5000	5000	500

Table 22. Atmospheric precipitation density

Observation period	Average annual density of atmospheric precipitation Bq/m^2 x months.					
	Quay 9	Quay 101	Quay 150	Bldg. 159	Transformer substation – 31	Town
1999 year	≤ 5,4	4,6	5,3		3,7	
2000 year	≤ 3,1	3,5	5,5		3,5	
2001 year	6,2	2,9	6,1	6,3	3,5	
2002 year	5,6	3,0	4,0	3,5	2,2	3,5
2003 year	2,8	2,7	4,3	3,6	2,7	6,1
Reference level	370,0	370,0	370,0	370,0	370,0	370,0

Table 23. Bottom sediments

Point No.	Specific activity, Bq/kg				
	1999 year	2000 year	2001 year	2002 year.	2003 year
1	470	580	-	580	600
2	350	230	420	320	360
2a	330	260	430	300	290
5(1)	580	690	710	615	700
5(2)	460	670	710	670	780
5(3)	350	610	620	510	860
6	530	380	620	670	580
8	250	350	300	450	-
9	375	330	260	270	290
10	540	470	640	615	520
11	520	660	480	460	-
12	600	590	620	720	690
13	540	600	710	570	750
13a	540	540	-	620	730

Table 24. Seawater radioactivity

Year	Activity, Bq/l	
	Sampling point	
	In area of sewage water treatment facility drainage pipe (buoy No. 2)	In bridge area
1999	≤4.9	≤4.1
2000	≤4.5	4,5
2001	4,6	4,5
2002	7,0±13%	5.8±13%
2003	7,0±13%	5.8±13%
Reference levels	11,1	11,1

Table 25. Radioactivity of faecal sewerage at sewage water treatment facility discharge in White sea water area.

Year	Volume activity of treated sewage at sewage water treatment facility discharge, Bq/l
1999	0,2
2000	0,2-0,6
2001	0,1-0,31
2002	0,2-0,49
2003	0,2-0,46

Table 26. Radioactivity of soil in observation area.

Sampling point	Surface activity of soil				
	1999 year	2000 year	2001 year	2002 year	2003 year
	Bq/km$^{2\times}10^{9}$		Bq/m^{2}		
Butoma street	≤15.0	9,0±15%	9400	18000±18%	18000±18%
Makarenko street	≤16.0	15,0±14%	12000	26000±16%	26000±16%
Sewage water treatment facility	≤16.0	9,7±16%	-----	-----	-----
Zone 3	≤12.0	8,8±16%	9800	14000±16%	14000±16%

Table 27. Total discharge of polluting substances with Zvyozdochka shipyard sewagefor 2002 year and specified maximum allowable discharge (MAD), kg/year

Components to be determined	Discharge sources 1-8		Discharge source 9		Total discharge	
	Actual	MAD	Actual	MAD	Actual, %	MAD
1. Ammonia nitrogen	2251,33	1432	24391	42768	60,3%	44200
2. Nitrate nitrogen	128,512	366	48699	40040	12,1%	40406
3. Nitrite nitrogen	3,8	24,84	1864	2330	79,3%	2354,84
4. Full biochemical oxygen demand	8250,86	1863	37208	66000	67%	67863
5. Suspended matters	7660,36	6558	41931	66000	68,4%	72558
6. Iron	802,71	249,4	842	1760	81,8%	2009,4
7. Cadmium	0	6,186	0	44	0	50,186
8. Manganese	88,47	74,9	126	440	41,8%	514,9
9. Copper	15,3	12,35	15,2	88	30,4%	100,35
10. Oil products	200,49	135,9	330	616	70,5%	751,9
11. Nickel	0,558	6,17	0	44	1,1%	50,17
12. Surfactants	127,9	62	351	440	18,5%	502
13. Lead	3,108	5,95	4,5	35	18,5%	40,95
14. Phosphates (expressed as P)	182,362	122,5	8444	9240	92,1%	9362,5
16. Chromium (III)	0,152	2,996	0	31	0,4%	33,996
17. Zinc	21,612	30,69	0	220	8,6%	250,69

Table 28. Methods of chemical risk evaluation, which are used for objects and procedures of NPS dismantlement

Description	**Developed by**	**Application range**	**Evaluation factor**	**Models**	**Capability of use for evaluation of risk at Rossudostroenye entreprises.**
Procedure of conditional (comparative) risk evaluation	Professor S.M.Novikov / NII ECh and GOS named after Sysin A.N	Social and sanitary monitoring of large industrial centres	Index of comparative conditional risk (qualitative evaluation of effects gravity)		Impossible to be used due to design factors for hazardous chemicals, forming during NPS dismantlement
"Integrated sanitary evaluation of degree of medical and ecological conditions tension in different regions, which is caused by environment con-	Approved by Onischenko G.G., Chief State Sanitary Inspector of Russia 30 July 1997		Probability of reflex phenomena occurrence (irritation sense, unpleasant odor, and other organoleptic effects)	Individual threshold model	Use is not practical, because the practice does not allow to compare risk of chemical and radiation factors impact

tamination by toxicants", Guidelines			Probability of nonspecific responses initiation under chronic poisoning	Probability model (nonthreshold) model of noncarcinogenic risk under chronic poisoning	
Procedure of risk evaluation basing on the factor of lost years of life	V.F. Demin / Russian Scientific Center "Kurchatov institute"	Evaluation of risk, caused by all factors	Factor of lost years of life L, caused by risk factor impact	Linear nonthreshold model	Use is considered to be practical, because the practice allows to evaluate and compare risk, caused by radiation and chemical factors

Table 29. Individual annual lethal risks and factors of lost years for personnel and population during NPS construction, repair and dismantlement

	Annual individual lethal risk, R	Annual individual factor of lost years of life, L
For personnel		
Electrical manual welding	5,90E-05	2,03E-03
Arc-air gouging	3,84E-05	1,33E-03
Gas cutting	1,67E-04	5,80E-03
Plasma cutting	3,35E-04	1,16E-02
Grinding operations	9,96E-04	3,48E-02
For population of Severodvinsk		
NPS construction	1,45E-03	5,09E-02
NPS repair	1,42E-03	4,99E-02
NPS dismantlement	1,43E-03	5,00E-02

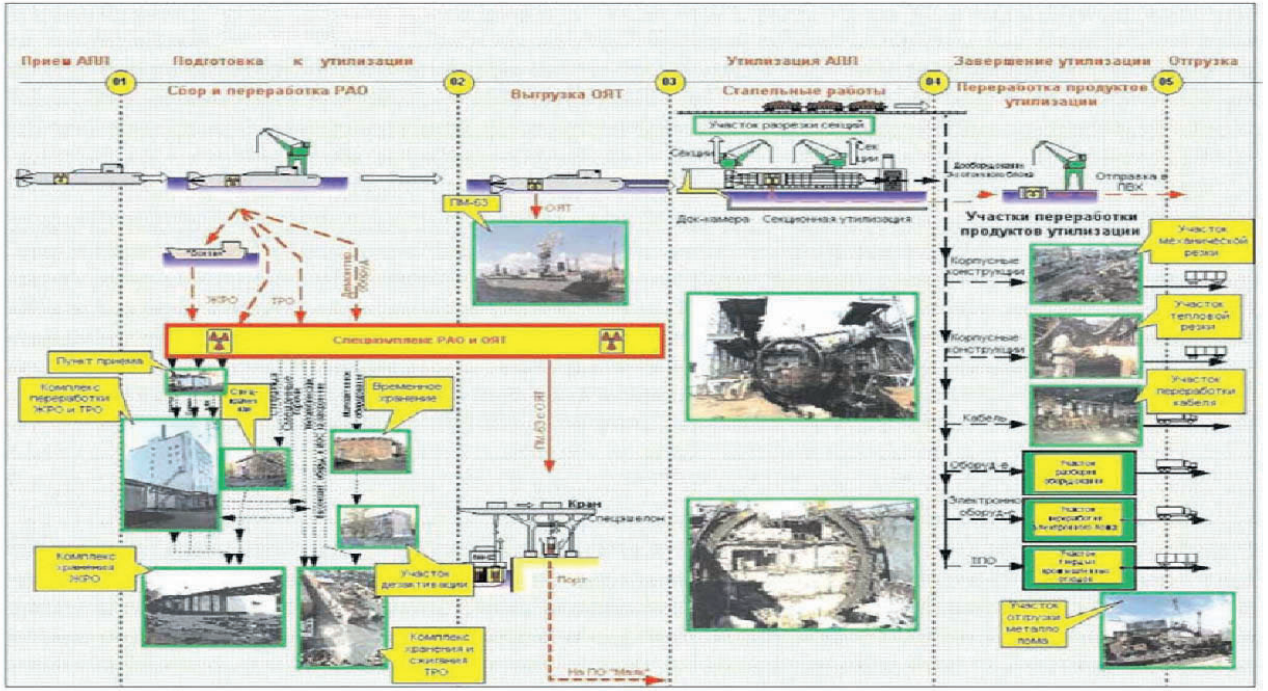


Fig. 1. Organization-technological scheme for utilization of NPS.

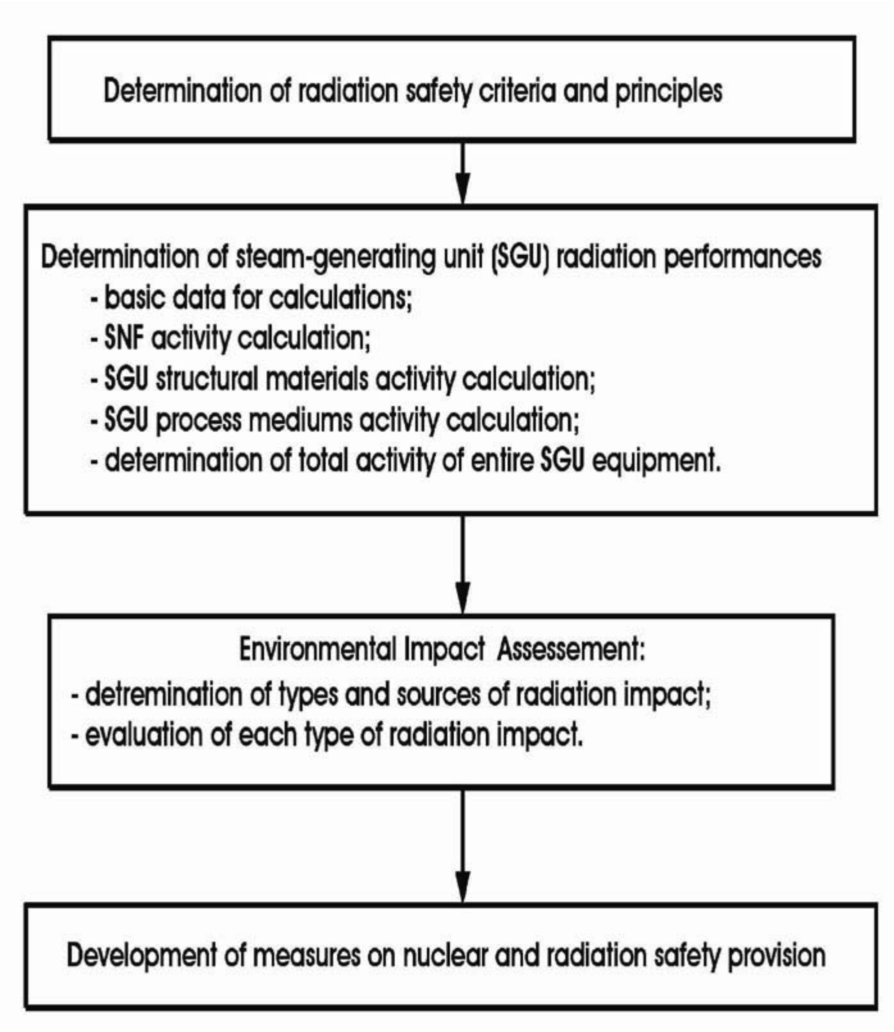


Fig. 2. Evaluation scheme of radiation factors impact on personnel, population and environment under normal NPS dismantlement.

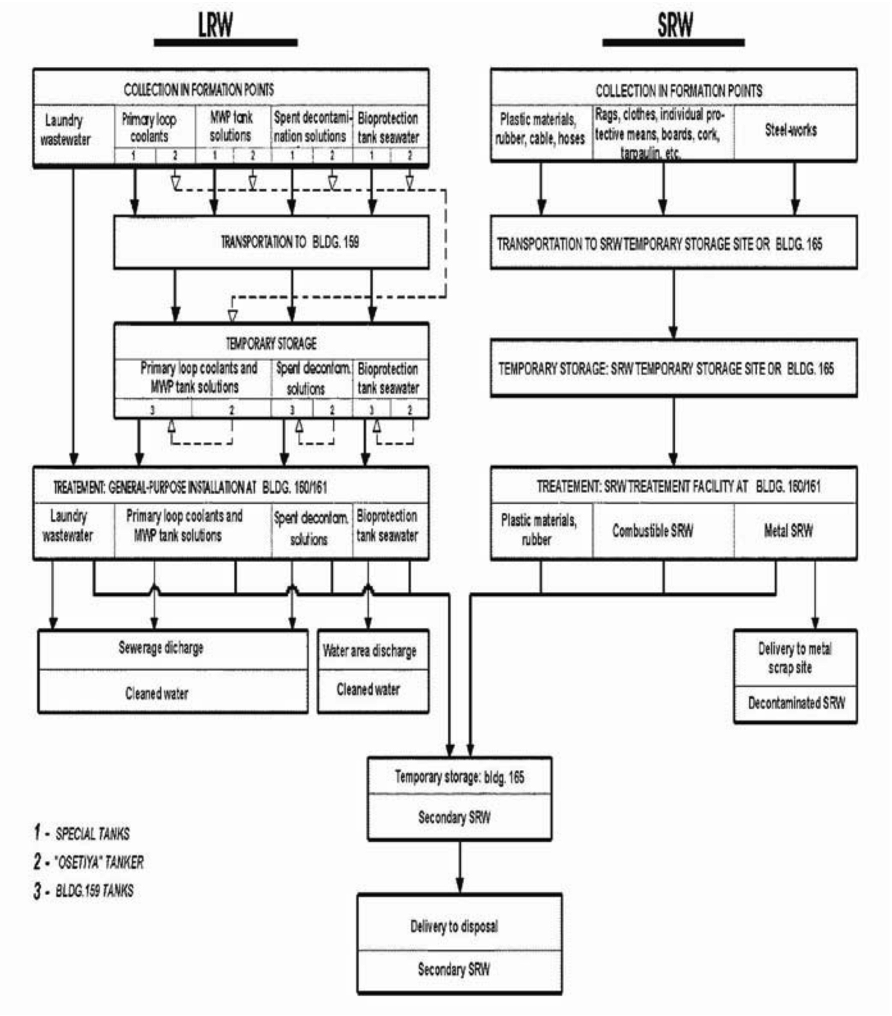


Fig. 3. Process flow diagram of RW management during NPS dismantlement at the shipyard “Zvjozdochka

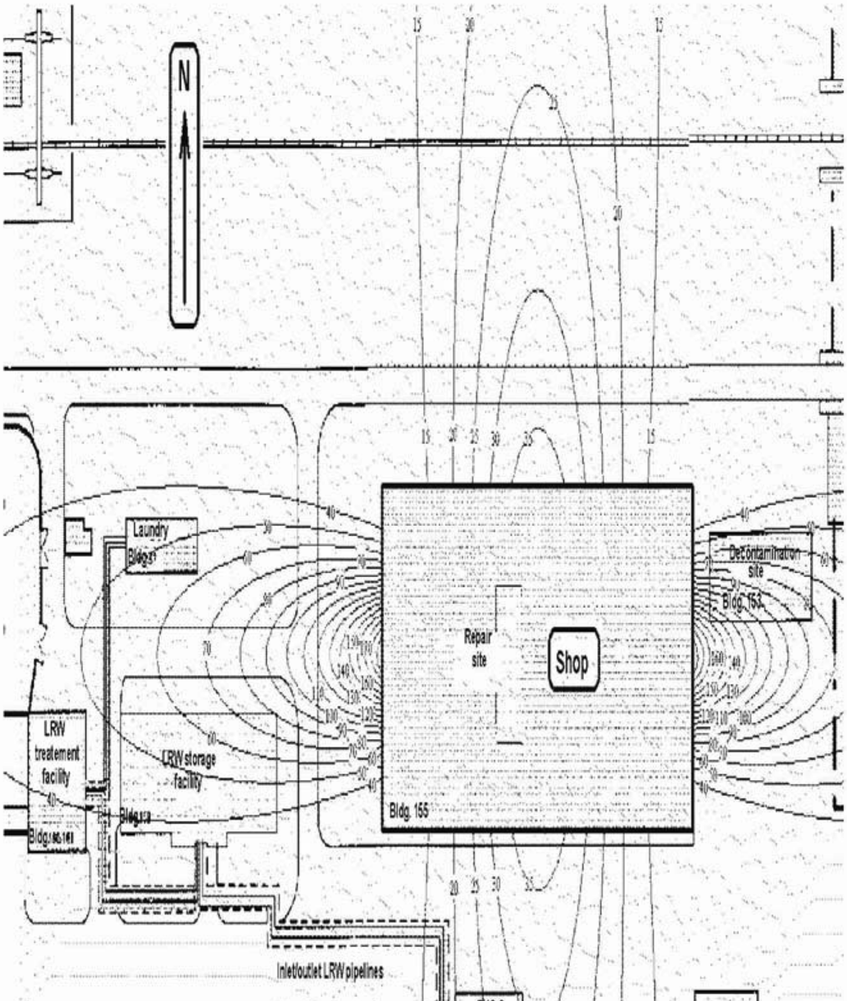


Fig. 4. Distribution of maximum dose equivalent (MDE), mSv/h, within the zone of shop aerodynamic shadow, which is drawn for 4 wind directions.

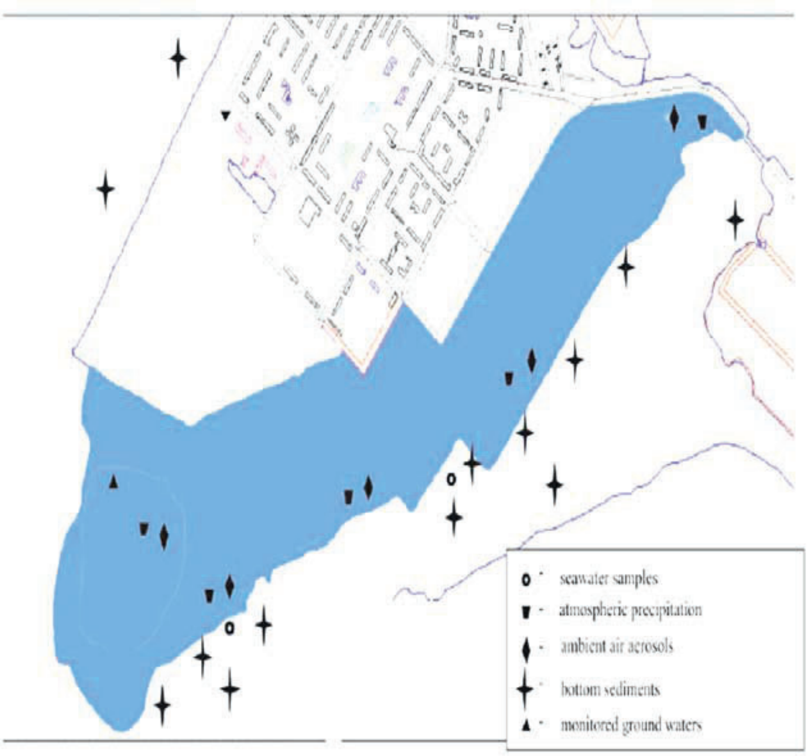
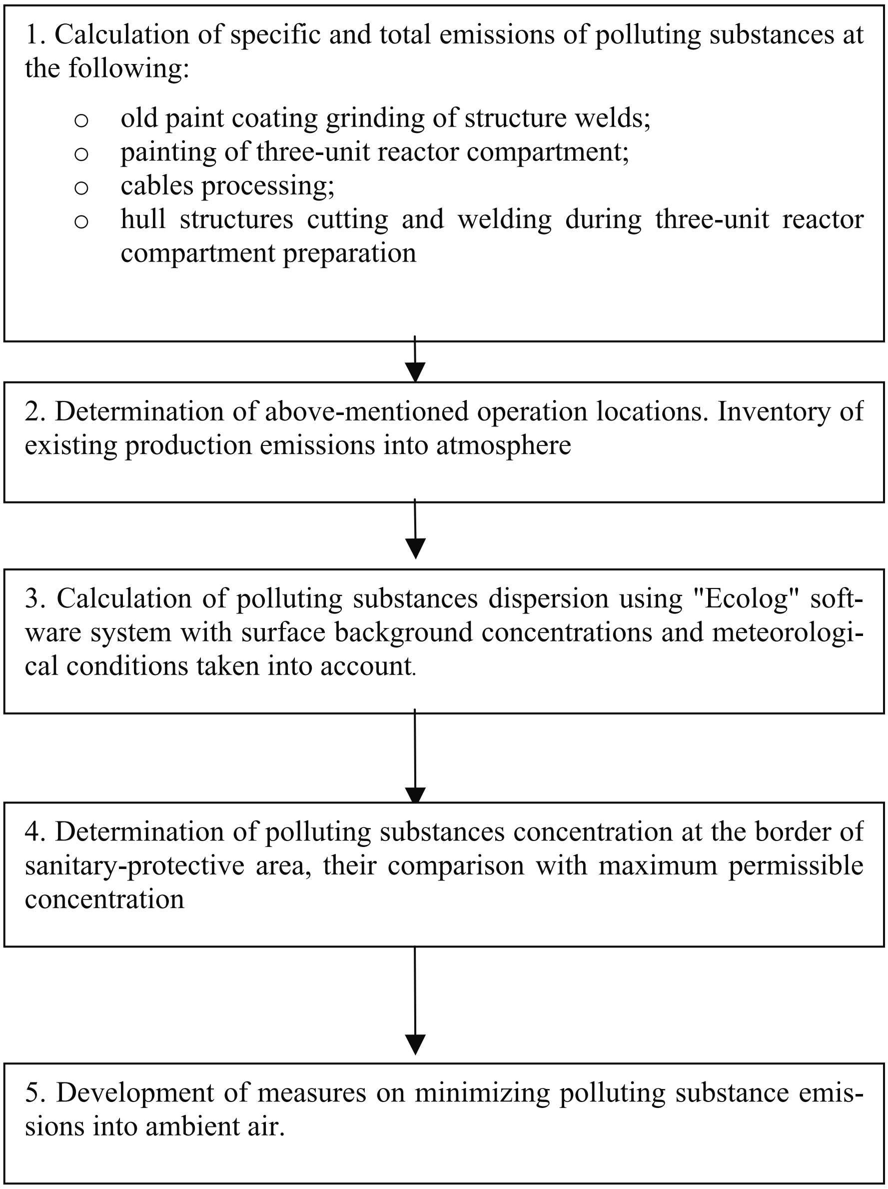


Fig. 5. Environmental Sampling Scheme



1. Calculation of specific and total emissions of polluting substances at the following:

- old paint coating grinding of structure welds;
- painting of three-unit reactor compartment;
- cables processing;
- hull structures cutting and welding during three-unit reactor compartment preparation

2. Determination of above-mentioned operation locations. Inventory of existing production emissions into atmosphere

3. Calculation of polluting substances dispersion using "Ecolog" software system with surface background concentrations and meteorological conditions taken into account.

4. Determination of polluting substances concentration at the border of sanitary-protective area, their comparison with maximum permissible concentration

5. Development of measures on minimizing polluting substance emissions into ambient air.

Fig. 6. Calculation procedure of hazardous chemicals dispersion into atmospher

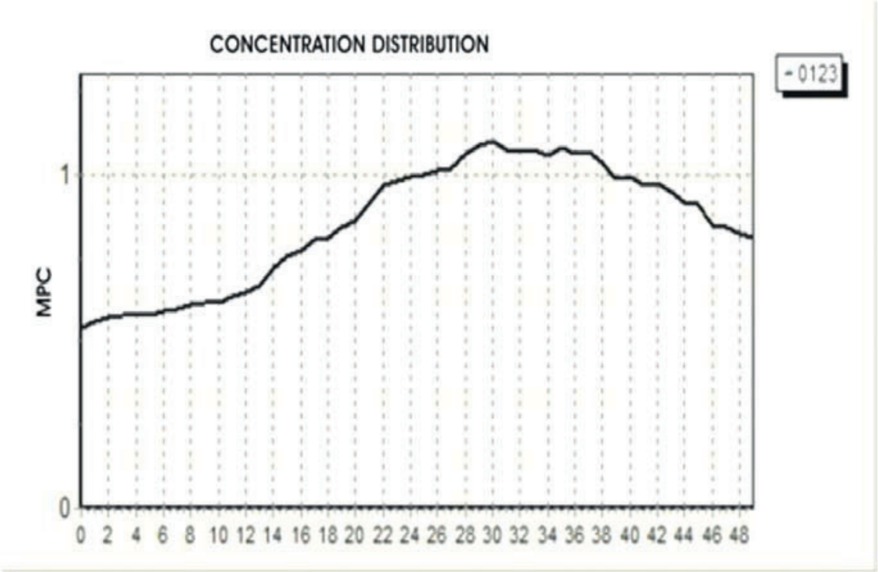


Fig. 7. Distribution of relative concentrations (MPC ratio) of ferrous oxide in reference points at the border of observation area during NPS dismantlement

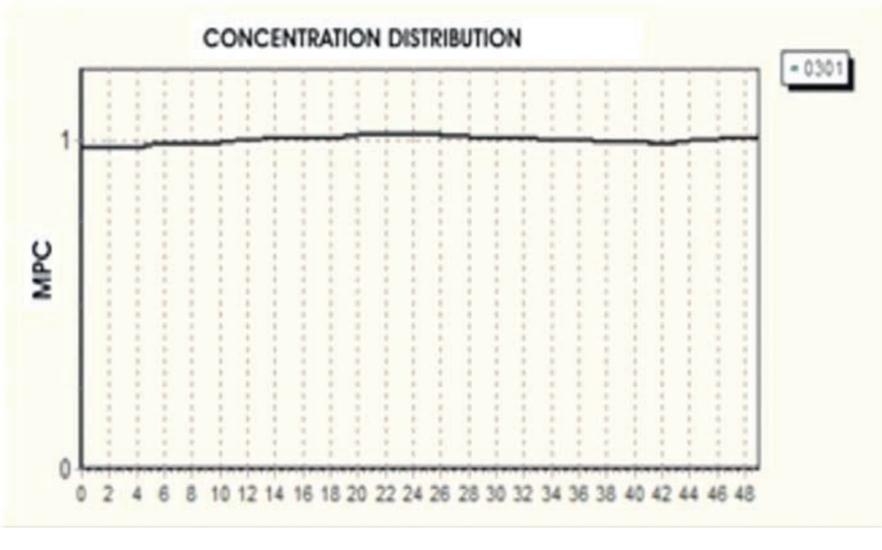


Fig. 8. Distribution of relative concentrations (MPC ratio) of nitrogen oxide in reference points at the border of sanitary-protective area during NPS dismantlement

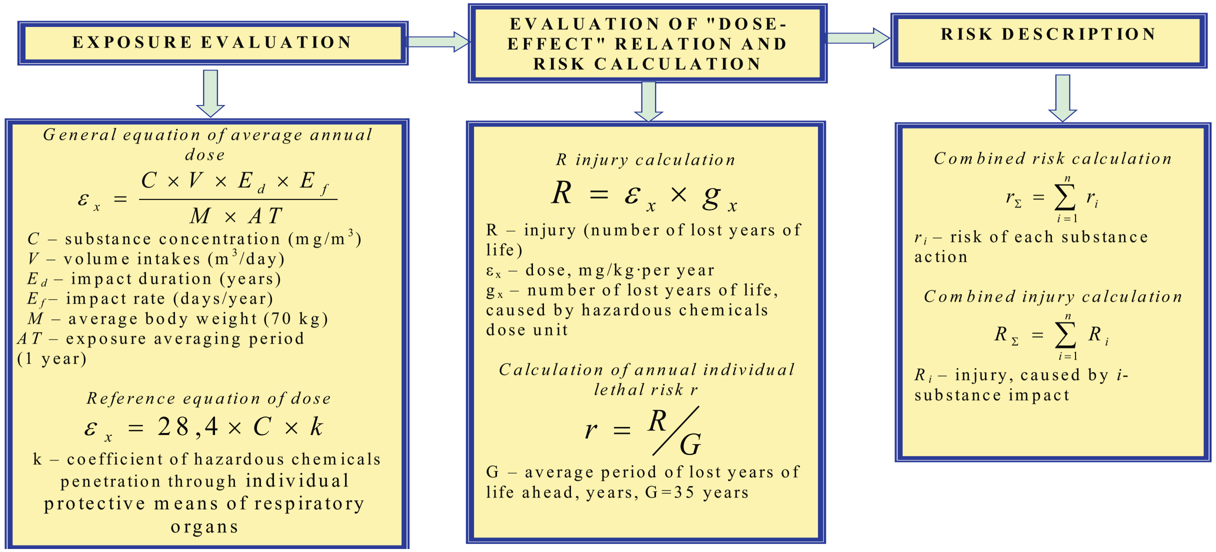


Fig. 9. Procedure of chemical risk calculation

ENVIRONMENTAL RISK ASSESSMENT – NORWEGIAN POLICY AND EXPERIENCE

INGAR AMUNDSEN

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1. Norwegian Action Plan for Nuclear Safety

The Action Plan for Nuclear Safety is the Norwegian Authorities' instrument for cooperation with Russia in the field of nuclear safety and environmental protection. It is headed by the Ministry of Foreign Affairs (MFA). The main focus for the Action Plan can be divided into three objectives: to prevent negative health, environment and economical effects from radioactive contamination; to contribute to preventing radioactive and fissile material from going astray; to strengthen Russian regulatory bodies with responsibility for nuclear safety and radiation protection (1, 2, 3).

At present the main priority areas are:

- Dismantling of non-strategic nuclear submarines from the Northern Fleet.
- Physical protection and infrastructure development at the Andrejeva Bay
- Removal and replacement of Russian strontium batteries (RTGs) in lighthouses, placed along the Russian coast of the Barents Sea.

MFA have established an interdepartmental advisory board to assist in the work of the Action Plan. The Norwegian Radiation Protection Authority (NRPA) has a specific role in the Action Plan. All project proposals put forward to the Action Plan for Nuclear Safety are assessed by the NRPA prior to funding, by considering, *inter alia*, the project's potential effects

P. Strand et al. (eds.), Radiation and Environmental Safety in North-West Russia, 161–170.

on man and environment. The NRPA is the main advisory body to MFA, assisting in questions of a strategic character and providing quality assurance of specific projects in the Action Plan. By the end of 2004, approximately 120 million Euros have been spent on nuclear safety projects. In 2004, 13 million Euros were spent, and about the same amount is allocated for 2005. The Norwegian Parliament allocates funding to the Action Plan for Nuclear Safety on a yearly basis.

