Regulatory supervision of sites for spent fuel and radioactive waste storage in the Russian Northwest

To cite this article: N K Shandala et al 2008 J. Radiol. Prot. 28 453

View the article online for updates and enhancements.

Related content
- Radiation safety during remediation of the SevRAO facilities: 10 years of regulatory experience
  M K Sneve, N Shandala, S Kiselev et al.
- Radiological criteria for the remediation of sites for spent fuel and radioactive waste storage in the Russian Northwest
  N K Shandala, M K Sneve, A V Titov et al.
- Medical and radiological aspects of emergency preparedness and response at SevRAO facilities
  M N Savkin, M K Sneve, M I Grachev et al.

Recent citations
- Dynamics of body burdens and doses due to internal irradiation from intakes of long-lived radionuclides by residents of Ozynorsk situated near Mayak PA
  K G Suslova et al
- Radiation safety during remediation of the SevRAO facilities: 10 years of regulatory experience
  M K Sneve et al
- Monitoring human factor risk characteristics at nuclear legacy sites in northwest Russia in support of radiation safety regulation
  V Y Scheblanov et al
Regulatory supervision of sites for spent fuel and radioactive waste storage in the Russian Northwest

N K Shandala\textsuperscript{1}, M K Sneve\textsuperscript{2}, G M Smith\textsuperscript{3}, M F Kiselev\textsuperscript{4}, O A Kochetkov\textsuperscript{1}, M N Savkin\textsuperscript{1}, A V Simakov\textsuperscript{1}, N Ya Novikova\textsuperscript{1}, A V Titov\textsuperscript{1}, V V Romanov\textsuperscript{4}, V A Seregin\textsuperscript{1}, A V Filonova\textsuperscript{1} and M P Semenova\textsuperscript{1}

\textsuperscript{1} Burnasyan Federal Medical Biophysical Centre, Moscow, Russian Federation
\textsuperscript{2} Norwegian Radiation Protection Authority, Oslo, Norway
\textsuperscript{3} GMS Abingdon Ltd, UK
\textsuperscript{4} Federal Medical–Biological Agency, Moscow, Russia

E-mail: shandala@srcibph.ru

Received 22 February 2008, in final form 15 July 2008, accepted for publication 7 August 2008
Published 24 November 2008
Online at stacks.iop.org/JRP/28/453

Abstract
In the 1960s two technical bases for the Northern Fleet were created in the Russian northwest at Andreeva Bay in the Kola Peninsula and Gremikha village on the coast of the Barents Sea. They maintained nuclear submarines, receiving and storing radioactive waste and spent nuclear fuel. No further waste was received after 1985, and the technical bases have since been re-categorised as temporary storage sites. The handling of these materials to put them into a safe condition is especially hazardous because of their degraded state. This paper describes regulatory activities which have been carried out to support the supervision of radiological protection during recovery of waste and spent fuel, and to support regulatory decisions on overall site remediation. The work described includes: an assessment of the radiation situation on-site; the development of necessary additional regulatory rules and standards for radiation protection assurance for workers and the public during remediation; and the completion of an initial threat assessment to identify regulatory priorities. Detailed consideration of measures for the control of radiation exposure of workers and radiation exposure of the public during and after operations and emergency preparedness and response are complete and provided in sister papers. The continuing requirements for regulatory activities relevant to the development and implementation of on-going and future remediation activities are also outlined. The Norwegian Radiation Protection Authority supports the work, as part of the Norwegian Government’s plan of action to promote improvements in radiation protection and nuclear safety in northwest Russia.

(Some figures in this article are in colour only in the electronic version)
1. Introduction

The Norwegian Government, through a plan of action implemented by the Ministry of Foreign Affairs, is promoting improvements in radiation protection and nuclear safety in northwest Russia. Some of this work is directed to the improvement of waste management and remediation operations at the former shore technical bases now operated as sites of temporary storage (STSs) by the federal enterprise SevRAO at Andreeva Bay and Gremikha village.

