REGULATORY SUPERVISION OF MANAGEMENT OF SPENT FUEL IN NORTHWEST RUSSIAN

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Spent fuel from Russian nuclear powered submarines has been stored at shore based facilities for more than 20 years, notably at Andreeva Bay and Gremikha in the Kola Peninsula of northwest Russia. The storage facilities were for some years poorly maintained and a significant fraction of the fuel is damaged. Over the last ten years or so, much work has been done to improve the infrastructure, prepare for recovery of the spent fuel and associated radioactive waste from temporary stores, and make arrangements for their further management. A similar situation has arisen concerning fuel from nuclear powered icebreakers, notably damaged fuel from the icebreaker Lenin, which is currently stored in the Lepse storage vessel. Preparatory work has been done with international and bi-lateral support. As a part of that support, the Norwegian Radiation Protection Authority has a substantial and long-standing regulatory cooperation program with Russian Federation counterpart authorities, particularly the Federal Medical Biological Agency of Russia. This paper describes projects organized within that program, with a focus on work at the Andreeva Bay site. The projects are designed to support an updated and improved regulatory basis for the management of the legacies mentioned above. The output covers a full range of radiation protection issues, including emergency preparedness and response, worker, public and environmental protection, site remediation, spent fuel and related radioactive waste handling, and overall optimization. Significant success has been achieved with the development of special procedures to address the abnormal conditions and circumstances of these legacies, and major spent fuel recovery is planned to begin in 2016.

I. INTRODUCTION

The industrial site at Andreeva Bay on the Kola Peninsula in the northwest of Russia was originally commissioned between 1961 and 1963 as a shore technical base for the servicing of nuclear powered vessels of the Russian Northern Fleet. Within the premises of this base, a basin-type wet storage facility (Building 5) was built in two steps, the first starting in 1962 and the second in 1973, for storing spent nuclear fuel (SNF). In February 1982, staff observed a falling water level in one basin. Subsequently, in 1984, removal of the SNF from the basins to dry storage was begun, and all subsequent SNF from scheduled re-fuelling was also consigned to dry storage. The stabilization of the situation in Building 5 lasted from 1982 to 1989, during which period about 700,000 tons of contaminated water was released into the Barents Sea. In 1989 the base ceased operation as a technical servicing base and received no further SNF or other radioactive waste (RW).

Due to a national directive, in 2000 responsibility for the site was transferred to Minatom, now called the State Atomic Energy Corporation, Rosatom. At the time, the condition of the facility's infrastructure did not fully meet the requirements for nuclear, radiation and environmental safety. The buildings and structures at the site were damaged or collapsed which made SNF and RW management extremely difficult. As a response to this, an enterprise dedicated to dealing with the situation was created, and the site was re-designated as the Site for Temporary Storage (STS) Andreeva Bay, a branch of Northwest Center for Radioactive Waste Management (SevRAO), part of the Federal State Unitary Enterprise for Radioactive Waste Management (RosRAO).

Today the facility stores 17,000 m^3 of solid RW, about 1000 m^3 of liquid RW, SNF from about 100 cores from nuclear submarines, and a further 5 thousand tons of solid radioactive waste collected from the contaminated areas of the site. The radio-ecological situation has been significantly improved, creating safe conditions for the personnel working within the site. However, according to an integrated expert evaluation of relevant assessment criteria, the industrial site of SevRAO has continued to be one of the most hazardous nuclear facilities in the Northwest of Russia [1]. Nevertheless, environmental rehabilitation of the site is in progress and, according to the schedule, final removal of the SNF is due to start in 2016. This progress has been supported internationally [2] mainly from the UK, Italy, Sweden and, with a strong regulatory focus, Norway, implemented via the Norwegian Radiation Protection Authority (NRPA).