2. Environmental impact assessments

All projects applying for funding from the Action Plan for Nuclear Safety involving the handling of radioactive waste, are required to produce documentation of, or plans for, environmental impact assessments. The impact assessments shall ensure that health, environmental and safety aspects are considered prior to project implementation. Performing specific work, e.g. transport of radioactive waste or removing spent nuclear fuel (SNF) may increase risks in the short term, while lowering the risk in the long term (see figure 1). The main task of the impact assessment is to reduce these risks during project implementation.

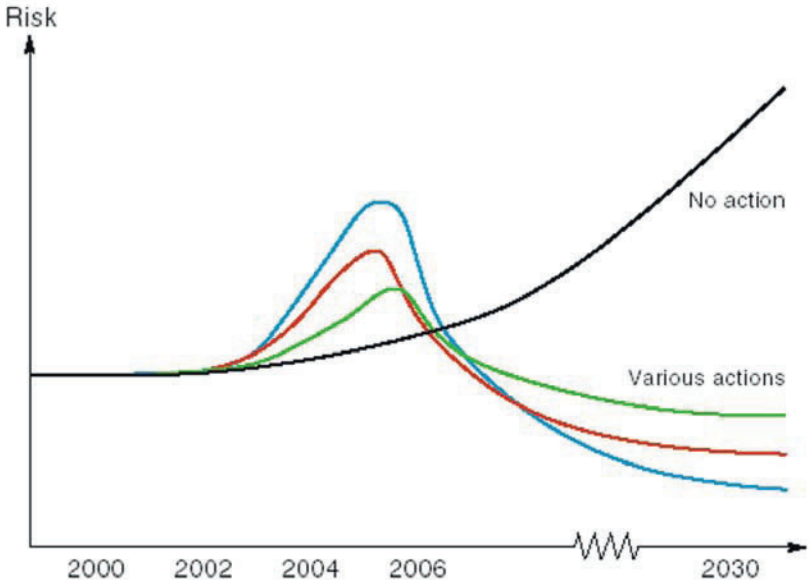

Fig. 1. Measures to reduce risk in the long term may increase the risk in a short term

The purpose of an independent assessment is to:

- Review the scope and content of the existing Russian assessment, their proposed working procedures and quality assurance measures
- Provide an independent analysis of the potential worker, public and environmental risks associated with the specific project
- Make recommendations on improvements to the work specifications and their implementation

In 2004, two independent assessment were performed for specific projects funded from the Action Plan for Nuclear Safety; decomissioning of nuclear submarines and removal of RTGs (Radioisotope Thermoelectric Generators). It is important to note that the different donor countries involved employ a common approach to requirements and implementation of impact assessments for individual projects, as far as possible. The CEG workshop in Oxford in March 2004 specifically adressed this issue with success, and this work is now being followed up in practice.

3. Decommissioning of Russian nuclear submarines

Well over 100 nuclear powered submarines have been taken out of service by the Russian Federation, many of them ahead of schedule following arms reduction agreements. More than 50 such submarines from the Northern Fleet are currently docked at bases on the Kola Peninsula in the Arctic region of North-West Russia. More than 30 of these still have nuclear fuel onboard and a significant number are in poor condition. There is an international wish to decommission these submarines as quickly as possible (figure 2,3,4).

The Norwegian Ministry of Foreign Affairs in June 2003 signed contracts to finance the decommissioning of two Victor II class submarines; one at Nerpa and the other at the Zvjezdochka shipyards. An independent review and assessment of the decommissioning process was carried out with a focus on the environment, health and safety. NRPA commissioned such a review, primarily concerned with radiological impacts but also considering those associated with other hazardous materials. The work was performed with assistence from the UK consultant company Enviros, and was completed in April 2004 (4). Dismantling generates considerable quantities of environmentally hazardous waste as well as radioactive solid and liquid waste. The handling and storage of SNF is of special interest. Furthermore, there has been emphasis placed on risk- and environmental assessment of the whole operation carried out with funding from Norway. This includes towing of the submarine, dismantling at the shipyard and subsequent transport of SNF and radioactive waste to their specific storage and/or treatment locations

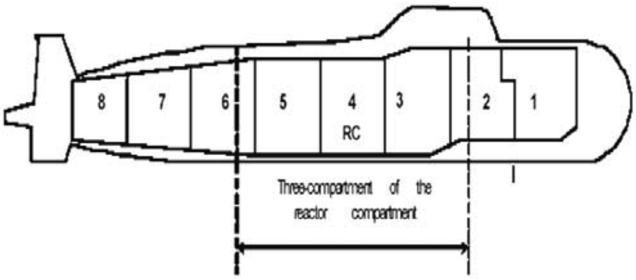

Fig. 2. The submarine is cut in three-compartment units, one compartment on each side of the reactor compartment, RC.

The aim of the project was to review whether the relevant impacts of decommissioning the submarines had been adequately addressed and, if not, to provide an assessment.

The review was to consider all environmental, health and safety impacts, including:

- radiological and chemical impacts;
- impacts on workers, members of the public and the environment, on-site and off-site; and
- impacts due to normal operations and potential accidents.

All stages of the decommissioning process including both the activities at the shipyards and the associated activities off-site, specified as essential elements of the decommissioning process (e.g. towing the submarines to the shipyards and transferring spent fuel and wastes to appropriate locations off-site for their further management), were to be considered.

Documentation on environment, health and safety aspects clearly had been conducted in Russia for each of the shipyards to satisfy the requirements of Russian regulators. However, information for the review study was difficult to obtain, for a number of reasons, e.g.: defuelling at Nerpa were carried out by the Russian Navy, who were not able to release relevant information; the EIA as part of the Russian regulatory regime (OVOS) was classified information. We repeatedly requested access to parts of this documentation and, on a successful note, nearly all of the information was ultimately declassified and handed over.

Fig. 3. Victor II submarine to be dismantled at Zvjozdochka shipyard at Severodvinsk (photo: Zvjozdochka shipyard).

Fig. 4. Cutting reactor compartments at Nerpa shipyard (photo: Nerpa shipyard).

Potential consequences of the decommissioning were compared with the consequences of the "no action" option, i.e. allowing the submarines to remain laid up for an unspecified amount of time, possibly without removing the fuel. If the fuel was not removed, this would continue to present a high risk of major discharges of radioactivity into the environment. On the other hand the delayed decommissioning of a submarine from which the fuel has been removed would probably not present a serious environmental risk, even if continuous management and monitoring were required.

Information provided by the two shipyards indicated that systems were in place for process control and control of radioactive and other hazardous material. Certificates for each stage in the receipt, transfer and dispatch of materials were available for inspection. Subject to a number of specific recommendations on areas in which more information would be beneficial or where improvements could be made (particularly relating to non-radiological impacts, and the impacts due to off-site activities), it was concluded that decommissioning of the two submarines had been undertaken in compliance with the applicable regulations. In addition, the safety requirements and methods for demonstrating compliance were broadly consistent with international recommendations and other national practice.

4. Removal of RTGs in Northwest Russia

Radioactive strontium-90 sources are extensively used in the former Sovjet republics especially for the purpose of providing power to lighthouses in remote areas without electricity supply. At present, about 750 RTGs are located in remote areas of Russia, most of them are located along the Arctic coast. The large majority of them belongs to the Northern Fleet or the Ministry of Transport. Decommissioning RTGs in Northwest Russia is a priority area in the Action Plan for Nuclear Safety. The specific project of removal and replacement of RTGs is headed by the Office of the County Governor of Finnmark (FMIF) (5,6). It is carried out in close cooperation with the Regional Administration in Murmansk and VNIITFA (the All Russian Scientific Research Institute of Technical Physics and Automation).

The Norwegian RTG project may be divided into three parts; 1) the removal and replacement or RTGs, 2) Independent impact assessment of the planed activity and 3) Regulatory cooperation with Russian authorities. The independent assessment is specifically addressed in this presentation.

Many of the RTGs are accessible to intruders and the general public. Due to their high specific activity (in the range 0,8 –15 PBq) they represent a threat to health and the environmental. It is evident that there has been insufficient regulations and control of these sources as well as lack of physical protection. A number of attempted thefts in recent years has drawn attention towards the security aspects of these sources. Decomissioning RTGs represent a complex challenge both regarding radiation protection of worker as well as physical protection aspects.

The process leading up to the independent assessment can be described as follows:

- Autumn 2003: NRPA in dialogue with FMFI to obtain an EIA from the Russian operator
- December 2003: NRPA comment on proposed table of content
- April 2004: A first version of EIA was received from VNIITFA, the Russian operator
- May 2004: NRPA asked for additional documentation
- June 2004: The final version with additional information were received.

- July 2004: NRPA were in dialogue with the russian regulatory body, Rostechnadzor
- August 2004: NRPA finalised the independent assessment. A number of specific reccomendations were given. The outcome of the assessment was a release of the allocated funding from the Action Plan to allow the project to start.

Based on results from the independent assessment, it is concluded that the decommissioning project should continue, as leaving the RTGs unmonitored could potentially lead to a risk of undesired access to radioactive materials (7). However, it is important to ensure that the relevant Russian regulatory authorities and organisations have clear responsibilities throughout the entire process of inspecting, collecting and dismantling the RTGs, as well as the storage and disposal of the sources. Radiation protection guidelines should be reviewed and amended where necessary with clear procedures and checklists to ensure compliance. The assessment showed that there was a low probability of significant environmental impact under both normal and accident conditions. Another aspect which was pointed out was that past experience should be taken into account to improve procedures and working plans and documentation. Furthermore it was a condition that relevant national and international transport requirements should be followed. A general comment was that the EIA should be further developed in close contact with Russian regulatory authorities.

Fig. 5. *An RTG (photo: NRPA)*

The following recommendations were stated from the independent assessment:

- Guidelines for radiation protection and procedures to ensure implementation should be documented both for normal operation and for emergency situations
- Transport by helicopter should be used only where the lack of other transport options means that it is necessary and over as short distances as possible
- When using helicopter transport, an emergency beacon should be used to help recover the RTG in case of an accident
- Experience from previous work on removal and handling of RTGs should be documented and a report summarizing the work in 2004 should be submitted to NRPA.

RTG removal and waste handling has, so far, not been a theme for detailed deliberation by the russian regulators, even though a number of different permissions and licences have been authorised. One important output from the independent assessment work was to focus a need for performing impact assessment prior to the start of the work. Another aspect was to focus the need for regulatory control. It was a requirement that the Russian operator should send all documentation to the relevant Russian authorities. From our point of view the contact and feedback from the Russian operator and the Russian regulators has been very valuable and forms a basis which needs to be developed further in the years to come.

5. Conclusions

The environmental impact evaluation of the project is of key importance. Performing such evaluation for the projects, RTG decommissioning and submarine dismantling, has given valuable information regarding health and safety aspects of the work. However, it has also showed the need to address these important issues, and many aspects need to be addressed in future. Exchange of experience with other countries that ultimately participate in this type of project is highly important. The outcome of these studies has been made available to all relevant donor countries. There is a need to have a common approach from the donor countries in this respect.

The Norwegian focus on receiving EIA documentation for submarine dismantling revealed that the documents (the Russian 'OVOS') were not publicly available. After repeated requests for these documents, nearly all of the material was finally released. This will be of benefit for other donor countries in future.

Later in 2004, negotiations began on the funding by the UK and Norway of the decommissioning of two Victor III class submarines at Nerpa. For these projects, following the experience with the Norwegian Victor II projects, considerable effort has been devoted to reaching agreements with the Russian contractors in advance on the content and timing of documentation expected on the assessment of environmental, health and safety impacts. As a result, EIA studies have been delivered to the donors, and have been reviewed.

RTG removal and submarine dismantling are high priority projects which will also be addressed in the future. Furthermore, independent assessments will be performed in 2005. These will build upon the experience gained in 2004, follow up the reccomendation and highlight potential new aspects and conditions of specific relevance for the work in 2005.

References

1. *Nuclear Safety in Northwest Russia*, Norwegian Ministry of Foreign Affairs, April 2005.
2. ISBN 82-7177-768-8. (http://www.mfa.no).
3. *Ministry of Foreign Affairs web site:* http://odin.dep.no/ud/english/doc/plans/032191-220007/dok-bn.html
4. *Norwegian Radiation Protection Authoritiy web site:* http://handlingsplan.nrpa.no/English/englishfrontpage.htm
5. *Review and Assessment of the Environmental Impact From Decommissioning of Two Nuclear Submarines.* Enviros Consulting Ltd, Oxfordshire, United Kingdom, April 2004.
6. *RITEG Dismantling on the Kola Peninsula*, The Murmansk Regional Government, The Office of Finnmark County Governor, 2003.
7. *Dismantling of RTGs on the Kola Penninsula*, NRPA bulletin, 07:2004. www.nrpa.no
8. *Assessment of environmental, health and safety consequences of decommissioning radioisotope thermal generators (RTGs) in Northwest Russia*, Norwegian Radiation Protection Authority, NRPA report 2005:4.

ENVIRONMENTAL RISK ASSESSMENT RELATED TO ITS REDUCTION, DTE

KONSTANTIN GOSPODINOV

Nuclear Safety Solutions Ltd. CANADA

1. Abstract

Dear Mr. Chairman, dear Colleagues.

I represent here the Canadian company "Nuclear Safety Solutions Ltd." (NSS) that is a branch of the British corporation NNC already mentioned here. I am glad to have an opportunity for presenting you the results of environmental impact assessment project “Program on the Dismantlement of Nuclear-Powered Submarines (NS) Removed from Service at the Enterprise “Zvezdochka” in the Town of Severodvinsk”.

The environmental impact assessment project was fulfilled by NSS in August-October, 2004 under the Contract with the Ministry of Foreign Affairs of Canada. The Program on NS Dismantlement comprises partition of 13 "Victor" class nuclear submarines, therewith the contract on the first three submarines has been already concluded, and the contract on the next three NS is at the stage of approval and conclusion. At present after completion of environmental impact assessment the works on NS partition have already been started.

2. Project Target

The target of the given presentation is to tell you briefly about the process and methods of environmental impact assessment according to the Canadian requirements, and present you information about an approach that is usually applied for this purpose in Canada in accordance with the standards of Canadian nature protection legislation.

P. Strand et al. (eds.), Radiation and Environmental Safety in North-West Russia, 171–176.

3. Requirements for Environmental Impact Assessment in Canada

The fact that no environmental impact assessment has been made according to the Russian requirements is the most remarkable feature of the project. In accordance with the Law on the Environment Protection currently in force in Canada for every foreign project involving Canadian companies and being financed by the Government of Canada an environmental impact assessment should be implemented on the basis of requirements of the Canadian nature protection laws and standards, and accepted by the Canadian regulatory authorities.

Except for the direct environmental impact assessment, the basic stages of the Project included consultations and public hearings in Canada and approval of the Canadian regulatory authorities. As a whole, the methods of such assessment comply with the requirements similar to those ones on environmental impact assessment in Russia and other countries. That is why much of the previously done can be used, with some limitations, for other similar projects.

Except for the above, within the Project frameworks the Practical plan on environment protection during NS dismantlement was developed, and it will be detailed below.

4. Project Plan

At given diagram "EA Approach" the step-by-step approach to environmental impact assessment is schematized:

- At first, possible potential interactions between the environmental aspects and each stage of Program realization are defined. If no interaction is detected, this aspect is not reviewed any more.
- In case when the mentioned impact is observed, then we can define if there is any potential possibility of environmental change as a result of such impact.
- If the above change is likely, we should define whether it will be a positive or negative factor of impact on the environment.
- If the impact is negative, possible ways for decreasing the above negative impact are determined.

- If after taking all acceptable measures on elimination of the negative impact, the latter remains negative, then in accordance with the Canadian legislation the financial support of such project is ceased.

5. Environmental Aspects

Within the Project frameworks the following environmental aspects were reviewed:

- radiation impact on personnel, public, marine and aerial media, and underground waters;
- non-radiation impact on aqueous and aerial media;
- potential impact on ecology of the region, geological and hydrogeological factors;
- social-and-economical, public health and cultural aspects.

6. Detected Interactions and Changes

It is more convenient to show interactions of natural and technical factors in kind of the table that may be considered as an example of assessment methods. The stages of Program on NS Dismantlement, namely, preparation of NS for transport to “Zvezdochka”, NS transport from the various bases of the Murmansk Region, arrival and acceptance, etc, are listed in the left column.

The aspects of impact on the environment mentioned above are listed in the titles across the columns. Using such a table, it is easy hereinafter to determine if there is any potential interaction between every particular stage of Program realization and every particular aspect of the environment. Such method is applied for maximum full coverage of all possible interactions, and, as a whole, it is rather effective.

7. Initial Level of Radioactive Contamination

It is more expedient to determine value of radiation impact by means of comparison with already existing contamination levels, or by means of comparison with current norms. In other words, in order to determine an impact extent, it is necessary to know a real situation as regards radiation contamination on the moment prior to the beginning of realization of the Program on NS Dismantlement.

British Corporation NNC has recently realized the project on definition of levels of Cs-137 content in the waters of the Baltic Sea, Northwest Atlantic and north of Russia. The results of studies showed that the levels, available for today, were caused by radioactive discharges made in the sixties-seventies, radioactive fall-outs from the Chernobyl discharge and over-ground nuclear tests. In doing so, it was found that, as a whole, the earlier performed works on NS dismantlement had not caused essential increase of CS-137 concentration. Though, at more in-depth analysis in some bays of the Murmansk Region the local concentrations of Cs-137 higher than those shown on the small-scale review map of the Region, were registered.

7.1. EXAMPLE 1: ANALYSIS OF EVENTS CONNECTED WITH SUBMARINE SINKING IN TRANSPORT

Within the frameworks of environmental impact assessment not only normal operations were reviewed, but also a due account of a possibility of accidental situations was taken. As an example, the case with the K-159 NS, which sank at tugging, may be mentioned. After this case special attention was paid to the environmental impact assessment in transport of a submarine. In the course of assessment it was stated that the degree of multi-level fuel containment was such that with the existing corrosion rate of 2.5 mm/year the release of radioactive products outside the fuel elements claddings, reactor vessel and reactor compartment cover would occur not before 24 years after the submarine was sunk. As a rule, the above period of time is enough for lifting the submarine upward and elimination of accident consequences. The above estimations are confirmed by monitoring data for those areas of the World Ocean where the submarines sunk in different years in the past are located.

7.2. EXAMPLE 2: ANALYSIS OF EVENTS CONNECTED WITH FIRE AT THE OFF-SHORE FACILITIES

The second example is related to those ones that have been already reviewed, namely, a fire in the compartment for radioactive waste management. As a result of analysis it was stated that outside the industrial sites of

"Sevmash" and "Zvezdochka" yards the levels of anticipated contamination would not exceed 10 μSv.

7.3. EXAMPLE 3: ANALYSIS OF RADIATION BURDEN ON PERSONNEL

Except for the above, the assessments of radiation burden on personnel during normal process operations without any accidents were made. Several successive stages of radiation burden assessment can be highlighted. It has been defined that there is a potential possibility for reducing such burdens on personnel, if the ALARA principle - "As Low As Reasonably Achievable"- is applied. In Russia the above principle of radiation burden optimization has not yet been widely spread. The principle of non-excess of maximum permissible doses is more widely applied, and an employee near obtaining such a maximum permissible dose value is just taken out of the zone of operations. Instead, the method of preliminary analysis of radiation burdens might be recommended for realization of measures on reducing the radiation levels in the zone of operations, that allows for personnel to work in more effective way.

These recommendations were included into the Plan on environment protection in realization of the Program on NS Dismantlement with appointment of concrete terms and persons responsible for the implementation of the above Plan. Thus, the realization of the Plan on environment protection is not a once-only action, but a constant multi-stage process with participation and under control of the Canadian regulatory authorities.

On the basis of environmental impact assessment results the following actions listed in the Plan on environment protection may be recommended:

- Reducing of personnel exposure level in accordance with the principle of radiation burden optimization – ALARA.
- Constant monitoring and taking measures in case of threat caused by NS sinking in transport.
- Constant monitoring of tritium leakages for the purpose to identify possible places of radionuclides leakages;
- Maximum increase of a share of mechanical cutting during partition of NS hulls instead of thermal types of cutting. Thermal cutting leads to release of a large amount of hazardous gases and, as a result, to a need in application of strictly severe measures and individual protection means. As a rule, in practice the abovemen-

tioned decreases work effectiveness, causes inconveniences and leads to personnel's motivation to neglect such protection means along with hazard for their health.

- An effective proactive mechanism of control over the use of corresponding individual protection means must be applied for any operations in the production area.

The key part of the Plan on environment protection presents in itself a table with a list of targets and tasks, reference to the Program part, to which the every given task is referred, indication of criterion for implementation of the given task, as well as a specific anticipated outcome, terms for realization and a responsible person.

8. Control of Implementation of Plan Provisions on Environment Protection

The consecutive process of Program realization consists of several successive stages. First of all, on the basis of results of the environmental impact assessment the measures on elimination of unacceptable impacts are defined. The above measures are included into the Plan on environment protection. In accordance with the Canadian requirements for implementation of such kind of projects a constant monitoring of actions aimed at realization of this Plan will be carried out. And only in case of successful implementation of each stage of the Plan the next stages will be given a financial support. Therefore, the environmental impact assessment is only an initial stage of work, and permanent attention will be paid to environment protection at all the stages of realization of the Program on NS Dismantlement.

With that let me finish my presentation. Thank you very much for your attention.

THE RADIOLOGICAL CONSEQUENCES OF RADIONUCLIDE᾿S DISCHARGE IN WATER ENVIRONMENT AT AFLOAT STORAGE OF UTILIZED SUBMARINES REACTOR COMPARTMENTS

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1. Introduction

The circuit of complex nuclear powered submarines (NPS) recycling accepted now is reduced to containerization of the highly active equipment of reactor installations in volume of reactor compartment and to time storage of reactor compartment afloat in the multi compartment block structure. Works on one compartment blocks formation for storage on the firm basis now are in an initial stage. Radioecological danger of mass afloat storage removed of operation NPS and cut out reactor compartments essentially grows, if from a reactor spent nuclear fuel (SNF) is not unloaded.

Under regular conditions of storage on плаву NPS sediment or blocks of compartments external surfaces of the strong case are exposed to destroying influence of seawater only. In case of the failure connected to loss of buoyancy, the following two variants can be realized:

- destruction only the strong case and receipt inside of it sea water;
- destruction of the strong case and reactor installations with receipt of seawater inside reactor installations.

P. Strand et al. (eds.), Radiation and Environmental Safety in North-West Russia, 177–193.

2. Pollution of the sea environment at flooding the block of a compartment and destruction reactor installations

At destruction of the strong case of the stored block and preservation of integrity reactor installations by the basic source of radio nuclides exit are products of corrosion of the case of a reactor and, to a lesser degree, fragments of a metal-water protection tank. At destruction of the strong case and reactor installations seawater acts inside reactor installations. As the existing technology of work does not provide restoration of tightness of a cover of a reactor utilized NPS after unloading SNF [1], at destruction reactor installations seawater can come into contact to internal surfaces of elements of a reactor. Speed of an exit in seawater of fission products and actinides can achieve 5.10^9 Bq/h [2].

Speed of generated inside a compartment radio nuclides exit in the over side water is defined by a loss of tightness degree, i.e. number of fistulas and their size, and also hydrological characteristics of a place of storage (the ebb-tide phenomena and ejection, the caused undercurrents). The ebb-tide phenomena and currents basically define Dispersion of radio nuclides in water area.

Dynamics of formation of radioactive pollution of a bay in which blocks reactor a compartment are stored, can be described as follows. During some time interval, which is defined by intensity of turbulent hashing, in the speed of circulation of water in a bay connected to tidal movements and currents phenomena, and an arrangement of the block in a bay, activity remains within the limits of a bay. Then activity achieves a throat of a bay and starts to leave it in a coastal zone. The average size of volumetric activity grows and achieves some equilibrium value. At intensive hashing volumetric activity in a torch of pollution ceases to differ from average on a bay on distance in some сот meters from a source of pollution. For conditions of intensive hashing water in a bay due to ebb-tide movements and currents factors of vertical and horizontal diffusion achieve accordingly values 10^2-10^3 sm^2/s and 10^4-10^5 sm^2/s.

Pollution of a bottom is defined by speed of sedimentation of the basic radionuclids. For estimation the factor of sedimentation can be accepted equal 10^{-5} cm/s.

Calculation of the contents in an active zone of fission products and transuranic nuclides was executed for a typical mode of operation NPS of the second generation under condition of full development(manufacture) energy resources, that creates additional conservatism in estimations. Speed of an output(exit) of fission products and transuranic radio nuclides is submitted in tab. 1. Speed of an exit)of products of corrosion is lower 2-3 order, than fission products. For a constant of an exit in the given calculations the conservative estimation of 10^{-2} years $^{-1}$ [3] was accepted.

In the report the most conservative variant is considered - from reactors of the block nuclear fuel is not unloaded and its contact to seawater is realized.

Results of calculations of equilibrium activity of fission products and transuranic radio nuclides in water of a bay are submitted in tab. 2.

Table 1. Speed of Fission products and transuranic nuclides exit, Bq/hour

Storage period after recycling, years	Duration of sediment NPS before recycling, years					
	5		10		15	
	FP *)	TUN **)	FP	TUN	FP	TUN
0	8,8·109	7,5·108	6,4·109	6,0·108	5,6·109	4,9·108
5	6,4·109	6,0·108	5,6·109	4,9·108	4,9·109	4,0·108
10	5,6·109	4,9·108	4,9·109	4,0·108	4,3·109	3,2·108
15	4,9·109	4,0·108	4,3·109	3,2·108	3,9·109	2,7·108

* FP - fission products
** TUN –transuranic nuclides

Table 2. Equilibrium radio nuclides specific activity in water of a bay, Bq/kg

A) Fission and corrosion products (CP)

Storage time after recycling, years			0	5	10	15
Time of sediment NPS before recycling, years	5	^{90}Sr	2,26	2,0	1,76	1,55
		^{90}Y	2,26	2,0	1,76	1,55
		^{134}Cs	0,34	$6{,}4.\ 10^{-2}$	$1{,}2.\ 10^{-2}$	$2{,}2.\ 10^{-2}$
		^{137}Cs	2,43	2,17	1,93	1,71
		^{147}Pm	1,49	0,40	0,11	0,028
		^{151}Sm	6.10^{-2}	$5{,}7.\ 10^{-2}$	$5{,}5.10^{-2}$.	$5{,}2.\ 10^{-2}$
		^{60}Co	$5{,}6.10^{-3}$	$2{,}92.\ 10^{-3}$	$1{,}53.\ 10^{-3}$	----
	10	^{90}Sr	2,0	1,76	1,55	1,37
		^{90}Y	2,0	1,76	1,55	1,37
		^{134}Cs	$6{,}4.10^{-2}$.	$1{,}2.\ 10^{-2}$	$2{,}2.\ 10^{-3}$	$4{,}1.\ 10^{-4}$
		^{137}Cs	2,17	1,93	1,71	1,53
		^{147}Pm	0,40	0,11	$2{,}8.\ 10^{-2}$	$7{,}5.\ 10^{-3}$
		^{151}Sm	$5{,}7.\ 10^{-2}$	$5{,}5.\ 10^{-2}$	$5{,}2.\ 10^{-2}$	$5{,}0.\ 10^{-2}$
		^{60}Co	$2{,}92.\ 10^{-3}$	$1{,}53.\ 10^{-3}$	$7{,}78.\ 10^{-4}$	----
	15	^{90}Sr	1,76	1,55	1,37	1,22
		^{90}Y	1,76	1,55	1,37	1,22
		^{134}Cs	$1{,}2.\ 10^{-2}$	$2{,}2.\ 10^{-3}$	$4{,}1.\ 10^{-4}$	$7{,}7.\ 10^{-5}$
		^{137}Cs	1,93	1,71	1,53	1,37
		^{147}Pm	0,11	$2{,}8.\ 10^{-2}$	$7{,}5.\ 10^{-3}$	$2{,}0.\ 10^{-3}$
		^{151}Sm	$5{,}5.\ 10^{-2}$	$5{,}2.\ 10^{-2}$	$5{,}0.\ 10^{-2}$	$4{,}8.\ 10^{-2}$

B) Transuranic elements (TUN)

Storage time after recycling, years			0	5	10	15
Time of sediment before NPS recycling, years	5	^{238}Pu	2,1. 10^{-2}	2,01. 10^{-2}	1,92. 10^{-2}	1,86. 10^{-2}
		^{239}Pu	1,43.10^{-2}	1,43. 10^{-2}	1,43. 10^{-2}	1,41$10^{-2}$.
		^{240}Pu	2,7. 10^{-2}	2,65.10^{-2}	2,65. 10^{-2}	2,65. 10^{-2}
		^{241}Pu	7,05. 10^{-2}	5,52. 10^{-2}	4,35. 10^{-2}	3,41. 10^{-2}
		^{241}Am	8,7. 10^{-2}	1,36. 10^{-2}	1,75. 10^{-2}	2,04. 10^{-2}
	10	^{238}Pu	2,01. 10^{-2}	1,92. 10^{-2}	1,86. 10^{-2}	1,78. 10^{-2}
		^{239}Pu	1,43.. 10^{-2}	1,43. 10^{-2}	1,41. 10^{-2}	1,41. 10^{-2}
		^{240}Pu	2,65. 10^{-2}	1,2. 10^{-2}	2,65. 10^{-2}	2,65. 10^{-2}
		^{241}Pu	5,52. 10^{-2}	4,35. 10^{-2}	3,41. 10^{-2}	2,68. 10^{-2}
		^{241}Am	1,36. 10^{-2}	1,75. 10^{-2}	2,04. 10^{-2}	2,26. 10^{-2}
	15	^{238}Pu	1,92. 10^{-2}	1,86. 10^{-2}	1,78. 10^{-2}	1,71. 10^{-2}
		^{239}Pu	1,43. 10^{-2}	1,41. 10^{-2}	1,41. 10^{-2}	1,41.10^{-2}
		^{240}Pu	2,65. 10^{-2}	2,65. 10^{-2}	2,65. 10^{-2}	2,65. 10^{-2}
		^{241}Pu	4,35. 10^{-2}	3,41. 10^{-2}	2,68. 10^{-2}	2,11. 10^{-2}
		^{241}Am	1,75. 10^{-2}	2,04. 10^{-2}	2,26. 10^{-2}	2,43. 10^{-2}

3. An irradiation of the personnel of points of storage at emergency receipt radio nuclides in the water environment

3.1. METHODOLOGY OF CALCULATION

For bays, being places of sediment removed from operation NPS and blocks reactor a compartment, a lot of ways of an irradiation, characteristic for the high sea, are not significant. So, there are no the ways connected with oral receipt of radio nuclides since on water area of points of storage extraction of sea foods etc. are not made, the water area and a shore are not used in the recreational purposes. Therefore for such places the basic ways of an irradiation are the following [4]:

1. inhalation of the weighed aerosol particles, sea aerosols (drop fraction) and water steam.
2. the external irradiation at industrial activity on piers, floating moorings, floating means, stored blocks etc.
3. the external irradiation from water at performance of diving works on distance of several meters from a bottom (for example, at a board of a vessel) when the irradiation from ground deposits can be neglected.
4. the external irradiation at performance of diving works near to a bottom or directly at the bottom. In this case there is the additional source of an external irradiation connected with probable lifting of ground deposits. Concentration of the particles lifted from a bottom, changes over a wide range depending on features of a structure of a bottom, thus it is necessary to mean, that at concentration of a suspension than 10-20 mg/l visibility high can become insufficient for performance of any underwater works.