Attention is focused on these sites due to the very poor storage conditions that exist for the significant inventories of spent nuclear fuel (SNF) and radioactive waste (RW). The handling of these materials to put them into a safe condition is especially hazardous because of their degraded state [1]. Furthermore, significant quantities of radionuclides have already escaped into the ground around the storage facilities. The potential for spread of this contamination and for further releases creates additional hazards, both locally and on a regional scale.

To address these issues within the plan of action, the Norwegian Radiation Protection Authority (NRPA) has set up a cooperation agreement with the Russian Federal Medical–Biological Agency (FMBA). The Burnasyan Federal Medical Biophysical Centre (FMBC) supports the FMBA technically. The overall objective of the collaboration is to promote effective and efficient regulatory supervision of the activities of SevRAO in Andreeva Bay and Gremikha. Within this scope, the cooperation has been implemented through three specific projects addressing regulatory supervision in the following three areas:

- radiation exposure of workers;
- radiation exposure of the public; and
- emergency preparedness and response.

To support the detailed development and implementation of these projects it was decided to carry out an independent examination and evaluation of environmental radioactivity on and adjacent to the sites. In addition, because of relatively recent updates in regulatory responsibilities within the Russian Federation, and because of the irregular conditions at the sites, a review was carried out of regulatory responsibilities and the need for improved radiation norms and standards, which take account of the existing situation and the need to improve the safety of waste and spent fuel. The output from this work was then used as input to an initial threat assessment to identify regulatory priorities [2].

2. General characterisation of the site and facilities of the temporary storage sites in Andreeva Bay and Gremikha village

The temporary storage site for SNF and RW in Andreeva Bay is situated in northwest Kola Peninsula in the coastal strip of the Barents Sea (Motovsky Bay, west bank of Zapadnaya Litsa Bay). The nearest settlements to the STS are Bolshaya Lopatka (2.4 km) and Nerpitchiye (1.8 km) villages and Zaozersk city (8 km). The Zaozersk urban area occupies about 520 ha and there are approximately 16,000 inhabitants.

The STS in Andreeva Bay consists of the following main constructions:

- an obsolete pier;
- blocks for dry storage: three partly underground 1000 m³ stores, re-equipped to serve as facilities for SNF storage;
- a service site for the SNF store, including some buildings;
- a basin-type SNF storage facility, called Building 5 which is being decommissioned after removal of SNF from it;
- liquid radioactive waste (LRW) storage facilities;
Regulation of radioactive waste and SNF in NW Russia

Figure 1. Areal categorisation of present STSs at (a) Andreeva Bay and (b) Gremikha village. SNF from 86 nuclear submarines has been stored at the sites for 25 years or more, as well as 17,558 tonnes of SRW and 3042 tonnes of LRW containing fission and (lesser amounts of) activation products. Actinides comprise less than 1% of the total activity now, but are important in the long-term management of RW.

- a building intended for water purification;
- a storage facility for high-level concentrates of LRW after treatment;
- numerous constructions and sites for solid radioactive waste (SRW) storage.

Since 2002, construction of new infrastructure and reconstruction of existing infrastructure has been carried out at the STS.

The site of temporary storage of SNF and RW in Gremikha village is located on the northwest Kola Peninsula in the coastal strip of the Barents Sea (Svyatonoosskiy Bay). Svyatoy Nos Peninsula bounds this bay from the east, which protrudes nearly 13 km to the northwest from the mainland. The nearest settlements are Gremikha village, located 0.7 km from the site, and the closest administrative territorial formation is Ostrovnoy city, located 1.2 km from the site. Approximately 3500 inhabitants live in these settlements.

The STS in Gremikha village consists of about 30 buildings, 19 of which have technological functions. SNF, SRW, LRW, containers for control rods and eight spent extracted parts from nuclear submarines equipped with liquid-metal heat-carrier reactors are stored here. In addition to the buildings and systems, there are obsolete service ships floating tanks and a dry dock.

