REMEDIATION
OF NUCLEAR AND RADIATION
LEGACY SITES
IN RUSSIA’S NORTHWEST:
AN OVERVIEW OF PROJECTS CARRIED
OUT AS PART OF INTERNATIONAL
COOPERATION

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List of abbreviations

CEA Alternative Energies and Atomic Energy Commission, France (Commissariat à l’énergie atomique et aux énergies alternatives)
CERS comprehensive engineering and radiological survey
EBRD European Bank for Reconstruction and Development
EIA environmental impact assessment
FSUE RosRAO Federal State Unitary Enterprise (FSUE) “Enterprise for Radioactive Waste Management RosRAO”
FSUE SevRAO regional division of the FSUE “Enterprise for Radioactive Waste Management RosRAO”
IAEA International Atomic Energy Association
IPPE A.I. Leipunsky Institute of Physics and Power Engineering
LRW liquid radioactive waste
LTSS long-term storage site
MNEPR Multilateral Nuclear Environmental Program in the Russian Federation
NDEP Northern Dimension Environmental Partnership
NEFCO Nordic Environment Finance Corporation
NIKIE T N. A. Dollezhal Research and Development Institute of Power Engineering
NII PMM Scientific Research Institute for Industrial and Naval Medicine of the Federal Medical-Biological Agency
NRC Kurchatov Institute National Research Center “Kurchatov Institute”
NRPA Norwegian Radiation Protection Authority
NWC SevRAO – Northwest Center for Radioactive Waste Management “SevRAO”
PA Mayak Production Association Mayak
PWR pressurized water reactor
RC reactor compartment
Rosatom State Atomic Energy Corporation Rosatom
RTG radioisotope thermoelectric generator
SFA spent fuel assembly
SMP Strategic Master Plan
SNF spent nuclear fuel

1 SevRAO is the legal successor to the Federal State Unitary Enterprise “Northern Federal Enterprise for Radioactive Waste Management” (FSUE “SevRAO”), regional division of FSUE “RosRAO.”
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Notes to the reader

1. The financial expenditures cited in this report are given in those currencies and those amounts in which they were originally given in the sources used to prepare the report. The amounts cited in Russian roubles, U.S. dollars, British pounds, and Norwegian kroner are supplied with euro equivalents in brackets, calculated using the currency exchange rates current at the time the Russian original of this report was being prepared (August 2014). Due to the substantial fluctuations of the exchange rates of various currencies to the euro during that period, however, the rates current as of August 10, 2014 were chosen (where RUR 1 was equal to €0.0205; $1 was equal to €0.745, £1 was equal to €1.2505, and NOK 1 was equal to €0.1194). Where the sources cited original euro amounts, these were left unchanged.

2. Slides from presentations used in this report have been rendered into English by the translator for the English version of the report.
INTRODUCTION

This report delves into issues related to the cleanup of nuclear and radiation legacy sites – or, if one were to more closely follow the Russian term, nuclear-and radiation-hazardous sites – in the Northwest of the Russian Federation. Historically, this was the region where in the 1960s and 1970s the Soviet Union deployed the main facilities to support the functioning of its nuclear-powered submarine fleet: onshore maintenance bases to provide submarine maintenance and shipyards to carry out repairs. Large amounts of spent nuclear fuel and radioactive waste – both solid and liquid – would be generated as a result of regular repairs and refueling operations. But while the spent fuel would mostly remain in storage facilities, from where it would subsequently be transported to PA Mayak, the radioactive waste was from time to time dumped into the Barents and Kara Seas. Altogether, some 17,000 tons of solid radioactive waste was buried at sea both in containers and without packaging.

Yet, buried or lost as a result of a sinking accident – as part of reactors, reactor compartments, or entire submarines – spent nuclear fuel would on a number of occasions end up on the sea bottom as well.

Buried in the Kara Sea among other objects carrying spent nuclear fuel were: a neutron shielding assembly with part of SNF from Reactor No. 2 of the nuclear-powered icebreaker Lenin, dumped in 1967 in Tsivolka Bay; the submarine K-27 (factory no. 601), with two reactors still loaded with SNF on board, buried in 1981 in Stepovoy Bay; the reactor compartment of the submarine K-452 (factory no. 901) with two reactors loaded with SNF and a barge with a reactor compartment containing two reactors (of which only the portside reactor contained SNF) of the submarine K-11 (factory no. 285), buried in Abrosimov Bay. In 1972, a lighter ship carrying the port reactor of the submarine K-140 (factory no. 421) was buried in the Novaya Zemlya Trench of the Kara Sea; this object has still not been found. Besides these, buried in the Kara Sea were the reactor compartment of the nuclear icebreaker Lenin, with no SNF on board; the reactor compartment of the submarine Leninsky Komsomol (or the K-3/B-3, factory no. 254) with two reactors; and the reactor compartment of the submarine K-5 (factory no. 260) with two reactors.
Additionally, SNF still remains on board of two submarines that went down as a result of accidents: the *K-278 Komsomolets* (factory no. 510), which sank in the Norwegian Sea in 1989, and the *K-159/B-159* (factory no. 289), which sank in the Barents Sea in 2003 [1]. The spent fuel of the *K-141 Kursk*, which sank in the Barents Sea in 2000, was retrieved when the submarine was raised in 2001 and unloaded for further handling in 2003 [2].

The Barents and Kara Sea region also received its share of radioactive contamination from the extensive nuclear bomb testing that was conducted in the Novaya Zemlya Archipelago. Altogether, 132 atmospheric, underwater, and underground nuclear test explosions were held here between 1955 and 1990. Two decades after the nuclear tests in the archipelago were ceased, background radiation levels at the range still exceeded the norm, while seabed sediments at the archipelago’s coastline revealed increased contents of cesium and plutonium, with plutonium showing the highest concentration across the Barents Sea [3].

As for the nuclear- and radiation-hazardous sites that were formed in Russia’s Northwest during the Soviet period, these, as Rosatom representatives and independent experts believe, can be ranged in the following order by the level of their danger: Andreyeva Bay, Gremikha, the nuclear service vessel *Lepse*, sunken submarines with SNF on board, and other nuclear maintenance ships.

One of the main events related to the nuclear and radiation risks in Russia’s North that have received international attention was the accident that developed in the early 1980s at the Northern Fleet’s onshore maintenance base in Andreyeva Bay, in the northwest of the Kola Peninsula. Base No. 569 in Andreyeva Bay, located 100 kilometers from Murmansk and just 45 kilometers from the Russian-Norwegian border, served as the largest storage site for the Navy’s radioactive waste and spent fuel. In 1982, the SNF storage facility at the base developed a leak; radioactive water started seeping from the cooling pool that contained spent nuclear fuel into the ground underneath the building, and from there into a small brook that took the water to Andreyeva Bay and further beyond, into the Motovsky Gulf of the Barents Sea. The accident was handled in two stages: the first stage in 1982 to 1983, the second in 1989. The Ministry of Defense, which had jurisdiction of the site in Andreyeva Bay at the time, eventually managed to stop the radioactive water from leaking into the Barents Sea, but the enormous amounts of spent nuclear fuel and radioactive waste that were still in storage in the facilities of the base remained a concern for the public, especially in Norway.
In 1993, the problem of Andreyeva Bay captured the attention of the international environmental non-governmental organization Bellona. In March 1993, the Norwegian daily *Aftenposten* broke the story about the accident [4]. In Russia, official information about what had happened in Andreyeva Bay was likewise only made public for the first time 11 years after the accident, in an April 1993 report by a government commission which was headed by prominent environmentalist Alexei Yablokov and worked with issues related to the radioactive waste dumped at sea [5].

More details on Andreyeva Bay, including data on the environmental condition of Base No. 569, came in Bellona’s reports “Sources of Radioactive Contamination in Murmansk and Arkhangelsk Regions” (1994) [6] and “The Russian Northern Fleet: Sources of Radioactive contamination” (1996) [7]. At the time, all information about the base in Andreyeva Bay was classified, and a lot of data published in the reports was insufficiently accurate. (Bellona later published a report about the accident and the measures undertaken to deal with it that was based, in a large part, on the first-hand account of one of the participants of the cleanup operation). Norway expressed utmost concern about the situation in Andreyeva Bay, since the base was situated quite close to the Norwegian border. Assistance was offered in handling the accident, however, the site was under the command of the Russian Navy, and access to the base was closed to civilians. The Russian government subsequently acknowledged the dangerous situation that had formed in Andreyeva Bay and the need for environmental rehabilitation of the territory. In 2000, a government decree transferred several bases that were at the time managed by the Russian Navy – including the base in Andreyeva Bay – into the jurisdiction of the Ministry of Atomic Energy, the predecessor agency to today’s State Corporation Rosatom.

The attention of the international community that the Bellona Foundation succeeded in marshaling to the nuclear problems of the Russian Northwest more than twenty years ago was what largely paved the way to the decision by a number of foreign nations to play a role in the dismantlement of the nuclear legacy of the Soviet past and start allocating funds to projects in Andreyeva Bay, Sayda Bay, and Gremikha, decommissioning nuclear submarines, the service vessel *Lepse* and other nuclear maintenance ships, etc.

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2 The Bellona Foundation was founded in 1986 in Oslo (Norway). The foundation operates a main office in Oslo and three international offices: in Brussels, in Belgium/EU, and in Murmansk (Bellona-Murmansk) and St. Petersburg (the Environmental Rights Center Bellona) in Russia.
This report also describes in detail the primary nuclear and radiation legacy sites in Russia’s Northwest: what they held and how dangerous they were or continue to be today for human and environmental well-being. The report also contains information about what has been done to date to reduce these hazards and what remains to be done still.
ANDREEVA BAY

Background

The most dangerous nuclear- and radiation-hazardous site in the Russian Northwest is the onshore maintenance base in Andreyeva Bay, which was built and commissioned in 1961 to 1964. The main responsibilities of the site included taking delivery of, storage, and further shipping of spent nuclear fuel to PA Mayak for reprocessing, as well as receiving and long-term storage of radioactive waste. A cooling-pool-type storage facility, Building No. 5, was built at the base to store spent nuclear fuel. The first stage of the storage building was taken online in 1962, and the second in 1973. Structurally, the storage facility consisted of two concrete rectangular chambers (cooling pools) 6 meters deep. The volume of water was around 600 cubic meters in the cooling pool of the first construction stage (right and left sections), and around 1,400 cubic meters in the second-stage pool (right and left sections).

Spent fuel was stored in the pools under a protective layer of water – using the so-called “wet” storage method – in casks holding five or seven spent fuel assemblies. The layer of water between the pools’ water surface and the fuel-containing sections of the fuel assemblies was four meters thick, which served to protect the personnel from radiation hazard. Water both filled the cooling pools and was in immediate contact with the fuel assemblies in the storage casks. The cantilevers from which the casks were hanging protruded above the water surface. The casks were held underwater by chains fastened to the cantilevers in a particular geometrical grid pattern at a specified spacing. Such a construction kept the casks at the needed distance between each other and thus provided nuclear safety by ensuring that a spontaneous nuclear fission reaction would not develop in the pools. Sometimes, during transportation operations, a chain banging accidentally against one of the cantilevers would force the cask being moved to break free from its suspension and tumble to the bottom of the pool. The eventual result of this was heaps of casks loaded with spent nuclear fuel lying at the bottom of the pool.

The designed holding capacity of the storage facility was around 2,000 casks, but in later years, as spacing between the casks in the second-stage pool was reduced to allow for more compact arrangement of casks with SNF, the building’s storage capacity was increased to 2,550 casks (around 550 and 2,000 casks stored in the pools of the first and second stages of construction, respectively). Increasing
further the number of spent fuel assemblies in storage at the facility was ruled impossible from the point of view of ensuring nuclear safety [8].

In 1982, a major accident developed at the base in Andreyeva Bay.

In February 1982, base personnel registered a reduction in the level of water in the right-hand pool of the Building No. 5 storage facility. The leakage was initially some 30 liters a day. By April 1982, the leaks had reached 150 liters a day, the background gamma radiation level on the outer wall, where a layer of ice had built up, was 15 mSv/h, the soil in the facility’s basement showed a radioactivity level of around 7 \(10^8\) Bq/l, and the brook near the building, around 7 \(10^6\) Bq/l. By the end of September 1982, leakage from the damaged right-wing pool had increased to 30 tons a day. This brought a very real risk of the top ends of the spent nuclear fuel assemblies in the pool losing their protective layer of cooling water, which meant a direct threat of radiation exposure to the personnel as well as of radioactive contamination of the entire adjacent basin and the estuary of the Zapadnaya Litsa River. In order to protect against gamma radiation, a proposal was made to blanket the right-wing pool with slabs of iron, lead, and concrete, and later move the SFAs held in the pool into dry storage.

On October 5, 1982, a plan of first-response measures was approved, in which building the biological shield over the right-hand pool was listed as the primary item.

In November 1982, work started to build the iron-lead-concrete shield over the right-hand pool. The huge weight of the slabs, however, likely caused the building’s structure to warp or sag sideways and thus triggered another leak, this time in the facility’s left-hand pool. Within one week, the leakage from the left pool jumped up to an average rate of 10 tons a day at a specific activity of 1÷2 \(10^7\) Bq/l. By December 1982, construction of the shield over the right-hand pool had been completed, but by then all the water from the pool had drained into the bay. In the left-hand pool, the leak continued on average at a rate of around 3 tons a day and then increased gradually, reaching over time some 350 to 400 tons a day. In order to keep the water in the pool at the four-meter mark – the minimal level required for safety – water had to be pumped into the pool from the boiler house using fire hoses.

On February 14, 1983, a special commission envoyed by the Ministry of Defense arrived in Andreyeva Bay and ordered to discontinue any further use of
the storage facility. A decision was made to urgently relocate the spent fuel from Building No. 5 into vacant tanks that had been initially meant to be used for liquid radioactive waste. The three 1,000-cubic-meter tanks had to be retrofitted into dry storage units. These dry storage units were thought to serve as a temporary storage solution for the SNF until a new storage facility was ready to receive it, which was being designed by Minatom organizations but was never eventually built. The tanks were equipped with steel pipes that were installed inside and welded into a rebar grid. These pipes were to serve as a kind of cells, holding spent fuel assemblies from the damaged cooling pools. For reasons of nuclear safety, the pipes stood at a particular interval from each other, and the space between them was filled with concrete.