The most exact estimations of an irradiation of the population caused by radioactive pollution of seawater, can be made with the help of direct calculation of dozes on various ways of an irradiation. Estimated calculations can be executed according to Manual "the Estimation of influence of the radiation-dangerous works which are carried out by the enterprises of nuclear shipbuilding on an environment and the population" [5].

Values of capacity of an effective doze of an irradiation on various ways of the influence, caused contained in seawater radio nuclides, are given in article [4] where results of calculation dose loadings of an individual on various ways of influence are given.

At calculation of inhalation receipt sizes doze factors and intensity of breath (8100 m^3/year) for the adult population, given in NRS-99 [6] were used. In view of absence of the detailed data under the relative contents of components in inhaled air for concrete places of storage and basing, in calculations appropriate IAEA recommendations [7] were used.

Calculation of an external irradiation at work on piers, courts, platforms was etc. carried out with the account radiations screen age by natural screens, thus were used recommended IAEA [7] sizes of screen age factors - 0,2 for scale-radiation and 0 for beta-particles.

The irradiation from a bottom for everyone radio nuclide paid off in view of factor of distribution of an element between water and ground deposits k_d, equal to the attitude of specific concentration of the given element in ground deposits and water [8]. Capacity of a doze was calculated on various distances from a bottom in the assumption, that the bottom represents infinite flat isotropic a radiating layer of final thickness. In calculations the contribution to capacity of a doze of absent-minded scale - radiation to water was taken into account.

With the help of Manual [5] it is possible on the given size of volumetric activity i-th radio nuclide in water a_i and to given time of an irradiation of the person on j-th ways t_j to determine a doze of radiating influence on this way D_{ij}, caused by pollution of water specified radio nuclide,

$$D_{ij} = a_i p_{ij} t_j \tag{1}$$

Where p_{ij} - capacity of an effective doze of an irradiation on j-th ways of influence at volumetric activity i-th radio nuclide in seawater of 1 Bq/m^3. The total doze of radiating influence D_i at an irradiation on the various considered ways is determined by expression

$$D_i = a_i \sum_j p_{ij} t_j \tag{2}$$

3.2. RESULTS OF CALCULATION

For the further calculations two variants from submitted in table 3 are chosen.

1. the most conservative variant: a storage time before NPS recycling 5 years, a storage time after recycling is equal to zero;
2. typical variant: a storage time before NPS recycling 10 years, a storage time after recycling 10 years.

Results of calculations of capacity of an effective doze for various ways of influence on these variants are submitted in table's 3A and 3B accordingly.

At work on water area an estimated time of an irradiation within one year variously for the various professional groups described by combinations of the listed above basic ways of an irradiation. It is possible to allocate three professional groups [4]:

- Group 1, for which basic way of an irradiation - inhalation radio nuclides receipt with aerosol particles, drop sea aerosols and pairs water. People, whose work concern to considered group, basically, are connected to stay on open industrial platforms near to a water table. Members of this critical group are exposed to radiating influence as directly in an operating time, and at stay on open air outside an industrial platform, but in a zone of influence transferable a wind of sea aerosols. Total time of an irradiation is conservatively estimated by size of 3500 hours per year.
- The group 2 is characterized by a combination of two basic ways of radiating influence - inhalation receipt radio nuclides with sea aerosols and an external irradiation from a surface of water. People, whose work concern to considered group, basically, is connected to stay on piers, floating moorings, floating means and other similar objects which are taking place in direct contact to water of a bay. For this group time of inhalation receipt is similar to group 1 - 3500 hours, duration of an external irradiation from water - 1900 hours per year.
- The group 3 is made by divers for whom the third way of radiating influence - an external irradiation from water and a bottom is added at realization of underwater works. Specific targets define duration of underwater works. As a conservative estimation the size of 600 hours per year is accepted.

Table 3. Capacity of an effective dose of an irradiation on various ways of influence, Sv/s

A) Time of sediment NPS before recycling 5 years, a storage time after recycling 0 years

Radio nuclide	Inhalation receipt due to sea aerosols	External irradiation					
		At works on piers, courts, platforms etc.	At underwater works				
			From water	From a bottom, on distance			From lifted ground deposits with concentration of 10 mg/l
				0,5 m	1,0 m	1,5 m	
Sr-90	$1,39 \cdot 10^{-15}$	-	-	-	-	-	-
Y-90	$2,25 \cdot 10^{-15}$	$1,08\cdot10^{-19}$	$1,08.10^{-18}$	$7,39\cdot10^{-28}$	-	-	$1,09\cdot10^{-16}$
Cs-134	$5,95\cdot10^{-17}$	$1,03\cdot10^{-14}$	$1,03\cdot10^{-13}$	$1,20\cdot10^{-12}$	$3,24.10^{-14}$	$8,77\cdot10^{-16}$	$3,10\cdot10^{-15}$

Cs-137	$3,01\cdot10^{-16}$	$2,79\cdot10^{-14}$	$2,79\cdot10^{-13}$	$3,11\cdot10^{-12}$	$8,11\cdot10^{-14}$	$1,99\cdot10^{-15}$	$8,35\cdot10^{-14}$
Pm-147	$1,05\cdot10^{-15}$	$1,48\cdot10^{-19}$	$1,48\cdot10^{-18}$	$2,80\cdot10^{-15}$	$4,62\cdot10^{-18}$	$6,11\cdot10^{-21}$	$2,97\cdot10^{-17}$
Sm-151	$3,46\cdot10^{-17}$	$4,01\cdot10^{-18}$	$4,01\cdot10^{-17}$	$2,28\cdot10^{-18}$	$1,98\cdot10^{-25}$	$2,01\cdot10^{-32}$	$7,99\cdot10^{-16}$
Co-60	$6,20\cdot10^{-18}$	$3,07\cdot10^{-16}$	$3,07\cdot10^{-15}$	$2,62\cdot10^{-12}$	$1,14\cdot10^{-13}$	$5,11\cdot10^{-15}$	$5,64\cdot10^{-14}$
Sum FP+CP	$5,00\cdot10^{-15}$	$3,85\cdot10^{-14}$	$3,85\cdot10^{-13}$	$6,93\cdot10^{-12}$	$2,28\cdot10^{-13}$	$7,98\cdot10^{-15}$	$6,88\cdot10^{-14}$
Pu-238	$1,68\cdot10^{-12}$	$2,39\cdot10^{-20}$	$2,39\cdot10^{-18}$	$4,73\cdot10^{-17}$	$1,93\cdot10^{-19}$	$4,10\cdot10^{-21}$	$2,39\cdot10^{-17}$
Pu-239	$6,85\cdot10^{-15}$	$3,13\cdot10^{-21}$	$3,13\cdot10^{-19}$	$3,42\cdot10^{-17}$	$5,13\cdot10^{-18}$	$2,29\cdot10^{-21}$	$3,13\cdot10^{-18}$
Pu-240	$1,29\cdot10^{-13}$	$3,45\cdot10^{-20}$	$3,46\cdot10^{-18}$	$8,42\cdot10^{-17}$	$1,93\cdot10^{-19}$	$1,76\cdot10^{-21}$	$3,46\cdot10^{-17}$
Pu-241	$3,60\cdot10^{-15}$	$4,14\cdot10^{-19}$	$4,14\cdot10^{-17}$	$3,66\cdot10^{-15}$	$5,99\cdot10^{-18}$	$7,97\cdot10^{-21}$	$4,15\cdot10^{-16}$
Am-241	$5,20\cdot10^{-15}$	$7,44\cdot10^{-19}$	$7,44\cdot10^{-17}$	$1,46\cdot10^{-14}$	$8,53\cdot10^{-18}$	$1,10\cdot10^{-19}$	$1,49\cdot10^{-14}$
Sum TUN	$1,81\cdot10^{-12}$	$1,22\cdot10^{-18}$	$1,22\cdot10^{-17}$	$1,83\cdot10^{-14}$	$2,00\cdot10^{-17}$	$1,26\cdot10^{-19}$	$1,50\cdot10^{-14}$
The sum	$1,81\cdot10^{-12}$	$3,85\cdot10^{-14}$	$3,85\cdot10^{-13}$	$6,95\cdot10^{-12}$	$2,28\cdot10^{-13}$	$7,98\cdot10^{-15}$	$8,38\cdot10^{-14}$

B) Time of sediment NPS before recycling 10 years, a storage time after recycling 10 years

Radio nuclide	Inhalation receipt due to sea aerosols	External irradiation					
		At works on piers, courts, platforms etc.	At underwater works				
			From water	From a bottom, on distance			From lifted ground deposits with concentration of 10 mg/l
				0,5 m	1,0 m	1,5 m	
Sr-90	$9,55.10^{-16}$	-	-	-	-	-	-
Y-90	$1,55\cdot10^{-15}$	$7,44\cdot10^{-20}$	$7,44\cdot10^{-19}$	$5,07\cdot10^{-28}$	-	-	$7,46\cdot10^{-18}$
Cs-134	$3,85\cdot10^{-19}$	$6,69\cdot10^{-17}$	$6,69\cdot10^{-16}$	$7,74\cdot10^{-15}$	$2,10\cdot10^{-16}$	$5,68\cdot10^{-18}$	$2,01\cdot10^{-18}$

Cs-137	2,12·10^{-16}	1,96·10^{-14}	1,96·10^{-13}	2,19·10^{-12}	5,71·10^{-14}	1,40·10^{-15}	5,88·10^{-16}
Pm-147	1,97·10^{-17}	2,78·10^{-21}	2,78·10^{-19}	5,26.10^{-17}	8,68·10^{-20}	1,15·10^{-22}	5,57·10^{-20}
Sm-151	2,95·10^{-17}	3,42·10^{-18}	3,42·10^{-17}	1,94·10^{-18}	1,69·10^{-25}	1,71·10^{-32}	6,82·10^{-17}
Co-60	8,63·10^{-19}	2,14.10^{-17}	2,14.10^{-16}	3,66·10^{-13}	1,58·10^{-14}	7,11·10^{-16}	7,88·10^{-17}
Sum FP + CP	2,72·10^{-15}	1,96·10^{-14}	1,96·10^{-13}	2,53·10^{-12}	7,31·10^{-14}	2,11·10^{-15}	7,35·10^{-16}
Pu-238	8,91.10^{-15}	2,12·10^{-21}	2,12·10^{-19}	4,19·10^{-18}	1,71·10^{-20}	3,63·10^{-22}	2,12·10^{-19}
Pu-239	6,75·10^{-15}	3,09·10^{-21}	3,09·10-^{19}	3,37·10^{-17}	2,42·10^{-19}	2,26·10^{-21}	3,09·10^{-19}
Pu-240	1,27·10^{-15}	3,39·10^{-22}	3,39·10^{-20}	8,27·10^{-19}	1,90·10^{-21}	1,73·10^{-23}	3,39·10^{-20}
Pu-241	1,74·10^{-15}	2,00·10^{-19}	2,00·10^{-17}	1,77·10^{-15}	2,90·10^{-18}	3,85·10^{-21}	2,01·10^{-17}
Am-241	1,22·10-14	1,74·10-18	1,74·10^{-16}	3,43·10^{-14}	2,00·10^{-17}	2,57·10^{-19}	3,49·10^{-15}
Sum TUN	3,09·10-14	1,94·10-18	1,94·10^{-16}	3,61·10^{-14}	2,29·10^{-17}	2,60·10^{-19}	3,51·10^{-15}
The sum	3,36·10-14	1,96·10-14	1,96·10^{-13}	2,60·10^{-12}	7,31·10^{-14}	2,11·10^{-15}	4,25·10^{-15}

At realization of underwater works the diver breaths cleared air, therefore duration of inhalation receipt of sea aerosols can be estimated in size of 2900 hours per year. Time of an external irradiation from a surface of water of members of considered group also should be corrected on duration of the immersing, therefore planned time of an external irradiation within one year is accepted equal 1000 hour.

It is accepted, that underwater works are carried out on distance of 1 m from a bottom, therefore in a total effective doze the external irradiation from a bottom and lifted ground adjournment is taken into account.

Duration of radiating influence on various ways for three professional groups is given in tab. 4, results of calculations of an effective doze - in tab. 5.

Table 4. Duration of radiating influence within one year for various professional groups, hour

Way of an irradiation	Group 1	Group 2	Group 3
Inhalation receipt due to sea aerosols	3500	3500	2900
External irradiation from a surface of water	-	1900	1000
External irradiation at underwater works	-	-	600

The analysis of results of calculation shows, that in the most conservative variant (time of sediment NPS before recycling 5 years, the storage time after recycling is equal to zero) at the accepted assumptions effective dozes of an irradiation of all professional groups are approximately identical and make about 20 mkSv/year. The basic contribution to a doze brings inhalation radio nuclides receipt with sea aerosols.

In typical variant of the most irradiated the professional group 3 (divers) for whom an effective doze about 1 mkSv/year, the basic contribution to a doze brings an irradiation from water is.

The probability of flooding of the block reactor a compartment at its finding in point of time storage does not exceed 1.10^{-7} 1/year. Using values of factors of individual life risk and damage at the professional irradiation, equal accordingly 0,056 1/Sv [6] and 0.8 year/Sv [9], we shall receive values of individual annual risk and damage at flooding the block reactor

Table 5. Effective doze of irradiation on various ways of influence, Sv

Professional group	Inhalation receipt due to sea aerosols	External irradiation				The sum
		At works on piers, courts, platforms etc.	At underwater works			
			From water	From a bottom	From lifted ground deposits	
Time of sediment NPS before recycling 5 years, a storage time after recycling 0 years						
1	$2,28.10^{-5}$	-	-	-	-	$2,28.10^{-5}$
2	$2,28.10^{-5}$	$2,61.10^{-7}$	-	-	-	$2,31.10^{-5}$
3	$1,85\cdot10^{-5}$	$1,38\cdot10^{-7}$	$8,25\cdot10^{-7}$	$4,92.10^{-7}$	$1,81.10^{-7}$	$2,01\cdot10^{-5}$
Time of sediment NPS before recycling 10 years, a storage time after recycling 10 years						
1	$4,23.10^{-7}$	-	-	-	-	$4,23.10^{-7}$
2	$4,23.10^{-7}$	$1,34.10^{-7}$	-	-	-	$5,57.10^{-7}$
3	$3,49.10^{-7}$	$7,06.10^{-8}$	$4,23.10^{-7}$	$1,59.10^{-7}$	$9,27.10^{-9}$	$1,09.10^{-6}$

compartment with destruction of the strong case and reactor the installations submitted in tab. 6.

Table 6. Radiating risk of different professional groups at works on water area of storage reactor blocks

Professional group	Effective doze, Sv	Individual risk of death, 1/year	Individual annual damage in terms of the lost years of life, years/year
Time of sediment NPS before recycling 5 years, a storage time after recycling 0 years			
1	$2,28.10^{-5}$	$1,28.10^{-6}$	$1,82.10^{-5}$
2	$2,31.10^{-5}$	$1,29.10^{-6}$	$1,83.10^{-5}$
3	$2,01\cdot10^{-5}$	$1,10.10^{-6}$	$1,58.10^{-5}$
Time of sediment NPS before recycling 10 years, a storage time after recycling 10 years			
1	$4,23.10^{-7}$	$2,37.10^{-8}$	$3,38.10^{-7}$
2	$5,57.10^{-7}$	$3,11.10^{-8}$	$4,46.10^{-7}$
3	$1,09.10^{-6}$	$6,11.10^{-8}$	$8,70.10^{-7}$

4. Conclusion

The carried out analysis shows, that at flooding the block reactor a compartment with destruction of the strong case and reactor installations the individual radiating risk caused by work on water area of storage within year, does not exceed 1.10^{-6}, i.e. a neglected risk level agrees NRS-99. The individual annual damage in terms of the lost years of life does not exceed 2.10^{-5} years at time of sediment NPS before recycling 5 years and a zero storage time after recycling (i.e. flooding at once after formation of the block) and does not exceed 1.10^{-6} years for more realistic variant - storage before recycling 10 years and as much after recycling.

References:

1. Andreev N.G., Vavilkin V.N., Mitenkov F.M. etc. the Analysis of processes of an exit of activity from reactor compartment NPS of 2-th generation at long afloat storage after unloading SNF. An epilogue to " the White book " (commissions A.V. Jablokov). Reports of the international seminar. N.Novgorod, January, 19-21 1998 г, page 29-33.
2. Blekher A.Ya., Kuchin N.L., Sergeev I.V. The Radiological Consequences of Radionuclide's Discharge in Water Environment at Afloat Storage of Utilized Submarines Reactor Compartments/An atomic energy, v.97, number 3, September 2004, page 210-218.
3. Dozhdikov S.I., Zhuravkov A.M., Zolotkov A.A. Corrosion resistance of spent nuclear fuel in sea water" Atomic engineering on the sea. Ecology and safety ". The collection of reports of International scientific seminar NS the USSR, September 24-28, 1990, Murmansk. -M., 1991.
4. Ganul M.N., Kuchin N.L., Sergeev И.В. About definition of allowable levels tecnogenical radioactive pollution of water of bays at operation of nuclear objects of sea engineering. An atomic energy, v.89, number 5, November 2000, page 396-403.
5. "Estimation of influence of the radiation-dangerous works which are carried out by the enterprises of nuclear shipbuilding on an environment and the population". Methodical instructions. MI 2.6.1.56-04, Federal management "Medbioextrem", M., 2004.
6. Norms of radiating safety (NRS-99) the joint venture 2.6.1.758-99. Ministry of Health of Russia, M., 1999
7. INTERNATIONAL ATOMIC ENERGY AGENCY, The Oceanographic and Radiological Basis for the Definition of High-Level Wastes Unsuitable for Dumping at Sea, Safety Series 66, IAEA, Vienna, 1984.
8. IAEA, Sediment Kd and Concentration Factors for Radionuclides in the Marine Environment, Technical Reports Series No.247. IAEA, Vienna, 1985.
9. Recommendations of the International commission for radiating protection 1990 (1994) Publication 60.

MEDICAL RISK ASSESSMENT

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1. Abstract

Risk: medical, radiation, ecological, social-hygienic monitoring. Radiation-Hazardous objects. Population. Personal. Shore technical bases.

Methodology of medical risk assessment is an important tool of social-hygienic monitoring.

Individual lifelong risk of occurrence of stochastic effects in population from all exposure sources for three regions of the North-West region of Russia in 2003 made from $2{,}3\ 10^{-4}$ to $3{,}1 \cdot 10^{-4}$ cases, including cases due to the work of radiation-hazardous objects ~ $1{,}0 \cdot 10^{-6}$ cases (i.e. correlated with unconditionally accepted risk). Risk of the professionals changed from $1{,}6 \cdot 10^{-4}$ to $5 \cdot 10^{-5}$, i.e. it was ten times lower than acceptable level of personnel risks set at the level $1{,}0 \cdot 10^{-3}$.

P. Strand et al. (eds.), Radiation and Environmental Safety in North-West Russia, 195–211.

At transition to potential risks relative role of man-caused exposure increased, due to the high territorial concentration of radiation potential accumulated in the Northwest region. STB in Andreeva Bay and Gremikha village may serve as an example of such deviation. In this connection the nearest prospect of work in STB area is connected with system development of rules and limitations that will guarantee provision of:

a) radiation safety of personnel and population,

b) prevention of radioactive contamination of the environmental objects and

c) necessary level of radiation control at rehabilitation and management of radioactive wastes.

Russian Federal Law "About Technical Regulation" defines risk as "probability of dandification to life and health of citizens, property of natural and juridical persons, state and municipal property, the environment, life and health of animals and vegetation with taking into account weight of this". This definition corresponds to total risk, as it integrates several diverse components – not only medical risk but ecological and property risk. It is obvious that total risk can be assessed only on the basis of preliminary profound separate assessment of each of the components, after which a possibility arises of comparatives characteristic of different by its nature risks on the basis of unified ratio of measurement of social-economical and material consequences of their realization (e.g. estimation appraisal).In the field of environmental hygiene in USSR due to the ideological strategy of absolute safety the term "risk" was substituted by the notion "danger" and only since the mid of 90-s an understanding of risk in the environmental hygiene as probability appeared in Russia [1]. However in respect to radiation hygiene no similar ideology was observed and all radiation regulation of radiation factor was based and is based at present on the concept of acceptable (admissible) risk [2].

However it should be stressed that due to different reasons at present there no unified approach and basic philosophy of ecological (radiation)[1] risk assessment in international experience.

Let's look into medical component of possible risk of the discussed nuclear projects implementation because, as it follows from existing conceptions, provision of radiation safety to people in certain territories automatically prevent development of radio ecological consequences for them. In the sci-

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[1] Notions of medical and ecological risk are considered from aspects of radiation safety

entific or close to the scientific lexicon such definitions as “ecological rehabilitation”, “green and brown lanes” are often used. However unfortunately there are no acceptable scientifically grounded “visual” criteria of such kind. Apparently that’s why in the frame of ICRP at the last session in China a special (fifth) ecological commission was organized with the purpose to formulate principals of ecological-radiation protection taking into account available scientific knowledge. During last years in the works [3–7] assessments of ecological dose limits are given, which for dominants of different ecosystems make from 20 to 500 Gy, and basic dose limit for animate nature 4–10 Gy/year is proposed. If we correlate it with 1 mSv (in accordance with the Russian norms of radiation safety - NRB -99 [8] the basic dose limit for population makes 1 mSv), ratio of difference will make 10^3 –10^4. At levels of radioactive contamination of the environment regulated by NRB-99 applicable to human maximum doses of biota exposure make 0,5 Gy/year, i.e. they are 20 times lower than basic dose limit for animate nature (10 Gy). Stated above stressed one more time that backbone unit of general radioecological safety is a human. At that in accordance with ICRP postulate if man is adequately protected by radiological standards then biota are also adequately protected.

During many years in Russia and foreign countries methodology of medical radiation (non-chemical) risk assessment is used at control of radiation safety and assessment of consequences of ionizing exposure impact on human health. Scientific precondition of assessment of medical radiation risk are levels of carcinogenic risks of low-intensity radiation impact. At applying epidemiological approach, e.g. at studying the Japanese -A-bombs survivors, an opportunity appears to assess possible risk level.

Ten years ago there were works that showed possibility of exceeding risks at exposure doses with low LPE of 50-100 mGy [9, 10]. In a number of other works analyzing data for A-bomb survivors are quite opposite, it stated that at doses lower that 300 mGy additional risk is absent and in some other cohorts risk is traced only at doses that exceed ratios traced in A-bomb survivors. Recently published works [11, 12] prove this, in which on the basis of careful epidemiological analyses of effects in the doses range of 100 – 3000 mGy, considerably lower (almost 5 times less) coefficients of risks of leucosis outputs and twice times -output of solid tumors are presented. “Chernobyl” epidemiology among all carcinogenic effects traced only significant acceleration of thyroid cancer [13]. At that in accordance with ICRP problems connected with risk assessment at exposure levels characteristic for professional conditions and the environment [14].

Since there is no reason to suggest zero risk, certain limited risk value is accepted in the system of radiation protection. Thus for annual doses of professional exposure level of lethal risk can make 10^{-3}, i.e. 1 case for 1000 persons. ICRP defined 0,3 mSv per year as acceptable maximum dose from single source for persons from population [15]. At this level of risk of lethal cancer makes about 10^{-5} per year. Level of death risk, equal to 10^{-6} per year is usually considered as insignificant and corresponding to it annual dose – about 10-20 mkSv – is accepted as criteria at which there is no necessity to consider measures of individual protection. Identified levels of medical radiation risk underlie native regulation of radiation factor. Radiation risk accordingly to NRB99 is a probability of appearance of some harmful effect in human and his descendants in result of exposure[2].

Since uncertainty in risk assessment conditioned by biology and by epidemiology still exist, it should be remembered that man-caused radiation effects are always an addition to existent natural background radiation by several mSv/year. Because of the uncertainty of precise scientific data, at present ICRP consider new approach to protection [16], which will be presented in ICRP recommendations – 2005.

Scientific studies of radiation risks for health in Russia since the foundation of nuclear industry and up to the present are based on monitoring data of the big radiation-hygienic "tree" (Fig.1), on the branches of which there is monitoring:

- around radiation-hazard objects, since 1946
- fallout products of nuclear exposures, since 1962
- after Chernobyl accident, since 1986
- radiation-hygienic certification[3], since 1999
- and, finally, appearance of collective branch – social hygienic monitoring (SHM), since 2000. Radiation hygienic monitoring (RHM), on which native system of medical risks assessments is based, is an important component of SHM.

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[2] Harmful effects are understood as a shortening of full life on average by 15 years for one stochastic effect (from lethal cancer, serious inherited defects and non-lethal cancer, considered by harm as consequences from lethal cancer)

[3] RF Government Regulation # 93 from January 28, 1997 "About Development of Radiation-Hygienic Certifications of Organizations and Territories"

Today methodology of medical risk assessment has become one of the most important SHM tools[4]. Social hygienic monitoring (SHM) is the system of state surveillance, analysis, assessment, and prognosis of the population health and habituated environment as well as the correlation of the population health versus the habituated environment factor exposure. By definition SHM is based on "three whales" (Fig.2). At solution of the problem of health conditionality (first "whale") it is not enough to define and enumerate diverse effects on it (third "whale"), it is necessary to find key conditions and factors of risk (second "whale"). We use this scheme in order to conduct study on medical risk assessment in an adequate way, as well as to illustrate principal construction of work which stipulates for scientific assessment of health condition. "Three whales" is a general scheme of vision of health study from medical risk aspect. Purpose of the present report is to give an account of state of affairs of results of medical risk assessment for one of SHM sections (third "whale" with its subsection - radiation), i.e. for provision of radiation safety on the basis of medical risk assessment in respect to functioning of nuclear objects. By this presentation we do not solve final problems of methodology of medical risk assessment but come near to theirs.

2. Radiation-hygienic monitoring in Russia

Medical risk assessments can be obtained only in result of research projects. One of the elements of these studies is data on dose exposure for different group pf people. The obvious question on the differences between research RHM and radiation control elaborated by different agencies and organizations is occurred. Figure 2 provides the organizational scheme for monitoring and control of the radiation situation of the radiation-hazard objects. It is clear that radiation situation monitoring in the NPP surveillance area is elaborated by the NPP operator and designer, hydrometeorology service, and sanitary and epidemiological surveillance service. Results of such control attributed to the agency responsibility as well as elaborated under the radiation hygienic certification of territories have some

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[4] Decree of RF Medical Chief Officer and RF Medical Chief Inspector About Nature Preservation "About Use of Methodology of Risk Assessment for Quality Management of the Environment and Population Health in the Russian Federation" (# 25 and #19-0-11/530 from 10.11. 1997) and Provision about SHM, approved by the RF Government Regulation from July 1 2000 # 426

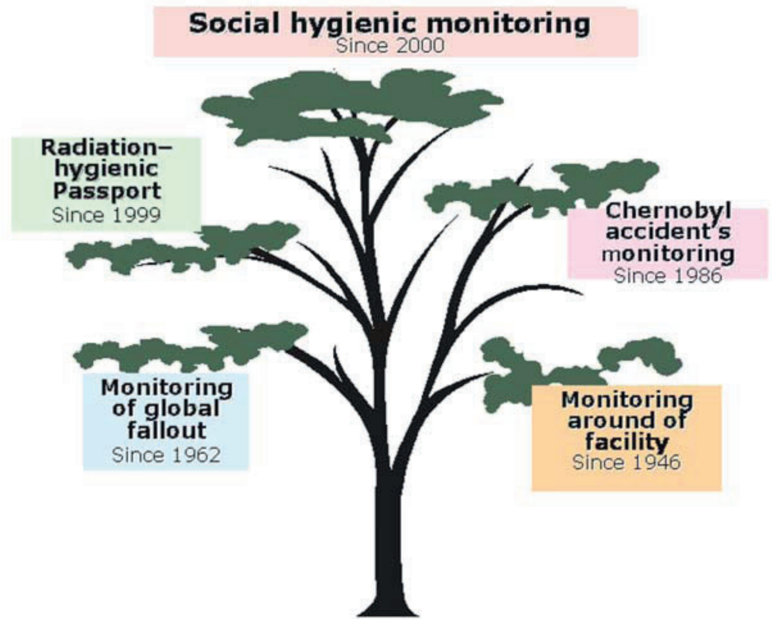

Fig. 1. Scientific studies of medical risk (Radiation-hygienic tree of knowledge)

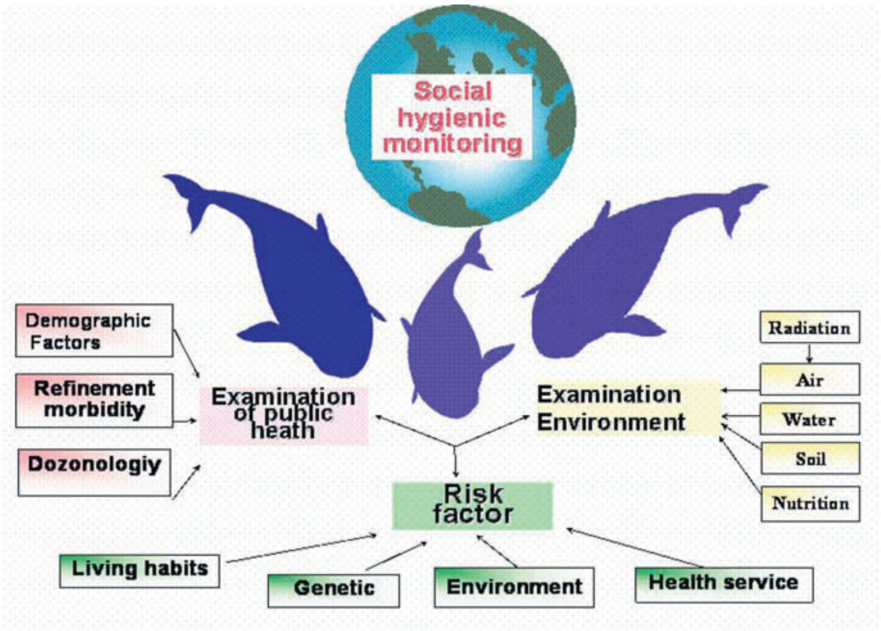

Fig. 2. SHM organizational scheme

disadvantages. These disadvantages include the rare application of radiochemical techniques, low periodicity of examinations, insignificant number of comparison points, and, in some cases, the absence of the comparison area and significant change of the list of objects subjected to the control. Finally, the radiation factor is not considered together with other non-radiation environmental factors affecting the human and the ranking of these factors is not provided. Unfortunately, low levels of radiation hygienic parameters are not recorded in practice. The indicated disadvantages of the practical radiation monitoring can be corrected by the implementation the detailed investigation RHM. The obvious question on the differences between research RHM and radiation control elaborated by different agencies and organizations is occurred. Figure 2 provides the organizational scheme for monitoring and control of the radiation situation of the radiation-hazard objects объектов. It is clear that radiation situation monitoring in the NPP surveillance area is elaborated by the NPP operator and designer, hydrometeorology service, and sanitary and epidemiological surveillance service. Results of such control attributed to the agency responsibility as well as elaborated under the radiation hygienic certification of territories have some disadvantages. These disadvantages include the rare application of radiochemical techniques, low periodicity of examinations, insignificant number of comparison points, and, in some cases, the absence of the comparison area and significant change of the list of objects subjected to the control. Finally, the radiation factor is not considered together with other non-radiation environmental factors affecting the human and the ranking of these factors is not provided. Unfortunately, low levels of radiation hygienic parameters are not recorded in practice. The indicated disadvantages of the practical radiation monitoring can be corrected by the implementation the detailed investigation RHM.