Lakes located within a few kilometres of the STS serve as sources of water. Soils at both STSs and in their vicinity are not suitable for agriculture. The flora and fauna of this region are typical for the tundra zone: lichen, 1.5–2 m birches, bushes (heather, berry-bushes etc), permanent grasses (hair-grass) and deer, elk and seals live here.

For the purpose of radiation protection of workers, the sites at Andreeva Bay and Gremikha village (figure 1) consist of four separate radiation protection areas:

Controlled access area (CAA). This is the area where SNF and RW are stored and where the most radiation-hazardous operations are carried out. The facilities in this area are the main subjects of remediation, with the areas demarcated by posts and notices and a special regime
for control of work being defined there. Personal protection equipment is used in the CAA to provide radiation protection to personnel designated as group A, subject to a dose limit of 20 mSv y\(^{-1}\).

**Uncontrolled (free access) area (UA).** The facilities located in this zone support work carried out in the CAA. No significantly radiation-hazardous operations are performed within this area. The main workplaces of the personnel (designated as B group) are located here. Personnel from B group are subject to a dose limit of 5 mSv y\(^{-1}\).

**Health protection zone (HPZ).** This is the area outside the CAA and UA which falls under STS administrative and technical provision. The external border of this area is limited by a system of physical protection.

**Supervision area (SA).** This area, with a radius of about 10 and 3 km, respectively, for the STS in Andreeva Bay and Gremikha village, is the subject of monitoring and control as regards the impact of the facility on the environment and the public (dose limit—1 mSv y\(^{-1}\)).

Figure 2 shows SNF and RW activities stored at the STS.

Figure 3 shows the composition of SRW and LRW at the STS in Andreeva Bay and Gremikha village. Most of the waste volume is low-level waste (LLW). However, with the purpose of improving management, criteria are under development for the definition of a new class of industrial wastes containing man-made radionuclides with a specific activity lower than the LLW category but above clearance levels, and the operative control methods for their separation, and requirements for their conditions of storage. In some systems, this waste corresponds to very low-level waste (VLLW).
3. Independent evaluation of the environmental radioactivity

In order to obtain independent information with respect to the current radiation situation, specialists from the Burnasyan Federal Medical Biophysical Centre (ex-Institute of Biophysics (IBPh) Moscow) completed a measurement programme, in the course of which monitoring of STS facilities was carried out.

In June–October 2005 and July–August 2006, a team of specialists from the IBPh made four expeditions to the STSs in Andreeva Bay and Gremikha village in order to:

- assess the radiation situation near the STSs;
- assess possible pathways of radiation exposure to the public and to the environment during remediation of the STSs; and
- select points for long-term radiation monitoring.

About 100 samples of environmental media and local foods were collected. The samples were examined using gamma-spectrometry and radiochemical and radiometric methods.

Quantification of the mobility of radionuclides in soils and bottom sediments is of very practical significance, because this permits prediction of migration rates in the system, and supports prognoses of the scope for further radionuclide migration. This in turn helps in the planning of contamination control and the need for remediation of contaminated land.

Radionuclide mobility has been evaluated using soil extraction methods. Extraction was performed with 1N acetic acid ammonium solution to identify the more mobile exchangeable fraction. To identify the less mobile exchangeable fraction, 1N hydrochloric acid was applied. The residual activity could be considered un-exchangeable and relatively immobile; however, this would not take account of the dynamics.

The following findings were obtained. The main radioactive contamination at the sites is due to the radionuclides $^{90}$Sr and $^{137}$Cs. Some parts of the site and offshore waters are contaminated with $^{60}$Co, but at concentrations 10–200 times lower than those of $^{137}$Cs.

Gamma dose rates at the STSs in Andreeva Bay vary over wide ranges. In the CAA they range from 0.2 to 140 $\mu$Sv h$^{-1}$. Maximum values here were observed near the radiation-hazardous facilities and in the area of the former mouth of the brook near building 5. In the UA, the range was from 0.2 to 12 $\mu$Sv h$^{-1}$ and in the HPZ and SA from 0.063 to 0.14 $\mu$Sv h$^{-1}$, with an average value of 0.12 $\mu$Sv h$^{-1}$.