In November 1982, retrofitting work began on the first tank of the would-be dry storage units, Tank 3A. In June 1983, Tank 3A was put into service. In that same period work started to unload spent fuel from the left-hand pool. This work was completed in January 1984. Altogether, over 1,114 casks with SNF – no fewer than 7,500 spent fuel assemblies – were retrieved from the left pool. Some of the casks were found lying at the bottom of the pool and were lifted. Around 70 casks, however, proved impossible to lift, and a decision was made to pull these piles of casks apart, spreading them out across the pool floor, to eliminate the risk of a spontaneous chain reaction. As they were being moved, those casks that were not too badly damaged were ultimately lifted as well and taken out of the pool, but 25 casks that had sustained significant damage were left lying in the left-hand pool until 1989. The bulk of the SNF was then relocated to the retrofitted Tank 3A (900 casks), with some of the spent fuel shipped off to PA Mayak.

The second phase of the unloading operation was carried out in 1989. During this stage, the protective shield over the right-hand pool was dismantled, the left-hand pool was completely drained, and the rest of the spent nuclear fuel that remained in Building No. 5 – some 1,500 casks (including the 70 casks in the left-hand pool) – was moved from the storage facility. All of the casks with spent fuel assemblies that had fallen to the bottom and were damaged (no fewer than 120) were retrieved during these works. Still, a number of damaged spent fuel assemblies, along with the fuel that had spilled out of them, remained at the bottom of the pools.

The process of reloading spent nuclear fuel from Building No. 5 into dry storage units was finished on December 13, 1989. It should be noted that the new,
dry storage facility could only be used to store spent fuel that had sat for a prolonged period of time in wet storage facilities – Building No. 5 or floating maintenance facilities – and whose decay heat had decreased significantly. The dry storage tanks now held all the spent fuel from the distressed Building No. 5, as well as, starting in 1984, the spent fuel assemblies that were unloaded from submarine reactors as part of routine refueling operations.

In 1994, information about the radiation situation in the areas of deployment of the Northern Fleet’s bases was first made public. The highest levels of contamination were found at Base No. 569 in Andreyeva Bay [6].

At this time, altogether 3,059 casks with spent nuclear fuel – or around 23,000 spent fuel assemblies – are in storage in dry storage tanks in Andreyeva Bay. The most unpleasant fact is that during the reloading operation, when the spent fuel was being moved from Building No. 5 to the dry storage units, the record-keeping system used to keep track of the SNF in storage was allowed to lapse, and information on the quantity and condition of the spent fuel assemblies was lost. The inaccuracies in the data on the fuel kept in dry storage in Andreyeva Bay may affect nuclear and radiation safety during its further relocation. The last delivery of spent nuclear fuel from nuclear service ships to the base and preparation for shipment to PA Mayak took place in Andreyeva Bay in 1993. After that, the base was mostly responsible for taking delivery of radioactive waste for storage on its territory.

As for the radioactive waste, before the beginning of remediation work at the base solid radioactive waste was kept in the storage facilities of Building No. 7 and at the open-air storage sites. Some of the high-level SRW was held in two tanks meant for storage of liquid radioactive waste in Building No. 6 – the former storage facility for reloading equipment. The exact composition and radioactivity levels of the SRW are unknown. The dose rate near the structures of Building No. 7 would reach 3 mSv/h. Liquid radioactive waste was stored in the designated LRW storage facility – in four tanks of Building No. 6; in an LRW storage tank of Structure 2C; in the basement of Building No. 6; in Tanks 2A, 2B, and 3A of the SFA dry storage units (due to atmospheric precipitation penetrating the dry storage units, the water collecting in the tanks had itself over time turned into liquid radioactive waste); in sections of the subsurface SRW storage facilities. The overall amount of radioactive waste in Andreyeva Bay was about 25,000 cubic meters of solid waste and some 50,000 cubic meters of liquid waste. But the exact
amount of radioactive waste stored on the territory of the base is rather difficult to
determine, since many of the buildings (especially Building No. 5), the wharf,
which was used to receive SNF and radioactive waste from nuclear maintenance
vessels, the soil contaminated with radionuclides, etc., are also solid radioactive
waste.

The report “Nuclear Andreyeva Bay” [8], published by Bellona in 2009,
contains the following data on radiation levels on the territory of Base No. 569: at
the outer surface of the walls of Building No. 5, the equivalent dose rate is as high
as 20 mSv/h. Samples of concrete and brick from the building’s walls and
foundation reveal specific activity levels of $3 \times 10^8$ Bq/kg for cesium-137 and
$1 \times 10^9$ Bq/kg for strontium-90. The stream of the brook flowing from under
Building No. 5 was contaminated to a depth of 1 meter. The dose rate along the
brook reached 450 $\mu$Sv/h, and activity levels of cesium-137 and strontium-90 in
the soil, $6 \times 10^6$ and $4 \times 10^6$ Bq/kg, respectively. The specific activity levels of bed
sediments where the brook flowed into the bay was up to 300 Bq/kg. Certain spots
at the bottom of the cooling pools of the storage facility of Building No. 5 showed
background gamma radiation readings of up to 600 mSv/h.

In 1997, information came from the Navy that a radioactive brook had been
discovered that they said ran from under Building No. 5 and into Zapadnaya Litsa
Bay. The source of the brook could not be identified, and a decision was made to
divert it and dam it up. The Norwegian government offered Russia its help
providing funds for eliminating the brook. Implementation of the project had its
difficulties since at the time, the Russian Ministry of Defense was not willing to
grant international experts access to the site in Andreyeva Bay. Despite these
impediments, Norway’s Ministry of Foreign Affairs in 1998 reached a decision to
earmark some $817,000 (€609,000) to improving the radiation situation on the
Kola Peninsula and, first and foremost, the project of containing the radioactive
brook [8]. As a solution to the brook problem, a suggestion was made to dig a
trench along the perimeter of Building No. 5 in such a way that it would block the
stream. The project was completed at the end of 1999, and succeeded in stopping
radioactive discharges into the bay. Altogether, some 3,000 cubic meters of liquid
radioactive waste had found its way into the bay. All the work on the project was
carried out by the Russian side. Norway received a report on the work performed
by way of photographs.
On May 28, 1998, the Government of the Russian Federation issued Decree No. 518 “On measures of expediting decommissioning of nuclear-powered submarines and surface ships with nuclear propulsion systems retired from the Navy and environmental rehabilitation of radiation-hazardous sites of the Navy,” in accordance with which Minatom was to assume jurisdiction over several onshore sites transferred from the Ministry of Defense and start working on comprehensive decommissioning of nuclear submarines taken out of service and remediation of onshore sites. By Order No. 200-r of the Government of the Russian Federation, of February 9, 2000, Base No. 569 in Andreyeva Bay was, among other naval sites, transferred into Minatom’s care. That same year, in order to prepare for and execute decommissioning and remediation work at the onshore sites, a special new structure was founded in Murmansk, FSUE SevRAO, a division of the central FSUE “Enterprise for Radioactive Waste Management RosRAO”; and in the closed administrative territorial entity Zaozyorsk, SevRAO Branch No. 1 was created to carry out decommissioning and remediation work at the naval base in Andreyeva Bay (today, Andreyeva Bay branch of NWC SevRAO).

Andreyeva Bay was opened for access by foreign donor countries. Great Britain, Norway, and Sweden expressed their willingness to participate in the environmental remediation of Russia’s former naval maintenance bases. In 2000, SevRAO began the procedure of assuming administration of the Navy’s onshore maintenance bases in Andreyeva Bay and Gremikha. All the formalities involved in the transfer of the bases from the Northern Fleet were completed in 2001.

Andreyeva Bay is the only place in Russia where such an enormous amount of spent nuclear fuel (unloaded from approximately 100 nuclear submarines) and radioactive waste has been accumulated and remains in storage and where, in addition, there is no reliable information on the number and condition of the spent fuel assemblies in storage. These two factors account for the specific nature of performing environmental rehabilitation work on the territory of the former base. At the time when Base No. 569 was being transferred into the management of Russia’s civilian nuclear authority, the base’s infrastructure was almost entirely in

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3 Known under the Russian abbreviation ZATO, “closed administrative territorial entities” are restricted-access single-industry towns used for classified military or nuclear research and manufacturing. They were created by the top Soviet authorities in the mid-20th century as part of the USSR’s atomic bomb project, a kind of “reservations” for the country’s scientific community to conduct highly sensitive research and production. Rosatom currently lists 10 ZATOs under its purview. Many other such towns are administered by the different branches of the Ministry of Defense, including several naval bases. – Translator
disrepair: there was no heating and no water supply, no sewerage; power supply was intermittent. Physical security was close to non-existent. Because the buildings and structures were severely contaminated with radioactive substances and were also in a general state of dilapidation, the surrounding environment was subjected to significant contamination as well: The accumulated radionuclides would be washed out by precipitation, carried into groundwater, and transported in air. At the time of the transfer into Minatom’s jurisdiction, the most contaminated sites in Andreyeva Bay were the former SNF storage facility (Building No. 5), the dry storage units (Tanks 2A, 2B, and 3A) and the area around them, the storage facility holding solid radioactive waste (Tanks 7A, 7B, 7F, 7D in Building No. 7), and the storage facility holding liquid radioactive waste (Building No. 6). Spent nuclear fuel was stored in casks kept in dry storage cells as well as in transport containers.
International cooperation

In 2002, at a summit in Kananaskis, Canada, representatives of the Group of Eight countries adopted a program called “Global Partnership against the Spread of Weapons and Materials of Mass Destruction.” Within the framework of this program, the United States, Germany, Italy, Great Britain, and other nations agreed to provide Russia $20 billion over the next 10 years ($10 billion earmarked by the United States and the other $10 billion by other Group of Eight members) toward reducing the threats posed by biological, nuclear, and chemical weapons [9]. The program envisaged decommissioning of nuclear submarines, environmental remediation of nuclear legacy sites, repatriation of spent nuclear fuel used in research reactors, setting up physical security at legacy sites, inventorying and ensuring control of nuclear materials, decommissioning RTGs, etc. In later years, the program was expanded to include raising nuclear submarines and other nuclear- and radiation-hazardous objects submerged at sea. The three largest and most important sites of those encompassed by the program are on the Kola Peninsula: the former naval bases in Andreyeva Bay and Gremikha and the radioactive waste management center under construction in Sayda Bay.

In 2012, the Global Partnership program came to a close; a lot had been accomplished. But already a year before, at the Group of Eight 2011 summit in France’s Deauville, participants had confirmed that international cooperation would continue and that funding would continue to be earmarked to projects as well. Bilateral agreements had been concluded between Russia and the Global Partnership members that envisaged continued work on the projects started until they were seen to completion. The Russian Federation provides material support to Global Partnership activities via funding allocated from the state budget under the Federal Target Program “Industrial disposition of weapons and defense equipment of the nuclear complex for 2011-2015 and for the period until 2020” and FTP NRS 2008-2015. For the FTP NRS 2008-2015, RUR 150 billion (€3.08 billion) was allocated from the state budget. Under the FTP NRS 2016-2020, the Russian government allocated RUR 57 billion (€1.17 billion) toward decommissioning nuclear submarines and rehabilitation of radiation-hazardous territories.

In October 2002, Bellona arranged a visit to Murmansk, Andreyeva Bay, and the Shiprepairing Yard Nerpa for a delegation of European Parliament members so that they could acquaint themselves first-hand with the situation at the sites [10].
In 2002, a comprehensive radiological survey of the territory of Andreyeva Bay was conducted by NIKIET specialists with the financial support of the Norwegian Radiation Protection Authority (NRPA). In particular, extremely high levels of background gamma radiation were registered at the old pier – up to 460-1000 µSv/h, as well as Building No. 5 and the stream bed of the old brook. Maps of radiation fields inside Building No. 5 were charted.

In 2003 to 2004, inventorying work was done to determine the specific categories and radiation parameters of the solid and liquid radioactive wastes at the base. It turned out that there was three times as much solid radioactive waste in Andreyeva Bay as was stated in official documents. This work was carried out with the support of the Norwegian and Swedish governments [11]. In 2005, a radiogeological survey of the territory was performed as well.

State Corporation Rosatom started its work in Andreyeva Bay in 1999 by building a roof over the dry storage units; the roof was completed at the end of 2004. The roof was expected to help reduce penetration of water from atmospheric precipitation into the dry storage tanks.

Beginning in 2000, bustling construction work was rolled out in Andreyeva Bay, building the new infrastructure needed for the area’s environmental remediation: personnel decontamination stations, roads, an administration and amenities complex, check points, guard houses, power lines and water pipelines, a sewage system, canteens, and many other sites and utilities. All this was mostly being built with the funding provided as international donor aid coming from Norway, Great Britain, Sweden, and other states. Russia’s budget allocations were primarily spent on the maintenance of Andreyeva Bay and Gremikha, and the international aid on creating the infrastructure needed for subsequent waste disposal.

In November 2003, a briefing was held with participation of representatives of the British side, where plans for first-priority works in Andreyeva Bay were put together. In 2003 to 2004, a Coordinating Group for Andreyeva Bay problems was formed that included representatives of State Corporation Rosatom, a number of Russian organizations, and donor countries – Great Britain and Norway. A decision was made that it was necessary to develop a master plan (see Pic. 1) for Andreyeva Bay. In 2005, VNIPRIET set to developing a justification of investment
document for the international project of environmental rehabilitation of the former Base No. 569.

For a number of reasons, however, the environmental remediation plan developed for Andreyeva Bay in 2004 was not carried out within the time frame that was initially set for it.

In 2003, work started on developing a Strategic Master Plan (SMP) called “Expediting threat reduction in the Russian Northwest” (see Pic. 2). The idea behind creating the SMP was for it to serve as a kind of a benchmark when putting together the FTP NRS 2008-2015, to provide guidelines for making strategic decisions, determining specific areas of work and specific sites for the international cooperation to focus on, as well as selecting priority projects for funding allocations. The SMP was also intended to help donor countries assess the efficiency of implementation of various projects. This work was financed by the EBRD. Decommissioning and remediation work at all sites was expected to be completed by 2025. In accordance with the SMP, 48 projects were slated for implementation in Andreyeva Bay to a total cost of around €550 million. The expenses for the implementation of the SNF and radioactive waste management project was to total RUR 24.7 billion (€506.4 million) over 15 years. The result expected from rehabilitation work in Andreyeva Bay is a brownfield – i.e., no buildings, structures, or storage facilities contaminated with radionuclides are to remain in place of the former base, but no land restoration and soil removal are planned [12].