Professionals is ten times lower of acceptable North - West region (NWR) of Russia can be attributed to the territory with enhanced hazard of damaging effects on population and the environment in case of emergencies at potentially radiation-hazard objects. Based upon presence of sources with radiation hazard and design index of possible loses among the population, in the territory of the region subjects to exposure are:

- in Murmansk region – 300 thousand people (26 %)
- in Leningrad region – 150 thousand people (8 % of population).

Thus 450 thousand people live in radiation hazardous areas. An epidemiological analysis reflects ill being of Severodvinsk in a number of nosologic forms (diseases of respiratory organs, of nervous system, congenital malformation of development in children). Main causes of death for grown-up population are diseases of blood circulation organs and malignant tumors. Among facility workers of nuclear shipbuilding a tendency for increase of malignant tumors is observed. Increase of children morbidity due to tumors is of especial concern [17].

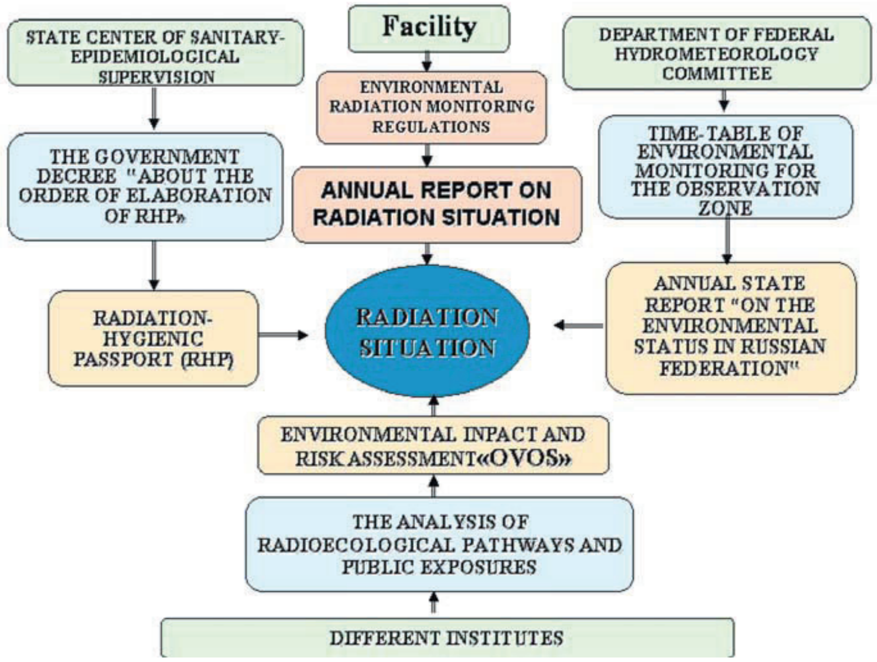

Fig. 3. Radiation situation control: organizational aspects

However declining health rate cannot be related only to the impact of radiation factor. That's why to explain reasons it is necessary to develop risk assessment methodology in other directions, since many human health disorders are conditioned by polyetiologic nature, dependency of their origination and clinical manifestations for big number of factors: genetic predisposition, harmful effects of the environmental factors, mode and quality of life. In this respect it is impossible to foresee the effects of numerous factors and to manage their impacts without determination of attributive part of each factor in total risk of health disorder development.

Radiation risks for population and personnel in a number of NWR presented in Tables 1 and 2 are obtained during radiation-hygienic certification by Gossanepidnadzor organs [18]. Indicated risks are averaged calculated on the basis of implemented dosimetry works with application of collective dose concept. As it can be seen individual risk for population from all exposure sources for all three regions makes (2,3-3,1)$\cdot10^{-4}$ cases per year (Table 1). Due to the work of radiation-hazard objects individual risk for population made about 1,0$\cdot10^{-6}$ cases per year, i.e. this risk is compared with unconditionally accepted risk. Similar conclusion can be drawn regarding average risks for personnel of the group A and B (Table 2). Risk of levels of risk that makes 1,0$\cdot10^{-3}$.

Table 1. Individual lifelong risk of origination of stochastic effects among SA population of radiation-hazard objects, year^{-1}

R from all sources of ionizing exposure	R due to the facility activities	In relation to unconditionally acceptable risk
	Murmansk region	
2,3$\cdot10^{-4}$	1,0$\cdot10^{-6}$	At the level
	Leningrad region	
3,1$\cdot10^{-4}$	9,0$\cdot10^{-7}$	10 times lower
	Archangelsk region	
2,3$\cdot10^{-4}$		

Table 2. Individual lifelong risk of origination of stochastic effects among personnel of the group A and B**,** year^{-1}

Regions	R due to the facility activities	In relation to unconditionally acceptable risk
Murmansk	5$\cdot10^{-5}$	20 times lower
Leningrad	9$\cdot10^{-5}$	10 times lower
Archangelsk	1,6$\cdot10^{-4}$	6 times lower

Among population in 2003 no basic doses excesses in the territory of Murmansk region was registered. At the same time excesses of basic dose limits in 4 workers of FSUE “SevRAO” personnel was registered (Table 3,Figure4).

Table 3. Annual doses of personnel exposure of Murmansk region

Personnel group	Number, pers.	Number of persons among personnel in the range of individual doses, mSv/year							Average dose, mSv/year	Collective dose, pers.-Sv/year
		0 –1	1 - 2	2 - 5	5 - 12,5	12,5-20	20-50	>50		
Group	4785	2603	1156	532	383	106	5	-	1.85	8.8674
Group	7080	7048	24	7	1	-	-	-	0.29	2.0601
TOTAL	11865								0.92	10.9276

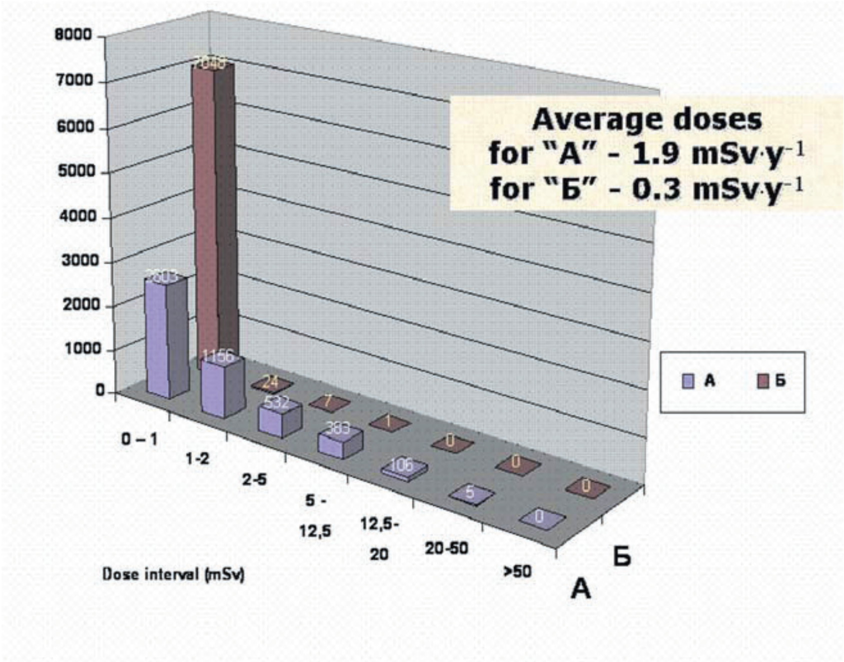

Fig. 4. Annual doses of the personnel exposure of Murmansk area, 2003

In 2003 three emergency situations were registered in Murmansk area:

11.07.2003	OF № 2 FSUE "SevRAO" ZATO Ostrovnoy	At cutting of SRW exposure dose rate made 4,7 Sv/h. Exposure doses of the personnel: one person –higher than 30 mSv, three persons –higher 20 mSv. There was not radioactive contamination of the place.
12.11.2003	ZATO Polyarni, hydrographic service of the North Fleet	Dismantlement of 2 RITEGs. The persons participated in the accident are still unknownЛиц.
29.11.2003	Murmansk custom (custom post "Lotta")	Short-term increase of radiation background. MED on tire covers of 9 cars made 0,4-4,4 mSv/h.

While one can satisfactorily state that risk for population is acceptable and for personnel it is admissible for health from work of indicated radiation-hazard objects, it should be stressed that this data is averaged. In case further exploitation of FSUE "SevRAO" is considered, significant increase (from hazard aspect for population and personnel health) of the "cost" of medical radiation risk could be expected. A special attention should be paid to the issue of synergism of exposure impact and chemical agents, issues of entombment of radioactive wastes, possible accidents at the NPS decommissioning objects and shore technical bases (STB).

At the present moment we consider NPS decommissioning as one of the most crucial one in provision of radiation safety in this and some other regions of Russia, since all NPS taken out of exploitation and subjected to decommissioning are real sources of radiation threat for the human and its habitat. It is conditioned by the following circumstances:

- presence of unloaded SNF in the reactors, which may cause a probability of nuclear emergency with SCR;
- significant accumulated radioactivity in SNF and elements of NPS reactor compartment;
- damps of toxic gases, dust, aerosols, originated at the facilities at NPS decommissioning;
- significant radiation contamination of STB areas of water in result of accumulation of big amount of RAW and SNF.

Table 4 shows on average a safe picture in Arctic region so far. Input in total effective dose of the objects and the facilities in the field of management of SNF and RAW in NWR makes 0,3-0,4 %%.

Table 4. Input of different sources of ionizing exposure in total effective equivalent population exposure dose in North-West region of Russia in 2003, %

Dose component	Murmansk r.	Leningrad r.	Archangelsk r.
Facilities activities using sources of ionizing exposure (SIE)	0,4	0,3	0,04
Man-caused sources	1,0	0,2	1,25
Natural sources	68,8	83,0	72,41
Medical exposure	29,8	16,5	26,3

Relative part of separate sources of radioecological threats changes completely when coming to potential risks. The situation is aggravated by high territorial concentration of accumulated radiation potential in NWR. An example of such deviation is STB in Andreeva Bay and Gremikha village. In accordance with available data [19] a dominant role of potential danger of accumulated quantities of SNF and RAW in comparison with global fallouts ($12 \cdot 10^{15}$ Bq) become obvious. SNF in NPS makes main input (1st place) making $190 \cdot 10^{15}$ Bq in radiation potential of North-West and on STB (2^{d} place) $150 \cdot 10^{15}$ Bq.

Created in 60s Navy STB ensured nuclear submarines exploitation, conducted receiving and storage of fresh and spent nuclear fuel (SNF), solid and liquid radioactive wastes (SRW and LRW), in result considerable amounts of RAW was accumulated. During long STB exploitation protective barriers of SNF and RAW storages degraded, partially lost ability to fulfill their functions. In result penetration of radioactivity in the ground, contamination of buildings, constructions and STB areas of water took place, sources of radioactive contamination of STB areas of water and ecological threat for the environment were generated, that require their localization, rehabilitation and further elimination.

More than 4500 tons of liquid and 60 000 tons of solid radioactive wastes are accumulated in storages in NWR. General radiation potential at North-West regions objects makes $3,5 * 10^{17}$ Bq(~10 mln Cu) – (in total SNF+LRW+SRW), from which $1,5 * 10^{17}$ Bq is concentrated in Andreeva Bay and Gremikha village, i.e. 42 % from all activity in NWR. In the area of STB constructed in 1962-65 in Andreeva Bay all LRW storages at STB is completely packed.

Taking into account existent wide spectrum and scale of radioecological problems, they all can be and must be solved. Gossanepidnadzor defines the priority of the solution depending on the threat degree of contamination to the population. More than fifty years experience of medical service of the Federal Department "Medbioextrem" (at present Federal Medical-Biological Agency – FMBA) testifies that industrial-sanitary laboratories attributed to each specific objects are formations that provide effective supervision and efficient control for provision of sanitary-epidemiologic well-being of the personnel at supervised radiation hazard facilities. ISL specialists at MSU during many years implement medical-prophylactics and sanitary supervision for implementation of legal laws, norms and rules. FMBA regulating functions include a number of questions – from analyses of work conditions at the facilities to SHM in settlements, located in the given region.

Basic problem issues in the field of environmental hygiene, in other words in the field of prevention of radioactive environmental contamination are the following:

- ensuring safe SNF management when unloading from NPS reactors and entombment of emergency reactor compartments with unloaded SNF;

- territory rehabilitation and deactivation of constructions at STB;
- radiation-hygienic provision of work on complex decommissioning of nuclear submarines and STB rehabilitation;
- increase of emergency preparedness.

Radiation emergencies in result of SCR at SNF unloading are of the most danger for the population. Thus at emergency in Chazshma bay at NS-K-314 in 1985 total dump in the environment PB reached 7 mln. Curie. In case of SCR population in the direction of emergency dumps had to be temporary evacuated in radius 3-4 km [20].

Fortunately it should be noted that in accordance with long-term observance after NS decommissioning radiation dose rate for the region as a rule is of local character, content of artificial radionuclides doesn't exceed $1{\cdot}10^{-4}$ of average annual dose (activity) acceptable for the population in accordance with NRB-99 and risk doesn't exceed 10^{-6} [20, 21]. However this value doesn't take into account the hazard connected with SCR at SNF unloading from the reactor. Conservative assessment of SCR probability at future SNF unloading makes $1{\cdot}10^{-5}$ cases for operation at more probable value $1{\cdot}10^{-6}$ [22].

So among numerous problems of NS decommissioning at least three of them in our opinion at the position of high potential danger of VI level (in total there are VII) in accordance with international scale of nuclear events. They are:

- possibility of SCR at SNF unloading,
- long sediment, NS storage afloat with unloaded SNF in reactors and possibility of their flood,
- contamination of STB areas of water and possibility of radioactivity penetration the base territory into environmental objects with further migration of radionuclides in underground water, above ground vegetation and etc.

From the point of radiation protection rehabilitation is related to the situation of interference. International recommendations for such work suggest application of principals of "justification" and "optimization" including ALARA. Procedure "optimization" should be set in the frame of dose constraints or risks in respect to individuals in case of potential exposure in order to minimize possible impact of specific economical and social decisions. Now the purpose of ICRP–2005 is to clarify meaning and use of this definition [16]. Previous methodology was closely connected with formal analysis “costs-effects”. On order to make decision necessary information has to presented in the form of matrix indicating number of persons exposed to the given dose and data when it was obtained. Principal task is introduction of the system of rules and limitations that will guarantee: a) ensuring of radiation safety of STB personnel and of the population living in the STB area, b) prevention of radioactive contamination of the environmental objects, c) necessary level of control for radiation-hygienic/ecological situation at rehabilitation and management of radioactive wastes.

In accordance with the stated above for preservation of health, decrease of risk and gravity of diseases, social-physiological rehabilitation of the population in the territory of radiation-ecological hazard the following is necessary:

- conduct of full detailed examination of the territory with the purpose of localization of areas which are hazard in radiation sense;
- subsequent constant monitoring of radiation situation;
- regular medical and dosimetry control and medical service to the population adequate to the level of hazard;
- running of special medical-dosimetry registers of personnel and as well as of population living in the territory of radiation hazard and participating in elimination of consequences of radiation accidents. As analogy, e.g. Kola register of birth rate, established in Monchegorsk Murmansk region, funded by Norway Ministry of Foreign Affairs [23]. Medical-dosimetry registers are sources of extensive data, not only of selected character, useful at the conduct of prospective studies “case-control”.

It is crucial to stress methodic importance of proper construction of social-hygienic monitoring and assessment of cause-and-effect relations. Today we have shown only a piece of medical risk. In the future studies assessment of cumulative attributive risk is necessary including issues of study of population health condition, its habitat, definition of the level of impact of separate negative exogenous factors n health, i.e. all necessary components for implementation medical risk assessment..

In the nearest further the following is planned:

- Development of general sanitary rules for operations at SevRAO.
- Development and Introduction of criteria and norms for territory rehabilitation contaminated with man0caused radionuclides with taking into account impact of the objects not only on the personnel

but on the population and environmental objects in the areat of water of the Barents sea.

- Definition of radiation-hygienic "future" of the SevRAO facilities and bringing them to so-called "de-licensing".
- Developments on emergency reponse.

References

1. Onischeko G.G. Risk assessment for health in the system of supervision for consumers' rights and sanitary-epidemiological well-being of the population from//Problems of population health risks from impact of the environmental factors. Edited by RAMS academicians Y.A. Rakhmanin and G.G.Ohischenko. – M.: RF MHSD, RAMS. – 2004. – p. 3–11.
2. Ilin L.A., Kirilov V.F, Korenkov I.P. Radiation hygiene: Textbook. – M.: Medicina, 1999. – p.384
3. Romanov G.N., Spirin D.A. Impact of ionizing exposure on live nature at the levels observed by modern norms of radiation safety //Reports of USSR Academy of Science. 1991. V. 318. No 1. – pp. 248–251.
4. Ilin L.A. Problems of regulation of radioactive exposure and levels of interference in radiation protection //Issue of radiation safety. Journal of PA "Mayak". 1999. No 3. – p. 3–15.
5. Thorne M.C., Kelly M., Rees J.H. et al. //J. Radiol. Protect. 2002. V.22. No 3. – P.249-277.
6. Alexakhin R.M., Fesenko S.V. Radiation Protection of the Environment: Anthropocentric end Ecocentric Principles //Радиационная биология. Радиоэкология. 2004. Т. 44. No 1. С. 93–103.
7. Annals of the ICRP. ICRP Publication 91. A Framework for Assessing the Impact of Ionising Radiation on Non-human Species //Ed. J. Valentin. Translation from English. Moscow. Москва. 2004. – 76 ps.
8. Norms of Radiation Safety. NRB-99. Hygienic norms SR 2.6.1.758-99, RF Ministry of Health. 1999. – p.116.
9. Cox R., Muirhead C.R., Stather J.W., Edwards A.A. and Little M.P. Risk of radiation-induced cancer at low doses and low dose rates for radiation protection purposes. Docs. NRPB. 1995. V. 6. No 1.
10. Pierce, DA, Shimizu, Y, Preston, DL, Vaeth, M and Mabuchi, K. Studies of the mortality of atomic bomb survivors. Report 12, part 1, Cancer 1950-1990. Radiat. Res. 1996. V. 146. – P. 1–27.

11. Little M.P., Muirhead C.R. Derivation of low-doses extrapolation factors from analyses of curvature in the cancer incidence doses response in Japanese A-bomb survivors // Int. J. Low radiation. 2004. V. 1. No 3. – P. 285–299.
12. Hiroshi Tanooka Threshold dose problems in radiation carcinogenesis a review of non-tumour doses //Int. J. Low radiation. 2004. V. 1. No 3. – P. 329–333.
13. UNSCEAR 2000 Report to the General Assembly. Annex J. Exposure and effects of the Chernobyl accident. United Nations. New York. 2000.
14. Clarke R. Control of low level radiation exposure: time for a change? //Radioprotection. 1999. V. 34. No. 2. – P. 224–236.
15. International Commission on Radiological Protection (ICRP). Radiological Protection Policy for the Disposal of Radioactive Wastes. ICRP Publication 77. – Ann ICRP 27, Supplement. 1978.
16. Clarke R. Memorandum. Radiation Protection System Evolution: The Justification of New ICRP Recommendations //Medical Radiology and Radiation Safety. 2003, T.48, No 4. – pp.26-37.
17. Dovgusha V.V. Radionuclides in the North-West region of Russia: system approach to the problem //Actual issues of radiation hygiene. Collection of thesis of scientific-practical conference, St-Petersburg, June 21-25, 2004 – St-Petersburg, 2004. – pp. 75–77.
18. Radiation-hygienic passports of Murmansk, Leningrad and Arkhangelsk regions territory for 2003 // CSSES of Murmansk, Leningrad and Arkhangelsk regions – Federal Center of state Sanitary –Epidemiological Supervision of RF. Moscow – 2004.
19. 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. – 28 pp.
20. Radiation situation in the Far East of Russia. Edited by V.V. Dovgusha. St-Petersburg: SRI of Industrial and Marine Medicine. 2002. – 400 pp.
21. Radiation situation in the North-West of Russia / V.V.Dovgusha, M.N. Tikhonov, Y.N. Egorov and et.al.; SRI of Industrial and Marine Medicine of the RF Ministry of Health. St-Petersburg – Murmansk. 1999. – 224 pp.
22. Blekher A.Y., Kuchin N.L., Sergeev I.V. Analyses of radiation risk at the stage of taking out of exploitation and complex decommissioning of NP // Medicine of Extreme Situations. 2001. V.11. No. 4. – P. 7–13.
23. Vaktskold A., Talikova Л., Chaschin B and et.al. Kola birth rate register (Monchegorsk Murmansk region) //Environment and health &/Proceeding of International Conference 2003 May 14-17 Perm-Kazan. Russian Academy of Medical Sciences. 2003 – C. 48–51.

SESSION III: SUMMARY AND CONCLUSIONS

1. Summary

The speakers in the session presented varying aspects of impact – and risk assessment. The first speaker, Mr. Kulikov, presented experience with EIA in a dismantling process. He stressed that the Russian equivalent to EIA is not the ecological expertise but the OVOS, and pointed to the positive aspects of the idea of generic EIA, or class EIA. He also showed the usefulness of scenarios in the risk assessment procedure, and pointed out that the risk assessment system does not include non-nuclear accidents, such as those that may occur involving oil or chemicals.

Mr. Amundsen described the background for the Norwegian engagement in the nuclear protection, as well as for the focus on EIA and risk assessment, namely that the Parliament demands the se studies in order to ensure safe and cost effective projects and programmes. He also stressed that there is a need to determine which information at which level of detail is needed at the different stages of project preparation and realisation.

The experience so far shows that there has been a problem to get the necessary information, mostly due to non-disclosure policies and regulations, but that this is now somewhat better. He also pointed out that important improvements was to include the security and safety outside the shipyards, to focus on workers' safety and to include non-nuclear waste.

Mr. Gospodinov presented the experiences form the Canadian run EIA process for a dismantling process. The Canadian system requires EIA to be made according to Canadian regulations, and also the public participation part of the process took place in Canada. The resulting EIA is available, and should contribute positively to the cumulating knowledge about the environmental and health risks connected to the dismantling of submarines. He also presented the environmental management plan (EMP), which serves as a bridge between the planning process and the project realisation as the EMP describes actions, e.g., mitigating measures, and ascribes the responsibility to actors in the realisation process.

The two presentations by Mr. Blekher showed in detail the possible sources of pollution to the marine environment, as well as the probability

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for those to occur. He also presented various considerations and aspects of the challenges presented concerning the rezoning of the areas after a clean-up.

Mrs. Shandala presented different aspects of risk, concentrating on risk for the population. The results she presented showed that the largest risk of exposure would be in connection with an uncontrolled nuclear chain reaction.

2. Conclusions

To sum up: in the sessions we had presentations of examples of EIA and RA processes as well as donors' expectation and work on this issue. In addition several more detailed examinations of risk assessment was included. There is obviously need for relevant information at all stages of project preparation and realisation in order to identify, reduce and mitigate negative effects, as well as to ensure that we identify and execute the best possible solutions. The trick seems to be to decide which information is necessary at what time, and how to obtain it.

5. SESSION IV: RISK ASSESSMENT METHODOLOGY

Co-chairmen:

O. KOTCHETKOV
SSC, “Biophysics”, RUSSIA

B. SALBU
Agricultural University of Norway (AUN), Aas, Norway

EXPERIENCE OF FRENCH ORGANISATIONS IN ENVIRONMENTAL IMPACT ASSESSMENT FOR REMEDIATION FO CONTAMINATED SITES

C. DEREGEL, J.M PERES, B. CESSAC

IRSN, FRANCE

1. Abstract

In the last years the existing organisation concerning the control and the licensing of activities related to the use of nuclear energy in France has been improved for more transparency and to warranty the independence between:

- expertise in the field of nuclear safety,
- control of nuclear safety and licensing of activities related to the use of nuclear energy (design, building, operation, decommissioning and dismantling of nuclear installations,
- transport, storage and disposal of nuclear material, radiological protection).

2. Overview of the existing organisation

2.1. NATIONAL AUTHORITIES

2.1.1. Nuclear safety authorities

For nuclear civil installations and activities, the Directorate General for Nuclear Safety and Radiation protection (DGSNR), placed under the joint authority of the minister for industry and the minister of health, is in

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charge of the technical and regulatory control of nuclear safety and radiation protection.

For nuclear installations and activities related to Defence, the Delegate for Nuclear Safety and radioprotection for activities and installations related to Defence (DEND) exerts the same functions.

The same principle is valid for the two Nuclear Safety Authorities (NSA) :

The NSA resorts to expertise of external technical supports, in particular the one of the Institute for Radiological Protection and Nuclear safety (IRSN) and requests the opinions an the recommendations of groups of experts coming from scientific and technical horizons diversified.

Environmental protection

The French Agency for Environment and Energy Management (ADEME), in charge of the prevention of pollution of the environment by chemical substances and of the promotion of the sustainable development, may be involved in the management of sites contaminated by radioactive substances in the special cases of mixed pollution (chemical and radioactive).

2.2. NATIONAL TECHNICAL ORGANIZATIONS

2.2.1. French Institute for Radiological protection and Nuclear Safety (IRSN)

The Institute for Radiological Protection and Nuclear Safety (IRSN), created by the AFSSE[1] law then by the decree n°2002-254 of February 22, 2002, is a public establishment of an industrial and commercial nature (EPIC), under the joint authority of the Ministers of Defense, the Environment, Industry, Research and Health."

It groups together more than 1 500 experts and researchers from the former “Institut de Protection et de Sûreté Nucléaire” (IPSN) (Institute for Protection and Nuclear Safety) and “Office de protection contre les rayonnements ionisants” (OPRI) (Office for Protection against Ionising Rays), and persons with expertise in nuclear safety and radioprotection as well as in the field of the control of nuclear and sensitive materials.

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[1] AFFSE: Agence française de sécurité sanitaire environnementale (French Agency for Environmental Health and Safety)

EXPERTISE AND RESEARCH

The IRSN carries out research, analysis and work within the fields of nuclear safety, protection against ionising rays, the control and protection of nuclear materials and protection against acts of malevolence.

Creation of the IRSN is similar to that of agencies for health and safety. Like them, the IRSN will play an active role in providing information to the public within its fields of expertise : nuclear and radiological risks.

SEPARATE CONTROL AND ANALYSIS

The IRSN will not exert any authority of control. For greater transparency, the government has decided to separate the technical analysis from the function of authority of control (authorisations and decisions of a regulatory nature). It is independent from operators of nuclear installations and from the nuclear safety authorities.

2.2.2. French National Agency for Radioactive Wastes Management

Governed by France's public authorities, ANDRA benefits from total independence with regards to radioactive waste producers. Its foremost vocation is to provide sustained protection for man and the environment.

The ANDRA :

- manages, operates and monitors radioactive waste repositories,
- designs and builds new centres for waste unsuitable for disposal in existing installations,
- defines packing, acceptability and disposal specifications for radioactive waste,
- contributes to both national and international R&D programmes,
- inventories all radioactive wastes present on the French national territory,
- informs the public, in particular persons living near the sites, on all ongoing and future work

  and projects.

3. Principles of decision making concerning activities in nuclear installations

For the licensing of activities in nuclear installations, for example for dismantling activities, the operator of the installation must write a nuclear safety report which includes a radiological environmental impact assessment (decree of December 31 1999).

The standard licensing process is as follows:

- The nuclear safety report is sent to the Nuclear Safety Authority (NSA).
- On the request of the NSA, this report is reviewed by the IRSN (technical talks with the

  operator if necessary).
- The IRSN issues an assessment report, which is sent to the NSA.
- On the request of the NSA, the nuclear safety report is rewied by its external technical support on the basis of the IRSN assessment report (one or several standing expert groups (group for reactors safety, group for transport safety, group for safety and criticality, group for radiological protection). The group issues a statement report and makes recommendations, which are sent to the NSA.
- According to this report and to its own analysis, the NSA issues the license for the planed activity (or refuses it, or asks for the improvement of the safety report) or gives its advice to the public authority in charge of the licensing decision.
- The public authority (minister in charge of the installation (industry, defence) issues the decree of licensing (in some cases and according to formal delegations issued by the public authority, the licensing authorisation can be issued directly by the NSA).

4. Environmental impact assessment

4.1 INTRODUCTION

One of the problems raised concerning the use of radioactive material is its real or potential consequences on human health, under normal conditions or in case of accident.

Depending on the nature of the radioactive source considered (sealed source, dissemination of radioactive substances in the soil, in water, in the air, fixed or loose contamination of surfaces), it is necessary to evaluate the consequences in terms of equivalent biologic dose for human beings due to external and internal irradiation.

In case of doses exceeding the accepted norms, it is necessary to take measures in order to achieve an acceptable detriment level for human beings.

A lot of difficulties exist when somebody tries to assess the environmental impact of the use of radioactive material (difficulty to characterize the source, to assess the release of the radioactive substances in the geosphere, to predict their diffusion in the different medias and their transfer to the food-chain of human beings and; consequently, to asses the effectiveness of the measures implemented to reduce the nuisance of this use).