At the Gremikha village site, within the CAA close to some radiation-hazardous facilities, the gamma dose rate reaches 500 $\mu$Sv h$^{-1}$. This is due to radiation from the storage facilities. In most of the HPZ and SA areas, the gamma dose rate does not exceed 0.23 $\mu$Sv h$^{-1}$.
Gamma dose rates off-site at both STSs do not differ considerably from the levels typical for the territory of Russian northwest, in particular the Murmansk region.

Contamination of both STS sites is very non-uniform. There are areas of a few square metres where radionuclide concentrations are an order of magnitude higher than in the adjacent soil. Maximum levels of soil contamination on-site in Andreeva Bay are observed in the area of the obsolete pier and around some storage buildings. The content of $^{137}$Cs reaches $5.7 \times 10^7$ Bq kg$^{-1}$, while the content of $^{90}$Sr is an order of magnitude less. The content of $^{137}$Cs and $^{90}$Sr in soil in the HPZ and SA at distances of more than 900 m is at the level of background values typical for uncontaminated areas of northern Russian and does not exceed 36 Bq kg$^{-1}$ for $^{137}$Cs and 4 Bq kg$^{-1}$ for $^{90}$Sr (figure 4).

In the HPZ of the STSs in Andreeva Bay, soil contamination with $^{60}$Co was detected only around the block for dry storage and near two of many sites for SRW storage, at levels in the range from 23 to 10 Bq kg$^{-1}$.

At the STS in Gremikha village, levels of $^{137}$Cs and $^{90}$Sr in some areas are 100 or more times greater than background values for the region. Some parts of the site (close to the interim SRW storage facility) are contaminated with $^{60}$Co. $^{137}$Cs soil contamination levels are 3–30 times greater than for $^{90}$Sr and 10–200 times greater than for $^{60}$Co. Maximum soil contamination with $^{60}$Co (780 Bq kg$^{-1}$) was observed in the area of SRW storage. Beyond the HPZ area in SA (Gremikha village and Ostrovnoy), contents of $^{137}$Cs and $^{90}$Sr in the soil are mainly at the background level (1–50 Bq kg$^{-1}$). In some cases, background values are exceeded by up to 100 Bq kg$^{-1}$ by $^{137}$Cs (figure 5).

The content of $^{137}$Cs in vegetation within the CAA was found to be $4.7 \times 10^3$ Bq kg$^{-1}$ in Andreeva Bay, and reaches $3.2 \times 10^4$ Bq kg$^{-1}$ in Gremikha. Within the HPZ and SA, the maximum contents of $^{137}$Cs and $^{90}$Sr in vegetation were 3 and 70 Bq kg$^{-1}$, respectively, i.e. not exceeding the background values of these radionuclides. The maximum activity found, of $^{60}$Co in plants at Gremikha, was 3.2 Bq kg$^{-1}$. At Andreeva Bay, the activity of $^{60}$Co in plants was lower than the minimum detectable activity of 1 Bq kg$^{-1}$. The specific activity of only one mushroom sample collected in CAA was 1.4 Bq kg$^{-1}$.

Figure 4. $^{90}$Sr (dark grey) and $^{137}$Cs (light grey) content in soil at the STS sites in Andreeva Bay.
In Andreeva Bay, the concentration of $^{137}$Cs in marine bed sediments adjacent to the coast was 100 Bq kg$^{-1}$ at the area of the former brook mouth and 36 Bq kg$^{-1}$ beyond the border of the HPZ, that is, up to 25 times greater than background values. The $^{90}$Sr content in the same samples of bed sediments varied from 2 to 36.6 Bq kg$^{-1}$, that is, up to 20 times greater than background. Contents of $^{137}$Cs and $^{90}$Sr in seaweeds exceeded background values only negligibly. At Gremikha, the concentration of $^{137}$Cs in marine bed sediments of the STS coastal strip varied from 64 to $1.2 \times 10^4$ Bq kg$^{-1}$, from 8 to 3000 times greater than background values. The content of $^{90}$Sr in the same samples of sediments varied from 9 to $2.0 \times 10^3$ Bq kg$^{-1}$, up to 250 times higher than background values. The $^{137}$Cs and $^{90}$Sr content in seaweeds is about four times above the background contents of these radionuclides. In samples of seaweeds and sediments collected in the offshore waters near the STS industrial site, the presence of $^{60}$Co was also registered. The content of $^{60}$Co in bed sediments reached $7.2 \times 10^3$ Bq kg$^{-1}$ in the area of Chervyanaya Bay.