II. INITIAL REGULATORY COOPERATION

Results of initial projects [3, 4, 5, 6] implemented thorough regulatory cooperation between NRPA and the Federal Medical Biological Agency of Russia (FMBA), the key authority with supervision over radiation safety at Andreeva Bay, have shown that the technical tasks involving management of SNF stored at the site involve considerable radiological hazards to personnel. In particular, a threat assessment [3] made from the perspective of regulatory supervision identified that hazards arise from the following conditions:

- Poor information on the radiological and physical condition of SNF and RW in facilities at the site, resulting in elevated risk associated with the operations to investigate and remove materials and complete decommissioning.
- Urgent movement of SNF from the above mentioned building to a dry storage facility that was not designed for this purpose.
- Presence of defective SNF assemblies.
- The presence of additional industrial buildings and structures used as temporary storage for RW that contribute to increased levels of man-made radionuclides and external radiation at the site.
- The need to develop and apply new technology and equipment, specifically designed for the management SNF and RW.
- The need to conduct several operations related to decommissioning and renovating old structures, and also constructing new facilities, e.g. for treating SNF and RW.
- Unsafe physical condition of a number of buildings and structures at the industrial site.
- The need to apply specialized personal protection equipment for protecting personnel during radiation-hazardous work in open areas and under adverse weather conditions.
- The need for utilising special protection for personnel handling SNF and other RW.
- Insufficient qualified workers.

Recognizing these issues, management of safety has become the overarching organizational goal of SevRAO. In order to achieve a high safety culture the basic general principles of radiation protection have to be fully adopted from all aspects and throughout the entire process. Based on international recommendations, e.g. the IAEA Basic Safety Standards [7], recommendations of the International Commission of Radiation Protection (ICRP) [8], and national legislation, notably Radiation Safety Standards NRB-99 [9], any activity that may result in radiation exposure of the workers or the public must be conducted according to three basic principles: Justification, Optimization, and the Dose Limitation. The Principle of Optimization dictates that resulting radiation dose (both individual and collective) should be kept As Low As Reasonably Achievable (ALARA). According to the combination of the principles of limitation and optimization the dose has to be lower than limits imposed by national regulation and internal policy, and should be further reduced as much as reasonable, taking into account economic and social factors. While the principle of limitation requires a simple comparison of estimated exposure limits to those applicable to the given situation, the other two principles require careful balancing of health, economic, technical, social and psychological consequences to find the optimal solution.

III. REGULATION OF OPTIMISATION

In addition to the principle of limitation, the principle of optimization should also be an integral part of the general safety culture of any enterprise. Good safety culture requires high preparedness, situation awareness (including self-awareness of responsibility), and a quality control system that takes into account all factors affecting overall quality of work. The principle of optimization must be applied at all stages of the life-cycle of a nuclear facility, starting with the design stage, and continuing during the operation and dismantling phase up until the final release of the site. Accordingly, the optimization process is meant to find the best balance between all relevant factors, significantly including the potential health consequences of exposure to radiation from activities, including:

- radiation exposure of personnel (workers) performing the work during planned situations,
- exposures of the public due to radioactive pollution released into the environment, including planned releases and disposal of solid radioactive waste resulting from the work activities performed, and
- radiation dose to the public resulting from accidental emissions.

The safety control system of any enterprise must have procedures for planning the work tasks with efficient ways of assessing the associated radiological risks. The system must also have procedures for preparing the personnel for performing the scheduled work tasks and emergency preparedness. Training programs for preparation of personnel need efficient techniques for communication of work plans, associated radiation risks and measures of protection for ensuring good situation awareness, i.e. understanding the plans, risks and safety measures, to the workers involved. Finally, the safety control system must incorporate efficient procedures for continuously monitoring radiation exposure to workers and the public during work execution, e.g. continuous, as well as, periodic and unscheduled monitoring, of work by team leaders and radiation protection monitors.

While the principle of optimisation plays an important role during training and monitoring of work, it has a particularly special role during work planning when alternative solutions are compared and analysed from various aspects. Application of optimisation has therefore been a significant feature of NRPA and FMBA regulatory cooperation activities. In 2008, the FMBA issued guidance on implementation of the ALARA principle at STS Andreeva Bay. These are described in Ref. [6]. According to this guidance, developed with the support of the Burnysian Federal Medical Biophysics Centre of the FMBA (FMBC), the optimization procedure should be a continuous process, initiated at the beginning of the preparation (planning, training, etc.) stage and continued throughout the implementation of the work plan up to the stage of results analysis and evaluation.