NIKIET and NWC SevRAO signed contracts with RWE NUKEM that included developing a project for the construction of a building to house an SNF storage facility, developing an SNF handling technology, creating conditions for safe storage and management of SNF kept in the dry storage units, and developing radiation safety measures when carrying out these works. Aside from building new infrastructure sites in Andreyeva Bay, work started on repairing those of the old buildings and structures that were expected to be needed still for further use or demolishing those that were deemed no longer useful.
In 2005 to 2006, a first comprehensive engineering and radiological examination was conducted of the operations hall and cooling pools of Building No. 5. In the decade and a half since all the damaged spent fuel assemblies had been unloaded from the cooling pools in 1989, no one had set foot into the former storage facility. No one knew what remained at the bottom of the cooling pools. A team of NIKIET specialists descended into the drained pools via openings in the protective slab that had been used during the accident cleanup operation for SNF removal and took measurements.

The level of background gamma radiation at the bottom of the pools was 100 mSv/h, climbing to 200-600 mSv/h in certain spots. The level of specific activity of corrosive sediments on the pool floor was up to $3 \times 10^8$ Bq/kg for cesium-137 and $7.5 \times 10^8$ Bq/kg for strontium-90, and the specific activity of alpha-emitting radionuclides was up to $7.5 \times 10^4$ Bq/kg.

In 2010, a detailed examination of all the pools – the two large ones and the two smaller ones – was carried out. For this operation, a special set of equipment had been devised: A gamma ray spectrometer and four gamma dosimeters had been placed on a remote-controlled cart; the cart moved across the bottom of the pools and took readings. A gamma radiation scanner and a device for taking samples of the floor sediments were also used. Several spots with high background radiation levels were detected at the bottom of the right-hand pool, which implied there were spent fuel assemblies, or assembly fragments, in those places. Based on the findings of the survey, the location of six spent fuel assemblies that had not been previously extracted was conclusively identified. NIKIET-developed technology makes it possible to carry out hands-free retrieval of SFAs or SFA fragments remaining on the pool floor and place them in protective containers. It is expected that, when the six SFAs discovered in the pool have been removed, background gamma radiation levels will drop in the facility, and perhaps fragments of other spent fuel assemblies may be found in the pool as well [11].

In 2006, an examination was also conducted of the dry storage units where SNF from the pools of Building No. 5 had been relocated. The survey of the dry storage tanks revealed that all the SFA-holding cells of Tank 2B were filled with water; the specific activity of the water reached $10^8$ Bq/l. Water was also found in the SFA cells of Tank 3A, and the gamma dose rate under the concrete slabs was measured at 40 mSv/h.
In 2006 as well, a CARTOGAM gamma imaging system was purchased that helped identify the most radiation-hazardous spots inside the structures located on the territory of Base No. 569 and in the areas where containers with high-level radioactive waste were held [11].

Bellona was at work keeping a close track of all the developments in Andreyeva Bay, studying the information that was being made available and taking part in the various events that took place as part of the rehabilitation efforts at the former naval base. Additionally, Bellona, jointly with State Corporation Rosatom, would regularly organize working seminars to discuss issues of nuclear legacy cleanup in the Russian Northwest in general and in Andreyeva Bay in particular.

In October 2006, a public hearing was held in Murmansk focused on the justification of investments into the SNF and radioactive waste management infrastructure to be developed in Andreyeva Bay. An Environmental Impact Assessment report developed as part of the justification of investment procedure was presented at the hearing [13]. Information was given at the hearing that in accordance with the Master Plan, the total time frame for the construction of the infrastructure (roads, personnel decontamination stations, boiler houses, garages, the physical security system, etc.) was projected to be 51 months.

In early 2007, a long-term timetable of works planned for Andreyeva Bay was prepared in order to facilitate working out budget projections, planning of expenses, and preparation of the needed resources. Talks began with the EBRD regarding funding for works that would be involved in decommissioning and disposition of Building No. 5, and in October 2007, an agreement was signed with the bank for the first stage of the planned works – decommissioning Building No. 5.

At the end of 2007, State Corporation Rosatom announced a tender to select a head contractor to carry out works involved in creating spent fuel and radioactive waste management infrastructure at the former naval base. The commissioning date for the infrastructure sites related to SNF management was set for 2012. Funding was to be coming from extrabudgetary sources. Under the international agreement called MNEPR, or Multilateral Nuclear Environmental Program in the Russian Federation, construction of Building No. 154/155⁴ was planned using

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⁴ Building numbers are given as per the numbering used in the project developed by VNIPIET.
funding provided by Great Britain under the Global Partnership program in the amount of $750 million (€559 million) [8]. Building No. 154/155 is intended for the decontamination and repairs of equipment used in SNF handling operations.

As of the end of 2007, the preliminary cost estimate for all sites in Andreyeva Bay totaled RUR 8.8 billion (€180.4 million). VNIPET was assigned the chief engineering responsibility for designing the SNF and radioactive waste handling complex in Andreyeva Bay and was in early 2008 given technical requirements to develop a detailed design for the construction of the future SNF handling complex. NIKIET was chosen as the scientific supervisor. Assembling Building No. 153 (the enclosure building over the dry storage tanks) was to become the first and main stage of the project. Horizontal shielding was to be installed over all the tanks that was to perform two functions: first, it had to ensure safety while building the enclosure structure and, second, it was to allow the reloading machine to prepare the cells for SNF extraction and then perform the actual extraction of the spent fuel.

In May 2008, a meeting was held in Murmansk to discuss the progress of the Strategic Master Plan [14]. It was noted that some of the work to reduce the nuclear and radiation threats in the Russian Northwest had already been accomplished: In particular, a storage facility for non-reprocessable spent fuel from nuclear icebreakers had been built and commissioned on the territory of Atomflot; 100 nuclear submarines had been dismantled (at the time of the meeting, of all the nuclear submarines under decommissioning only 15 were left still to be dismantled); 140 reactor cores of decommissioned submarines had been taken out of the region. In Andreyeva Bay, an engineering and radiological survey had been performed, and in Gremikha, a site for reloading of spent submarine reactor cores had been restored. As of 2007, donor countries had spent some $50 million (€37.3 million) on sites in Andreyeva Bay. Total investment expenses for the building and operation of Andreyeva Bay’s infrastructure were to amount to RUR 13.5 billion (€276.8 million).

At the time, the total cost of nuclear legacy removal in Russia’s Northwest was estimated at €2 billion. In preliminary assessments, around €600 million of this is to be spent on Andreyeva Bay. Funding for the work carried out at the former naval base is allocated from the Russian budget and from donor countries – as funding provided jointly by Norway, Sweden, Italy, Great Britain, and France. Great Britain’s area of responsibility is SNF management, Norway’s is
infrastructure, Italy is responsible for the solid and liquid radioactive waste, and Sweden for solving the problem of low-level radioactive waste, public relations, and personnel training in the standards and rules of radiation safety.

In October 2008, Bellona held a seminar in St. Petersburg [15] where participants summarized some of the results of the work done in Andreyeva Bay over the past years and reviewed plans for the future.

In 2009, Bellona published its report “Nuclear Andreyeva Bay” [8], which provided a detailed account of the accident in Andreyeva Bay and described the radiological conditions at the former naval base as they were at the time the report was being prepared. The report also stated Bellona’s position on the technical, technological, and economic decisions made with regard to the situation at the base.

In November 2010, Frederic Hauge, President of the Bellona Foundation, visited Murmansk on an official invitation extended by the Murmansk Regional Duma. The discussions held during the meetings there spanned a range of environmental issues as well as those of nuclear and radiation safety in the region [16]. (The first visit by Bellona representatives to the Kola Peninsula had taken place as early as 1989, and the foundation’s Murmansk office was opened in the early 1990s). Frederic Hauge had previously visited the Kola Peninsula in the fall of 2002, when Bellona brought a delegation of European Parliament members to the region so that they could familiarize themselves onsite with the Cold War legacy in the Northwest of Russia. This was followed by allocation of funds by foreign countries toward addressing nuclear and radiation safety problems in Russia, with Murmansk Region assigned a dedicated budget line. Securing foreign donor aid was the result of the efforts that Bellona had undertaken to attract the global community’s attention to the problems of nuclear safety in the region. This is what made possible the work done on the dismantlement of decommissioned nuclear submarines or the expensive projects started on the nuclear maintenance vessel Lepse as well as in Andreyeva Bay, Sayda Bay, Gremikha, etc.

In September 2011, the base in Andreyeva Bay was visited by representatives of the Public Council on the Safe Use of Atomic Energy in Murmansk Region [17].

In February 2012, participants of a joint seminar held in Moscow by Bellona and State Corporation Rosatom [18] discussed the status of nuclear- and radiation-
hazardous sites in Russia’s Northwest and prospects of solving the issues at hand. It was noted that within the ten years that had passed since the start, in 2002, of the Global Partnership program, a vast array of work had been accomplished remediating these legacy sites, and this especially was manifest in the area of submarine decommissioning: 47 one-compartment reactor compartments had been prepared and parked at the reactor compartment long-term storage site in Sayda Bay, and over 50 tons of spent fuel shipped off to PA Mayak. In addition, 23 infrastructure sites had been taken online. Russia’s foreign partners had allocated RUR 40 billion (€820 million) to various projects, with Russia itself providing about RUR 20 billion (€410 million). Norway’s annual contribution was around €10 million.

Discussed during the seminar were also the status of works under way at the former naval base in Gremikha (closed administrative territorial entity Ostrovnoy), the creation of a regional center for addressing the problems of radioactive waste management and nuclear service ship dismantlement in Sayda Bay, and the implementation of the dismantlement project of the floating maintenance base Lepse. Attention was also given to the issues of surveying the objects sunken or buried in the Kara and Barents Seas, objectives set in the area of enhancing nuclear and radiation safety in the Russian Northwest for the period until 2020, etc. Besides Russia, funding for work carried out in Andreyeva Bay was being provided by Norway, Italy, the United States, Great Britain, Sweden, the European Commission, and the EBRD. It was noted that the works slated in Andreyeva Bay as per the plan approved in 2005 (see Pic. 1) were slipping approximately two years off schedule. In 2010, the retrofitted special-purpose tanker Serebryanka had taken the first shipment of reprocessable SNF out of Gremikha and to an accumulation pad at Atomflot, and in 2011, the first batch of solid radioactive waste had been shipped to Sayda Bay. In Andreyeva Bay, preparations were under way to start operations with radioactive waste and begin implementing the main project: extraction of spent nuclear fuel from the dry storage units. In 2011, SevRAO had completed construction of biological shielding over Tanks 2A and 2B and had assembled the automated equipment control system for the dismantlement of slabs and concrete blocks. Construction of biological shielding over Tank 3A was started in 2012 (according to initial plans, the shielding over all the tanks was to have been installed in 2010).

As of February 2012, the plan for Andreyeva Bay for year 2014 was to commission the SNF handling complex, complete the design and manufacturing of
equipment for radioactive waste handling, and finish the rehabilitation of the SNF storage facility. The plan for 2015 was to start removing the spent fuel and complete the radioactive waste handling complex. Already in March 2014, however, the SNF removal operation was not anticipated to start until mid-2016.

In April 2013, a second working seminar, entitled “Projects of Cleanup of Nuclear- and Radiation-Hazardous Sites in Northern Regions of Russia. Status, Problems, and Prospects,” was held in Moscow jointly by Bellona and State Corporation Rosatom. The seminar reviewed the progress made at the region’s nuclear legacy sites, including that in Andreyeva Bay. It was stated that since the start of the Global Partnership program, the funding allocated to the works had totaled already more than RUR 2.5 billion (€51.3 million), taking the aid provided by Russia’s foreign partners into account [19].

It was noted that the more immediate plans for Andreyeva Bay included an inspection of the existing equipment for the project, rendering safe Building No. 5, and solving issues of power supply. The radioactive waste handling complex was already designed, with the construction completion date slated for 2015-2016. The most important achievement of 2012 could be considered the installation of biological shielding over the SNF dry storage facility. Construction had also been completed on two enclosures over the solid radioactive waste storage facilities. This work had started in 2010 and cost €5.66 million; the funding had been provided by Italy. Development work had finished on a project for installation of decontamination equipment. In addition, to ensure power supply for the future works, two transformer substations and three one-megawatt diesel-fueled generators were planned to be installed. Construction was in progress, since 2012, of the SNF and radioactive waste handling complex; the estimated cost of this project is RUR 3 billion (€61.5 million). SevRAO had begun building the complex’s main workshops. The first one is a building located a little uphill from the SNF storage facility; this will be in charge of the entire cycle of SNF extraction as well as re-casking the spent fuel and packaging it into shipping casks for transportation to PA Mayak. The second workshop will handle conditioning of solid radioactive waste for further shipment to Sayda Bay. Construction of the SRW conditioning workshop was financed by Italy and had finished in July 2012. Additionally, a mooring berth had been built to accommodate the spent fuel and radioactive waste transportation vessel Rossita.
In March 2014, in Murmansk, a third joint seminar of Bellona and State Corporation Rosatom took place, entitled “Results of International Cooperation in Nuclear and Radiation Safety Enhancement in Russia’s Northwest” [20]. Prior to the seminar, members of Rosatom’s Public Council had the opportunity to visit Andreyeva Bay and see for themselves how the project was progressing. It was noted that a lot had been done over the past years, especially in the area of submarine dismantlement. Radiation environment had been significantly improved in Andreyeva Bay, spent fuel had been shipped off to Atomflot and further to PA Mayak, and solid radioactive waste had been removed from open-air storage sites. Designs for all infrastructure sites had been developed and construction was underway; work was also continuing at the SNF management sites. Removal of spent fuel from dry storage units was expected to start in 2015, but construction of the SNF handling facilities will – based on realistic expectations – likely be finished by end 2015, and will then be followed by commissioning the handling complex. The start of SNF removal works can thus be expected no earlier than mid-2016, and their completion in 2020. By 2025, the environmental rehabilitation of the former naval base of Andreyeva Bay is to be brought to conclusion.