With the purpose of evaluating possible radionuclide intake via the trophic chains, the concentration ratio (CR) was determined between soil and vegetation. The CR values for $^{90}$Sr ranged from 0.3 to 4.2 and those for $^{137}$Cs from 0.003 to 1.5 (Bq kg$^{-1}$ wet weight)/(Bq kg$^{-1}$ soil). An examination of the relative radionuclide mobility in soil has confirmed that $^{90}$Sr is the most mobile element, both in Andreeva Bay and in Gremikha. The desorption coefficient of $^{90}$Sr was found to be 0.83–0.98 for soils, i.e. about 90% of gross $^{90}$Sr can be in the mobile form and be available for plant uptake and susceptible to further migration. The desorption coefficient of $^{137}$Cs was found to be much lower, so it is more fixed in soils. The relative mobility found for $^{137}$Cs and $^{90}$Sr was to be expected, but the site-specific data can be used in future site-specific assessments. The presence of significant fractions of $^{90}$Sr and to a lesser extent $^{137}$Cs in mobile form suggests that activity can migrate from the terrestrial into the offshore environment.

In the marine environment, $^{137}$Cs dominates in bed sediments and in seaweeds. A single sample from the former brook mouth presents an exception: a comparatively high $^{90}$Sr content, 690 Bq kg$^{-1}$, was observed here.

The desorption coefficient of mobile forms of $^{90}$Sr and $^{137}$Cs for bed sediments in Andreeva Bay is 0.70–0.82. In Gremikha, near Chervyanaya Bay, the desorption coefficient is much...
lower—0.22 and 0.16 for $^{90}$Sr and $^{137}$Cs, respectively. The difference is probably due to special features of the bed sediments in the relatively enclosed bay.

In Andreeva Bay, contents of $^{137}$Cs and $^{90}$Sr in offshore seawater, collected from places with significant contamination of bed sediments, were 3.8 Bq l$^{-1}$ and 0.21 Bq l$^{-1}$, respectively, that is about 33–950 times greater than average background values of $^{137}$Cs and $^{90}$Sr. In Gremikha, contents of $^{137}$Cs and $^{90}$Sr in off-shore seawater were 3.9 Bq l$^{-1}$ and 0.41 Bq l$^{-1}$, respectively, about 100-600 times greater than average background values of $^{137}$Cs and $^{90}$Sr concentrations in waters of Barents Sea. Such locally high concentrations are probably due to re-suspension from bed sediments, contaminated following anthropogenic radionuclides washing out from the coastal strip into offshore seawaters.

Concentrations of $^{137}$Cs and $^{90}$Sr in drinking water were found to be considerably less than the intervention levels set for the public, 11 and 5 Bq l$^{-1}$, respectively.

Foodstuffs collected locally include berries, mushrooms and sea fish. The contents of $^{137}$Cs and $^{90}$Sr (in samples collected within the SA) do not exceed the acceptable activity levels for these radionuclides [3].

Having in mind the possibility of further contamination of the STS area, dynamic surveillance is needed of the radiation situation during routine operations, and during special operations for removal of SNF and RW. With the purpose of achieving integrated organisation and performance of radiation hygiene control and monitoring, a regulatory document is being developed, called methodical guidance: ‘Radiation monitoring of the environmental media in the operational area of facilities for nuclear submarine decommissioning’.