These difficulties are resumed on the following scheme:

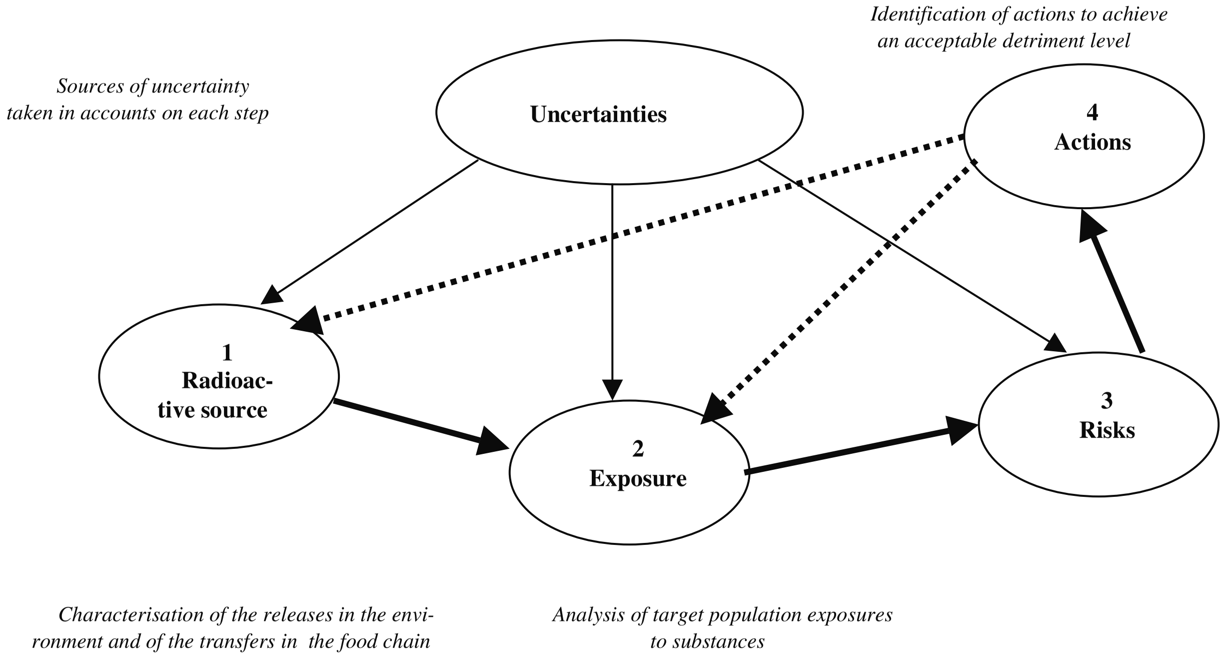


Fig. 1. Difficulties .

4.2 EXPERTISE AND RESEARCH OF THE IRSN

In the field of polluted sites and soils, the IRSN carries out the following activities :

- radiological expertise on the sites contaminated by radioactive substances : characterization of the sites and evaluation of their dosimetric impact on all the populations concerned, including the workers, and on the environment;
- security of the sites, development of the protocols of cleaning and technical aid to the administrative follow-up of the works;
- control of work and work of building site of drainage work. Reception of work and checking of conformity to the remediation objectives;
- research in support with these expertises, for a better comprehension of the phenomena, which lead to the dissemination of the radionuclides in the environment.

(Fore more details, see the IRSN web-sites www.irsn.org and www.irsn.org/net-science/)

4.3 METHODOLOGY FOR THE MANAGEMENT OF INDUSTRIAL SITES CONTAMINATED WITH RADIONUCLIDES IN FRANCE

4.3.1. A Methodologic guide

The French authorities assigned the task of preparing a guide for sites potentially contaminated by radioactive substances to the Nuclear Safety and Radiological Protection Institute (IRSN). For the sake of consistency, they requested that the guide be based, as far as possible, on the approach adopted for sites contaminated by chemicals. The study completed by the end of 1999 has been approved by the two ministries (Health and Environment) that commissioned it and made public in 2000.

The aim of the guide is to provide an operational framework for the management of radioactively contaminated sites, which will replace the current case-by-case approach by a set of recognized procedures that will ensure the "trace ability" of the whole process from assessment to decision. It will provide a system of reference for all the stakeholders involved and will permit dialogue on a common basis.

This guide deals with the various situations that may be met in France when rehabilitating industrial (non nuclear) sites (potentially) contaminated with radioactive substances. These sites are defined as ones where the ground or buildings have been contaminated by activities involving radioactive substances, which have taken, place either on the site itself or nearby.

In principle, various forms of “contamination” are to be found at these sites:

- the soil and buildings at the site may have been contaminated by radioactive substances involved directly, or as by-products, in manufacturing processes and in research work. In soil contamination, these substances are present in various concentrations. Contamination of buildings occurs in two forms: loose contamination and fixed contamination;
- sealed or unsealed sources may have been handled and left on site, in such a way that the radioactive substances are still contained in their packaging or have migrated following degradation of the packaging.

The guide presents an approach involving several stages:

- removal of the doubt,
- pre-diagnosis,
- initial diagnosis,
- simplified risk assessment,
- detailed risk assessment,
- assistance in selecting the remediation strategy for a given use.

The guide outlines the criteria which enable the assessment sequence to be interrupted and the appropriate decisions to be taken. For example, one can stop at the stage of the simplified risk study when the site is small and if it is relatively easy to remove and store the contaminated soil. The selection of the appropriate strategy presupposes the identification of several alternate options which must be characterized in terms of reduction of dosimetric impact, reduction of contamination, costs and associated nuisances. The choice of a remediation strategy requires the close involvement of the stakeholders.

The radiological aspect is generally only one of the elements of the choice and conditions have to be created to enable the stakeholders to discuss all the aspects relevant to the specific context of the site.

It may not be necessary to implement all stages. In particular, the guide distinguishes between contaminated soils and contaminated buildings, where the approach is applied in different ways. In any event, the assessment effort, which is often very costly and time-consuming, should take into account the characteristics of the situation encountered (level of contamination, future use of the site (sensitive use as for example residential area, non sensitive use as for example car-park), and so on.

EXAMPLE OF PROCESS: THE SIMPLIFIED RISK ASSESSMENT

The simplified risk assessment (SRA) involves the calculation of the potential dosimetric impact associated with various scenarios for the use of the site and buildings, based on the results of radioactivity measurements of the soil and buildings at the site.

It takes in account the results of the initial diagnosis (historical analysis, vulnerability of the environment due to the geological and geographical characteristics (consistency of the soil, ground water, surface water, air), radiological characteristics (mapping of the surface, first subsurface studies, measurements of radioactivity in water, crops and animals which may enter the human food chain).

In order to facilitate the calculation of the dosimetric impact, generic scenarios (home, primary school, offices; market garden, car park) have been prepared and then evaluated using a dose calculation model. This model determines the individual effective dose in mSv/year associated with soil contamination that is incurred per unit of specific activity (1 Bq/g of soil) for the radionuclides likely to be found at contaminated sites. The generic scenarios incorporate simple assumptions that prudentially over-estimate the dose impact.

The following tables give some examples of the results obtained:

	Annual effective dose (mSv/year) for 1 Bq/g of each radio nuclide or decay chain						
	Residential area	Agricultural land	Primary school	Office	Parking area	Waste land	Building site
232TH+	0,640	1,160	0,230	0,064	0,016	0,220	0,240
238U +	0,490	0,805	0,170	0,045	0,011	0,175	0,170

	Activity (Bq/g) for a dose of 1 mSv/year of each radio nuclide or decay chain						
	Residential area	Agricultural land	Primary school	Office	Parking area	Waste land	Building site
232TH+	1,6	0,9	4,4	16	62	4,5	4,2
238U +	2,0	1,2	5,9	22,4	89	5,7	5,9

Public authorities lay down the acceptable limits for each category of use (selection level or SL) in mSv/year (generally a fraction of 1 mSv/year) and this selection level is used to decide if remediation work has to be carried out and/or if limitations in the use of the site or of some parts of it must be established.

The calculations made allow determining the effective dose DJ corresponding to the different "generic uses" of the site considered.

Depending on the comparison between DJ and SL, and on the sensitivity of the considered use (for example the use as primary school is sensitive) different decisions can be taken as illustrated on the diagram on next page.

SUMMING UP

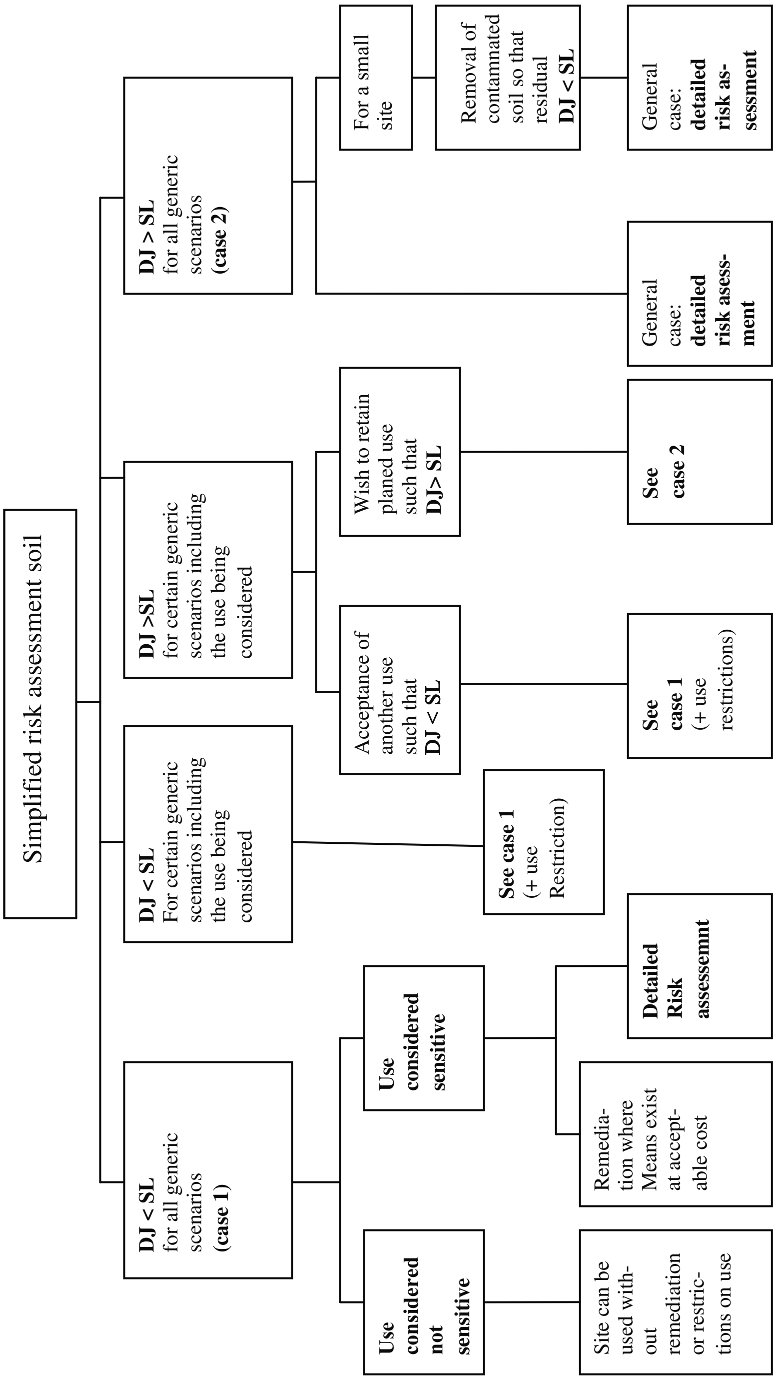
One of the main features of the assessment approach presented here, which resembles that used in the guide on chemical substances, is its sequential nature.Bearing in mind the cost and length of the studies involved in implementing the approach, the latter must be adapted to specific circumstances if it is to be effective. It will not always be necessary to carry out every stage of the assessment.

If a detailed risk assessment turns out to be necessary, it may be useful to divide the site into various sectors if it is large and has a highly non-uniform contamination. This division could be made on the basis of the remediation techniques that should be applied to each sector.

Finding the appropriate strategy means identifying several options which then have to be described in erms of various factors such as reduction in radiological impact, cost, reversibility, service life of the remediation measures, need for institutional monitoring and maintenance of the site, and so on. Regardless of whether this investigation is accompanied by a discussion on selecting a site use, consultations involving all the stakeholders should take place. The scale of these consultations will, of course, depend on the context.

Generally speaking, managing a contaminated site is often a lengthy process, which may extend over several years, from the time contamination is found until remediation has been completed.

The following diagram presents the simplified risk assessment for a contaminated soil: (For more details: contact persons jean-marie.peres@irsn.fr, bruno.cessac@irsn.fr Environment and Emergency Operations Division)


Simplified risk assessment soil
DJ < SL for all generic scenarios (case 1)
Use considered not sensitive
Site can be used without remediation or restrictions on use
Use considered sensitive
Remediation where Means exist at acceptable cost
Detailed Risk assessemnt
DJ < SL For certain generic scenarios including the use being considered
See case 1 (+ use Restriction)
DJ >SL for certain generic scenarios including the use being considered
Acceptance of another use such that DJ < SL
See case 1 (+ use restrictions)
Wish to retain planed use such that DJ> SL
See case 2
DJ > SL for all generic scenarios (case 2)
General case: detailed risk asessment
For a small site
Removal of contamnated soil so that residual DJ < SL
General case: detailed risk assessment

4.3.2. Some methods and tools available

(For more details: contact persons jean-marie.peres@irsn.fr, bruno.cessac@irsn.fr, Environment and Emergency Operations Division)

CALCULATION OF DOSES

CERISE calculation code

The CERISE code (Code for Individual Radiological evaluation for activities in firms and in open air)allows calculating the exposure for preplaned scenarios (generic scenarios as fallow land, building place, residential area, primary school, offices, market gardener, car park) considering:

- the external exposure (β, γ) due to simple geometric forms (point sources, cube, sphere, infinite flat surface etc)
- mixed exposures (inside a house with all ways of aggression and atmospheric emission (external exposure and inhalation).

Results are given in Sievert/year/man of by activity.

Ciblex programme

The characterization of situations that may lead to an exposure of the persons living on a contaminated site or within its immediate environment needs to have some knowledge of the routes of exposure of the individuals concerned, but also to be able to perceive the parameters that best characterize the behaviour of these individuals in their daily life.

In order to characterize the French population related to the management of contaminated sites, the Environment and Energy Management Agency (ADEME) and the Institute for Radiological protection and Nuclear Safety(IRSN) have established a study agreement named the « Ciblex Study », which aims to establish a data base usable for sanitary risks assessment in case of an exposure to radioactive substances.

ASTRAL calculation code

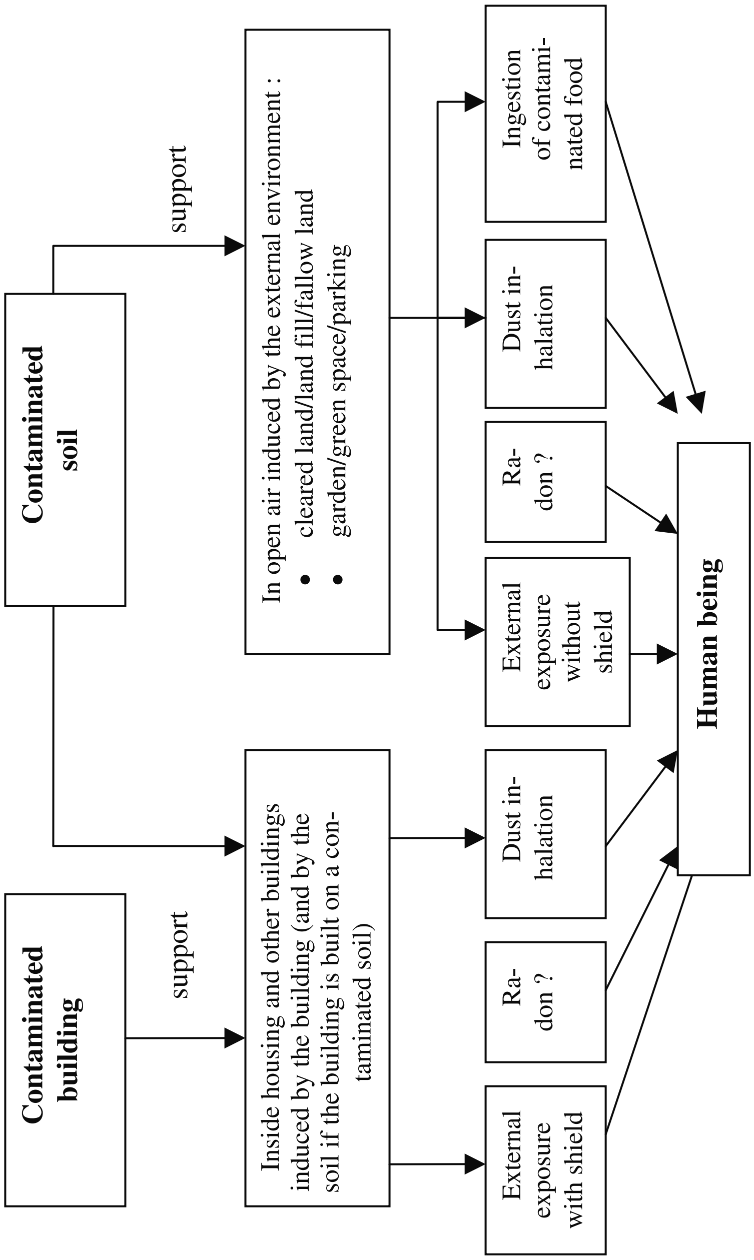
For the assessment of the release of radioactive substances outside a nuclear installations in case of an emergency, the ASTRAL code (Technical Assistance in Radioprotection after an accident) has been developed in order to quantify the transfer of radioactive elements in agricultural areas after an accident.

The ASTRAL code:

- evaluates in time and space the contamination levels in the food chain and the radiological impact on human beings,
- takes in account the transfers from soil to plant, from plant to animal and humans, from animal to humans,
- evaluates the radiological impact on humans due to the external exposure and to the internal exposure by inhalation and ingestion.

DETERMINATION OF THE WAYS OF AGGRESSION OF HUMAN BEINGS BY REDIOACTIVITY

The different routes of exposure of human beings to the radioactivity are represented on the following diagram:


Contaminated building
support
Contaminated soil
support
Inside housing and other buildings induced by the building (and by the soil if the building is built on a contaminated soil)
In open air induced by the external environment :
- cleared land/land fill/fallow land
- garden/green space/parking
External exposure with shield
Radon ?
Dust inhalation
External exposure without shield
Radon ?
Dust inhalation
Ingestion of contaminated food
Human being

RESEARCH EXPERIMENTS CONDUCTED BY IRSN AND TOOLS AVAILABLE FOR IMPACT ASSESSMENT AND RISK EVALUATION

G. DAMETTE, C. DEREGEL

IRSN, FRANCE

1. Abstract

The primary objective of the workshop is to examine how scientific research and environmental studies, including the effects and distribution of radiation and radio-nuclides, can contribute to development of practical standards for protection of the environment and human health. The output is intended to be useful to operators and regulators involved in radioactive waste management projects in Northwest Russia, who are also responsible for Environmental Impact Assessment and regulatory aspects of risk estimation. Secondary objectives include the exchange of information on the application of risk assessment methods as applied to these projects and the regulatory process applied to these projects.

In accordance with its missions, the IRSN conducts or takes part in research programs and experiments concerning the environmental impact assessment of releases of radioactive substances and risk assessment.

Some programs and research activities in these two fields are presented here after.

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2. Environmental impact assessment

Prepared with the help of the "Environment and Emergency Operations" division (DEI) and the "Plants, Laboratories, Transports and Waste Safety" Division (DSU)

Inside the "Environment and Emergency Operations" division (DEI), the departments for the "study of radio-nuclides in ecosystems" (SECRE) and for "environmental radioactivity study and monitoring" (SARG) conduct a lot of studies and experiments with the help of their different sections and laboratories. Inside the Plants, Laboratories, Transports and Waste Safety" Division (DSU), the department for "safety of storage and Waste" (SSD) has developed a 3-D code used for modelling of migration of radio-nuclides from deep geological disposal or from any other source of radio-activity.

2.1. THE ENVIRHOM PROGRAM

(contact person: jean-christophe.gariel@irsn.fr, DEI/SE/CRE)

Launched in 2001, the ENVIRHOM program, connected with the European ERICA and FASSET programs, is aimed at bringing together human health and environmental specialists to observe the effects of very low-level chronic exposure to radio-nuclides. The program studies radio-nuclide bioaccumulation phenomena in ecosystems and humans. The knowledge bases thus obtained will represent a major step forward in efforts to set up an environmental protection system.

ENVIRHOM sets out to assess the integration of radio-nuclides into trophic networks in abiotic media (water-soil-sediments), as the great diversity of transfer mechanisms within ecosystems stems from radio-nuclide biogeochemical cycles and from the nutritional strategies adopted by organisms found in these media.

The program focuses particularly on the study of induced biological disturbances in the long term. At present, insufficient knowledge of these phenomena represents a potential flaw in future assessment systems. ENVIRHOM will also attempt to establish dose-effect relationships between the concentration of radio-nuclides found in the medium and the ecological impact on individuals and on the population at large. Lastly, as the ENVIRHOM program addresses both human health and environmental aspects of the problem, it fully integrates the approach underpinning the future human and environmental radiological protection system.

2.2. SYMBIOSE: AN INTEGRATED PLATFORM FOR ASSESSMENT

(contact person: marc-andre.gonze@irsn.fr, DEI/SECRE)

Launched in 2002 and sponsored by Electricité de France, the SYMBIOSE program is aimed at developing a software platform to provide assistance in assessing and managing the risk of radioactive contamination of the environment. The purpose is to address the health risk (environmental impact) from the scale of an individual to that of an entire population.

The approach adopted must allow models of varying complexity to be implemented, ranging from basic models dedicated to preliminary analysis work to more realistic conceptual, mathematical and spatial descriptive models. This platform has a major pioneering advantage on existing tools – its ability to develop or activate increasingly complex models within a single computer environment. This flexible tool can also be used to assess the reliability of forecasts by testing various alternatives or hypotheses adopted in models and thus address the problem of structural uncertainties.

The platform uses an integrated approach aimed at processing a relatively broad spectrum of situations.

Its medium-term scope is as follows:

- consideration of radioactive sources such as subsurface disposal facilities or Basic Nuclear Installations under normal operating or accident conditions,
- dynamic modelling of the various media making up the continental biosphere and of spatial heterogeneity over a wide range of spatial-temporal scales.

In 2002, existing models were restructured and integrated into a set of modules. So far, the work has focused on the dosimetric impact on human health through the intake of contaminated food from a simplified (non)spatialized continental biosphere. Contamination is induced by nuclear facility operation under normal or accident conditions. The risk management aspect will be addressed during the next phase of the project.

Since 2003, efforts have focused on the development of a feasibility prototype, consisting of : a modeling and simulation environment (GoldSim toolbox), a data and information management system (DataBase & Web technologies), and a preliminary analysis and decision-support component. The calculation environment is used to develop and manage reusable modules (stored in a library), build and customize site- or scenario-specific simulators, and perform and analyze deterministic/stochastic calculations. Future work will be devoted to the specification and development of the Symbiose platform in Matlab/Simulink environment.

2.3. FARMING PROGRAM

(Contact person: jean-marc.peres@irsn.fr, DEI/SARG)

The Chernobyl accident led to a long-term crisis that affected agriculture, food industry, economy, life conditions through complex ways. It disrupted the interactions between the public and private institutions through the economical, political and social aspects, at local, national and international levels.

In France, nuclear power is the main energy source and food production is, from an economic but also historical point of view, a very significant activity. In this context, such an event could deeply and durably unsettle this country.

Until recently, emergency planning for nuclear accidents has tended to concentrate on the protection of public health during the emergency phase and the short-term and was mainly initiated by radiation protection experts. However, the complexity of the migration of radio-nuclides into the environment and into the food chain, but also the important number of concerned actors and the unavoidable incompatibilities between their respective expectations of the rehabilitation, make the post accidental management a challenging question for the responsible organisations at local, national and international levels.

Within the 5th PCRD research and development program of the European Community, the EC FARMING program (2000 – 2004) aimed at creating a European multi-field stakeholders network in order to reflect on rehabilitation strategies of a rural contaminated area after a nuclear accident, at national and European levels. Coordinated by the Institute of Patrimonial Strategies of the Institute for Agronomy (Paris), the French FARMING group was the opportunity for radiation protection actors, like IRSN, and other stakeholders from, for example, agriculture to exchange knowledge and establish a common culture and language in order to deal with the stakes and conditions of the post accidental management of the agriculture and food industry.

The results of the work-progress dealt with two main aspects. Firstly, the evaluation and the improvement of a compendium of rehabilitation countermeasures produced by another European network, STRATEGY, allowed the technical knowledge on the rehabilitation means to be increased. Secondly, the mobilization of different stakeholders enriched the strategic reflection on what a nuclear accident could be and how to deal with its complexity.

The French working group gave various comments, on the scientific, technical and strategic points of view. It first addressed the two main options of rehabilitation objectives, "concentration" or "dilution" of radioactivity, with their respective advantages and drawbacks. It then suggested some actions to realize "in normal time" in order to facilitate the management of the nuclear crisis, and finally, proposed some new strategic criteria to add to the datasheets.

The conclusions of the FARMING program are now developed through the 6th PCRD, within the EURANOS program.

2.4. BORIS PROGRAM

(contact person: christian.tamponnet@irsn.fr, DEI/SECRE)

The BORIS project was launched by the European Community within the scope of the fifth PCRD research and development program. The purpose of this project is to increase our understanding of the mechanisms involved in the transfer of radio-nuclides from soil to plants in order to reduce the large uncertainties concerning those transfer coefficients displayed in the scientific literature.

BORIS investigates mainly the role of the biological elements (plants, mycorrhiza, microbes) in radio-nuclide sorption/de-sorption in soils and radio-nuclide uptake/release by plants. Because of the importance of the chemical nature of the involved radio-nuclides, the bio-availability of three radioactive nuclides is followed: caesium, strontium, and technetium. The role of additional non-radioactive pollutants is also scrutinised as they may interfere with the mechanisms governing radio-nuclide transfer to plants.

Knowledge acquired from the experiments will be incorporated into two mechanistic models, CHEMPHAST and BIORUR, specifically modelling radioactive nuclide sorption/de-sorption from soil matrices and radioactive nuclide uptake by/release from plants. These mechanistic models will be incorporated into assessment models to enhance their prediction ability. It is expected to extract from these experiments scientific bases for the development of bioremediation methods of radio-nuclide-contaminated soils.

NOTA: Teams involved in BORIS with those in MYRRH (use of mycorrhizal fungi for the phytostabilisation of radio-contaminated environments), two programs of the fifth framework program, have decided to publish their results in a special issue of *the Journal of Environmental Radioactivity*.

2.5. THE CHERNOBYL EXPERIMENTAL PLATFORM

(contact persons: jean-christophe.gariel@irsn.fr, jean-marc.peres@irsn.fr, DEI/SECRE)

Since the beginning of the nineties, IRSN is conducting studies on the Chernobyl site.

IRSN, has been coordinating the "Chernobyl Pilot Site" project since June 1999. In cooperation with the Ukrainian institutes, the objective of this project is to study the behaviour of radio-nuclides in the environment and more specially, of strontium 90 and caesium 137.

The earth and debris contaminated by the accident were buried in 1987 in the "Red Forest" area a few kilometres from the Chernobyl plant in rapidly dug trenches. The trenches are not leak tight and rainfall induces the release of radio-nuclides into the environment.

The experimental platform is a 4 hectares area located near one of these old trenches and is equipped with all the resources required to conduct research into radio-nuclide migration to the soil and plant life.

2.5.1. Soil

Researchers study the transport of radioactivity in three quite separate areas with various levels of contamination:

- the first area is a former trench – now filled in – representing the most highly contaminated part of the site as it contains many fuel particles,
- the second area is the unsaturated part of the ground from the surface down to a depth of 3.5 m in which the interstices have not been completely filled with water,
- the aquifer, more than 3.5 m deep, is the area in which the gaps left by solid material have been completely filled with water.

2.5.2. Transfer to plants

Open-field plots have been sown with various crops to monitor radioisotope migration.

Significant results have been obtained, particularly in the trench and aquifer areas. This work, summarized in 2002, identified predominant particles, characterized their respective dispersion, and compared observations with models. For the unsaturated area, other phenomena must be investigated before long-term forecasts can be made. This will call for a specific program.

Radio-nuclide transport in the environment results from a combination of several basic mechanisms for which laws must be defined:

- dissolution of fuel particle,
- diffusion (dispersion of radio-nuclides independently of the overall motion of the liquid),
- entrainment of radio-nuclides by the overall flowing motion of the fluid (advection),
- exchange of material between the fluid and the rock.

The relative significance of these various mechanisms depends on the medium studied - trench, unsaturated area, or aquifer. For each of them, the study entails identifying predominant mechanisms, then defining the parameters (permeability, chemical composition, etc.) governing them.

This data has been gathered in models describing the behaviour of each medium studied. Overall consistency is sought in a global model integrating the partial models. Each step undergoes experimental validation using equipment on the platform and from external laboratories.

2.6. THE MELODIE CODE

(contact person: christophe.serres@irsn.fr, DSU/SSD)

The Melodie code has been developed for modeling radio-nuclides transfer in heterogeneous porous medium. It is applicable to deep geological storage, but it can also be used for near-surface disposal and any other type of radioactive source.

The calculation is carried out in two steps. First, the flow equation is solved to calculate Darcy's velocities; then, for each radio-nuclide, the transient transport equation is solved. The physical properties (such as hydraulic conductivity, porosity...) are averaged in a volume of rock.

Flow mass balance: porous medium saturated by an incompressible fluid, steady-state or transient fluid flow may be simulated.

The general form of the macroscopic mass balance is expressed by the continuity equation and using Darcy's law:

$$div\left(-\overline{\overline{K}}\,\overrightarrow{grad}\,h\right)=Ss\frac{\partial h}{\partial t}+q \tag{1}$$

where *h* is the hydraulic head (m), solution of the system.

Darcy equation requires following input data :

- $\overline{\overline{K}}$: permeability tensor (m.year^{-1}),
- S_S: specific storage coefficient of the aquifer (m^{-1})
- q: a source term corresponding to the outside flow (pumping, recharge ...) (year^{-1}).

Transport equation: single phase miscible solute is transported by advection/dispersion; sorption is simulated via retardation coefficient (linear, reversible and instantaneous sorption kinetic); radioactive decay and daughter nuclides are considered in transport equation. The groundwater physical properties (density and viscosity) are supposed not to be disturbed by the presence of transported elements.