In the planning stage, when different options are considered, priority should be given to those options resulting in the lowest detrimental impact on workers, the public and the environment. Different options should be balanced taking into account dose restrictions and projected health consequences to the workers involved. Resulting dose and associated health implications should be assessed and analysed both for the whole team (collective dose) and at the individual level (personal dose). A whole team medical examination should be performed prior to the workers engaging in the planned activities for establishing control levels. Possible alternatives should also be balanced based on foreseen planned and possible accidental emissions and discharges of radioactivity impacting the public and the environment. Finally, options should be compared from associated from the perspective of economic, social and psychological implications.

In the assessment and comparison of different alternatives, among possible others, the following issues and data should to be considered:

- Lessons-learned, e.g. concerning projected and actual exposure levels, from previous or parallel activities in which radiological or other circumstances were similar and extrapolation of the results is possible.
- The required team composition (the number, desired expertise, and envisaged role of the team members) for each of the envisaged work steps.
- The availability of the human resources required over the different work periods, available staff, possibility of employees leaving during the process, options for employees who temporarily or permanently cease to be required, scope for acquiring staff with the missing skills, etc.
- Need for suitable communication tools between the team members, including communication with radiation monitors, in-the-field team leaders and supervisors in the control room.
- Scope for efficient (safe and cost/time effective) training of supervisors and field operators.
- Availability of the required tools and equipment (including grippers, manipulators, automation, etc.) in-house or on the market.
- Availability of suitable data for preliminary radiological characterisation of the targeted site, and possibility (safety and cost implications) for acquiring additional data for a thorough radiological characterisation of the site.
- Physical constraints, e.g. space required by large items of equipment and components, weight limitations, etc.
- Availability and costs of protection systems, e.g. physical radiation shielding, ventilation and air purification system, coating films, dust suppression devices, protective clothing, etc.
- Systems for monitoring worker reliability and task execution during the process ensuring efficient protection, without significantly deteriorating working conditions but within reasonable costs.
- Possibilities for ensuring good working conditions to the workers during the process, especially in the case of tasks that require working in dark, confined places, and in extreme temperature, noise and vibration levels.
- The most suitable organisation of the team (roles and responsibilities, chain of command) for achieving low risk and high efficiency.
- How to assess and handle uncertainties in available risk projections.
- What kind of permits and authorizations are required and how the dose can be controlled, etc.

Regulatory supervision by FMBA Regional Management №120, based on the guidelines elaborated by the FMBC and others, is designed to ensure full implementation of the ALARA principle within the remedial actions planned to be performed by SevRAO.

IV. ON-GOING REGULATORY DEVELOPMENT

Progress with industrial projects at STS Andreeva Bay, designed to provide for safe working conditions and prepare for recovery of the SNF and RW from the poor condition stores, has been matched by parallel development of additional necessary regulatory documents as well as further independent field investigations. These measures have addressed a full set of issues connected with nuclear and radiation safety ranging from special arrangements linked to the abnormal conditions at the site, including: emergency preparedness and response, control of discharges to the environment, protection of workers the public and the environment, and coherent regulation with other sites due to receive RW and SNF recovered and removed from STS Andreeva Bay. The program was set up as described in reference

[10] and has been further elaborated in specific aspects in references [11 – 15].

Key examples include the following.

- Adaptation of the databases on individual doses to workers and the radiation situation parameters to the practical work conditions at the site.
- Application of the information and analytical system for prediction of doses to workers corresponding to alternative operational plans.
- Hygienic requirements for management of industrial waste which is radioactively contaminated at very low levels.
- Requirements for radiation protection of workers, the public and environment during arrangement of RW management at the Center of Conditioning and Long-Term Storage, the SevRAO facility at Saida Bay, also located in the Kola Peninsula.
- Updated methodology for regulatory aspects of management of emergency planning and response, and related multi-organization training exercises.
- Development of an expert diagnostic informational system for monitoring risks to individual performance reliability for use at pre-shift and annual medical and psychological examination of workers involved in critical hazardous operations.
- Methods for safety culture assessment and regulatory actions in case of its reduced level.
- Re-categorization of nuclear materials as RW at the enterprises of northwest of Russia. Among other things, this provided an answer to the question, how small is a small fragment of SNF which is small enough not to be regulated as SNF.