4. Regulatory responsibilities and requirements for improved radiation norms and standards

The responsibilities of FMBA include the following activities associated with hazardous operations and emergencies, both on-site and off-site:

- regulatory supervision of radiation protection of workers and the public;
- monitoring of the on-site and off-site environment related to health protection of workers and the public;
- epidemiological control;
- cooperation with local authorities;
- definition and identification of preventive risk reduction measures;
- medical services related to extreme conditions and emergencies; and
- scientific research in areas of hazardous situations, assessment and mitigation of health impacts, and requirements for medical remedial preparedness and response.

The extreme radiological conditions at Andreeva Bay and Gremikha present novel difficulties for the regulatory supervision of operations. The existing regulations were developed for routine (normal) conditions of SNF and RW management and they must be amended for the specific conditions existing currently at these sites.

Problematic challenges include:

- test recovery, re-packaging and transportation of irradiated fuel assemblies (IFAs) to Mayak;
- logistical organisation of working areas for re-packaging other SNFs and work with RW, taking account of the hazardous radiation situation; and
- so far as practical, minimisation of further production of RW and spread of contamination.
Two strategies can be considered: Option I for fuel management minimises the time until the SNF is removed from the site and the cost of the work, whilst providing necessary safety at work. According to preliminary estimates, it would reduce by at least 6–7 years the duration of storage of SNF before its treatment, because it does not require new infrastructure to be constructed on the site before work starts. Option II includes the creation of new infrastructure, such as ‘hot cells’, temporary storage sites, a new road, additional changing rooms for personnel, decontamination points and a new ship for container transportation. On the one hand, this will increase the safety of SNF management operations when they are carried out, particularly the re-packaging operations. On the other hand, it would not change the basic nature of the work that has to be carried out in the most hazardous radiation conditions, namely recovery of the SNF from the storage cells and removing water from the containers and transporting them to the re-packaging point.

Moreover, the time spent building improvements to the infrastructure would increase the time during which SNF is kept in unsatisfactory conditions, with water in many of the containers and storage cells. This is more dangerous from the point of view of fuel degradation, and could lead to a worsening of the radiation and contamination situation. The doses that will have to be incurred when the SNF is finally removed could rise as a consequence. Furthermore, by the time the new infrastructure has been created, a qualitative change of fuel state may have occurred, which would make it impossible to use the currently developed methods and equipment intended for fuel handling.

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

Thus, one could suppose that measures to mitigate one type of risk, by constructing additional safety barriers for SNF treatment, might cause a greater increase in other risks, for example due to significant additional fuel degradation from prolonged storage in abnormal conditions. The situation creates an interesting application of the principle of optimisation.

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

It is clear that the participation of regulatory bodies and their support organisations in the evaluation of proposed project decisions is very important. In particular, methodical approaches need to be developed and applied for evaluation of:

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

An improved regulatory process, including the development of special norms and rules, is required to take account of this unusual situation.
5. Initial threat assessment and identification of regulatory priorities

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

(1) The current situation before undertaking SNF removal:
   - dose rates, worker and public doses under current conditions;
   - the risk to workers and the public from accidents (before any action);
   - the likely development of the situation (including changes in the dose rates and accident risks) if no action were taken.

(2) The risks of undertaking SNF removal:
   - detailed identification and description of work procedures;
   - doses and accident risks implied by different procedures, taking account of: (i) the detailed characterisation of dose rates, from (1) above; (ii) different timescale strategies; and (iii) other options for reducing doses and risks as appropriate (e.g. personal protective equipment);
   - identification of appropriate procedures to reduce the probability and/or impact of potential accidents: priorities for emergency planning and response capabilities are likely to depend upon the strategy adopted on-site (the focus on medical treatment of workers is partly a result of the greater likelihood that removal of SNF will be dealt with first and that the most likely accidents are therefore those affecting a few workers rather than causing environmental contamination).

(3) The future situation:
   - residual doses and risks following different remedial action strategies.