The transport mechanisms taken into account are:

- the advection governed by the average water velocity (Darcy's velocity),
- the diffusion (Fick's law),
- dispersion depending on the tortuosity of the medium.

The radio-nuclide transport equation to be solved has the following form:

$$\omega_c R\frac{\partial C}{\partial t}=div\left(\overline{\overline{D}}\,\overrightarrow{grad}C-\vec{U}C\right)-\lambda C\omega_c R+\lambda C_p\omega_c R_p \tag{2}$$

where *C* and C_p , respectively the radio-nuclide and the radio-nuclide mother activity per unit mass of the liquid phase (Bq.kg-1), *t* time (y). *C* is the solution of the system.

Transport of reactive or non reactive solute requires following input data:

- ω_c: kinematic porosity,
- λ: radioactive decay constant (year^{-1}),
- $\vec{U}$: Darcy's velocity (m.year^{-1}),
- $\overline{\overline{D}}$: diffusion-dispersion tensor, computed with :

✓ α_L α_T: longitudinal and transversal dispersion (m) respectively,

✓ d: molecular diffusion coefficient (m^2.year^{-1}),

✓ ω: total porosity.

✓ the retardation coefficient R is defined:

$$R=1+\frac{1-\omega}{\omega_c}\rho_s K_d \tag{3}$$

✓ ρ_s: mass per volume unit of the matrix solid particles (kg.m^{-3}),

✓ K_d: distribution coefficient (m^3.kg^{-1}).

✓ LS: solubility limit for each elements (kg.m^{-3})

Effective coupling between flow and transport is considered in MELODIE. Darcy velocity is calculated and then taken into account in the advective term of the transport equation. Coupling between flow conditions around canisters, concentration around canisters and release of activity from canisters through the geo-sphere is also effectively modelled. Both solubility limit of waste matrix and elements are tested to calculate effective amount of released and precipitated element.

MELODIE runs under Linux PC system and graphical interfaces are available to build input files and visualise results via pre and post programs.

Numerical discretisation is based on an up to date Finite volume/Finite element scheme allowing the hyperbolic/elliptic behaviour of the transport equation to be handled and respecting the maximum principle.

3. Risk assessment

Prepared with the help of:

- the "Plants, Laboratories, Transports and Waste Safety" Division (DSU), "Industrial Risks, Fire and Containment Assessment and Study " department (SERIC), “Airborne Pollutants and Containment Study and research “ Department (SERAC) - laboratory for the experimental study of containment, air cleaning and ventilation and "Criticality Assessment Study and Research" Department (SEC),
- the “Prevention of Major Accidents” Division (DPAM), “Accident Experimental Studies and Research” Department (SEREA) – laboratory for fire experiments.

3.1. FIRE AND EXPLOSION RISK

(herve.boll@irsn.fr and herve.baltenneck@irsn.fr DSU/SERIC)

3.1.1. Introduction

The risk of fire is a major safety concern, given the probability of a fire in a nuclear facility and the severe consequences that a non controlled fire might cause. The research, studies and expertise conducted by the IRSN on fires allow better assessment of the measures taken by the licensees to ensure the safety of their facilities and promote improvements.

The studies conducted to support safety assessment focus on all mechanisms, which generate release of radioactive products following a fire.

Among these studies, the Probalistic Safety Assessment conducted on the risks of core meltdown in case of fire in a French 900 MWe NPP particularly highlighted significant uncertainty areas that led IRSN to perform research to improve knowledge on topics like fires inside electrical boxes, propagation of a fire from room to room inside a building, behaviour of division into compartments and containment equipment in case of fire, characterisation of fuels.

3.1.2. Carmela programme

(contact: laurence.rigollet@irsn.fr and jean-marc.such@irsn.fr DPAM/SEREA)

The CARMELA programme provided in 2002 first results related to the propagation of fire inside electrical boxes. The first experiments were conducted in the French Cadarache nuclear research centre using models representing electrical boxes.

Experiments continue (CARMELO campaign) with real electrical boxes (validation of the results of the first CARMELA experiments conducted in France).

Cooperation with Finland exists in this field.

3.1.3. DIVA experimental platform

(contact: william.le-saux@irsn.fr and jean-marc.such@irsn.fr DPAM/SEREA/)

The study of the propagation to adjoining premises via ventilation and the openings of a fire started in a close and ventilated room conducted IRSN to set up in 2002, in the Cadarache nuclear research centre, the DIVA experimental platform to improve knowledge on the propagation of hot gas or particles to adjoining premises via the ventilation systems and the other communicating channels (doors, openings, and so on).

3.1.4. STARMANIA programme

(contact: laurent.bouilloux@irsn.fr DSU/SERAC and jean-claude.laborde@irsn.fr DPAM/SEREA)

The STARMANIA programme, started in 2001 studies the behaviour of division into compartments and containment equipment (doors, fire–dampers, filters…) submitted to stresses resulting from a fire.

An experimental platform (BANCO) allows the filter clogging to be studied, which may lead to a loss of containment of the radioactive substances, in particular by breaking the filter medium.

3.1.5. FLIP programme

(contact: jean-marc.such@irsn.fr DPAM/SEREA)

In collaboration with the COGEMA company (now AREA), the FLIP test programme (Liquid fuel fires interacting with a wall) was conducted between 1996 and 2002 to study the development of a pool solvent fire that might occur in a room dedicated to the storage of solvents used for the reprocessing of nuclear fuel (characterisation of temperature, pressure, movement of hot gas, smoke, soot…).

3.1.6. MAREX method

(contact: herve.baltenneck@irsn.fr DSU/SERIC)

IRSN has developed a methodology for the approach of internal explosion risk in nuclear installations. The goal of this methodology is to concentrate information and experience gained on explosion in a logical and clear scheme to allow technicians, not necessarily experts in explosion mechanisms, to point out, when assessing a safety report, potential risks of explosion and determine the types of risk generated. Products are classified in categories depending on their nature and their physic-chemical form. For each category, potential risks are analysed and induced consequences listed. This methodology is completed with several attachments giving clear explanations on chemical reactions, racing of reactions, oxidation and combustion, deflagration and detonation, burst, backdraft or smoke explosion…).

3.1.7. Conclusion

The results of all the experiments are used to qualify calculation codes, which allow prediction of the different effects of the development of a fire (FLAMME code), the interface with the ventilation systems (SIMEVENT code) and it is possible to use together the FLAMME code and the SIMEVENT code in order to study the influence of the ventilation on the development of a fire.

They allow the existing database concerning the characterisation of fuels to be improved and the suspension factors of radio-nuclides in case of a fire to be determined (improvement of the database BADIMIS).

These results were considered for the elaboration of the new version of the Fundamental safety regulation 1.4A related to fire protection in basic nuclear installations.

3.2. RISK ASSOCIATED TO LOSS OF CONTAINMENT

(contact: Pierre.cortes@irsn.fr DSU/SERIC)

3.2.1. Introduction

Assessment of containment of radioactive/toxic material has to be carried out everyday by IRSN in the framework of the technical support provided to the French and foreign safety bodies, in particular when giving advices on the acceptability of Safety Analysis Reports submitted to these regulatory authorities. All the field of nuclear activities is thus addressed, including non nuclear installations and various types of installations under decommissioning (from reactors to sub-marines). IRSN has thus developed tools allowing efficiency of containment to be assessed, relying on research and experiments mainly aimed at determining transfer coefficients in various configurations.

3.2.2. Tools developed

When assessing containment properties, two functions have to be considered:

- Static containment and phenomena challenging the integrity of tightness of the containment barriers (chemical risks, ageing, fire, handling risks, earthquake…)
- Effectiveness of dynamic containment during normal and accidental situations (including filter efficiency)

The result of this assessment is the quantification in all these situations of the contamination levels inside the installation (protection of workers) and releases (protection of environment and public).

The accuracy of the results is of course strongly depending on the knowledge of the different parameters characterizing a given situation, and in particular the transfer coefficients of radio-nuclides into environment, whatever their physic-chemical form.

These coefficients have to be determined, for each physic-chemical form, for every type of events such as:

- Liquid or powder drop (including drop of casks and drums)
- Loss of cooling of a medium containing radio-nuclides (solvent, fuel, effluent)
- Glove rupture in glove boxes containing contaminated dust or powder
- Pipe rupture or leakage
- Cutting operation on contaminated material
- Deposits and re-entrainment in vent ducts
- Fire
- Effect of wind (creation of differential pressures on the different faces of buildings and equipment)

A program of experiments has been launched for many years at IRSN and it is still ongoing. It allows the knowledge of these transfer coefficients to be improved, constituting a major element of the database which is used in the code CAIMMAN, developed by IRSN for calculating the release of activity in the different normal and accidental situations that can be anticipated.

3.2.3. Conclusion

Experience feedback show that, very often, big uncertainties in term of doses are associated to contamination (when compared to quantification of irradiation doses) in the safety analyses. This statement led IRSN to implement a R&D program in order to reduce this uncertainty range, and the results reached through this program and its application in safety assessment is of utmost importance, especially for actions linked to dismantling of building and equipment, during which contamination hazard keeps a high level of probability.

3.3. CRITICALITY RISK

(contact: veronique.rouyer@irsn.fr DSU/SEC)

3.3.1. Introduction

IRSN deals with various aspects of criticality risk, from prevention to the assessment of consequences. The purpose is above all to prevent the development of a chain fission reaction out of a nuclear reactor, i.e. in a facility not intended for that purpose (plant, laboratory or transport packing). This type of reaction involves the release of neutron and gamma radiation as well as the production of radioactive products likely to be spread out of the concerned facility. The main consequence of a criticality accident would therefore be to irradiate persons who might be close to the accident site. The institute develops qualified computer codes and applies them to the assessment of the measures used to prevent criticality risk and, in case of accident, it assesses the consequences on health and the environment.

Beyond research, IRSN also provides expertise, in particular for laboratories, plants and transport.

Every year, over 50 files concerning the transport of fissile materials, each corresponding to multiple contents, are studied in the Institute. Such studies include systematically the verification of criticality calculations of carriers and; in the case of assessments carried out with third party software, counter-calculations are conducted.

3.3.2. Specifity of the activities related to decommissioning

In the framework of decommissioning activities, different activities concerning fissile material are performed, mainly the unloading of the nuclear fuel, its temporary storage (decrease of the residual power) and its transport to reprocessing facilities.

Due to history, in addition to these "standard" activities", the retrieval of irradiated fuel stored in bad conditions has sometimes to be considered, as well as its new conditioning and its transport to temporary storage facilities or to repositories.

All these activities request handling and transport activities and the criticality risk has to be assessed very carefully as well as during normal operation as in case of an accident. It means that the Keff of spent nuclear fuel must be assessed in all possible configurations, including in case of aggression of a fuel element alone (unloading operation), of several fuel elements inside a canister (5 to 7 fuel elements) or inside a transport cask (35 to 49 elements).

The assessment of the criticality risk requests the use of specific calculation codes in order to determine the new geometric configuration of the fuel elements after the accident (3D modelling) and, after that, neutron calculations in order to evaluate the Keff of the fissile material in the most unfavourable situation after an accident (drop, collision of the transport vehicle, fire, and so on). The necessary tools have been developed and qualified by IRSN (3D modelling of fuel elements and packages, calculation of the deformations in case of mechanical aggressions, calculation of the temperature inside a transport cask in case of fire).

Concerning the criticality risk assessment IRSN, together with CEA and COGEMA has developed the CRISTAL code.

3.3.3. The new CRISTAL criticality-safety package

From 1995 to 1998, the Commissariat à l'Energie Atomique (CEA), the Institute for Radioprotection and Nuclear Safety (IRSN) and the COGEMA company have developed and validated the new CRISTAL criticality-safety package V0 version, a software system containing a code package which is designed to meet the requirements of works on nuclear fuel facilities and transportation for criticality survey work, for criticality-safety studies and for benchmarking.

The CRISTAL package was developed as an easy-to-use system using cross-section libraries (JEFF 2.2 and CEA 93), well established computer codes (APPOLO 2, MORET 4 and TRIPOLI 4) and including a Graphical User-Friendly Interface.

In 2002, the CRISTAL code has been improved in order to take in charge the new nuclear fuels (MOX) and the influence of the burn-up on the reactivity (credit Burn-up).

System overview

The functional architecture of the CRISTAL criticality package is organised around two calculation schemes, which use the nuclear data issued from the JEFF 2.2 data file:

- the "standard scheme" uses a multi-group formulation of cross-sections of the CEA 93 library possibly condensed and homogenised by the APOLLO 2 computer code and used in the multi-group Monte Carlo computer code MORET 4 or in the Sn modules of APOLLO2;
- the "reference scheme" based on the continuous-energy computer code TRIPOLI 4 for which the principle is to use the minimum of physical approximations and modelling; this scheme uses the point-wise cross-sections; the cross-sections are represented as a point in the energy range, except for the unsolved range for which specific methods are used (temperature dependant probability tables, for example).

The nuclear data of the JEFF 2.2 data file can be used in two different ways:

- for the calculations done with the "standard" scheme upstream the APOLLO 2 calculation, it is necessary to make a multi-group nuclear data library from the NJOY processing of the JEFF 2.2 evaluation. The library created is designed by "CEA 93" and the versions associated with CRISTAL are the V3 and V4 versions both with 99 and 172 energy groups,
- in the calculations made with the computer code, TRIPOLI 4 ("reference" scheme of CRISTAL), we directly use the nuclear data form the JEFF 2.2 evaluation. The partial cross-sections in relation with energy, anisoptropy, fission spectrums and secondary particles productions are integrally read in the JEFF 2.2 data file.

3.3.4. Conclusion

CRISTAL is a new criticality-safety code system, which combines the best properties of the APOLLO 2, MORET 4 and TRIPOLI 4 code packages. In this way, we are able to perform calculations in complicated three-dimensional geometries. The validation of this new code system is in progress and significant efforts are made to propose accurate and comprehensive database of experiments for use in validating calculation methods developed in the CRISTAL package.

IRSN participates in the International Criticality Safety Benchmark Evaluation Project, under the auspices of the OECD. This project consists in pooling criticality experiences, which have been conducted around the world for over 20 years. This work is essential for the qualification of calculation systems such as CRISTAL since in fact, almost 1200 criticality experiences from various sources were recalculated by this code..

(Fore more details, see the IRSN web sites: www.irsn.org and www.irsn.org/net-science/)

References

1. *Lessons learnt from IRSN modelling performed for the 5th EC PCRD BENIPA exercise* - D. Pellegrini, F. Besnus, C. Certes,F. Deleruyelle, C. Serres (IRSN – Institut de Protection et de Sûreté Nucléaire, BP 6, 92265 Fontenay-Aux-Roses, France), EUROSAFE 2003, Paris 2003.
2. *Evaluating Effect of Design Options on Flow and Transport* - C. Serres, A. Claisse, F. Besnus (IRSN – Institut de Protection et de Sûreté Nucléaire, BP 6, 92265 Fontenay-Aux-Roses, France) – *International High-Level Radioactive Waste management Conference 2001.*
3. *Radiological Impact of a Spent Fuel Disposal in s Deep Geological Granite Formation* – Results from the European SPA Project – P. Baudoin, D. Gay, C. Certes, C. Serres (IPSN – Institut de Protection et de Sûreté Nucléaire, BP 6, 92265 Fontenay-Aux-Roses, France) –, *Safewaste 2000, Les déchets nucléaires : de la recherché à la maîtrise industrielle » Montpellier 2 au 4 octobre 2000.*
4. Influence of Biosphere Modelling on Integrated Performance Assessment results : *Lessons Learnt From the SPA Project* – D. Gay, F. Besnus, P. Baudoin (IPSN – Institut de Protection et de Sûreté Nucléaire, BP 6, 92265 Fontenay-Aux-Roses, France) – *IRPA 10, 10th International Congress of the International Radiation Protection Asoociation "Harmonization of Radiation, Human Life and the Ecosystem", Hiroschima, Japon, May 14-19, 2000.*
5. Some comments from the integrated performance assessment point of view on the behaviour of a deep geological disposal system. Cases of I-129 and heavy nuclides releases – F. Besnus, D. Gay, P. Baudoin, C. Certes, C. Serres (IPSN – Institut de Protection et de Sûreté Nucléaire, BP 6, 92265 Fontenay-Aux-Roses, France) – *WM symposia "HLW, LLW, Mixed Wastes and Environmental Restoration – Working Towards a Cleaner Environment" Tucson, Arizona, February 27 – March 2, 2000.*

RADIATION-HYGIENIC ZONES OF TERRITORIES TRANSFERRED TO ROSATOM COASTAL TECHNICAL BASES OF NAVY

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1. The concept of radiation-hygienic zones

At work in territory of coastal technical bases (CTB) in an environment act radio nuclides, contained on technical objects and in objects of an environment in CTB territory. During works they are essentially redistributed, pollute the process equipment, surfaces of working rooms, CTB territory and objects of an environment, concentrating in some cases up to significant levels, at which probably increased irradiation of the personnel and population and secondary pollution of objects of an environment.

Generally, potential sources of an irradiation of CTB personnel are:

- technical objects of CTB;
- radioactive polluted CTB territory (separate sites of territory);
- radioactive pollution of surfaces of the process equipment and working rooms;
- radioactive polluted vehicles and the process equipment directed to repair and in places of their time storage;

P. Strand et al. (eds.), Radiation and Environmental Safety in North-West Russia, 251–258.

- technological processes on CTB renovation, preservation and liquidation as a result of which in working rooms and objects of an environment intensively can act radio nuclides;
- the radioactive waste products formed at rehabilitation of objects of the natural environment.

Hygienic basis of maintenance of radiating safety and preservation of the environment is division of rooms and territories of object on radiation-hygienic zones on a degree of radiating danger, with an establishment of the appropriate limits of radiating factors. Thus, radiation-hygienic zones are the territories distinguished on levels of radiating factors where the various organizational - technical actions limiting influence of radiating factors on the personnel of the enterprise are carried out, the population and an environment, and the radiating control will be carried out.

In territory CTB the following radiation-hygienic zones are established:

- zone of controllable access (CAZ);
- zone of a free mode (FMZ).

In CAZ rooms, buildings entirely are placed, the sites of territory intended for work with radioactive substances and other open sources of radiation, the polluted sites of territory and distribution of radioactive substances by contact or aerogenic way for limits of these rooms and sites of territory is possible. The level of an irradiation of the personnel working in CAZ, in conditions of normal operation can exceed a limit of a doze for the personnel of group. To work in CAZ the personnel of group A is supposed only.

On border CAZ it is organized a compulsory sanitary-carrying mode. Entrance and departure of motor transport in CAZ is carried out through stationary item (items) of the radiating control and deactivation of motor transport.

The entrance on the technical objects located in territory CTB in limits CAZ, is carried out through sanitary sluices of objects with clothing additional means of an individual defense (IDM).

In turn, the zone of controllable access on territories CTB depending on levels of radiating factors can be subdivided into two or more categories:

1. Rooms and sites of territory, where work of the personnel daily within a full working day is allowable (1700 hours per year), concern to CAZ-3 (rooms of constant stay of the personnel).
2. Rooms and sites of territory where work of the personnel during half of annual norm working hours (850 hours) is allowable, concern to CAZ-2 (rooms of time stay of the personnel, periodically served rooms).
3. Rooms and sites of territory where work of the personnel during half of annual norm working hours can result to it inadmissible irradiation, i.e. working hours should be even more reduced, concern to CAZ-1.

All works in CAZ-1 concern to radiation-dangerous and should be made under the special plan under the control of service of radiating safety and with use of additional measures of protection.

Territory CTB where in normal conditions of operation the limit of a doze for the population cannot be exceeded, concerns to a zone of easy approach (FMZ). In FMZ industrial buildings and objects where works from scientific research institutes are not conducted, administrative, sanitary - household and auxiliary buildings and constructions are placed, and also items of a feed and health services can be placed.

The levels of radiating factors determining reference of a workplace to this or that zone (category) are given in tab. 1.

Before export spent nuclear fuel (SNF) and radioactive waste (RW) BTB concern to radiating objects of a first category as at failure probably radiating influence on the population and measures on its protection can be demanded. Around of territory CTB the sanitary - protective zone and a zone of supervision are established.

Table 1. Allowable levels of radiating factors of radiation-hygienic zones system

The name of a zone (category)	The characteristic of a zone (category)	Capacity of a γ-radiation doze, mkSv/h	Allowable pollution, $Sm^{-2} \cdot min^{-1}$	
			α	β
FMZ	Workplaces of the personnel group B	≤ 2,5	2	20
CAZ-3	Constant workplaces of the personnel group A	2,5 - 12	20	2000
CAZ-2	Stay of the personnel group A during 50 % working hours	12 - 24	200	10000
CAZ-1	Allowable working hours is defined on actual capacity of a doze, but 50 % are not higher	> 24	> 200	> 10000

The note. In FMZ the maximal values of capacity of a doze g radiations, in CAZ - average are normalized.

2. The zones of territories of object in Andreeva lip

The object of SNF and RW time storage in Andreeva lip is one of most radiation-dangerous objects of Rosatom in Northwest region of Russia. High levels of radioactive pollution of ground and the radiations much exceeding normative values, create serious difficulties for work of the personnel, which is carrying out rehabilitation works.

The specified circumstance defines necessity and an urgency radiation-hygienic zoning of object territories and system engineering of measures of radiating protection at realization of rehabilitation works.

Zoning of Andreeva lip territories is executed on the basis of results of the measurements maked by NICIET experts. Object circuit is given on fig. 1. The circuit of splitting of territory on radiation-hygienic zones is submitted on fig. 2.

In the report the system of object territory zoning is offered. Development of measures of maintenance of radiating safety and preservation of the environment is a subject of the further researches.

The basic sources of radioactive pollution of object territory are: former storehouse SNF (a building 5), blocks of dry SNF storage, storehouses of firm radioactive waste products (platform SRW) and storehouse LRW. For the account not tightness of buildings and contact to an atmospheric precipitation from these constructions there is a migration of radioactive substances in an environment.

In object territory two sites located in northwest and southwest corners can be allocated, levels of radiating factors in which do not fall outside the limits, allowable for the population. These sites can be allocated in a zone of a free mode (a zone 1). A stroke - dashed line designates FMZ borders.

Three sites of object territory should be allocated in zones of controllable access with the organization in each of them sanitary-carrying mode. Recommended borders CAZ are shown on fig. 2 by a continuous line.

For simplification of the sanitary-carrying mode organization three separate CAZ are expedient for uniting in one. Measures for prevention of radioactive pollution carry on "conditionally pure" sites of territory inside CAZ in this case should be accepted.

According to offered zoning system, inside everyone CAZ zones of the second level - CAZ-1, CAZ-2 and CAZ-3 could be allocated. On fig. 2 of border CAZ-2 are designated by a dot line.

On the sites of territory referred to CAZ-2, total working hours of the personnel working hours (850 hours) should not exceed half of annual norm.

In turn, inside CAZ-2 the sites concerning to CAZ-1 are allocated. Fig. 2 (the general circuit of object zoning) does not allow to show scale on it the sites concerning to CAZ-1, however they can be determined on levels of capacity of the doze, designated on figure by various colors.

To CAZ-1 sites in area of an arrangement of the most significant sources of radiation in territory, which are, concern:

- walls and the bottom of pools of a building 5;
- a radioactive ground in the former river area;
- containers with SRW, the storehouses established by a roof 7A in area of its east end face;
- a radioactive ground on separate sites of SRW platform;
- superficial pollution of designs of an old pier;
- the polluted ground in area of a metal farm of the illumination established near to coastal feature in area of a pier.

On the sites of territory referred to CAZ-1, allowable working hours of the personnel is defined on actual capacity of a doze of radiation on a workplace, but 850 hours for one year are not higher. Works in CAZ-1 can be carried out only with use of additional measures of radiating protection (for example, a ground laying or installation of concrete blocks), thus the personnel should be provided with programmed operational dosimeters.

3. Conclusion

The offered radiation-hygienic zoning system of Andreeva lip territories can be put in a basis of development of measures of radiating protection, instructions on radiating safety at various kinds of works and the project of rehabilitation of object territory as a whole. In view of the stated zoning system the Research institute of industrial and marine medicine prepares the Manual «Radiation-hygienic requirements for work on rehabilitation of territories of coastal technical bases of the Navies transferred to Rosatom of Russia»

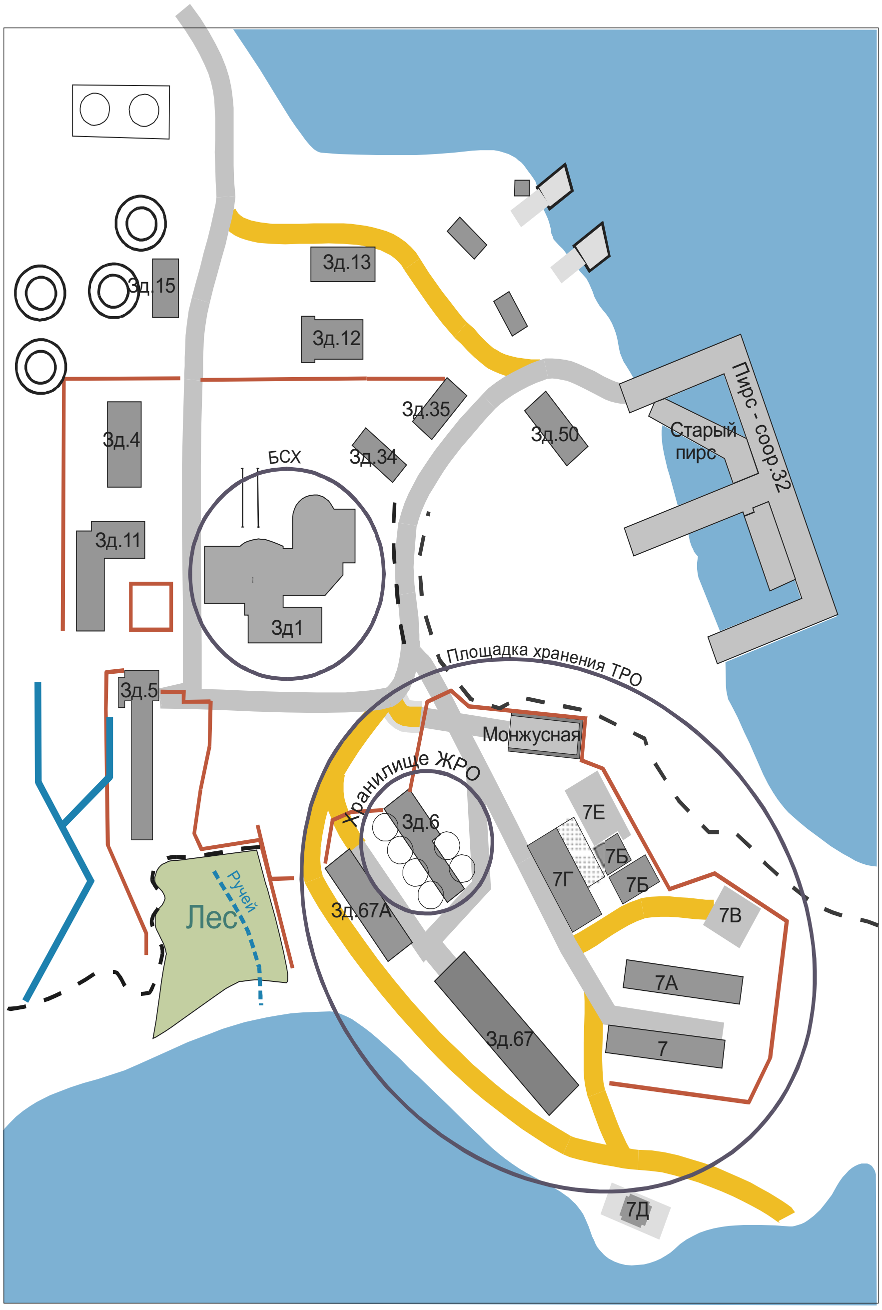

Fig. 1. Schematic plan CTB in Andreeva lip

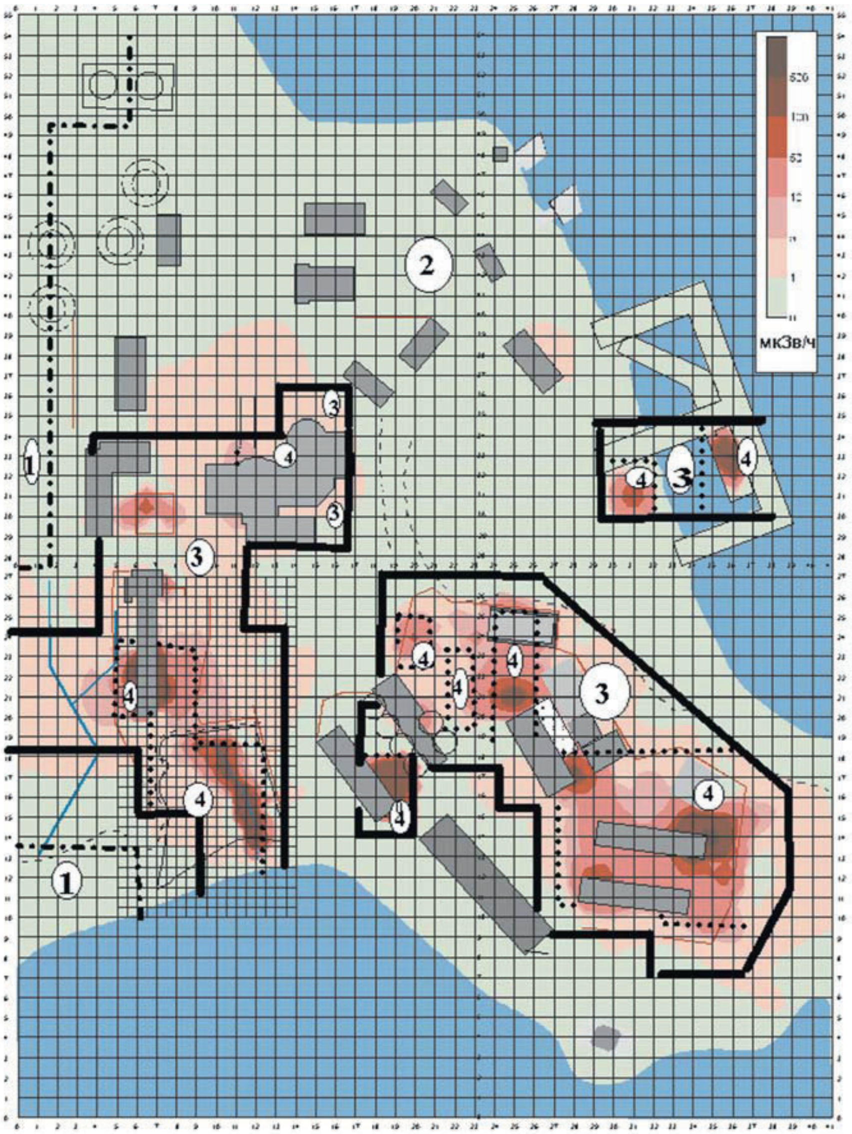

Fig. 2. The circuit of zones of Andreeva lip territories

Continuous line – CAZ border

Dot line - border of a zone of time stay of the personnel

Stroke-dotted - FMZ border

ASSESSMENT OF RADIATION IMPACT ON MAN DUE TO MARINE ENVIRONMENT CONTAMINATION

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1. Assessment of radiation impact on man due to marine environment contamination

In planning and realization of various nuclear projects it is often necessary to make an evaluation of radiation impact levels and assess the values of the associated risks due to possible radiation contamination of the marine environment.