Much of the work has been carried out in consultation with the military regulatory authorities, to ensure coherence of supervision as responsibilities are transferred from military to civilian authorities [Ref. 16], and with the Federal Environmental, Industrial and Nuclear Supervision Service of Russia (Rostechnadzor) whose focus is on nuclear safety.

To support the implementation of the above regulatory guidance and procedures, various software tools have been developed within the NRPA-FMBA regulatory cooperation program. These tools facilitate understanding of the radiation situation in the site and its environs and within buildings; planning and optimization of work tasks, and training the safe implementation of those activities. Their relevance and application is illustrated in the figures below and further described in Ref [15].

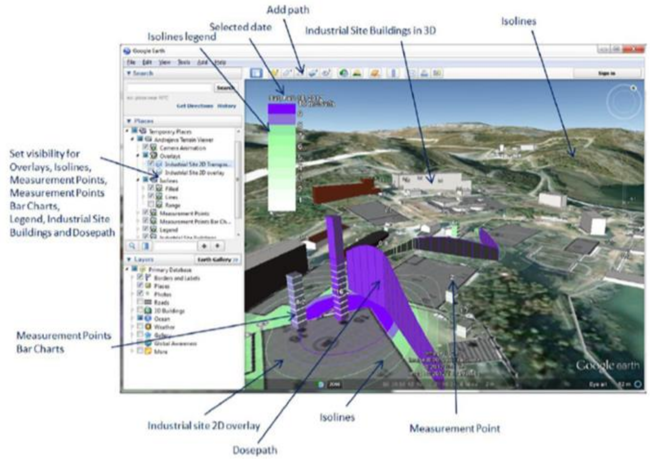

Fig. 1. Screenshot of Andreeva Terrain Viewer.

Fig. 2. Example of worker routes through STS Andreeva Bay.

Monitoring data are collected and input to generate an image of the radiation situation (Fig. 1) and dose rates for prospective routes can be used to calculate individual and collective doses linked to site movement of workers (Fig. 2).

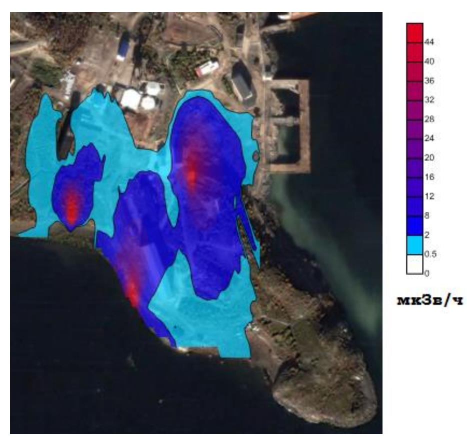

Fig. 3a. External dose rate at STS Andreeva Bay in 2012, μSv/h.

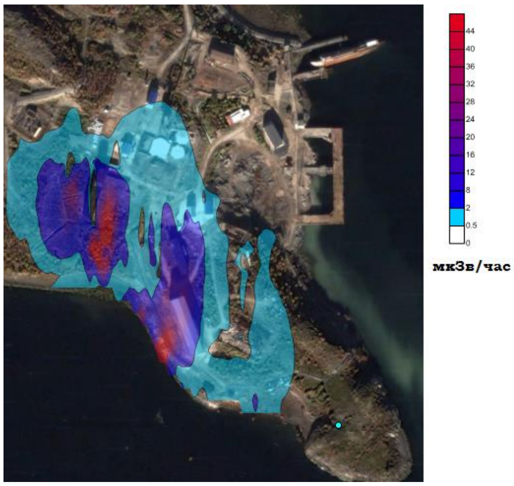

Fig. 3b. External dose rate at STS Andreeva Bay in 2013, μSv/h.

Figures 3 a and b show how dose rates are being reduced over the site, but it is noted that dose rates can be increased temporarily from time to time, especially during recovery work when shielding may need to be moved. The availability of the software tools linked to monitoring schemes makes dose control and optimisation much easier to manage. Similar arrangements apply inside buildings, see Figs. 5 and 6.