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

In parallel, activities can be undertaken preparatory to future decision-making on the decommissioning and eventual de-licensing of the sites and any necessary clean-up in the surrounding areas. The main preparatory activities would aim to: (1) obtain better information on radiological conditions off-site, and how these are changing due to conditions on-site (this information can also be an input to defining the current situation in point (1) above); and (2) develop regulatory criteria and guidance for the clean-up of contaminated areas and de-licensing of the sites.

These aspects are outlined in more detail below, based on the outcome of the initial threat assessment.

Characterisation of the current situation

Currently, detailed plans for operations to improve the management of SNF and RW at the SevRAO facility at Andreeva Bay are in the design stage, based on requirements of the Russian regulatory documents OSPORB-99 and NRB-99, which do not take full account of the conditions at SevRAO sites.

In order to assess the radiation risk due to the current situation and future industrial activities at the STSs it is necessary to have data not only about the radiation situation in working areas and in the control zones (gamma dose rate, concentration and dispersal of radioactive aerosols, levels of superficial contamination), but also about exposure of the controlled population groups directly adjacent to STS areas. Relevant data include: the ambient...
dose rates; radionuclide concentrations in air in specific areas, defined for given time intervals; and radionuclide concentrations in locally derived food and water, to allow assessment of annual individual and collective doses, taking account of the habits of the population.

**Actions necessary to undertake SNF removal**

Analysis of proposed project decisions will be based on both the assessment of parameters defining the radiation situation during SNF management operations and on the set of normative-methodical guidance documents currently being developed within the FMBA–NRPA regulatory cooperation programme, including:

- classification of radiation-hazardous technological operations and the range of measures to ensure radiation safety during their performance;
- recommendations on the use of personnel protective equipment in real operating conditions;
- recommendations on the application of collective protection means for the workforce in real operating conditions;
- development of the guidance ‘Sanitary rules of radiation protection for the operation at SevRAO facilities’ and realisation, as a result, of regulatory functions in the field of radiation protection.

The guidance has to address the following tasks to provide for the selection of optimal project decisions:

- radiation protection of SevRAO personnel during operation in the most radiation-hazardous conditions where removal of SNF from the storage cells has to be conducted, as well as the draining of water from SNF containers and their transportation to the point of re-packaging; and
- radiation protection of SevRAO personnel in the abnormal and/or emergency situations which could arise during SNF removal from the storage cells, draining water from containers and their transportation to the point of re-packaging.

**Identification of accident risks and emergency preparedness**

At the present stage of development of the system of emergency preparedness and medical–sanitary provision at SevRAO sites, one of the first actions is the initialisation of procedures aimed at obtaining an officially authorised list of possible emergency situations at different stages of SNF/RW management (including transportation). This can then be used to prepare a list of categorised objects related to their potential emergency hazard, according to the requirements of normative documents. In turn, assignment of objects to categories will determine the necessary level of planning for protective and medical actions with respect to both the personnel and the population. The above procedure is likely to be iterative, as the category of an object could be changed due to improvement of technology, conditions of storage or removal of RW, etc.

As a result of the analysis of possible emergency situations, and the pathways and factors affecting emergency exposure of the personnel, it is planned to consider two variants of a possible structure of casualties (numbers of people involved and injured, and the degree of injuries). The first variant of the estimates will be based on the formal data received from SevRAO, available within the framework of the existing plan of emergency preparedness and response. The second variant of estimates will be obtained using a special expert-analytical technique. Comparison of those estimates will allow the optimisation of medical provisions
capable of rendering the necessary medical aid, and of the documents regulating the work of medical personnel.

Preliminary analysis has shown that, even in the worst-case emergency situations at the STSs, the population is unlikely to be exposed to a clinically significant level of dose. At the same time it is necessary to estimate the ability of the territorial medical service to provide emergency response related to the public during intervention (evacuation, shelter, restrictive actions in the contaminated areas). It is planned to analyse available plans, including plans for interaction between the medical–sanitary unit (MSU-120) and territorial medical institutions.