The radiation impact on man from the technogenic radionuclides entered the sea water can occur in different ways as a result of re-distribution of contamination among marine environment objects.

Exposure pathways for personnel and public in the open sea, at the sea coast and from consumption of sea food products have been reviewed in detail by the IAEA [1] experts and working groups.

For comparing the individual radiation burdens from the radiation impact coming by various pathways as a result of radionuclides contained in sea water, a comparison of the exposure pathways was made, including the following:

- peroral intake of radionuclides with various marine fishing products (fish, mollusks, crustaceans, food algae, zooplankton);
- consumption of food salt produced from sea water;
- consumption of desalinated water;

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- inhalation of sea water vapours and aerosols;
- external exposure above the water surface and during sea-bathing.

The first of the above listed exposure pathways is related, mainly, to radioactive contamination of marine fishing areas, while the other ones - to the contamination of coastal waters

In making the above comparative analysis, the data on quantitative characteristics of various exposure pathways provided in the paper [1], were used. The comparison was made for all the basic radionuclides showing practically complete picture of the technogenic radioactive contamination of the sea. The results of comparison expressed in the form of annual effective dose for the volume activity of each radionuclide in sea water, equal to 1 Bq/m^3, are given in Table 1.

From the data above it follows that the maximal exposure dose is caused by the peroral intake of radionucludes, which creates a serious motive for monitoring of principal fishing areas. For operative assessment of the results of radionuclides' detection in sea water we need a working criterion - a reference concentration of radionuclides in sea water - a volume activity adopted as a permissible value by its effect to man's health [2]. The radiation-hygienic value of the reference radionuclide concentration corresponds to the concentration value limit for the given radionuclide, with which the annual effective dose for an individual of a critical group from consumption of the sea food products containing only the one specified radionuclide shall correspond to the allocated quota of annual maximum permissible dose for the public [3].

Below are some calculations of reference concentrations of radionuclides in sea water carried out by the research staff of TSNII Krylov on the basis of the latest achievements of marine radio-ecology and the up-to-date normative base in the sphere of radiation safety. As an upper quota limit, the value suggested in the paper [4] and equal to 10% of the annual dose limit corresponding to the dose limit of 0.1 mSv /per year, was used.

The hydrobionts' capability for accumulating waterborne chemical elements, and accumulation of the above elements in food salt during its extraction from sea water, as well as their concentration in marine aerosols and dust particles is characterized with the coefficient of accumulation (Cac). In calculation of reference concentrations the accumulation coefficients developed by IAEA expert group [5], were used, and in doing so, the recommended average values were applied.

Table 1. Annual effective exposure dose (μSv) from various pathways of impact, with the volume activity of each radionuclide contained in sea water as 1 Bq/m^3.

Radionuclide	Ways of exposure									
	Internal intake								External exposure	
	Fish	Mollusks	Crustaceans	Algae	Plankton	Sea water salt	Desalinated water	Marine aerosols	Above the sea surface	During sea-bathing
Mn-54	0.063	0.13	0.013	0.16	$7.8 \cdot 10^{-4}$	$2.4 \cdot 10^{-5}$	$5.2 \cdot 10^{-7}$	$2.0 \cdot 10^{-6}$	$6.0 \cdot 10^{-4}$	$9.0 \cdot 10^{-5}$
Fe-55	0.22	0.37	0.061	0.37	$3.7 \cdot 10^{-3}$	$1.1 \cdot 10^{-5}$	$2.4 \cdot 10^{-7}$	$3.7 \cdot 10^{-7}$	$3.6 \cdot 10^{-5}$	$6.0 \cdot 10^{-6}$
Co-60	0.77	0.63	0.63	1.3	$7.6 \cdot 10^{-3}$	$1.1 \cdot 10^{-4}$	$2.5 \cdot 10^{-6}$	$3.8 \cdot 10^{-5}$	$1.8 \cdot 10^{-3}$	$2.7 \cdot 10^{-4}$
Ni-63	0.095	0.032	0.016	0.031	$4.8 \cdot 10^{-4}$	$1.4 \cdot 10^{-5}$	$3.2 \cdot 10^{-7}$	$4.9 \cdot 10^{-7}$	–	$9.2 \cdot 10^{-9}$
Sr-90	0.012	0.001	0.002	0.005	$3.0 \cdot 10^{-5}$	$9.1 \cdot 10^{-4}$	$2.0 \cdot 10^{-5}$	$2.2 \cdot 10^{-5}$	–	$1.4 \cdot 10^{-8}$
Y-90	0.012	0.099	0.099	0.099	$3.0 \cdot 10^{-3}$	$8.9 \cdot 10^{-5}$	$2.0 \cdot 10^{-6}$	$1.4 \cdot 10^{-6}$	$1.7 \cdot 10^{-9}$	$1.9 \cdot 10^{-6}$
Tc-	$4.1 \cdot 1$	0.023	0.02	0.02	$6.9 \cdot 10^{-5}$	$2.1 \cdot 10^{-5}$	$4.6 \cdot 10^{-7}$	$3.5 \cdot 10^{-}$	–	$3.0 \cdot 10^{-8}$

99	0^{-3}		3	3				6		
I-129	0.071	0.04	0.04	0.4	0.36	$3.6 \cdot 10^{-3}$	$3.2 \cdot 10^{-4}$	$3.3 \cdot 10^{-5}$	$3.4 \cdot 10^{-5}$	$5.0 \cdot 10^{-6}$
Cs-134	0.41	0.021	0.021	0.034	$6.2 \cdot 10^{-4}$	$6.2 \cdot 10^{-4}$	$1.4 \cdot 10^{-5}$	$6.1 \cdot 10^{-6}$	$1.1 \cdot 10^{-3}$	$1.6 \cdot 10^{-4}$
Cs-137	0.28	0.014	0.014	0.024	$4.3 \cdot 10^{-4}$	$4.3 \cdot 10^{-4}$	$9.5 \cdot 10^{-6}$	$4.3 \cdot 10^{-6}$	$4.2 \cdot 10^{-4}$	$6.2 \cdot 10^{-5}$
Po-210	528	435	2,220	44	39.6	0.04	$3.5 \cdot 10^{-3}$	0.129	$7.2 \cdot 10^{-9}$	$1.1 \cdot 10^{-9}$
Th-232	30.6	8.5	8.3	1.7	2.5	$7.6 \cdot 10^{-3}$	$1.7 \cdot 10^{-4}$	0.117	$1.3 \cdot 10^{-7}$	$1.9 \cdot 10^{-8}$
U-235	0.81	0.41	0.14	1.4	0.002	0.012	$2.7 \cdot 10^{-4}$	$6.9 \cdot 10^{-3}$	$1.5 \cdot 10^{-4}$	$2.2 \cdot 10^{-5}$
Pu-238	2.0	25.5	2.5	17	0.25	$7.6 \cdot 10^{-3}$	$1.7 \cdot 10^{-4}$	$1.7 \cdot 10^{-2}$	$4.0 \cdot 10^{-8}$	$6.1 \cdot 10^{-9}$
Pu-239	2.2	27.4	2.7	18.3	0.27	$8.2 \cdot 10^{-3}$	$1.8 \cdot 10^{-4}$	$1.7 \cdot 10^{-2}$	$7.9 \cdot 10^{-8}$	$1.2 \cdot 10^{-8}$
Pu-240	2.2	27.4	2.7	18.3	0.27	$8.2 \cdot 10^{-3}$	$1.8 \cdot 10^{-4}$	$1.7 \cdot 10^{-2}$	$4.6 \cdot 10^{-8}$	$6.9 \cdot 10^{-9}$
Am-241	2.2	146	3.7	58.4	0.44	$6.6 \cdot 10^{-3}$	$1.5 \cdot 10^{-4}$	0.199	$3.1 \cdot 10^{-5}$	$4.6 \cdot 10^{-6}$

With the above initial data available, we can determine the reference concentration, as follows: reference concentration of the radionuclide in sea water is equal to the relation of permissible annual radionuclide intake to the coefficient of its accumulation in the particular object of sea fishery multiplied by annual consumption of the given hydrobiont (see Eg.1.1e.i. 1.2.).

$$\text{КК}_{ij} = \frac{\varepsilon \cdot \text{ПГПнас}_i}{\text{Кн}_{ij} \cdot G_j} \tag{1.1}$$

$$\text{RC}_{ij} = \frac{\varepsilon \cdot \text{AILpub}_i}{\text{Cac}_{ij} \cdot G_j}, \tag{1.2}$$

where RC_{ij} – is reference concentration of the *i*-th radionuclide for the *j*-th type of sea fishery practice, Bq/m^3; ε – quota for radionuclides' intake with marine hydrobionts (0.1); AILpub$_i$ –annual intakelimit of the *i*-th radionuclide for public, Bq/year; Cac$_{ij}$ – coefficient of accumulation of the *i*-th radionuclide in the *j*-th hydrobiont, m^3/kg; G_j – annual consumption of the *j*-th hydrobiont for the critical group of public, kg/year.

The results of reference concentrations' calculations for the areas with different scope of fishery practices (with reference to the initial data) are given in Table 2.

For the areas of mixed fishery practices, it is recommended to accept the lowest of the reference concentrations established for each object of fishery trade.

The obtained reference concentrations allowed to set the limits in determination of the zones of contamination emerging from different ways of discharge of radioactive substances into water basin. The application of the above approach in preparing the mathematic evaluation of radiation aftereffects as a result of the emergency sinking of atomic ship in the open sea with application of the model for formation of post-accident contamination of the marine environment, developed at TSNII Krylov, allowed to make a conclusion about the local character of the contaminated zone at any state of radiation-hazardous systems of sunk facility.

Table 2. Reference concentrations of radionuclides in sea water (Bq/m^3) during long-term contamination of the areas of different fishery practices.

Radionuclide	Areas of fishery			
	Fish	Mollusks	Crustaceans	Food algae
^{54}Mn	$1.6 \cdot 10^3$	770	$7.7 \cdot 10^3$	640
^{55}Fe	460	270	$1.6 \cdot 10^3$	270
^{60}Co	130	160	160	79
^{63}Ni	$1 \cdot 10^3$	$3.2 \cdot 10^3$	$6.3 \cdot 10^3$	$3.2 \cdot 10^3$
^{90}Sr	$8.2 \cdot 10^3$	$9.86 \cdot 10^4$	$4.93 \cdot 10^4$	$1.97 \cdot 10^4$
^{90}Y	$8.4 \cdot 10^3$	$1 \cdot 10^3$	$1 \cdot 10^3$	$1 \cdot 10^3$
^{99}Tc	$2.43 \cdot 10^4$	$4.4 \cdot 10^3$	$4.4 \cdot 10^3$	$4.4 \cdot 10^3$
^{129}I	$1.4 \cdot 10^3$	$2.5 \cdot 10^3$	$2.5 \cdot 10^3$	250
^{134}Cs	240	$4.8 \cdot 10^3$	$4.8 \cdot 10^3$	$2.9 \cdot 10^3$
^{137}Cs	350	$7 \cdot 10^3$	$7 \cdot 10^3$	$4.2 \cdot 10^3$
^{210}Po	0.19	0,23	$4.5 \cdot 10^{-2}$	2.3
^{232}Th	3.3	12	12	59
^{235}U	120	250	740	74
^{238}Pu	49	3.9	39	5.9
^{239}Pu	46	3.7	37	5.5
^{240}Pu	46	3.7	37	5.5
^{241}Am	46	0.68	27	1.7

Same as contamination of the open sea areas, the issue of great importance for Russia at present, is the problem of radioactive contamination of the bays and estuaries used as basing and repair sites for floating atomic power units, for the ships and vessels equipped with nuclear-powered plants (NPP), as well as for storage of the fragments of dismantled nuclear-powered submarines (NS) and laid-up of decommissioned submarines. The radiation-hygienic aspect of the above problem is related to constant presence of considerable amount of people, both in the water areas and in the near-shore zones, including ship and vessel crews, the personnel working at base sites and ship-repairing facilities, and the population living in the adjacent towns and settlements.

In contrast to the above discussed fishing areas, where the activity introduced into sea water impacts people through sea food products, the radioactive contamination of the water areas of the enterprise has more direct impact on people, even on those who find themselves at a significant distance from the mentioned water area. It is anticipated, therefore, that regular monitoring of water contamination in the water area should be carried out, as well as observations of meteorological and hydrological conditions in the water basin of the enterprise and adjacent territory.

As a working criterion of radionuclides' concentration in bay water we can use the reference concentration of radionuclides; however, the ways of determination of concentration in the water basin of the enterprise considerably differ from the methods applied in the area of fishery.

The principal exposure pathways with corresponding quantitative characteristics in the water basins and the adjacent territories pertaining to the enterprises, are the following:

1. The principal exposure pathway for the people being at the open platforms near the water surface – is from inhalation of radionuclides.
2. Radiation impact on people working at piers, floating facilities and other similar objects is characterized by combination of the two pathways: inhalation of radionuclides and external exposure from the water surface.
3. The people engaged in underwater operations are impacted in addition to the above two sources of radiation impact by the way of external exposure from the water and sea-floor.

For the purpose of quantitative contribution a mathematical modeling for each of the above discussed pathways of radiation impact, was carried out.

Table 3. The rate of effective exposure dose (Sv/sec) from various impact pathways, with the volume activity of each radionuclide contained in sea water, as 1 Bq/m^3.

Radionuclide	Inhalation together with marine aerosols	External exposure			
		During work at piers, ships, etc.	During underwater operations		
			From the water	From the sea-floor (in 1 m)	From suspension (1 mg/l)
^{54}Mn	$5.75 \cdot 10^{-20}$	$1.68 \cdot 10^{-17}$	$1.68 \cdot 10^{-16}$	$7.57 \cdot 10^{-15}$	$3.36 \cdot 10^{-17}$
^{59}Fe	$1.01 \cdot 10^{-19}$	$2.53 \cdot 10^{-17}$	$2.53 \cdot 10^{-16}$	$2.53 \cdot 10^{-15}$	$1.26 \cdot 10^{-17}$
^{60}Co	$1.11 \cdot 10^{-18}$	$5.03 \cdot 10^{-17}$	$5.03 \cdot 10^{-16}$	$2.03 \cdot 10^{-14}$	$1.01 \cdot 10^{-16}$
Zn-65	$7.79 \cdot 10^{-20}$	$1.32 \cdot 10^{-17}$	$1.32 \cdot 10^{-16}$	$5.17 \cdot 10^{-16}$	$2.64 \cdot 10^{-18}$
Sr-90	$6.16 \cdot 10^{-19}$	–	–	–	–
Y-91	$5.58 \cdot 10^{-18}$	$1.18 \cdot 10^{-19}$	$1.18 \cdot 10^{-18}$	$2.38 \cdot 10^{-15}$	$1.18 \cdot 10^{-17}$
Zr-95	$4.03 \cdot 10^{-19}$	$1.33 \cdot 10^{-17}$	$1.33 \cdot 10^{-16}$	$1.3 \cdot 10^{-14}$	$1.33 \cdot 10^{-16}$
Nb-95	$9.2 \cdot 10^{-20}$	$1.34 \cdot 10^{-17}$	$1.34 \cdot 10^{-16}$	$6.52 \cdot 10^{-15}$	$6.71 \cdot 10^{-17}$
Cs-134	$1.75 \cdot 10^{-19}$	$3.04 \cdot 10^{-17}$	$3.04 \cdot 10^{-16}$	$9.54 \cdot 10^{-17}$	$9.12 \cdot 10^{-19}$

Cs-137	$1.24\cdot10^{-19}$	$1.15\cdot10^{-17}$	$1.15\cdot10^{-16}$	$3.34\cdot10^{-17}$	$3.44\cdot10^{-19}$
Ba-140	$2.59\cdot10^{-20}$	$4.10\cdot10^{-18}$	$4.10\cdot10^{-17}$	$8.66\cdot10^{-18}$	$2.05\cdot10^{-19}$
Po-210	$3.91\cdot10^{-15}$	$2.01\cdot10^{-22}$	$2.01\cdot10^{-21}$	$9.08\cdot10^{-18}$	$4.02\cdot10^{-20}$
Th-232	$3.53\cdot10^{-16}$	$3.61\cdot10^{-21}$	$3.61\cdot10^{-20}$	$9.66\cdot10^{-22}$	$7.22\cdot10^{-20}$
U-235	$1.98\cdot10^{-16}$	$4.08\cdot10^{-18}$	$4.08\cdot10^{-17}$	$1.48\cdot10^{-19}$	$4.08\cdot10^{-20}$
U-238	$1.87\cdot10^{-16}$	–	–	–	–
Pu-239	$4.79\cdot10^{-16}$	$2.19\cdot10^{-22}$	$2.19\cdot10^{-20}$	$1.72\cdot10^{-20}$	$2.19\cdot10^{-21}$
Am-241	$5.98\cdot10^{-16}$	$8.55\cdot10^{-20}$	$8.55\cdot10^{-18}$	$9.81\cdot10^{-19}$	$1.71\cdot10^{-17}$

In calculation of the intake by inhalation the values of dose coefficients and intensity of breathing for the grown-up public specified in the Radiation Safety Norms (NRB-99) [6], were used. For determination of relative percentage of the components in the inhaled air the relevant recommendations of IAEA [1], were applied.

The calculation of external exposure during the work at piers, ships, platforms, etc., was made with due account for natural shielding against irradiation.

The comparative analysis of different exposure pathways is given in Table 3.

Using the values presented in Table 3, we can, basing on the magnitude of the volume activity of the i-th radionuclide in the water a_i and the period of radiation by the j-th way t_j determine the radiation impact dose D_{ij}, caused by water contamination with the indicated redionuclide

$$D_{ij} = a_i p_{ij} t_j \tag{1.3}$$

where p_{ij} – the dose coefficient for the i-th radionuclide during exposure by the j-th way from Table 3.

The substitution in formulation (1) of actual time of radiation t_j for the planned time over a year period T_j gives the expression for determination of the RC of i-th radionuclide in the water for the j-th pathway of impact

$$\text{ÊÊ}_{ij} = \frac{\varepsilon \cdot \text{ÏÄ}}{p_{ij} T_j} \tag{1.4}$$

$$\text{RC} = \varepsilon \cdot \text{DL} \ / p_{ij} T_j \tag{1.5}$$

where DL – is the annual dose limit (m/Sv), and ε – is the quota from the annual dose limit.

The total radiation dose D_i in exposure by several pathways is defined by the following expression

$$D_i = a_i \sum_j p_{ij} t_j \tag{1.6}$$

The substitution of actual time of exposure for the planned time over a year period gives the expression for determination of the RC of the *i*-th radionuclide in the bay water for combination of several ways:

$$D_i = a_i \sum_j p_{ij} t_j \qquad (1.7)$$

$$\mathrm{RC}_i \;=\; \varepsilon \cdot \mathrm{DL} \;/ \textstyle\sum_i p_{ij} T_j \qquad (1.8)$$

or, inserting the formulation (1.4),

$$\text{КК}_i^{-1} = \sum_j \text{КК}_{ij}^{-1} \qquad (1.4a)$$

$$\mathrm{RC}_i^{-1} \;=\; \textstyle\sum_i \mathrm{RC}^{-1}{}_{ij}. \qquad (1.9)$$

As seen from the expressions (2) and (3), the magnitude of reference concentration of a radionuclide in bay water essentially depends on the contents and regulations of the work performance at a particular enterprise, and therefore, in contrast to the areas of fishery practice, it is hardly possible to develop a unification of reference concentrations for different enterprises.

2. Radiation aftereffects of atomic ship sinking

The maximal square area of the contaminated zone with the level exceeding RC of nuclides, with the activity release from the reactor compartment through a hole of 10 m^2 section, and NPP primary circuit seal failure/ leaking/ with gross section f at different speeds of current U.

The maximal square area of the contaminated zone with the level exceeding RC of nuclides, with the activity release through the holes of different sections S and NPP primary circuit seal failure /leaking/ with gross section 10^{-4} m^2 at different speeds of current U.

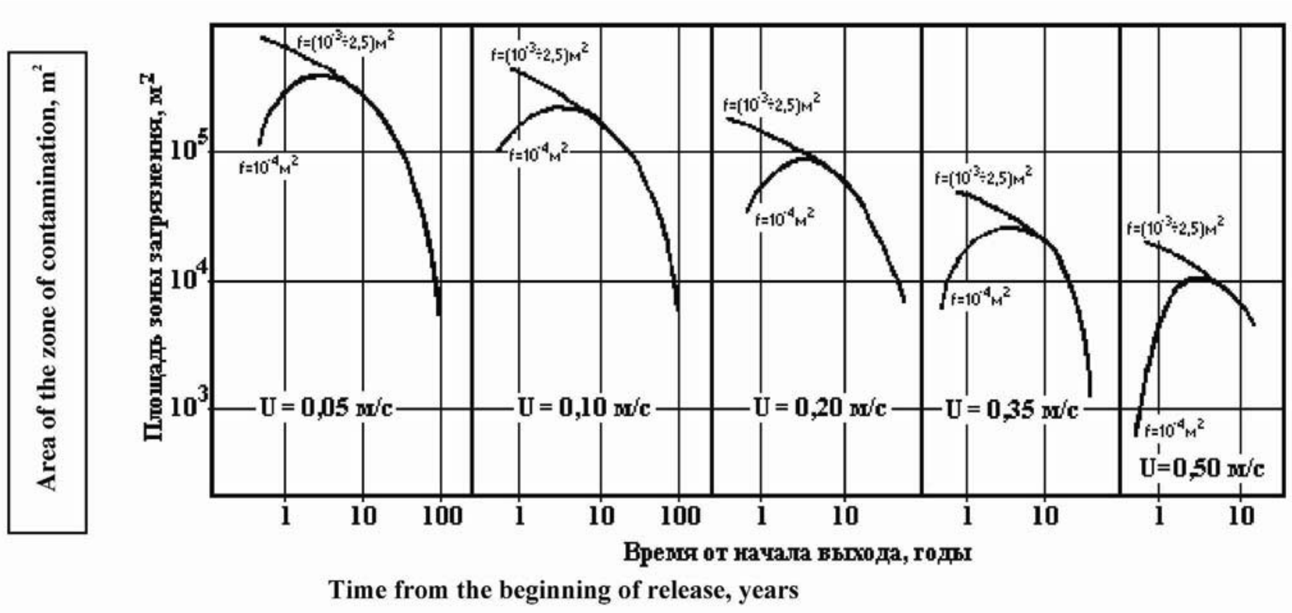

Fig. 1. The results of calculation of the areas of contaminated zone for various options of ship sinking, are given in the Figures below.

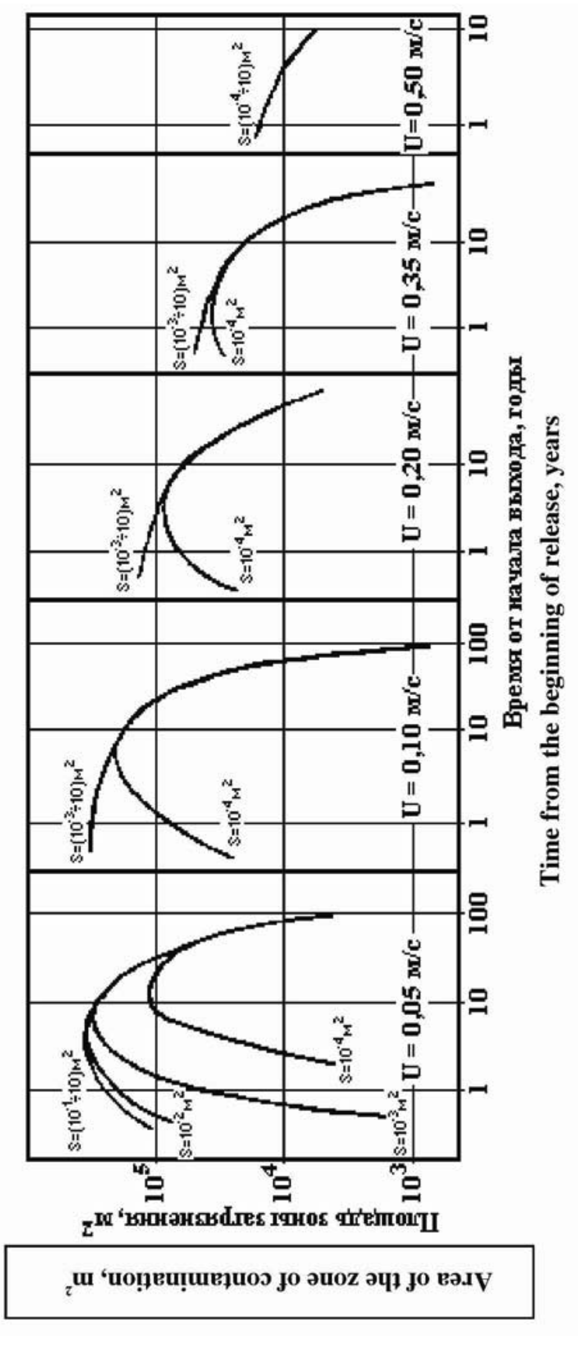
Area of the zone of contamination, m²
Площадь зоны загрязнения, м²
10^5
10^4
10^3
S=(10^-1÷10)м^2
S=10^-2 м^2
S=10^-3 м^2
S=10^-4 м^2
S=(10^-3÷10)м^2
S=(10^-4÷10)м^2
U = 0,05 м/с
U = 0,10 м/с
U = 0,20 м/с
U = 0,35 м/с
U=0,50 м/с
1
10
100
Время от начала выхода, годы
Time from the beginning of release, years

Fig. 2.

3. References

1. IAEA, The Oceanographic and Radiological Basis for the Definition of High-Level Wastes Unsuitable for Dumping at Sea, Safety Series No 66, IAEA, Vienna 1984.
2. Катков А.Е. Введение в региональную радиоэкологию моря. М., Энергоатомиздат, 1985. - A.E.Katkov. Introduction to Regional Radio-ecology of the Sea. M., Energoatomizdat, 1985.
3. IAEA, International Basic Safety Standards for Protection against Ionizing Radiation and for the Safety of Radiation Sources. Interim Edition, Safety Series № 115-1, IAEA, Vienna, 1994.
4. D.I.Gusev. Гигиенические критерии к оценке загрязнения радионуклидами прибрежных морских вод. - Impacts of radionuclide releases into aquatic environment. Proc. Symp. Otaniemi, 1975, Vienna, p. 363.
5. IAEA, Sediment K_d and Concentration Factors for Radionuclides in the Marine Environment, Technical Reports Series No.247. IAEA, Vienna, 1985.
6. Нормы радиационной безопасности (НРБ-99) СП 2.6.1.758-99. Минздрав России, М., 1999. - Radiation Safety Norms (NRB-99) SP 2.6.1.758-99. Minzdrav of Russia, M., 1999.

UNCERTAINTIES IN ENVIRONMENTAL IMPACT AND RISK ASSESSMENT FROM RADIONUCLIDES RELEASED FROM DIFFERENT NUCLEAR SOURCES INFLUENCING THE ARCTIC

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1. Abstract

There is a significant number of past, present or potential nuclear sources, which have contributed, are still contributing, or have the potential to contribute to radioactive contamination of the environment. To protect the environment from past, present and future contamination, impact and risk assessments should be performed in contaminated areas, prior to and after the implementation of any countermeasure. The ecological risk characterisation represents the integration of hazard identification, dose-response assessment and exposure assessment. Hazard identification can be described as a qualitative description of radionuclides having potential negative effects on biota; and raise questions as which nuclides are present and which are the negative effects that these agents can cause.

The present paper will focus on key factors and processes contributing to large uncertainties in environmental impact and risk assessments for contaminants released to vulnerable ecosystems scientific, in particular:

- Sources and source terms, including the activity concentrations and the speciation of radionuclides released and deposited in ecosystem compartments,

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- Time-dependent interactions influencing mobility, bioavailability and ecosystem transfer under relevant conditions (process dynamics, uptake mechanisms, biomarkers, food-chain effects)
- Bioaccumulation, dose – effects relationship (sublethal, different biological endpoints), associated with the environment including man.

Thus, a major scientific challenge is to reduce the overall uncertainties in impact and risk assessments of vulnerable ecosystems such as the arctic region by implementing basic radioecology and new advanced analytical tool.

2. Introduction

To reduce the overall uncertainties in impact and risk assessments of contaminated ecosystems site-specific information is needed; such as sources and source terms, including the activity concentrations, isotopic ratios and the speciation of radionuclides released and deposited in ecosystem compartments. Usually source term characteristics are restricted to inventory estimates, estimated released fractions and activity concentrations of released or deposited radionuclides. However, information on radionuclide speciation, in particular radioactive particles, is essential for assessing the mobility, bioavailability, biological uptake, accumulation, doses and effects of radionuclides in various ecosystems (Salbu, 2000).

Furthermore, information on time-dependent interactions influencing mobility (time dependent distribution coefficients, Kd f(t)), bioavailability, accumulation (time dependent concentration factors, CF f(t)) and ecosystem transfer under relevant conditions is essential. The behaviour of radionuclides in different ecosystem is also strongly dependent on the speciation of deposited radionuclides and transformation processes occurring after the deposition. Finally, dose – effect relationships for fauna and flora in various ecosystems need to be established for specific biological endpoints. Thus, the amount of the input data needed to perform a proper environmental impact and risk assessment is large (Fig. 1).

Table 1. Input data needed to model environmental impact and risks

Environmental impact and risk	Risk factors Dose conversion factors
Biological effect	Biological endpoints Critical organs Critical load
Bioaccumulation Biological uptake	Uptake/depuration Bioavailability
Mobility	Interactions f(t) Transformationf(t) Weathering f(t)
Source term	Speciation Isotopes, activity ratios, activity concentrations
Model compartment	Information needed

3. Sources

There is a significant number of past, present or potential nuclear sources, which have contributed, are still contributing, or have the potential to contribute to radioactive contamination of the environment. The major sources contributing to past and present radioactive contamination of long-lived radionuclides in different ecosystems include:

- More than 2000 nuclear weapon tests, in particularly atmospheric tests resulting in global fallout and underground and underwater tests resulting in local contamination.