As RosRAO Deputy Director V. N. Panteleyev noted in his presentation [20], a considerable achievement of 2013 was finishing the development of the transportation flow chart for SNF removal. By mid-2014, an overhead crane was to be assembled and put in service, and by end 2014, a transfer cart was to be put into operation that would deliver shipping casks with spent fuel to the wharf, where a crane would load the casks onto a vessel for further transportation.
**Status in the first quarter of 2014 [21]**

*Russian-Norwegian contracts.* As was stated above, the first funding for rehabilitation work in Andreyeva Bay was allocated by Norway in 1998. In 2003, restored – or, essentially, built anew – was the road to the former base from the Murmansk-to-Norway Federal Highway R-21 “Kola”; the repairs cost NOK 15 million (€1.79 million). In 2003 to 2006, joint financing by Russia and Norway sponsored work conducted to develop the physical security system. Norway earmarked NOK 20 million (€2.39 million) for the construction of the guard house and a section of the physical security perimeter. The administration and amenities complex was built and put into service in 2003, as well as a personnel changing room. In late 2006, dismantlement of the old pier was completed and work started on the reconstruction of a new service wharf. A survey of the wharf and its modernization were completed with funding provided by Norway and Great Britain. The wharf was commissioned in 2008.

Altogether, between 1998 and 2009, Norway allocated some NOK 140 million (over €16.7 million) toward construction of various sites and facilities in Andreyeva Bay. In 2010, NOK 18 million (€2.15 million) was spent on building the canteen and training center building; work is under way to outfit the training center with the necessary equipment. In 2011, construction was completed of a three-megawatt transformer substation near the diesel power station, with installation at the site of backup diesel generators and their connection to the diesel power station’s restored RU-6-kilowatt switchgear. In 2012, Norway allocated an additional RUR 100 million (€2.05 million) beyond the funding specified in its contract, including RUR 60 million (€1.23 million) to build a high-durability road that would withstand transportation of heavy containers with spent fuel and radioactive waste and RUR 25.5 million (€523,000) for the construction of the third stage of utilities needed to maintain the operation and daily activities of the site [22]. Long-term implementation projects that are part of Russia and Norway’s cooperative efforts include the construction of internal roads and major utility installations, reconstruction of the power supply system, designing and construction of a unified low-voltage network system, and developing a computerized training program.
Pic. 4. A slide from a RosRAO presentation made by V. V. Yeryomenko, 2014 [21].
Results of Russian-Norwegian contracts in Andreyeva Bay

Construction of the canteen and training center building completed (2010)

Pic. 5. A slide from a RosRAO presentation made by V. V. Yeryomenko, 2014 [21].
Plans for 2014-2015 include completing the second stage of Building No. 154/155. In 2014, process equipment is to be purchased, manufactured, and delivered to outfit the mechanical repair shop with the decontamination station in that building. In 2015, construction and assembly works are planned, as well as developing and finalizing the EIA statements for the process operations involved in extracting SNF from dry storage cells and preparations for SNF shipment in TUK\(^5\)-18 (TUK-108/1) shipping casks [16].

As Per-Einar Fiskebeck, a representative of the office of the Governor of Norway’s Finnmark – neighbor to Russia’s Murmansk Region – showed in his presentation in Murmansk in 2014, Norway allocated NOK 215 million (€25.7 million) for the first stage of works in Andreyeva Bay (1997 to 2012), which envisions building the necessary infrastructure. For the second stage (2013 to 2017), which envisions preparation of sites built at the base for SNF removal, Norway plans to allocate between NOK 70 million and NOK 80 million (€8.36 million to €9.55 million) [23].

**Russian-Italian contracts.** Italian funding was used to build the vessel *Rossita*, intended for transportation of TUK shipping casks from Andreyeva Bay to the accumulation pad at Atomflot. The vessel was designed as an all-purpose containership for shipping containers with SNF and radioactive waste of all types, including a spent reactor core of an Alfa-class nuclear submarine. In 2011, the *Rossita* was transferred into Atomflot’s ownership. The cost of this project was €71.5 million. In Andreyeva Bay, construction of two shelter buildings, No. 201 and No. 202 (the SRW management complex located uphill, above the SRW storage facilities), was completed with Italian funding in 2012. This construction started in 2010 and cost €5.66 million. Work continues furnishing these buildings with equipment needed to start operations involved in radioactive waste management.

**Russian-British contracts.** Great Britain earmarked £3 million (€3.75 million) toward dismantling old buildings and structures at the base. Liquid radioactive waste was removed from Tanks 2C and 2D, and the tanks dismantled. Two portable personnel decontamination stations were built, a temporary equipment decontamination station (2005), two stationary personnel decontamination units for 88 staff each, near the SRW storage area and dry storage...
units, as well as a stationary equipment decontamination unit for equipment used at the SRW storage area.

Capital repairs were completed on Building No. 50 (where the radiochemical laboratory is assigned). That same building houses the automated radiation monitoring system. Work was completed assembling the horizontal biological shielding needed to bring down radiation levels above Tanks 2A, 2B, and 3A of the dry storage units. In 2006, Great Britain allocated funds to install a dockside gantry crane at the wharf, dismantle the old boiler house (Building No. 12), and build a landfill for construction waste. In 2007, Great Britain provided an additional £6 million (€7.49 million) to various projects in Andreyeva Bay.

**Russian-Swedish contracts.** Construction is under way of an interim modular-type radiation monitoring and dosimetry station equipped with a set of radiation monitoring means, and of systems that handle the access of transport to the base’s service area. The completion date for this construction was set for July 2014. Radiation-measuring equipment has already been supplied to Andreyeva Bay, as well as personal protective equipment, etc. A contract has also been signed to develop the project and detailed design for the connection of the diesel-fueled generator set with three one-megawatt diesel generators to the power system to ensure stable electricity supply at the base.

**Contracts between Russia and the EBRD.** Construction work on Building No. 151 (temporary TUK accumulation pad) is nearing completion. Delivery is expected in the second half of 2014 of a crane with a lifting capacity of 50/12.5 tons and a transfer cart with a lifting capacity of 50 tons. Construction work is under way on Building No. 153 (the enclosure over the dry storage units). Work has started installing the pile foundation and fabricating structural steelwork for the building’s frame. Works are being implemented in accordance with the decommissioning project of the former SNF storage facility in Building No. 5. An examination has been conducted of the facility’s smaller pool. Contracts for further work involved in retrieving SNF from the pools are currently at the signing stage.

**Contracts between Russia and the European Commission.** Under agreements with the European Commission, in 2013, the automated nuclear materials accounting and control system was delivered as well as SFA gamma scanning equipment, and 175 ChT-type casks for storage and transportation of spent fuel assemblies were manufactured and delivered to the base.
Results of Russian-British contracts in Andreyeva Bay

Capital repairs and furnishing of Building No. 50 (radiochemical laboratory) completed

Before

After

Pic. 6. A slide from a RosRAO presentation made by V. V. Yeryomenko, 2014 [21].
Removal of spent fuel from dry storage

State Corporation Rosatom did not work specifically on the issues of SNF retrieval from the dry storage units until 2008, when the first technical assignment was issued for the development of a retrieval project and actual development work started on the infrastructure and technology project for the extraction of the spent nuclear fuel from dry storage. Funding for this work was provided jointly by Rosatom and Great Britain. Safety issues were examined: how and by which means the spent fuel would be extracted, where it would be reloaded, what equipment would have to be used, designed and manufactured, or purchased. Calculations and assessments for the SNF retrieval project were done by specialists from NIKIET and the Obninsk branch of the IPPE. These assessments were then confirmed by the British side and experts from NRC Kurchatov Institute. A decision was made that it was necessary to create a building with an SNF reloading and re-casking complex. Thus, the assembly-by-assembly retrieval option was adopted and is being implemented to extract the SNF from the storage facility. It is expected that after carrying out preparatory operations, the SFAs, conditioned, would be loaded into new casks. Damaged casks with spent fuel assemblies would be cut open using a specially devised technology, following which work will be conducted to restore the structural parts of the damaged assemblies and their loading into new casks. The new casks will then be loaded into TUK shipping casks for further transportation [12].

Retrieval of spent fuel from the dry storage units will proceed according to this principle: Extraction will first start of those spent fuel assemblies that are anticipated to be extracted without difficulty (most of the SFAs are of this category and can be quickly unloaded and removed from the site); next, work will begin on the fuel whose extraction is expected to prove challenging. The following sequence of works has been adopted: First, retrieval of SNF from Tank 2A, then from Tank 2B, and, lastly – given the level of complexity of the task – from Tank 3A. At this time, Building No. 153 has practically been completed, the SNF handling complex has been created and is awaiting approval of the Russian Main Directorate for State Expert Evaluations6. In Building No. 153, the SFAs will be

6 The Main Directorate for State Expert Evaluations (Glavgosexpertiza, in its Russian acronym) is an oversight agency subordinate to the Ministry of Construction, Housing, and Utilities of the Russian Federation that reviews design and other documentation for construction, renovation, and engineering projects for compliance with safety and legal standards. – Translator.
loaded into new casks using a reloading machine. Each of the casks will then be moved from a transfer cask into a TUK-18 or TUK-108 shipping cask, and these TUK shipping casks will be placed in Building No. 151 for temporary storage before transportation to Atomflot’s accumulation pad.

State Corporation Rosatom experts believe that considerable experience performing these operations has been accumulated in Great Britain, France, and Sweden. This experience has been tested in the Russian Federation as well. Special test facilities have been put together at research and development centers to model a section of a dry storage unit. Personnel is being prepared for the SNF retrieval operation. A personnel training program has been created jointly with Norway’s Finnmark province and the NRPA [24].
Conclusion

Andreyeva Bay is the most dangerous nuclear legacy site in Northwest Russia. Some 23,000 spent fuel assemblies continue to remain in storage here. Much has already been done at the site, but the projects that have been completed mostly relate to the creation of the necessary infrastructure and preparatory work. The task of solving the main problem – removing spent nuclear fuel from the site – has been pushed back to later dates from the time frames that were planned initially. Today, according to statements made by Rosatom’s top management, the realistic date when SNF retrieval from dry storage in Andreyeva Bay can be expected to start is no earlier than mid-2016. The total cost of works at the former naval base is around €55 million; the works are currently being implemented and are funded by the EBRD. The Russian side is responsible for manufacturing container packaging and casks designed to be suitable for spent fuel in any condition, developing the necessary tools and equipment to carry out the retrieval works, and construction of the shielding over the storage site. The portion of financing provided by the Russian Federation is estimated at €15 million. SNF retrieval from dry storage in Andreyeva Bay is slated to be finished in 2020, unless particularly challenging problems emerge. By 2025, rehabilitation work at the base is expected to be completed. In Russia’s estimations, the effort to turn Andreyeva Bay into a brownfield will require no less than $1.5 billion (€1.12 billion) over the fifteen years until that date.
GREMIKHA

Background

Gremikha – a former naval maintenance base located on the eastern coast of the Kola Peninsula – was set up in the early 1960s [7]. The territory of Gremikha (closed administrative territorial entity Ostrovnoy) housed the Northern Fleet’s second largest – after Andreyeva Bay – onshore storage site for spent nuclear fuel, and, in addition, this was the largest site for laid-up submarines taken out of active naval service. The base was used for the maintenance and refueling of nuclear submarines. Its infrastructure included floating maintenance facilities, a dry dock, and onshore bases for submarine refueling. The main operations site for SNF reception was the chamber of the dry dock, which was cut out in solid rock on the shore. All the operations, including repairs and reactor refueling, were done there. In the early 1960s, after the first nuclear submarines with pressurized water reactors underwent refueling, some 110 casks of the TK-6 (TK-11) type holding 672 spent fuel assemblies were delivered to the base in Gremikha [7]. In the mid-1960s, Gremikha also took delivery of, and accommodated in concrete containers (at the dry dock wall), two spent reactor cores of the first submarine that operated liquid-metal-cooled reactors (the K-27) and that had been refueled in Severodvinsk.

After the breakup of the Soviet Union, the base in Gremikha practically morphed into a waterborne storage center for retired submarines, an SNF storage site, and the only place where submarines with liquid metal cooled reactors could undergo refueling. For storage of solid radioactive waste, an open site was arranged in the area around the dry dock, which accommodated – both in containers and without protective packaging – large-size equipment and vehicles. For storage of liquid radioactive waste, the base had underground tanks on the coast where up to 2,000 cubic meters of LRW was held. Over the course of more than 40 years, spent nuclear fuel was stockpiled in an open-air site, posing a serious environmental hazard. As of 2007, the base had in storage around 800 spent fuel assemblies unloaded from PWRs and holding about 1.4 tons of fuel composition, as well as six spent cores of liquid metal cooled reactors. Remaining in waterborne storage at the wharves were 19 decommissioned nuclear submarines with 38 reactors on board that still contained SNF in them [7].
Storage of two types of SNF was provided in Gremikha: spent fuel from pressurized water reactors and spent fuel from reactors with liquid metal coolant used to power Alfa-class submarines. Structurally, the storage facility for spent PWR fuel (Building No. 1) was designed as four stand-alone cooling pools with one shared operations hall. SFA storage was arranged with assemblies held separately (i.e., without storage casks) under a layer of water, with each assembly fixed to its own cantilever. The storage facility’s total capacity was around 1,500 fuel assemblies and could accommodate SNF from four first-generation submarines at a time.

In 1984, a reduction in the water level was registered in one of the pools of Building No. 1, and the water flowing out of the dock was discovered to have an increased radioactivity level. The water, it was established, was leaking from Pool 1. The total volume of water that had leaked from the pool was estimated at 30 tons. The cause of the water leak from Pool 1 was later identified to have been a crack in the metal lining of the pool. In 1984, spent fuel was unloaded from the pools and shipped out of Gremikha, Pools 1, 3, and 4 were drained, and the remaining 95 damaged SFAs, which were not suitable for transportation for reprocessing at PA Mayak, were moved to Pool 2. As per a decision issued by the Ministry of Defense, further operation of the storage facility was discontinued [7].

In 2001, the former naval base in Gremikha, just like its counterpart in Andreyeva Bay, was transferred out of the Navy’s jurisdiction into that of FSUE SevRAO.