**Development of remediation criteria and a better understanding of the off-site conditions**

For the most part, work on radiation-hygienic control of the environment of the STSs in Andreeva Bay and Gremikha village has been conducted in the area of the industrial site and in the HPZ. The radiation situation at the industrial sites is relatively clear, whereas the situation in the supervision area (SA) off-site requires additional examination, especially on land. Information on the radiation situation in the SA is extremely limited or absent. There is no picture of the dynamics of the environmental radiation situation outside the STS, as monitoring of the radiation situation only started in the late 1990s. It is necessary to conduct additional studies of the radiation situation in the supervision area around the whole perimeter of the STS, not only along the coastline, but especially in the inhabited areas of Gremikha village and Ostrovnoy.

Predictions of future radionuclide migration and related prognosis of radiation exposure are a basic part of the safety assessment of the contaminated areas and must be conducted taking account of the specific human-modified and natural conditions in the areas of interest. This will allow the development of appropriate remediation measures and associated normative documentation.

Regulatory documents will need to be developed to provide for radiation protection of the personnel and public during and following the remediation of the site by means of development of criteria for the residual contamination of land, buildings and constructions of SevRAO facilities with radioactive substances. These criteria shall be related to the more probable options for their decommissioning (unlimited use, restricted use as an industrial facility using radioactive materials, restricted use as an industrial facility without radioactive materials, etc).

The state sanitary-epidemiological supervision of the off-site environmental conditions will require improvement of the relevant methodological documents:

- ensuring radiation protection control and supervision of the STS remediation requires development of a special document—a procedure (regulation) for the conduction of control and monitoring. Guidance will be provided in this document on issues such as the required amount, frequency and type of monitoring and inspection;
- development of criteria and hygienic norms on remediation, providing social guarantees of the public radiation protection in territories affected by radioactive contamination associated with the STSs; and
- setting of ‘dose quotas’ to limit radiation exposure in the STS areas, as well as development of reference levels for measurable radiation parameters, which can be monitored during radiation measurement and control.

**6. Conclusions**

The work carried out under the joint FMBA/NRPA project is an important step forward in improved Russian–Norwegian regulation of work implementation that considerably facilitates
the management of existing and potential radiological risk sources at SevRAO STSs and will support the regulatory authorities in:

- creating a system covering the entire range of objectives relating to medical-hygienic regulation of radiation and environmental protection of the personnel, public and environment at SevRAO facilities;
- optimizing the order of the operations, by means of selection of acceptable technologies, and assessing the radiological, economical and social factors, and accordingly, providing for and guaranteeing a series of preventive and operative measures;
- guaranteeing a socially acceptable level of radiological protection and public health during operations at SevRAO facilities, based on common approaches to the national normative documents and international recommendations;
- improving the system of emergency preparedness and that of medical and sanitary provision of emergency response in terms of the radiation situation at the STS facilities; and
- identifying the points for improvement of the regulatory system within the framework of international cooperation, based on a detailed assessment of the scale of potential threats.

Three further papers support this paper, devoted to (i) radiological protection of SevRAO’s workers [4], (ii) development of the remediation criteria [5] and (iii) emergency response [6].

The work completed so far and described here has provided the solution to many problems; however, a number of urgent matters still exist and require additional effort. In particular, as industrial project descriptions are made more precise, additional data on the radiological situation is made available and prognostic assessments become more accurate, then improvements in the existing regulatory documentation to support evaluation of proposed project options become urgent. The FMBA is confident it is moving in the right direction. Much of the work reported here has been new to those involved, and although no one can foresee all the problems in the future, there is growing confidence that the knowledge and experience obtained in cooperative activities promise a positive outcome from future Russian–Norwegian collaboration in the field of radiation protection regulation.

References

[1] Strategic master-plan 2004 Strategic approaches to the solution of problems of complex decommissioning of the Russian atomic fleet taken out operation in north-west of Russia, Review prepared for preliminary consultations with the community in Murmansk, Severodvinsk and in Moscow on November 22–26, 2004, p 28
[3] Hygienic requirements for safety and food value of foods Sanitary and Epidemiological Rules and Norms SanPiN 2.3.2.1078-01 Moscow 2002 (in Russian) p 168