- Nuclear accidents such as the Chernobyl explosion in 1986 and the fire in the Windscale pile in 1957.
- Marine transport of radionuclides in effluents from European reprocessing plants, in particular from Sellafield, UK, Dounreay, UK and La Hague, France, since 1950s and 1960s. Due to remobilisation, previously contaminated sediments represents a diffuse source of radionuclides, which is the case for plutonium being remobilised from Irish Sea sediments and is now being transported into the North Sea. Transport of Chernobyl fallout from the Baltic Sea to the North Sea is ongoing.
- Transport from rivers such as Ob and Yenisey, having large drainage areas affected by global fallout and where several nuclear installations (Mayak PA, Tomsk-7, Krashnoyarsk-26) are situated.
- Dumping of radioactive waste in the Barents and Kara Sea.
- Aircraft accident at Thule, Greenland and Kosmos satellite accident in Canada

For most of these historical sources, site-specific information is available. Thus, environmental impact and risk assessment should be performed, although the assessments will suffer from rather high uncertainties due to lack in dose-biological endpoint response data.

According to IAEA, there is a huge number of sources with release potentials for radionuclides, e.g., 438 reactors are in operations and 31 are under construction in year 2000, and more than 1000 tonnes of Pu from power reactors, 100 tonnes of Pu from civil reprocessing and 100 tonnes of Pu from dismantling warheads were to be stored world-wide in 1998 (Oi, 1998). Potential nuclear sources of particular concern for arctic vulnerable areas include

- Potential accidents associated with nuclear accidents in particular in the Kola NPP nuclear reactors (i.e. two VVER-440/230, built 1973/4 and two VVER-440/213, built 1981,1984),
- Potential accidents with reactor driven ships such as nuclear submarines in operation or out of duty,
- Potential accidents associated with unsafe waste storage. Large amount of waste including more than 20 000 fuel rods are stored under non-satisfactory conditions in the Andreeva Bay and Litza fjord, and additional spent fuel is stored onboard ships (Lepse, Murmansk) or on shore (Gremikha) on the Kola peninsula.

- Potential accidents associated with storage, transport and handling of nuclear weapons.
- Leakage from contaminated nuclear Test sites at Novaya Zemlya.
- Continued marine transport of radionuclides in effluents from European reprocessing plants, in particular from Sellafield, UK and La Hague, France and continued transport of Chernobyl fall-out from the Baltic Sea to the North Sea.
- Continued transport from rivers such as Ob and Yenisey, which may increase if accidents occur at the nuclear installations situated in the drainage areas (Mayak PA, Tomsk-7, Krasnoyarsk-26) are situated.
- Continued leakage from dumped radioactive waste in the Kara Sea.Potential accidents with ships carrying spent fuel.For most of these potential sources, site- should be performed, although the assessments specific information is usually not available. Thus, any environmental impact and risk assessment will suffer from very high uncertainties.

4. Speciation of radionuclides

To characterise the source term information on radionuclide activity concentrations, and radionuclide speciation is essential. Radionuclides released from a source can be present in different physico-chemical forms (speciation) varying in size (nominal molecular mass), structure, morphology, density, valence, and charge properties. Low molecular mass (LMM) species are believed to be mobile and potentially bioavailable, while high molecular mass (HMM) species such as colloids, pseudocolloids and particles are inert, although HMM species are retained in filter-feeders or ingested by aquatic organisms (Salbu et al., 2000).
Speciation depends on the sources and release scenarios, distance from the source, dispersion and deposition conditions. A significant fraction of radionuclides released by high temperature nuclear events, such as nuclear weapons tests or peaceful nuclear explosions (PUNES), explosions or fires in the nuclear installations is associated with fuel particles. U-particles have also been released under low temperature conditions such as atmospheric emission from the Windscale reactor during normal operations in the early 1950s (Jakeman, 1986; Salbu et al, 1994) and

during the Windscale fire (Chamberlain, 1987). Thus, man-made U particles have been released from nuclear sources more frequently than usually anticipated. Radioactive particles are formed due to critical or subcritical destruction of fuel matrices (e.g., explosions, fires, corrosion processes). Following high temperature accidental scenarios associated with nuclear installations (i. e. Chernobyl accident) a range of different uranium fuel particles has been observed, varying in composition, crystallographic structures (Kasparov et al, 1999; Salbu et al., 1998). Furthermore, the oxidation state of U in fuel particles depended on the release scenario; apparently reduced U were released during the explosions, while oxidised U from were released during the subsequent reactor fire (Salbu et al., 2001). Following low temperature releases (i. e. pre-fire Windscale releases), however, flake-like uranium fuel particles significantly different from those collected at Chernobyl have been identified.. Therefore, the activity concentration and activity or isotopic ratios of matrix elements and refractory elements reflecting burn-up (e.g. lanthanides, actinides) are source-specific, while particle characteristics like crystallographic structures and oxidation states of matrix elements also depends on specific release conditions. The activity concentrations and isotopic ratios of released radionuclides are source dependent, while the speciation of radionuclides is also release scenario related. The matrix, the refractory radionuclide composition and isotopic ratios will reflect the specific source (e.g, burn-up), while the release scenarios e.g., temperature, pressures, redox conditions, will influence particle characteristics of biological significance. Composition, particle size distribution and specific activity are essential for acute respiration and skin dose, while factors influencing weathering rates like particle size distribution, crystallographic structures, porosity, and oxidation states are essential for long term ecosystem transfer. Furthermore, localised heterogeneities (particles) represent an analytical challenge; representative sampling may be questionable and dissolution of radionuclides from particles prior to measurements may be partial (IAEA, 2000). For areas affected by particle contamination, impact assessment will suffer from large uncertainties unless the impact of particles are included. Therefore, advanced speciation techniques, as well as process-oriented information influencing speciation, is essential to improve the prediction power of assessment models.

5. Mobility and interactions in soil-water, sediment-water systems

Ecosystem transport depends on source term characteristics and ecosystem properties. Radioactive particles released from a source and deposited in the environment represent point sources of short- and long-term radioecological significance. Direct effects relate to internal doses following inhalation of respiratory particles, as well as skin doses received from surface contamination. Long-term effects relate to ecosystem transfer of radionuclides remobilized from radioactive particles over time, due to weathering. Thus, information on particle characteristics influencing weathering rates (e.g., size, structure, oxidation states) and subsequent radionuclide remobilization is essential for long-term environmental impact and risk assessments, but is usually ignored within most monitoring and assessment programmes.

If mobile species are present, ecosystem transfer is relatively fast, whereas the ecosystem transfer is delayed if particles are present. The speciation of radionuclides deposited in the environment will change with time due to interactions with components in soils or sediments. By interaction with clays or humic substances the mobility may decrease. Under cold climate conditions processes such as particle weathering, diffusion into soil solid phases and microbial degradation are slow and ecological half-lives of radionuclides are long. Thus, arctic and alpine ecosystems are particularly vulnerable to contamination.

Soil-water or sediment-water interactions are usually described by distribution coefficients, Kd, assumed to be constants at equilibrium. However, the distribution of radionuclides between solid and solution is a time depended process and the thermodynamic constant should be replaced by a time-function obtained for instance from kinetic tracer experiments. Information on binding mechanisms in soils and sediments is essential for estimating potential remobilisation, which can be obtained from sequential leaching experiments. During precipitation runoff will transport radionuclides as ions or associated to soil particles to rivers and river runoff increases radionuclide burden in estuaries, especially during flooding.

6. Biological uptake and effects

LMM radionuclide species can cross biological membranes, directly or indirectly after interactions with ligands or carrier molecules. LMM organic ligands such as citrate may stimulate the uptake, while HMM organics such as Prussian Blue reduce uptake and is used as countermeasure. Information on bioavailable forms is, however, still scarce. For soil-to-plant transfer, transfer coefficients, TC (m^2/kg), and for soil-plant-animal transfer, aggregated transfer coefficients, TC (m^2/kg), are utilised for modelling purpose. These are time-dependent variables and depend on several factors (speciation, soil types and microbial activities, plant species, animal species and dietary habits etc.). In semi-natural ecosystems with organic soils recycling of radionuclides increases the ecological half-lives. Uptake in fish and invertebrates depends on ionic species interacting with external organs (gills, skin) or by digestive uptake. In filtering organisms, however, particles and colloids are retained and radionuclides may accumulate due to changes in bioavailability in the gut (digestion) or through phagocytosis. Bioconcentration factors (BCF) vary according to the radionuclide speciation of the exposure and can be distinguished for different compartments within organisms. Thus, development of microdosimetry methods is needed to assess doses to biota. Relationship between accumulation, dose and effect responses i.e. key biological endpoints such as oxidative stress, mutagenesis, immune system deficiency, DNA damages, reproduction failure, morbidity, mortality on individuals are still needed to document. To extrapolate from effects on individuals to population effects or to ecological effects are very difficult to quantify, although biological responses from molecular to ecosystem level have been identified for different organisms in contaminated areas such as the East Ural Trace. When biological systems are exposed to radiation, deleterious effects are caused by the induction of free radicals; such as

- formation of reactive oxygen substances (ROS)
- oxidative stress and endocrine disruption,
- genetic effects from DNA/RNA damage, affecting key bio-molecules such as chromosomes to change or degrade;
- stimulation of DNA repair
- change intracellular communication and signalling

- effects on the immune system, altering susceptibilities for infectious diseases;
- effects on the neurological system, affecting developmental and differentiation processes, reflected in behavioural disorder.

Furthermore, fallout or releases represent usually a mixture of radionuclides. Mixtures of stressors can result in multiple types of interactions and interactions can occur with multiple target sites. Thus, synergetic and antagonistic effects may occur from a mixture of stressors. Thus, the hazard identification used in ecological risk characterisation can be underestimated in areas affected by mixtures.

7. Environmental impact and risk assessments

To assess long-term environmental impact, integrated dynamic models taking into account the source term, mobility and ecosystem transfer, biological uptake, accumulation and effects are needed. To move from impact (consequences) to risk the probability for an event must also be introduced (risk x consequence). The ecological risk characterisation integrates hazard identification, dose-response assessment and exposure assessment. Hazard identification can be described as a qualitative description of radionuclides having potential negative effects on biota; and raise questions as which nuclides are present and which are the negative effects that these radionuclides can cause. Identification of hazards is also based on source term characteristics (e.g., inventory, total activity released, activity concentrations, and radionuclide speciation such as radioactive particles) and /or spatial distributions of contaminants (e.g. activity concentrations), often derived from field measurements. To link ecosystem contamination to exposure of specified organisms communities, detailed information on routes within different ecosystem compartments on a temporal scale is needed. To link an identified, estimated or assumed defined exposure to defined effects/biological endpoints, quantitative dose-response studies, usually performed in laboratories, are utilised and extrapolated (e.g. from one organisms to another, from high to low dose if data is lacking). Thus, to quantify the risk or the probability that an adverse effect occur if individuals or populations are exposed to a specified amount of a hazard, increased emphasis has been put on developing scientifically sound benchmarks; i.e. identified thresholds such as *no observed adverse effect levels* (NOAEL) or *lowest observed adverse effect levels* (LOAEL), taking the uncertainties into account.

Such models form the basis for regulations, authorisation and clean-up strategies, and reducing the uncertainties should be highly relevant for several stakeholders. However, the links between early effects and risks are extremely complicated and existing dose conversion factors are questionable. Models also suffer from insufficient data on site-specific experimental information. Thus, significant improvement can be made by including information on speciation, time-dependent interactions (Kd), accumulation (BCF) and early effects in the assessments. Many regulations on environmental protection are fragmented: varying for different pollutants, different ecosystems and often differing for man and other organisms. A topical area is within radiation protection, which has traditionally maintained a tenet that if man is protected from ionising radiation, the environment should also be adequately protected (ICRP). The view that if man is protected the environment is protected has now been challenged to such an extent that most scientists agree that a system of protection of the environment is highly needed.

8. Uncertainties

Key factors contributing to large overall uncertainties in environmental impact assessments for radionuclides released to vulnerable ecosystems are:

- Source terms, in particular the speciation of radionuclides. Following a severe nuclear accident and release of refractory radionuclides, the particle fraction may reach 100 %. Uncertainties by not including the particle fraction may reach a factor of 10^2.
- Time-dependent interactions influencing mobility, bioavailability and ecosystem transfer under relevant conditions (process dynamics for Kd, uptake and accumulation (CF, biomarkers, food-chain effects). If mobile radionuclides are present, the apparent Kd will be low and the uptake in fish will often be high. If radioactive particles are present the apparent Kd will be very large, the uptake in fish will be low, while the retention in filtering organisms will be high. If particle weathering occurs and mobile radionuclides are released, the apparent Kd will decrease, the retention in filtering

organisms may decrease while uptake in fish may increase. Thus, the long term impact will be underestimated if speciation (particles) and transformation (weathering and mobilisation) are not taken into account. The uncertainties may reach 10^3 for Kd and 10^3 for CF.

- Bioaccumulation, dose – effects relationship (sublethal, different biological endpoints), associated with the environment including man. At present relevant dose units are not available for fauna and flora. We have not identified relevant biological endpoints and we have no information on low dose-effect relationship for the environment, except for man. Due to lack on knowledge, the uncertainties are orders of magnitude, and basic research is needed to identify biological endpoints and to establish dose-effect information.
- Uncertainties associated with the extrapolation from effects on individuals to population level and ecological systems, are expected to be about similar as for other stressors, orders of magnitude.

9. Conclusions

Information on a series of potential nuclear sources is still rather limited and the uncertainties of any environmental impact and risk assessment will be very high. Although environmental impact and risk assessments suffer from large uncertainties, these assessments should be performed prior to all decisions made with respect to countermeasures, i.e. prior and after the measures have been taken. Furthermore, these assessments should be made to select between alternative countermeasures and to prioritise between sources of risk. It is also essential that the uncertainties involved are understood and communicated.

To reduce the overall uncertainties in impact and risk assessments scientific effort should be put on key factors contributing to the uncertainties, namely improvement in the source term characterisation, characterization of radionuclide speciation using advance technology, derive time-dependent functions for distributions i.e. Kd and accumulation i.e. CF in organisms in different ecosystems and characterise dose-biological endpoint responses in biota for individual radionuclides and mixtures.

References

1. Chamberlain, A.C., *Environmental impact of particles emitted from Windscale Piles* 1954-57. Sci. Tot. Environ. 63, 139-160, 1987.
2. IAEA International Atomic Energy Agency *Coordinated Reseach Programme on radioactive particle* Tech. Doc. 199
3. Kashparov, V.A., Oughton, D.H., Protsak, V.P., Zvarisch, S.I., Protsak, V.P., and Levchuk, S.E. *Kinetics of fuel particle weathering and* ^{90}*Sr mobility in the Chernobyl 30 km exclusion zone*. Hlth Physics, 76: 251-259, 1999.
4. UKAEA, AEEW Report 2104 Jakeman, D. (1986). *Notes of the level of radioactive contamination in the Sellafield area arising from discharges in the Early 1950s*, Atomic Energy Establishment, Winfrith.
5. Oi, N. *Plutonium Challenges* . IAEA Bulletin 40, 1, 12-16.
6. Salbu, B., Krekling, T., Oughton, D.H., Østby, G., Kashparov, V.A., Brand, T.L., and Day, J.P., *Hot particles in accidental releases from Chernobyl and Windscale Nuclear installations.* Analyst 119, 125-130, 1994.
7. *Characterisation of radioactive particles in the environment.* Salbu, B., Krekling, T. and Oughton D. H. (1998). Analyst 123, 843-849. 1998.
8. Salbu, B.. *Encylopedia of Analytical Chemistry*. Speciation of Radionuclides. In: (Ed. R.A Myers). John Wiley & Sons, Ltd, Chichester, UK, 12993-13016, 2000.
9. Salbu, B., Krekling, T., Lind, O. C., Oughton, D. H., Drakopoulos, M.,Simionovici, A., Snigireva, I., Snigirev, A., Weitkamp, T., Adams, F.,Janssens, K. and Kashparov, V.A. *High energy X-ray mi-croscopy for characterisation of fuel particles*. Nucl. Instr. and Meth. A, 467 (21), 1249-1252, 2001.

APPLICATION OF LASER TECHNOLOGIES FOR STABILIZATION OF ENVIRONMENTAL SAFETY IMPROVEMENT IN THE COURSE OF UTILIZATION OF NUCLEAR-POWERED SUBMARINES

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1. Abstract

Ensuring of safety and reducing of ecological hazard during dismantlement of nuclear-powered submarines present one of the most urgent issues. In the course of repairing and dismantling a large number of demountable equipment built in nuclear-powered plants that have been operated for a long time under the conditions of elevated temperatures, corrosive impact of working medium, high density of neutron flux, and being contaminated, is produced. The above equipment is manufactured, mainly, of expensive high-alloy stainless steels, titanium and copper alloys, and other valuable materials.

Traditional methods of decontamination such as vacuum machining, sand-blasting, etc., based on mechanical removal of contaminants, treatment of surfaces with water or organic solvents, as well as methods based on physical-and-chemical processes, possess a number of shortcomings. The application thereof leads to production of a large amount of liquid radioactive waste, to a significant increase of pollution hazard for the

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environment, besides, requires use of expensive materials and, in some cases, toxic agents.

Therefore, the solution of a problem on development of new perspective know-how of decontamination will allow reducing significantly radiation and ecological hazard in the regions for disposal of atomic power-machinery installations, to ensure recycling of not only expensive steels and alloys, but also serviceable equipment for the national economy with the purpose of their further usage.

In our opinion, the laser know-how can be effectively used in dismantlement of nuclear-powered submarines for cutting of metalwork, welding of containers for nuclear fuel storage, decontamination of NS units and assemblies.

A. We are in the process of development of laser decontamination know-how. The work was initiated in 2001.

B. For the process of decontamination the following requirements were stated (slide 1):

  - High effectiveness;
  - Removal of surface radiation contaminants in a solid phase, without use of liquid chemical reagents;
  - No pollution of the environment in the course of decontamination;
  - Capacity for processing the components of complicated geometrical shape;
  - Remotely controlled process for minimization of radiation impact on personnel;
  - Mobility of equipment.

2. Stages in the work

The three-staged work was executed (slide 2):

1. Selection of equipment and trying-out of know-how for oxide films removal –in 2001.
2. Manufacture of a hot chamber for operations with radioactively contaminated articles –in 2001-2004.

3. Development and manufacture of a mobile laser prototype – in 2003-2004.

For work performance we selected solid-state lasers due to their compactness and capability for adjustment of temporary emission parameters within wide band.

Products of “contamination” are located on surfaces as a part of oxide films, so it is possible to remove the above products along with removal of the films. Steel samples with oxide films of the thickness up to 100 μm were treated.

Vertical beam laser complex (slide 3) was used for the work; test pieces were moved by means of a coordinate table. Range of changes of temporary emission parameters from continuous regime to n-second band of pulses duration was studied. Theoretical evaluations corroborated by experimental work have shown that the most effective process of surface cleaning off oxide films takes place during attack to the surface by pulses of n-second duration. In the above case the mechanism of thermo-shock removal of oxide films from the metal surface based on rapid heating and rapid cooling of the surface oxide film, is fulfilled. The process is accompanied by formation of “fireworks” of luminous products generated from cleaning operation. The torch size above a component surface measures to tens of centimeters and directed to the emitter side. Particles have the size from several microns up to millimeters, and the asymmetrical shape.

3. Results

The work resulted in a number of peculiarities of the oxide film removal process, as follows:

1. Films are removed under the action of beam with 5 – 7 mm diameter, while for cutting and welding the fine-focused beams of 0.1-0.3 mm order are required.
2. Removal of film results from the effect of one pulse, thereby high speeds of cleaning are reached, for instance, in theory the output of 3-5 m^2 per hour can be reached at 50 Hz pulse frequency (slide 4).
3. Process is carried out at the distance of several meters and slightly depends on the distance from emitter to component surface.

4. Cleaning of surfaces is possible to carry out at grazing angles of beam incidence to the surface of articles (slides 5,6).

During use of emission with pulses of larger duration, μs, ms, and permanent mode the flashing of metal surface and “sintering-in” of oxide films into the melt are observed.

One of the main requirements for cleaning process is to exclude contamination of the environment. We elaborated method of 100% trapping of the products generated from cleaning operation on sorption films. Treatment, in the above case, is performed by means of laser emission penetrating through the film; therewith oxides flying away from the surface are sorted on glue compound applied on one of the film sides. Due to the use of films it appears possible to separate the “dirty” and “clean” zones during products treatment. Particles absorbed on the film can be disposed together with the latter. At the second stage of the work a trial-experimental complex for laser decontamination was prepared for the use, on the basis of which a working chamber of laser decontamination for operations with radioactively contaminated articles was created (slide 7). The complex is located on the territory of the Nuclear Physics Institute in the town of Gatchina, the Leningrad Region. The chamber is equipped with two laser facilities for implementation of research works. Emission from lasers is supplied to the chamber through input window, and may be scanned by two coordinates with the help of reflectors controlled from processor (slide 8). It has been stated by experiments that during treatment of surfaces with radioactive contaminants the contamination level decreases to more than 70% (slide 10). At the third stage of the work in 2003 a mobile laser complex was developed and manufactured (slide 11). The complex comprises the following: emitter, laser power unit, cooling system “water-air”, control computer. The weight of the complex is equal to 40 kg in total, power consumption is 3 kW, from the mains of 220 V. The output is up to 2 square meters per hour. Distance from emitter to treated surface is up to 1.5 m. The complex comes complete with turn-device with remote control for laser emitter movement (slide 12).

4. Conclusions

The conclusions are as follows:

- Method of a “dry”decontamination was developed;

- Prototype of a mobile laser complex was manufactured;
- Technique for protection of the environment from radioactive products during decontamination was completed;
- The experiments have proved that during laser treatment of radioactively contaminated products the contamination level is reduced to more than 70%;
- Complex of equipment for laser decontamination was manufactured.

6. FINAL SESSION: SUMMARY OF WORKSHOP AND ADOPTION OF RECOMMENDATION

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FINAL SESSION: SUMMARY OF WORKSHOP AND ADOPTION OF RECOMMENDATION

The chairs of the previous sessions each provided a brief summary of the main conclusions from their sessions. Sneve (NRPA) and Pechkurov (FSETAS) also made brief introductory remarks, highlighting major issues from the Norwegian and Russian perspectives respectively.

1. Discussion

1. There was a strong focus in the workshop on environmental impact assessment and risk assessment (as well as corresponding Russian regulatory terms such as OVOS), but it was clear that understanding of the meaning of these terms differed significantly, both among the participants in the workshop and around the world. A review of EIA practice in Russia, Norway and other countries by a joint Russian-Norwegian Expert Group found that, even when EIA was defined in similar ways on paper, the practical interpretation (what was to be done, by whom, when, and for what purpose) might still differ markedly. EIA has a specific regulatory meaning in EU Member States and other Western countries, as does OVOS in the Russian Federation: when these specific regulatory meanings are not intended, more general descriptions should be used. Clear working definitions of such terms would help to ensure that discussions were based on a common understanding. It was suggested that the IAEA might help to promote international agreement on the definitions and concepts, and perhaps move towards internationally agreed methodologies. However, this should not stop work from proceeding: there was general agreement that the potential impacts on the environment of actions at nuclear sites must be assessed systematically, and measures taken to mitigate any significant impacts.
2. In western countries, assessments of environmental impacts (including safety assessments) are 'living' documents, which are continuously updated throughout the course of the project to reflect changes, unex-

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pected developments, and the feedback of experience gained during the project. The content and level of detail of the assessments at a given stage of the project is appropriate for that stage (e.g. outline assessment at early stages of planning, more detailed specific assessment when the project design is well advanced, etc.). At a defined stage before the project begins, the assessments are approved by relevant bodies, but subsequent changes can be agreed with the regulator without repeating the approval process, provided the operator can demonstrate to the regulator that the changes do not significantly alter the original case that the impacts of the project are acceptable. Such an approach is more difficult to adopt under the Russian system because, after documents have been approved through the State Environmental Expertise process, any changes need to be approved through the same system. This effectively makes it a new project, and this can cause severe delays. [In practice, this difference may not be as great as it seems, because SEE is often completed while the project is being implemented, and changes can still be made prior to completion of SEE –indeed, changes may be required during the SEE process.]

3. Western countries also typically require an assessment of environmental impacts prior to a project starting (e.g. the European Union EIA Directive requires an environmental statement during the planning stage). In practice, the Russian OVOS is normally prepared in parallel with the design and early stages of implementation of a project. For international projects, agreement is needed on the scope and content of environmental impact information that is required before the project starts: such an agreement is currently being developed in negotiations about documentation for dismantling of two Victor III submarines at Nerpa shipyard with UK and Norwegian funding.

4. Two specific issues were discussed as areas in which regulations are lacking: these are disposal routes for solid radioactive wastes and criteria to define an acceptable final state for a site after rehabilitation:

    - Uncertainty about the final disposal of waste –particularly radioactive waste – to be generated during risk reduction projects makes it more difficult to plan those projects adequately, because operators do not know into what forms to put different types of waste so as to minimise the likelihood that they have to recondition and/or repackage it for disposal in the future. It is recognised that policy decisions on final waste disposal options are taken at the political level and so are beyond the control of regulators, but operators and regulators need to find adequate solutions within the existing policy (or lack of policy). If final disposal routes are known, then regulations should indicate how wastes are to be segregated, characterised, conditioned and packaged for that route. If final disposal routes are not known, then operators and regulators should cooperate to identify acceptable forms for waste to be put into for the time being.

- Planning for rehabilitation of sites such as Andreeva Bay needs to be based on assumptions about the final condition of the site. A regulatory position (regulations or guidelines) needs to be developed on the question of what final condition would be acceptable, in terms of the residual hazard and risk to people using the site. But the operators also need to develop their own objectives for the future of the site after rehabilitation: do they want the site to be available for any use, including agriculture or housing, or for a specific use, such as another industrial application? This should not affect the level of residual risk that is acceptable, but it will affect the levels of radioactive or hazardous materials that can be left on the site, because it will influence which pathways have to be considered in risk assessment.

5. International standards are clear that the prime responsibility for protection of health, environment and safety rests with operator. The regulators' job is to ensure that operators fulfil that responsibility, and where necessary to help them do so (or at least not hinder them without good reason). Operators should identify health, environmental and safety issues and measures to resolve them, and propose these solutions to the regulator. The regulator should consider such proposals critically, seek changes where necessary, and ensure that approved solutions are implemented. It appears that the Russian regulations and regulatory system, and/or established regulatory practices, do not encourage this type of dialogue between operator and regulator: typically the regulations impose prescriptive requirements on operators, and regulators check that operators have met these requirements. This approach may not be sufficiently flexible to allow innovative solutions to be found for the unique problems in North West Russia.

(There do, however, need to be limits to the cooperation between operator and regulator. Careful judgement is needed to decide how far a regulator (or, perhaps more likely, a TSO) should assist the operator before it calls into question his independence to make (or support) regulatory decisions.)

It was recognised, however, that Russian operators and regulators must work according to Russian law, and that changing their law was beyond their power, as well as being a long process. Some progress was noted towards making Russian laws and regulations less prohibitive, but there would be no dramatic change soon, and for the time being operators and regulators could only try to make improvements within the current legal and regulatory framework.

6. Limitations on the availability of information on Russian projects was raised repeatedly as an issue that is seen as hindering progress in international cooperation. It was recognised that the level of openness and transparency has improved very greatly in recent years, but it was felt that too much information is still difficult or impossible to obtain. Russian participants recognised that there was still some occasional tendency towards excessive secrecy, but that this was gradually being eliminated, and stressed that there would always be some information that had to be classified (as it would be in any other country). With the right spirit of cooperation, they felt that Russian colleagues could help their western counterparts to obtain the information they needed.
7. The Russian Federation has made substantial progress towards making its regulations and regulatory system consistent with international obligations and recommendations. While the workshop identified a number of areas in which improvements to Russian regulations and regulatory practice would be desirable, it was emphasised that work could not be stopped to wait for improvements. Where priority measures could be taken safely, within the existing Russian framework, to reduce significant risks at nuclear sites in North-West Russia, then they should continue to be taken. Great progress had been made through cooperation between Russia and its international partners, but there was still much to do, and regulation should promote measures that would benefit health, safety and the environment.

2. Recommendations on regulation

1. Within the Russian legislative and regulatory framework, regulators should emphasise and encourage operators taking prime responsibility for safety and environmental and health protection in respect of their facilities. This includes not only complying with regulatory limits but also taking measures to reduce risks to a level as low as reasonably achievable.

2. Efforts should continue to ensure that the division of regulatory responsibilities among Russian regulators –particularly following the administrative reorganisations –is clear to all interested parties, and to further improve cooperation between regulators on areas of common interest.
3. Within the framework of Russian law and fundamental safety and protection objectives, regulators should consider the possible scope for flexibility in applying detailed regulations in abnormal situations to facilitate risk reduction measures.
4. Regulators should seek to provide more guidance to operators on acceptable ways of conditioning and packaging solid radioactive and hazardous wastes for which final disposal routes are not yet established, so as to provide for safe interim or long-term storage and minimise the likelihood of any future need for reconditioning or repackaging.
5. Regulations or regulatory guidance should be developed, within the framework of Russian law, setting out criteria to be applied in judging the acceptability of long-term states for sites following rehabilitation.
6. Efforts should continue to minimise, as far as possible consistent with national security and other essential confidentiality requirements, restrictions on the availability of information relevant to assessing environmental, health and safety risks associated with nuclear objects in North-West Russia.

3. Recommendations on risk assessment

1. The terminology of 'risk', different types of impact and different types of assessment should be used carefully, and the terms used defined clearly. Efforts should continue to obtain a common terminology.
2. Prioritisation of risk reduction measures and selection of projects should be based on systematic and integrated assessment of safety, health and environmental impacts.
3. As a minimum, an assessment of safety, health and environmental impacts should be made prior to the start of a project that includes:
    - identification and description of all expected and potential impacts, and assessment of the approximate magnitude and likelihood of each impact:
        - if the project is implemented, and
        - if the project is not implemented (the 'no action' option);

- description of measures that will be taken if the project is implemented to mitigate the more significant expected and potential impacts, and assessment of how these measures will affect the magnitude and likelihood of these impacts.
- all assumptions made in the assessment should be clearly stated and justified. During the detailed design and implementation of the project these assumptions, and the results of the assessment, should be verified and the assessment updated if necessary.

4. Efforts should be supported to develop common agreed methodologies for assessment of safety, health and environmental impacts. Many tools for such assessments exist in different countries that could potentially be 'internationalised'. International action in this area, e.g. by the IAEA, would be welcome.
5. Impact assessments should include systematic consideration of the uncertainties in all stages of the assessment. The degree of uncertainty in estimates of impacts should be indicated and explained in the assessment.
6. Key areas of uncertainty in impact assessments for projects in North-West Russia should be identified and agreed, and joint efforts focused on reducing these uncertainties

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