Gremikha is the only onshore maintenance base in the USSR (or in Russia) where infrastructure has been created for the management of liquid metal cooled reactors and spent reactor cores. Technologically, unloading the cores of liquid metal cooled reactors is different from handling spent PWR fuel in that the entire core is removed in the assembled condition, or as one unit, rather than separate fuel assemblies. Because liquid (molten) metal is used in these reactors as coolant, this coolant needs to be melted before the reactor core is removed. In the early 1980s, two facilities were built in the dry dock area – Building No. 1A and Building No. 1B. Building No. 1A housed all the equipment necessary for the unloading of a spent core of a liquid metal cooled reactor in the assembled condition and provided interim storage with forced cooling for these reactor cores. Building No. 1B was intended for subsequent storage of spent fuel of liquid metal cooled reactors with natural cooling. The total storage capacity for SNF with liquid metal coolant was
10 sets: two storage areas in Building No. 1A and eight in Building No. 1B. A reloading complex was built that included the dry dock, a boiler shop to heat up and then drain the coolant, a 75-ton crane to remove the spent core, the spent core storage facility, etc. The boiler shop produced high-temperature high-pressure steam needed to heat up the spent reactor cores. The SNF discharging process was as follows: the core in a reactor was heated up by steam and pulled up into a special unloading cask installed over the reactor compartment. The leftover molten metal drained back into the reactor, after which the unloading cask was hermetically sealed and moved by a gantry crane into the storage area – Building No. 1A, and from there, following a two-month cooling period, into Building No. 1B [7].

Between 2000 and 2005, work was under way in Gremikha building infrastructure for spent core unloading. By 2007, four unloading operations had been performed removing spent cores from Alfa-class submarines. All the six unloaded cores, including the two reactor cores of the K-27, had been moved to Building No. 1B.

With liquid metal cooled reactors that had sustained damage, the standard defueling method proved inapplicable. On a proposal by FSUE RosRAO deputy director V. N. Panteleyev, a special SNF extraction test bench was developed and built at the IPPE, and a manipulator unit was constructed that turned a reactor 180 degrees. Next, a section of the reactor’s bottom head was cut off, providing access to the core. This was how all the 60 fuel assemblies were extracted from the first defective reactor in Gremikha, and placed in a cask. All the highly radioactive components were placed back into the reactor vessel. The other defective reactor compartments defueled using this technology will be shipped from Gremikha to Sayda Bay: the reactor compartment of submarine Order No. 910 in 2014, and of submarine Order no. 900 in 2015. By 2020, all spent cores and spent fuel from liquid metal cooled reactors are planned to be removed from Gremikha.

As was stated by NIKIET chief scientist A. P. Vasiliyev at the March 2014 seminar in Murmansk, a radiological survey of the base and the bay area conducted in 2003 showed that the most serious environmental hazard was presented by the temporary storage site for solid radioactive waste, with the casks holding SFAs and containers with SRW stored there. The TSS SRW is an open-air site located on a hillock near the base’s main structures and is fenced off on three sides by a concrete wall about 3 meters high. With precipitation, radioactive substances
spread from the yard over the territory of the base, washed out into the sea. As of 2003, 116 casks (Types 6 and 11) with non-reprocessable SNF were in storage at the TSS SRW. The lids of the casks were not sealed shut, and some of the casks did not have lids at all and were filled with water. The second SNF storage site at the base was Building No. 1, where 106 spent fuel assemblies were held in Type 22 casks in areaways; some of the SFAs were damaged (fractures, spilled fuel composition). In some of the Type 11 casks, about seven spent fuel assemblies had been placed against normal procedure.

The main task of the environmental remediation effort in Gremikha was elimination of the TSS SRW and removal of SFAs for reprocessing at PA Mayak. For that purpose, the casks and the spent fuel assemblies in them had to be moved from the storage site into an interim shelter and examined for defects. The results of work conducted jointly by FSUE SevRAO and NRC Kurchatov Institute demonstrated that some 85 percent of the spent PWR fuel was fit for transportation. Before the end of 2008, 294 spent fuel assemblies were shipped off to PA Mayak. Prior to sending the SFAs for reprocessing, they had be reloaded from their old canisters and casks into modern, ChT-type canisters placed into TUK-18 shipping casks.
International cooperation

International cooperation projects in Gremikha were started in October 2003 in France by an IAEA Contact Expert Group seminar dedicated to the issues of environmental remediation of the former naval base. Russia presented its rehabilitation concept, and participants from Western countries, their experience in managing spent fuel and radioactive waste. At the seminar, the main tasks that needed to be solved were outlined: first, improving the radiation situation at the base in order to conduct the works safely; and second, preparing the necessary infrastructure and removing spent nuclear fuel from the base [22].

In 2004, in Moscow, the condition of the naval base in Gremikha and the first-priority proposals for its rehabilitation were reviewed; remediation work started in Gremikha that same year.

In 2005, France agreed to finance the manufacturing and delivery of two portable personnel decontamination complexes for the SNF storage site in Gremikha [25]. A contract was signed in the amount of €150,000 and another in the amount of €750,000, for the manufacturing of the first and second decontamination complexes, respectively. The complexes were delivered in 2006. France’s participation in the remediation program in Gremikha proceeded in accordance with an agreement reached between Russia, France, the EBRD, and the European Union’s TACIS program. In an SMP developed for comprehensive submarine decommissioning, out of the nine first-priority projects proposed for financing by the EBRD for 2005, five had to do with works to be carried out in Gremikha.

By 2006, out of eleven submarines with liquid metal cooled reactors that have been built in Russia, one submarine and one reactor unit with SNF inside remained to be dismantled yet. (Another reactor unit still loaded with spent fuel was at one point mothballed and will have to be dismantled using non-standard methods).

In August 2005, an agreement was signed with the EBRD on projects in Gremikha that provided for allocation of four grants. On the side of the Russian Federation, the responsibility for the implementation of the agreements reached with the bank was shared by Rosatom, the administration of Murmansk Region, and FSUE SevRAO. The side of Russia’s foreign partners was, as stated above,
represented by the EBRD, which manages the Support Fund of the Northern Dimension Environmental Partnership, the TACIS program, and France, which in late 2004 had ratified the MNEPR agreement [26]. In November 2005, the first contract was signed for establishing safe conditions for the storage of the reactor core of the Alfa-class submarine that had undergone the spent core unloading operation in Gremikha in August-September 2005 [27]. In 2006, a contract (fourth) was signed with the EBRD for setting up physical security at the base (VNIPiET and the IPPE were chosen as the contractors in the first and fourth contracts). The second and third contracts had to do with developing the concepts for the removal of SNF and SRW out of open-air storage and ensuring safe conditions for storing SNF in the existing storage facilities. In total, the combined cost of the project was €7 million.

The first-priority objectives for Gremikha were thus set as follows:

– implementing a complex of measures ensuring personnel safety while conducting works on the territory of the base;
– completing the preparation of necessary systems and equipment of the infrastructure and conducting SNF unloading from liquid metal cooled reactors of Alfa-class submarines with subsequent submarine dismantlement;
– developing and implementing plans for removing SNF unloaded both out of liquid metal cooled reactors and PWRs from the base;
– developing and implementing projects for handling and subsequent removal from the base of solid and liquid radioactive waste, as well as remediation of buildings, structures, and territory of the base.

In 2006, NIKIET and NRC Kurchatov Institute specialists conducted a comprehensive radiological survey of the territory of the base in Gremikha. A remote radiation detection method was used to identify gamma radiation sources at the TSS SRW, using a CARTOGAM gamma imaging camera and thermoluminescent dosimeters. Then, using robotic equipment and other methods of remote control, the major sources of gamma radiation were removed, and, in the period between 2006 and 2008, the radiation environment at the TSS SRW was improved significantly (for example, after the first stage of works, by the fall of 2006, background gamma radiation levels had been reduced from 3.21 mSv/h to 0.50 mSv/h; after the second stage, by the fall of 2007, gamma background had been brought down to 0.34 mSv/h [22]). Following that, preparatory works were conducted: infrastructure was prepared for the reloading and removal of spent fuel,
the needed equipment purchased, and two portable personnel decontamination stations delivered and put into service. The nuclear maintenance vessel (special-purpose tanker) Serebryanka was in 2008 retrofitted to ship spent PWR fuel in TUK-1 casks. (For the removal of SNF from the base in Gremikha, the Italian-built Rossita can also be used, since it can also dry-dock at Gremikha). SFA labeling was done and loading of spent fuel assemblies into shipping casks. In December 2008, work started removing SNF from first-generation submarines out of Gremikha; 14 TUK-18 casks with conditioned SNF were shipped out. In 2009, another six casks were shipped. Removal of all the conditioned PWR SNF from Gremikha for reprocessing at PA Mayak was thus completed. In September 2009, an unloading operation was performed in Gremikha on the damaged reactor of the Order No. 910 Alfa-class submarine that had sustained an accident in 1989, as a result of which its fuel was only burned to 77 percent [28]. This work was done with the financial support of France, which allocated €5 million for the decontamination of the reactor compartment and defueling.

Pic. 7 shows the progress of spent core unloading operations done in Gremikha on submarines with liquid metal cooled reactors.

In 2012, assembly-by-assembly dismantlement of the core of the Order No. 900 Alfa-class submarine was finished, and SFAs with defective SNF and SNF cartridges were removed from Gremikha. In 2013, FSUE SevRAO started the dismantlement of the spent core of another Alfa-class submarine and assembly of one-compartment units. Work is under way to design shipping casks for transportation of spent cores of liquid metal cooled reactors. The plans for 2014 include completing construction of the SNF handling complexes, begin shipping out SNF from liquid metal cooled reactors, as well as initial treatment and removal of SRW to Sayda Bay, and LRW reprocessing. Before the end of 2014, some 4,000 cubic meters of solid radioactive waste is expected to be shipped out of Gremikha. Between 2012 and 2020, shipment from Gremikha to Sayda Bay and dismantlement of all ten spent cores are to be carried out [22].

Investments made by donor countries into projects at the former naval bases in Sayda Bay and Gremikha were used to create the infrastructure necessary for the management of spent nuclear fuel and radioactive waste, decommissioning nuclear fleet vessels, and creating infrastructure for safe storage of reactor compartments. Funding for Gremikha in the period between 2003 and 2013 came in equal portions of about €70 million each from Russia (Rosatom) and from foreign sources, of
which around €1.78 million was allocated by the United States, around €14.5 million by Italy, €46 million by France (CEA), €0.173 million by Sweden, €1.2 million by the European Commission (TACIS), and around €7 million by the EBRD. The United States rendered help in the work involving liquid metal cooled reactors; Italy was responsible for manufacturing ten casks for management of spent reactor cores; the EBRD was in charge of improving the radiation environment at the base, setting up the physical security system, and upgrading SRW storage conditions; the European Commission participated in the effort of improving the radiation environment as well; and Sweden’s area of responsibility was delivery of six 20-foot containers for shipment of solid radioactive waste to Sayda Bay [22].
Pic. 7. A slide from a presentation made by V. V. Yeryomenko, 2014 [22]. (The chart shows years of removal of spent submarine reactor cores for storage at the temporary storage site in Gremikha during the dismantlement of the submarine of the corresponding factory number. TSS: temporary storage site; Port: spent core of the port reactor; Stbd: spent core of the starboard reactor).
Current status and future plans

As was noted at the March 2014 international seminar in Murmansk, the implementation of the Gremikha project succeeded in improving considerably the radiation situation at the base [20], and that made it possible to start works involving SNF management. A spent reactor core reloading complex was built, as well as a test bench for reactor dismantlement and defueling. Between 2008 and 2012, 898 spent fuel assemblies were prepared for transportation and removed from Gremikha – i.e. all the SNF from PWRs: 757 (structurally intact) SFAs were shipped off to PA Mayak for reprocessing, and 141 (damaged) SFAs were taken to the accumulation pad of Atomflot. In 2014, the damaged fuel assemblies are to be shipped for reprocessing in a hot cell for managing defective SNF canisters at PA Mayak. (The hot cell for defective SNF was created at PA Mayak using Russian and French funding for the reprocessing of non-standard spent fuel assemblies that were previously considered non-reprocessable. The hot cell is expected to be put into operation in 2014). France also paid for the work carried out to install a 100-ton gantry crane at the Atomflot wharf for transshipment of casks with SNF onto railway flatbeds for shipment to PA Mayak.

As of today, all ten reactor cores have been unloaded from submarines that operated liquid metal cooled reactors, a spent core dismantlement and defueling technology has been developed. New technologies have been developed to handle defective spent nuclear fuel. Upgrades have been made to the infrastructure of the temporary storage site for reactor compartments. In 2012, the reactor compartments of the Order No. 900 submarine were shipped off for storage in Sayda Bay, and its SNF to Atomflot’s accumulation pad; shipment of this SNF to PA Mayak is planned to start in 2016. Before 2020, spent fuel of all ten spent reactor cores is to be placed into TUK-108 casks and shipped first to Atomflot and then to PA Mayak, while the defueled reactor cores will be packed into TUK-143 containers as solid radioactive waste and transported for long-term storage in Sayda Bay. Thus, the immediate plans for Gremikha comprise the dismantlement of all liquid metal cooled reactors, SRW removal, and ecological remediation of the territory.
Pic. 8. A slide from a presentation made by V. V. Yeryomenko, 2014 [22].
Temporary storage site for solid radioactive waste

Before (2003)

After (2012)

Pic. 9. A slide from a presentation made by V. V. Yeryomenko, 2014 [22].
Conclusion

Today, all PWR SNF has been removed from Gremikha. A unique spent core reloading complex has been created as well as a facility for dismantlement of liquid metal cooled reactors and for unloading of SNF from reactors of Alfa-class submarines. All ten spent cores of liquid metal cooled reactors have been unloaded from submarines. According to Rosatom’s plans, by 2020, all the spent cores and SNF from liquid metal cooled reactors are expected to be removed from Gremikha.