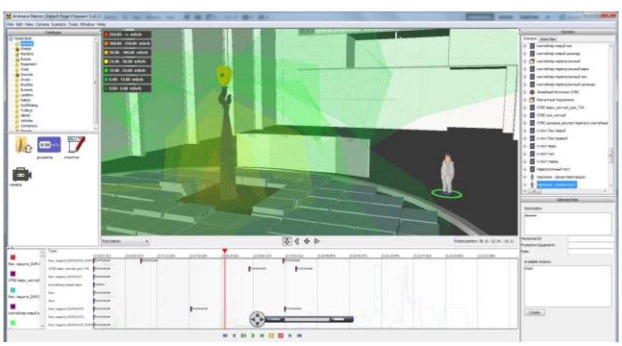

Fig. 4. Screenshot of Andreeva Planner.

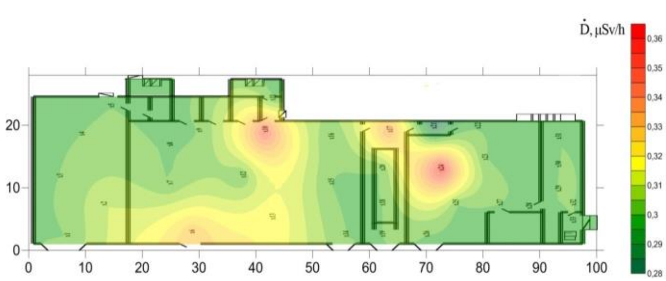

Fig. 5. Example illustration of visualization of radiation conditions inside a building.

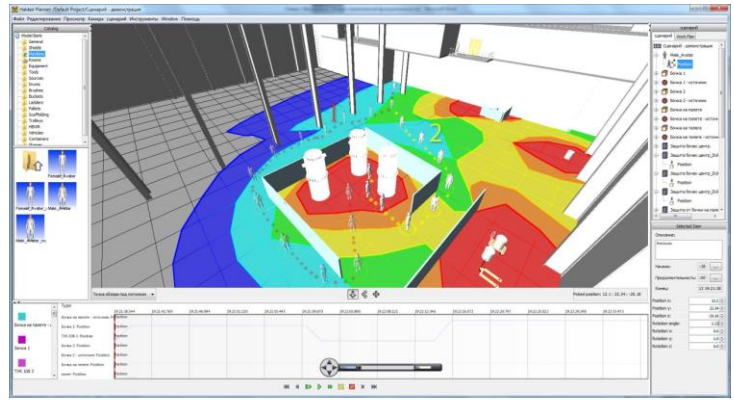

Fig. 6. Screenshot of the Andreeva Planner demonstrating application supporting classroom training.

III. NEXT STEPS AND CONCLUSIONS

The program of cooperation between NRPA and FMBA is planned to continue, notably over the period of time when the most hazardous SNF and RW recovery operations are due to take place at STS Andreeva Bay. The program is based on an updated regulatory threat assessment [17] that has taken account of progress with technical and infrastructure developments, and further definition of the plans for SNF and RW recovery, but also relevant updated international recommendations and guidance.

At the present time, the NRPA is also participating in an international review of regulatory documentation for the decommissioning of the Lepse SNF and RW storage vessel. This vessel also contains damaged SNF and RW in a poor condition, and is another recognized major radiation hazard in northwest Russia. As with STS Andreeva, the regulatory basis was also developed with international support [18].

Among the lessons learned from this cooperative work, the complexity of dealing with multiple safety issues simultaneously is one of the most important. There is little point, for example, in developing a strategy for management of legacy sites without there being a parallel strategy for managing the SNF and RW waste arising from that process, including their final disposal. Improved international guidance on how to balance short- and long-term safety, or worker and public doses and risks, could be very helpful. In the meantime, NRPA and FMBA have been very happy to share experience and learn from others engaged in legacy management activities, in the USA and elsewhere [Refs. 19 and 20]. Such cooperation, generating mutual benefit, is to be encouraged.

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