Funding for Gremikha was between 2003 and 2013 allocated more or less equally by the Russian Federation (about €70 million on the part of Rosatom) and donor nations (about €70 million in total as well). As for the infrastructure for SNF unloading from the reactors of Alfa-class submarines, by 2020 it may be dismantled since, according to plans, by 2025 Gremikha is to be completely rid of spent nuclear fuel and radioactive waste, and its territory rehabilitated. These time frames may only be pushed back if a decision is made to lift the K-27, which was buried in the Kara Sea, and to unload the core from its reactor unit. Experts at NRC Kurchatov Institute have serious concerns about this object since the reactor still contains highly enriched fuel (some 90 percent enrichment in uranium-235), and if the reactor takes in water, development of a spontaneous chain reaction is not ruled out.
NUCLEAR SERVICE SHIP LEPSE

Background

In 1961, a 1934-built motorboat was retrofitted into the floating maintenance base Lepse. As a nuclear service ship, the Lepse was used to refuel nuclear-powered icebreakers. In 1981, a new floating maintenance base, the Imandra, was put into service, and the Lepse’s operation for the purpose it had been assigned was discontinued. For a while, the Lepse was used as a floating storage facility for SNF, solid and liquid radioactive waste, and tooling. In 1988, the vessel was taken out of service completely, and in 1990 reclassified as a berth-connected ship. At present, the Lepse is one among Northwest Russia’s most hazardous nuclear and radiation legacies, since its holds contain damaged SNF unloaded from icebreaker reactors. The issue of decommissioning the Lepse was first raised by the Murmansk Shipping Company and Bellona in 1994. Today, the effort to decommission the Lepse is an international project funded by the EBRD. The project’s total cost is estimated at €75 million, of which around €53 million is funding provided to the Russian Federation from abroad.
The Lepse’s condition: nuclear and radiation risks

The main source of nuclear and radiation hazard on the Lepse is its SNF storage hold. The storage hold is represented by two tanks located in the bow of the ship and equipped with biological shielding. The tops of the tanks are sealed by the revolving plates of coordination and guiding devices that allow selective positioning of the devices in order to open access to individual channels with SFAs slated for reloading. Each tank has on its periphery four caissons filled partially with SFAs [29]. Removal of decay heat from the SFAs stored in the channels was implemented using a double-circuit cooling system. Today, decay heat is practically absent, and the cooling system is not used.

Stored in channels (canisters) in the SNF storage hold’s two tanks (total capacity is 732 channels) are 621 spent fuel assemblies, and the caissons of the two tanks hold 18 damaged SFAs with broken shroud tubes, unloaded from the reactors of the nuclear icebreaker Sibir, in 1980, and the icebreaker Lenin, in 1981. Thus, altogether 639 SFAs are stored in the Lepse’s tanks, of which some are damaged or destroyed.

The nine SFAs unloaded from the Sibir’s reactor, in Caisson 3 of the starboard SNF storage tank, were put there with great effort—in fact, simply rammed into it with the help of a sledge hammer. As this was done, the fuel assembly heads – which are used to grip SFAs for extraction – came to be deformed, and deformed as well or destroyed were, therefore, the fuel pin bundles. The other nine SFAs, from the icebreaker Lenin, also had to be jammed into other caissons with considerable effort. One of the damaged SFAs unloaded from the Sibir had been extracted with a broken shroud tube, and after it was loaded into a transfer cask, the gate of the cask would not close. After a number of unsuccessful attempts to properly accommodate the damaged SFA into a channel of one of the tanks of the Lepse’s storage hold, a decision was made to place all the defective SFAs into the storage caissons. It is very likely that the SFAs stored both in the channels and the caissons of the Lepse’s storage hold have sustained corrosion damage and changes to their geometrical dimensions. Extraction of these SFAs is a complicated technological operation associated with radiation hazard. Additionally, some 50 cubic meters of solid radioactive waste is stored on the Lepse in containers, and other facilities on board contain equipment that had been used when carrying out radiation-hazardous works and had been contaminated with radionuclides as a result [29].
Calculations have been done that show that the SFAs in storage on the *Lepse* contain approximately a combined 260 kilograms of uranium-235 and 156 kilograms of fission products. Some 8 kilograms of plutonium-239 is contained in the left-hand tank in the SFAs with low-enriched fuel that were used in the OK-150 reactors of the icebreaker *Lenin*. The radioactivity of the spent fuel held in the *Lepse*’s storage is today some $2.5 \cdot 10^{16}$ Bq (680,000 Ci), which is commensurate with the radioactivity of the fallout from the accident that took place at PA Mayak in 1957.
Radiological conditions on the *Lepse* today

The gamma radiation dose rate in the storage hold and adjacent areas is thousands of times in excess of natural background radiation levels, which are commonly measured at 0.1-0.2 μSv/h [29].

In particular, measurements have provided the following data on the dose rates (in μSv/h):
- inside the controlled area in the aft: 50÷150;
- inside the rooms of the process tanks: 150÷2500;
- on the open decks of the controlled area: 2÷300;
- on the open decks of the monitored area: 0.1÷1.0;
- in the working rooms of the monitored area: 15÷30.

The gamma dose rate at the revolving plates of the storage tanks ranges between 300 and 15000 μSv/h.

The gamma dose rate under the revolving plates of the SNF storage tanks reaches 20 Sv/h.

The dose rate with the channel plug open above an SFA channel is 20÷50 μSv/h.

The radioactive contamination of the surfaces of the SNF storage hold is at levels of 60÷6000 beta particles per square centimeter per minute.

More data on the specific types, quantity, and other characteristics of the spent fuel and radioactive waste remaining on board the *Lepse* is available in the report “Decommissioning of the Floating Maintenance Base *Lepse*” by Yury Chernogorov [29].
Lepse dismantlement plans. International cooperation

The need to decommission the floating maintenance base *Lepse* as a nuclear-and radiation legacy site was determined by Decree No. 1095-296, of September 10, 1989, issued by the Central Committee of the Communist Party of the USSR and the Council of Ministers of the USSR, and by Decision No. 132, of April 25, 1988, issued by the Military-Industrial Commission under the Council of Ministers of the USSR, on an initiative forwarded by the Murmansk Shipping Company.

In 1992, VNIIPromtekhnologii (one of former Minatom structures), jointly with other scientific and design organizations, began working on a scientific and technical basis in order to develop a comprehensive management plan for the *Lepse*.

In 1989, decommissioning work started on the *Lepse*, but due to funding restrictions, only the first phase of the planned works was completed. In October 1991, the space between the two SNF tanks was filled with 208 tons of concrete to grout the space and the radioactive water contained there. Additionally, concrete was used to stabilize the tanks and improve the radiation situation in the storage hold. These works were being implemented with funding provided by the Murmansk Shipping Company and were ceased in 1994 due to a lack of funding needed to continue the work.

In 1999, after dock repairs at the Shiprepairing Yard Nerpa, the *Lepse* was classified as a berth-connected non-self-propelled vessel with a permanent mooring location assigned at the Atomflot wharf. In 2002, due to worsening radiation conditions in the bow of the ship, a protective barrier was created out of the same concrete mix that had been used to fill the intertank space under the bottom and around Process Tank 1, which had been used to collect liquid radioactive waste [29].

Due to the environmental significance of decommissioning the *Lepse*, as well as the high cost of works involved in the project, the project was included in the Federal Target Program “Management of radioactive waste and spent nuclear materials, their disposition and geological disposal for 1996 to 2005.” Funding, however, was not allocated for the works due to a lack of budget funds.
On an initiative of the international environmental NGO Bellona Foundation, a pilot decommissioning project for the *Lepse* was in 1994 included on the working schedule of the Barents/Euro-Arctic Region for 1994-1995.

In 1995, the *Lepse* project was also included on the European Commission’s agenda and attained a higher international profile. At the stage of discussing the international “Comprehensive decommissioning project of the Floating Maintenance Base *Lepse*,” Western donor nations expressed their willingness to allocate funding toward solving the *Lepse* problem. Under the TACIS program, two reports were prepared by a consortium of the French company SGN and the British AEA Technology in 1996-1997 [30].

In 1998, the *Lepse* decommissioning project became part of an agreement signed by the Russian Federation and Norway on cooperation in the field of environmental protection related to the decommissioning of Russian nuclear-powered submarines in the Russian North.

In 2000, the Murmansk Shipping Company and the French Development Agency (Agence Française de Développement, AFD) signed an agreement on providing financial assistance to the shipping company toward implementation of the *Lepse* decommissioning project; under this agreement, the AFD pledged to provide a subsidy in the amount of €1,372 million.

In 2001, in order to minimize radiation exposure for the *Lepse*’s personnel, a complex of containers worth about NOK 1 million (€120,000) for a container village was purchased and installed, with the Bellona Foundation’s funding and direct participation, near the berth where the *Lepse* was moored. The complex was an onshore rotational camp to provide housing for personnel working to maintain the vessel in a safe condition. Before the village was built, the *Lepse*’s crew were accommodated on board the vessel, exposed to increased radiation levels.

Because project financing was not provided for under the FTP NRS 2000-2006, the Ministry of Transport of the Russian Federation earmarked for 2002 a targeted allocation of budget funding to the Murmansk Shipping Company toward maintaining safe waterborne storage of the *Lepse* and implementation of maintenance works on the vessel in the amount of RUR 50 million (€1.03 million).

In 2002, in accordance with the “Plan of First-Priority Measures for the Management of the Floating Maintenance Base *Lepse*,” approved by Minatom in
May 2001, a program was developed entitled “Program for Ensuring Environmental Safety of Waterborne Storage of the Floating Maintenance Base Lepse and a Complex of Measures Ensuring Long-Term Storage of Spent Nuclear Fuel and Disposal of Radioactive Waste.” Within the framework of this program, the following research and technical works were conducted [30]:

– preliminary assessment of personnel exposure during SNF extraction (NII PMM, St. Petersburg);
– “Research note on the determination of the scope of works, time frame of implementation, and cost during conversion of the floating maintenance base Lepse, including SNF and SRW unloading. Project No. 325” (ZAO Atomenergo).

Work was done on preliminary feasibility and EIA studies. A cask design for SNF was developed and certified.

In order to achieve safe radiation conditions on the vessel, the following measures were implemented:

– decontamination and application of protective film coating in the rooms of the controlled area;
– creating engineering and immobilization barriers in the room of Process Tank 1 and in the tank itself, removal and reprocessing of high-level LRW from the tank;
– preparatory work for the removal of cooling water from Circuit B.

As a result of decontamination work and installation of protective barriers in the rooms of the controlled area, gamma radiation levels were decreased by two to five times, and radioactive contamination was reduced by 50 to 1,000 times.

In July 2003, the Murmansk Shipping Company and the Nordic Environment Finance Corporation (NEFCO) signed an agreement that provided for a grant to be allocated toward unloading spent fuel from the Lepse. Signing this agreement was what essentially marked the beginning of implementation of the international Lepse project. To finance the project, NEFCO pooled together its own funds as well as funding provided by Norway and the Netherlands in the amount of around €4.62 million. The total amount of subsidies provided by these project participants was €5.96 million. In addition, the European Commission confirmed its intention to make its own contribution in the amount of €6.03 million. Altogether, international donor funding for the project was to total about €12 million.
In October 2003, an agreement was signed between the Murmansk Shipping Company and the French SGN called “Agreement on engineering services within the SNF extraction project, Phase 1A,” which envisioned, with participation of Russian subcontractors, preparation of a baseline report, a technical assignment, and a justification of investment document. Donor funding for the development of these documents was provided to SGN [30].

In accordance with the analysis done by ZAO Atomenergo experts, who had prepared the research note on the determination of the scope of works, time frame of implementation, and cost of the comprehensive decommissioning work on the Lepse – this document had been approved by the Inspectorate for Nuclear-Powered Vessels of the Russian Maritime Register of Shipping – the decommissioning project was to have been completed before 2008, i.e. before the Register’s documents were to expire.

Even though the Lepse project was included into the European Commission’s plans in 1995, the project had barely seen any progress up until 2003, when the necessary funding agreements and documents for the decommissioning program were finally signed. The Lepse decommissioning project was included on the list of first-priority projects proposed for EBRD funding for 2005. Western countries contributed €13 million toward extracting spent nuclear fuel from the Lepse’s storage tanks. In experts’ assessments, the overall cost of the project was to total about €30 million.

In 2005, in a decision made by Rosatom and the Federal Maritime and River Transport Agency (Rosmorrechflot), the Autonomous Non-Profit Organization (ANO) Aspect-Conversion was appointed contractor for the development of the Lepse comprehensive decommissioning project. In accordance with a contract signed by TACIS, ANO Aspect-Conversion, and the European Commission, by April 2007, a package of design and procedural documentation for comprehensive decommissioning of the Lepse was prepared. The implementation of the Lepse project was broken down into three main phases: preparing for, and towing of the vessel to the Shiprepairing Yard Nerpa, and placing it onto a slipway; unloading of spent fuel with subsequent shipment of the SNF to PA Mayak for reprocessing; cutting the vessel into blocks and preparing a compartment for long-term storage in Sayda Bay.
The design and procedural documentation package outlined the following steps [30]:

1. Developing a detailed project.
2. Preparing the vessel for towing to the Shiprepairing Yard Nerpa.
3. Preparing the special infrastructure at the Shiprepairing Yard Nerpa.
4. Designing and construction of an annex to the SNF storage facility (Building No. 5) at Atomflot.
5. Towing the Lepse to the Shiprepairing Yard Nerpa and placing it on a slipway.
6. Dismantling hull structures and equipment.
7. SNF extraction.
8. Transportation of casks with SNF to Atomflot.
9. Placing the casks with SNF for temporary storage in the annex to the SNF storage facility (Building No. 5) or shipping the casks to PA Mayak.
10. Reprocessing liquid and solid radioactive waste.
11. Preparation of two storage packages out of the remainders of the vessel’s structures.
12. Shipping the storage packages to the long-term storage site for reactor compartments in Sayda Bay and placing them in long-term storage.

On the Russian side, the project was managed by ANO Aspect-Conversion. Rosmorrechflot represented the federal bodies of executive power of the Russian Federation as the project beneficiary. On the TACIS side, the Lepse project managing committee was headed by NEFCO representative Magnus Rystedt.

The Shiprepairing Yard Nerpa was chosen as the decommissioning location since the enterprise has many years of experience decommissioning nuclear-powered submarines at its disposal.

Decommissioning funds were allocated from the federal budget under the FTP NRS 2008-2015. Rosatom’s Federal Center for Nuclear and Radiation Safety established a Project Management Unit. Participation of an International Consultant was provided for to ensure that all works conducted on the Lepse were in conformity with international standards and technologies. At the same time, all works had to comply with current Russian legislation and standards. The initial plan was for the Lepse to be towed to the Shiprepairing Yard Nerpa in 2009.

Today, the entity responsible for the implementation of the Lepse project is the Federal Center for Nuclear and Radiation Safety of State Corporation Rosatom.
In 2008, an implementing agreement was signed that provided for the allocation of a *Lepse* decommissioning grant; the parties to the agreement were the EBRD, as the NDEP Support Fund manager, Rosatom, and the Federal Center for Nuclear and Radiation Safety as the grant recipient. The share of foreign partners’ participation in the project was estimated at €53 million. On the Russian side, funding is provided by State Corporation Rosatom, under the FTP NRS 2008-2015. Rosatom’s portion of the funding was allocated toward waterborne maintenance of the vessel, carrying out repairs, and extraction of part of the solid radioactive waste. The grant funding encompasses the first phase of the project, which includes developing detailed project documentation for the vessel’s decommissioning, improving radiation conditions on the *Lepse*, transferring the *Lepse* to the Shiprepairing Yard Nerpa, and preparation of infrastructure at the Nerpa for SNF extraction, including delivery of specialized equipment. The *Lepse* decommissioning project has been added to the list of nine first-priority projects included into the Strategic Master Plan for decommissioning and ecological rehabilitation of nuclear fleet sites taken out of operation in the Russian Northwest.

The current nuclear service vessel decommissioning concept developed by State Corporation Rosatom implies, in the first place, ensuring nuclear safety of these vessels via the removal of spent nuclear fuel stored on board. Following the SNF extraction step is decontamination of radioactively contaminated equipment, systems, and facilities, their dismantlement into fragments that will constitute solid radioactive waste, and relocation of this SRW into protective containers. Non-contaminated parts are cut up into sections and transferred, after radiation control, to metal manufacturing enterprises as scrap metal. In accordance with this concept, during the first phase of works, the *Lepse* will be cut up into several parts. After the vessel has been moved onto a slipway, the bow and the aft are to be cut off. An enclosure will be built over the remaining section of the vessel, which holds SFAs and solid radioactive waste; a crane and all the necessary equipment for SNF extraction will be assembled inside this enclosure.

In August 2008, management of nuclear-powered icebreakers and nuclear service ships was transferred from the Murmansk Shipping Company to State Corporation Rosatom, which, by extension, assumed responsibility for the *Lepse* decommissioning problem. In 2010, an International Consultant was chosen, and decommissioning work on the *Lepse* began.
In 2010, head of Rosatom’s project office for Comprehensive Nuclear Submarine Decommissioning A. A. Zakharchev presented a preliminary timetable for the implementation of the Lepse comprehensive decommissioning project. The start of SNF extraction, according to that timetable, was scheduled for the third quarter of 2012 or the first quarter of 2013. In 2013, the hull of the vessel was to be cut up and the bow compartment prepared for SNF extraction, and SNF extraction was to be started as well as works involved in SNF and radioactive waste management and disposal of scrap metal and process waste [31]. But time frames set in this plan kept being pushed back.

In 2011, an analysis of the draft project was done, a baseline schedule developed as well as a procurement plan for the first phase of the project, an analysis of transportation options was prepared for the Lepse and an assessment report on the safety of different transportation options [32]. ANO Aspect-Conversion worked out a quality assurance plan, engineering surveys were carried out at the Shiprepairing Yard Nerpa, design concepts were settled on for the management of liquid and solid radioactive waste, and design options analyzed for the project of placing the Lepse on the slipway and for the construction of an enclosure building for the implementation of SNF extraction from the Lepse’s storage hold. A transportation concept to move the Lepse from Atomflot’s wharf to that of the Shiprepairing Yard Nerpa was developed. A decision was made that the Lepse would be towed to the shiprepairing yard. Other transportation options (in dock, by pontoons, or using a special semi-submersible vessel) were deemed impractical. Atomflot developed technical assignments and technical requirements to prepare the Lepse for transportation and to improve the radiation situation on board the ship. By the third quarter of 2012, the nuclear service ship was to be prepared for towing.

At a December 2011 meeting at Atomflot of the Public Council on the Safe Use of Atomic Energy in Murmansk Region [33], the following contracts were reported as concluded: a contract for international support to the Project Management Unit, a contract for the development of the SNF extraction project, and two contracts for preparing the vessel for SNF extraction and transportation. An International Consultant had been chosen – the British firm Nuvia Limited – which was to ensure that all works were being conducted in compliance with international standards and technologies. The principal sponsor of the project is the EBRD; its share in the project is RUR 938 million (€19.23 million). Another RUR 320 million (€6.56 million) is provided by the Russian Federation. In 2008,
RUR 50 million (€1.03 million) was allocated for initial preparations (development of engineering documentation, expert reviews, examination of the vessel’s condition etc.) [33].

In 2011, construction work began at the Shiprepairing Yard Nerpa on the enclosure building that will be installed over the Lepse’s storage hold, and on other Lepse decommissioning infrastructure; work also started adapting the yard’s existing infrastructure to upcoming decommissioning tasks, as per the terms of the contracts concluded. Under the contract concluded with the shiprepairing yard, Nerpa is manufacturing part of the sections of storage packages needed at the stage of sheltering the Lepse when the vessel is moved ashore, and is upgrading the slipway pad. Funding for the Lepse project was allocated by a group of donor countries. The EBRD serves as the manager of these funds. The Lepse decommissioning project is financed both with funds out of the federal budget and the EBRD grant. Implementation of the first phase of works on the Lepse is estimated at €42 million [34].

Initially, towing the nuclear service vessel to the Shiprepairing Yard Nerpa was planned for 2010 (with full completion of all decommissioning works expected in 2015-2016), and then for 2011. However, it was not until September 14, 2012, that the Lepse was finally towed from the Atomflot wharf to that of the Shiprepairing Yard Nerpa. Prior to the voyage, preparatory works had been conducted on the vessel: all hatches (with the exception of the main entrance) were welded shut, all rooms and facilities inside were decontaminated, additional biological shielding was installed, and what radioactive waste could be unloaded was unloaded from the vessel [35].

On December 6, 2013, the Lepse was towed from its temporary mooring location at Pier 6 to Quay N1, where the nuclear service ship will be placed onto the slipway pad. It will be here that a number of operations will be carried out dismantling the upper hull structures in the Lepse’s superstructure and preparing the ship for docking.
Status in the first quarter of 2014

In 2013, the Lepse’s dismantlement never started. The main reason is that the only slipway pad suitable for conducting dismantlement works on the former nuclear service ship is occupied by the first Soviet nuclear submarine the K-3 *Leninsky Komsomol*. The fate of this submarine had long remained uncertain: The two proposals were either to dismantle it or place it in moorage in St. Petersburg as a museum. The Ministry of Defense had not been earmarking funds for any works on the *Leninsky Komsomol*, and the Shiprepairing Yard Nerpa had no other place to move it. In 2013, negotiations began between State Corporation Rosatom and the Ministry of Defense on the submarine’s future. As a result of these talks, the ministry earmarked RUR 43 million (€882,000) as part of the state defense procurement program for 2014 toward ship conversion works on the K-3 – assembling the cut-up sections of the submarine – and floating the submarine. The time frame for these works was set, in approximate assessments, for the first six months of 2014 [36].

The Lepse dismantlement project is expected to proceed over the course of several years. In preliminary projections, the completion date is planned for 2017, when a storage package with what will remain of the Lepse as a result of dismantlement works will be shipped off for storage in Sayda Bay.

As was shown in a presentation given at the March 2014 seminar in Murmansk by Ken Mizen, an expert with the Lepse decommissioning Project Management Unit, the status of the project as of March 2014 was as follows [37]:

- approval had been obtained from regulatory agencies for the project’s detailed design;
- ANO Aspect-Conversion was working through the last comments received on the project following a review by the Project Management Unit and the EBRD;
- a consolidated EIA report was being prepared for review by donor members of the NDEP Support Fund;
- the scope of support works provided to ANO Aspect-Conversion as the principal designer at the stage of implementation of onsite works was at the approval stage.

Atomflot and the Shiprepairing Yard Nerpa were preparing the Lepse for the start of dismantlement work. Development of working design documentation had been completed for the dismantlement project, a controlled access area had been
established at Quay N1, work was in progress manufacturing sections of storage packages. Docking the *Lepse*, as was stated in the presentation, was scheduled for May 20, 2014, and its placement onto the slipway pad was planned for May 30, 2014. However, at the time of publication of this report (September 2014), the slipway was still occupied by the submarine *K-3*, and the *Lepse* remained at the pier of Quay N1; work was under way cutting off the *Lepse*’s superstructure.

The plan for 2015 includes assembling storage packages of the vessel’s bow and aft sections and disposal of the hull. In 2016, the enclosure will be built at the shiprepairing yard on the slipway pad, and equipment will be manufactured for SNF extraction. The project, as stated above, is expected to be completed in 2017, when the spent nuclear fuel stored on the *Lepse* has been unloaded and the storage package containing the SNF storage hold shipped off to LTSS RC in Sayda Bay [1].
Spent fuel removal

Spent nuclear fuel held in storage on the *Lepse* is in a poor condition. In his report “Decommissioning of the Floating Maintenance Base *Lepse,*” Yury Chernogorov, who had worked for a long time as chief special technologist with the Special Technical Supervision Group of the Murmansk Shipping Company, detailed the principal technological process of SNF extraction from the *Lepse*’s storage hold [29]. By 2004, specialized organizations had developed four alternative process procedures for SNF extraction. Chernogorov analyzes them in detail and points out, in particular, that under all the four options presented, the work that personnel will have to perform cutting out and unloading canisters with SFAs from the storage hold will have to be performed in conditions of exposure to high levels of gamma radiation. These operating procedures, furthermore, do not factor in the possibility of SFAs getting “stuck” inside as a result of swelling and deformation. Damaged spent fuel assemblies with broken shroud tubes will present a serious challenge during the extraction work as these SFAs had been placed into the caissons of the tanks with an effort that had resulted in deformation of both the assembly heads and the fuel pin bundles. Extracting these SFAs could lead to a radiation or, possibly, nuclear accident caused by fuel pins dropping out or fuel composition spilling out of fuel pins. Chernogorov concludes that not only is it inadvisable but also practically impossible to ensure nuclear safety of the *Lepse*’s SNF storage hold by extracting this damaged SNF – in particular, because of the enormous individual and collective radiation doses that personnel could be exposed to when performing these works.

In March 1997, a trial SFA extraction was performed out of Caisson 3 of the portside tank of the *Lepse*’s storage hold. An examination of the fuel assembly showed that the diameter of the shroud tube in the fuel-containing section of the SFA was enlarged to 100 millimeters (the diameter of the fuel-containing section of an undamaged spent fuel assembly is 62 millimeters). Out of five SFAs that were planned for extraction, only two were successfully removed, since the inside diameter of the transfer cask, which was 88 millimeters, would not allow accommodating fuel assemblies that had sustained swelling. Subsequent unloading of the SFAs out of the transfer cask and into the storage hold of the nuclear service vessel *Imandra* resulted in radioactive contamination of the open decks both in the controlled area and everywhere on the vessel (contamination levels were mostly within the range of 100÷2000 beta-particles per square centimeter per minute, reaching in one spot 45000 beta-particles per square centimeter per minute), as
well as in the enterprise’s dockside area (100÷6500 beta-particles per square centimeter per minute).

Removal of the 639 spent fuel assemblies from the Lepse remains in fact the main problem in the vessel’s decommissioning project, as many of these SFAs have mechanical defects that could complicate the retrieval work significantly.

According to ANO Aspect-Conversion Engineering Director A. Tsubannikov, 313 SFAs can be retrieved from their storage canisters, 307 SFAs are non-removable and will have to be extracted together with the canisters, 19 defective SFAs are in the caissons. More details on the proposed methods of extracting these SFAs are available in ANO Aspect-Conversion’s presentation [38]. The most challenging work will be the extraction of the chaotically accommodated SFAs stored in the caissons. For implementation of this work, special manipulator equipment has been developed and is being manufactured, as well as a simulation bench to practice the damaged SFA extraction process. This equipment should, first and foremost, ensure radiation protection for the personnel: as much as it will prove possible, SFA retrieval operations will be performed using remote-controlled equipment.

The choice of technology that will be used for the extraction of defective SFAs from the Lepse’s storage hold will be determined by the condition of the spent fuel assemblies in storage there. The extraction of damaged SFAs will require unique technological solutions that will have to be worked out in the course of the extraction work itself. The actual work to retrieve the damaged SFAs will be carried out inside a special protective enclosure, using remote-controlled equipment, and without personnel’s direct involvement. Next, those SFAs that will prove extractable will be removed from their storage canisters and caissons, placed into casks, and shipped off to PA Mayak.

At the moment, the following preliminary scheme has been adopted for the SNF extraction operation:

- verifying the possibility of extracting an SFA from its storage channel with an effort not exceeding the weight of the SFA itself (such SFAs are removed using standard procedure with the help of a transfer cask and are placed into shipping casks);
- an SFA whose extraction is impossible by the standard method is cut out together with the canister where it was stored and is placed into a ChT-14Sh cask;
– the issue of how extraction work will proceed on Caisson 3, which holds nine SFAs with ruptured shrouds, is still not resolved; the options proposed suggest cutting out the entire caisson or concreting the space inside the caisson with special radiation-resistant mixes without cutting out the caisson (i.e., the caisson will be left in the storage hold of the Lepse for a prolonged period of time).
Conclusion

The nuclear service ship *Lepse* remains among the most hazardous nuclear and radiation legacies in the Russian Northwest. Its storage tanks hold 639 spent fuel assemblies including some that are damaged or destroyed. The issue of dismantling the *Lepse* has been the focus of continued discussion since the end of the 1990s, but project implementation has repeatedly fallen behind schedule. According to most recent plans, placing the *Lepse* on the slipway pad for dismantlement was slated for May 30, 2014, but at the time of publication of this report, the ship was still afloat at a pier of Quay N1. The *Lepse* decommissioning project, planned to proceed over a number of years, should, in preliminary projections, be completed in 2017 with transportation of two storage packages with the vessel’s fragments that will be left after dismantlement for long-term storage in Sayda Bay. Under the FTP NRS 2008-2015, RUR 320 million (€6.56 million) was allocated for the decommissioning project. The total cost of decommissioning the *Lepse* is estimated at €75 million, of which around €53 million is funding provided from abroad.
SAYDA BAY

Background

Following the breakup of the USSR, an active process of nuclear submarine decommissioning started at the Russian Northern Fleet. Russia did not have sufficient funds, resources, or capacities for submarine decommissioning, and the dismantlement of the first nuclear submarines in the early 1990s proceeded with funding provided by the American program called Cooperative Threat Reduction (CTR), also known as the Nunn-Lugar Program (named so for the U.S. senators who founded it, Sam Nunn and Richard Lugar). Under this initiative, Russia and CIS countries were given funding to dispose of surplus nuclear and other types of weapons of mass destruction. In 1990, on the coast of the Kola Bay, a temporary storage site for nuclear fleet reactor compartments was organized in Sayda Bay in what used to be a fishing village handed over to the Northern Fleet. The reactor compartments that were left after dismantling nuclear submarines were towed here from enterprises both in Murmansk and Arkhangelsk Regions (Severodvinsk). Year on year, reactor compartments kept collecting at the floating docks in Sayda Bay (including an Alfa-class submarine reactor compartment with liquid metal cooled reactors). For safety considerations, the term of waterborne storage for these reactor compartments was limited to ten years [39] – since there was no guarantee that, when the ten years had passed, the reactor compartments, kept there afloat, would still retain their buoyancy and would not sink – and then the compartments were to be moved into onshore storage.

In 2000, the Northern Fleet made the decision to build in Sayda Bay an onshore storage facility for long-term storage of reactor compartments cut out of decommissioned submarines. By that time, laid up at the piers were 25 reactor compartment units from dismantled submarines. By 2003, their number had increased to 50, with some still containing unloaded SNF. But due to a lack of funding, construction of the onshore storage facility had still not begun. The reactor compartments had been in waterborne storage for more than ten years already and came to present a serious hazard. At the end of the 1990s, the nuclear and radiation-hazardous site in Sayda Bay drew the attention of many countries that were willing to help Russia eliminate its nuclear and radiation safety risks and started to allocate funding toward that goal.
International cooperation

The 2003 G8 summit in Évian-les-Bains (France) ushered in a busy period when the Group of Eight nations and a number of European countries concluded numerous contracts with Russia for submarine decommissioning and activities to improve nuclear and radiation safety in Russia’s Northwest. Norway – not a Group of Eight member – was first to allocate €10 million to dismantle two nuclear submarines. Norway’s lead was followed by Japan, which earmarked funding to decommission nuclear submarines of Russia’s Pacific Fleet. Next, Great Britain provided funding to dismantle another two Russian submarines [40]. Money started flowing from European nations into the account of NDEP’s environmental support fund, managed by the EBRD. (Freeing this money for participation in nuclear and radiation safety projects in Russia became possible after the signing in Stockholm, Sweden, in May 2003, of the MNEPR agreement). The combined effort to provide this financial aid resulted in a total of €142 million. At a meeting in 2003, NDEP fund contributor nations determined the primary nuclear and radiation safety projects to be implemented in Northwest Russia – i.e. projects that most badly required financial assistance.

In 2003, Germany and Russia signed an agreement on creating in Sayda Bay over the next six years an onshore storage site for reactor compartments of nuclear submarines being decommissioned by Russia. Germany regarded its €300 million contribution to this project as part of the commitment it had pledged under the Global Partnership program the Group of Eight nations had adopted at the Kananaskis summit in 2002 [40].

The RC onshore storage site was arranged on a small cape between the bays of Lesnaya and Yepachinskaya, on the territory of that same temporary storage site for reactor compartments in Sayda Bay.

Germany contracted the firm EWN to build a 5.6-hectare yard that would accommodate the storage site. Germany also took it upon itself to improve the infrastructure involved in the management of reactor compartments and solid radioactive waste. The Russian-German project, developed jointly by EWN and NRC Kurchatov Institute, envisioned safe onshore storage of defueled reactor compartments for 70 years. During this period, radiation levels in the irradiated parts are expected to decrease significantly, and the bulk of the metal structures can then be shipped off as scrap for remelting. In accordance with the contract, the
Russian side assumed the responsibility for the actual construction, which made up 60 percent of the works encompassed by the project. The task of implementing the remaining 40 percent of works – including developing the building design, carrying out various studies, manufacturing and adjustment of machinery components etc. – was placed with German firms.

Implementation of the Russian-German cooperation project in Sayda Bay proceeded in two stages.

The first stage (2003 to 2011) included:

- creating the LTSS RC to accommodate 150 reactor compartments of nuclear submarines and 25 compartment units of surface ships and vessels with nuclear propulsion systems;
- development and delivery of a heavy-load transport system for transportation of reactor compartments;
- creating auxiliary infrastructure;
- preparing and putting into operation an SRW accounting and control system;
- achieving environmentally safe conditions in Sayda Bay.

The cost of the first stage of works was €300 million.

The second stage of the project (2006 to 2014) includes creating in Sayda Bay the “Regional Center for Conditioning and Long-Term Storage of Radioactive Waste.”

In 2004, construction of the onshore RC storage site started in Sayda Bay. German companies were developing technologies and were directly involved in building all the infrastructure for the long-term onshore storage facility. In 2005, work started to prepare the site for the construction of a metal-concrete slab that the LTSS RC would sit upon, as well as soil removal, rock blasting, and removal of blasted rock; underwater works were also under way to install the dock [41].

According to preliminary plans, the onshore storage site was to accommodate 77 reactor compartments, but by early 2000, 110 Northern Fleet submarines had already been decommissioned; 72 of these had SNF on board that had to be unloaded prior to dismantlement and towage of reactor compartments to Sayda Bay. A decision was made to expand the storage yard to provide the possibility of accommodating 150 reactor compartments there.
In September 2007, a Russian-German coordination meeting took place in Murmansk on the project of the RC long-term storage site in Sayda Bay [42]. A decision was made that it was necessary to build a site for long-term storage of one-compartment units of submarine reactor units, reactor units of surface ships, and storage packages of compartments of nuclear service ships, with a total capacity of 175 spaces. The other task is building here a regional center for SRW conditioning and storage with a capacity of 100,000 cubic meters. Solid radioactive waste will be transported here in containers for long-term storage until a regional repository for radioactive waste is built.

In 2008, 25 reactor compartment units weighing 1,600 tons each were already in storage at the LTSS RC. In June 2010, another seven RC units were shipped for storage in Sayda Bay from the Shiprepairing Yard Nerpa. This was already the sixth transport operation to Sayda Bay [43]. By August 2010, 40 RC units were already stored onshore in Sayda Bay, and 39 reactor compartments remained at Sayda Bay’s four piers in waterborne storage [44].

Pic. 10. A slide from a presentation made by V. N. Panteleyev, 2014 [46].
Construction progress at LTSS RC: September 2008

Pic. 11. A slide from a presentation made by V. N. Panteleyev, 2014 [46].
Construction progress at LTSS RC: September 2011

On September 1, 2011, an official commissioning ceremony marked the launch of the LTSS RC. The complex comprises 175 storage spaces, a rail track system, a wharf for the floating dock and vessels to moor at, an RC grit blasting and paint shop, and all the infrastructure needed for the LTSS operation.

The LTSS RC is an open-air storage site. Construction and commissioning were carried out on a phased basis in two stages:

Operation of infrastructure built at the LTSS RC

Between 2006 and 2013, nine transportation and handling operations were carried out delivering reactor compartments for long-term storage in Sayda Bay.

On September 1, 2011, the LTSS RC, which is an open-air storage site, was officially commissioned. The necessary process equipment had been delivered, and support infrastructure built. Construction and commissioning had been implemented on a phased basis in two stages: In 2006, the initial section of the LTSS RC was taken online and the first transport and handling operation to deliver seven RC units to the LTSS RC carried out [45]; beginning in 2006 and up to 2013, nine operations were performed delivering RC units for long-term storage at the site [46].

Today, the first and second stages of construction have been completed in Sayda Bay. The storage complex, designed for 180 spaces, comprises: a rail track system, a wharf to accommodate mooring of the floating dock and vessels, an RC scrubbing and paint shop, and all the necessary infrastructure needed for the LTSS RC’s operation. The complex has spaces for long-term open-air storage of 155 submarine RC units and 25 packaging units with compartments of nuclear service ships, surface ships with a nuclear propulsion system, and nuclear-powered icebreakers, as well as 100,000 cubic meters of solid radioactive waste. The transportation and handling operations involve transportation and placement of a reactor compartment from the floating dock PD-42 to the LTSS RC storage pad.

In 2011, the paint shop was commissioned. Its capacity provides for preparing for painting, and painting of, seven or eight reactor compartments annually. After grit blasting, painting, and special preparations, the reactor compartments are moved to the LTSS RC. Radioactive substances are locked inside the reactor compartments and cannot escape into the surrounding environment. Every ten years the reactor compartments are to be transported back to the paint shop for paint restoration and radiation monitoring.

As of 2013, FSUE SevRAO had dismantled four submarine reactor units with liquid metal cooled reactors, 54 one-compartment RC units had been placed in long-term storage, 32 three-compartment units (including reactor compartments) were afloat at the piers [47]. By the end of 2013, all but one submarine taken out of service in the Navy had been dismantled. The last remaining decommissioned submarine was being dismantled.

It should be noted that nuclear and radiation safety projects implemented in Russia as part of international cooperation efforts and with the help of financial assistance from donor countries are not solely carried out in Russia’s Northwest.
Thus, the example of Norway, which was the first country to provide funding to decommission old Russian nuclear submarines, was followed by Japan, which earmarked money to decommission nuclear submarines of the Russian Pacific Fleet. On May 18, 2012, in Razboynik Bay in the Russian Far East, on the territory of the Far East Center for Radioactive Waste Management (FEC) DalRAO (a FSUE RosRAO division), an official inauguration ceremony took place commissioning the long-term storage site for reactor compartments of dismantled Pacific Fleet submarines that had been built as per a cooperation agreement between Russia and Japan. FEC DalRAO took delivery of Japanese equipment necessary to perform placement of reactor compartments at the storage site: the tugboat Sumire, two jib cranes, and the floating dock Sakura. The Japanese government will also finance the construction of the RC preparation and paint shop, whose estimated cost is around $8.5 million (€6.3 million) [48].

Since 2005, when works started building the storage site in Sayda Bay, and until 2013, the German government invested around €700 million into the project [41]. In 2014, the Regional Center for Conditioning and Long-Term Storage of Radioactive Waste, capable of accommodating 100,000 cubic meters of solid radioactive waste, is to start operating at full capacity; the center will receive and handle radioactive waste from the entire region. Should it prove necessary, the center’s storage capacity may be increased incrementally by 20,000-cubic-meter storage segments.

As part of the work undertaken to place in storage at the LTSS RC storage packages of dismantled nuclear service ships, the floating maintenance base Volodarsky was in July 2013 towed from Atomflot’s wharf to Sayda Bay. The motorboat Volodarsky, built 1928, was retrofitted in 1966-1969 into a floating maintenance base to service nuclear-powered icebreakers. In 1991, the boat was reclassified as a berth-connected vessel with use as a temporary storage facility for radioactive waste and process equipment. Dismantlement of the service ship Volodarsky is proceeding in the framework of the FTP NRS 2008-2015. The program budget is made up by RUR 2.02 billion (€41.4 million) in federal budget funding and RUR 940 million (€19.3 million) in technical support. This money is planned to be used for the dismantlement of the service ship Volodarsky, as well as the nuclear service ships Lepse and Lotta, developing the concept of dismantling nuclear-powered icebreakers, etc. [49]. In November 2013, the Volodarsky was placed on the storage pad of the LTSS RC, and in December that year, all solid radioactive waste was unloaded from the vessel. In 2014, dismantlement work on
the Volodarsky is expected to be completed; two storage packages are to be put together as a result of the dismantlement work that will be placed in long-term storage in Sayda Bay.
Operation of infrastructure built at the LTSS RC

RC units are scrubbed, grit blasted, and painted.
An RC unit being wheeled out for placement in its designated long-term storage space.

Pic. 15. A slide from a presentation made by V. N. Panteleyev, 2014 [46].
The floating maintenance base Lepse, as was noted above, was in 2012 towed to the Shiprepairing Yard Nerpa; work is under way to prepare the vessel for dismantlement and unloading of spent nuclear fuel from its storage hold. Next, the nuclear service ship Lotta will be shipped to Sayda Bay. The Lotta, a former lumber carrier retrofitted into a nuclear service vessel in 1984, has two SNF storage holds with a combined capacity of over 4,000 SFAs. At present, one of the storage holds on board the Lotta has been emptied; the plan is to use it for high-level radioactive waste [49]. Dismantlement of the Lotta is to start after spent fuel has also been unloaded from the second storage hold, into casks that have been supplied by Great Britain [50]. According to plans, dismantlement work on the Lotta will start in 2015. Additionally, Atomflot is preparing for dismantlement the nuclear icebreakers Rossiya, Arktika, and Sibir.

In October 2013, the 27th IAEA Contact Expert Group plenary meeting took place in Murmansk, where participants reviewed the progress of international SNF and radioactive waste management projects and projects of nuclear submarine and nuclear service ship dismantlement for 2012-2013 and discussed the need for international cooperation in projects involving cleanup of Arctic seas from nuclear-and radiation-hazardous objects [51]. Out of 200 Russian nuclear submarines taken out of service, only four, in the Far East, were reported as awaiting dismantlement. Dismantlement of the last submarine taken out of service in Russia’s Northwest had been started with Italian funding. A trilateral contract had been concluded toward the implementation of this project between Russia, Italy, and the United States. Italy’s contribution to the project will total €5.25 million, Russia will allocate the same amount, and the United States will provide €1 million.

It was also stated that 54 out of 120 legacy submarine reactor units in Russia’s Northwest were already in onshore storage at the LTSS RC in Sayda Bay. (Similar work had begun in the Far East as well, with funding provided from the Russian budget and technical assistance provided by Japan. As of October 2013, three units had been placed in long-term storage for reactor compartments on Cape Ustrichny. The cleaning and paint shop for reactor compartments was being completed).

Meeting participants also reviewed the results of implementation of international cooperation projects in Andreyeva Bay. Spent nuclear fuel from the first submarine reactor with liquid metal coolant (Order No. 900) had been
unloaded and removed from Gremikha. Preparations for submarine reactor core (Order No. 910) dismantlement and defueling were under way. Both projects are the result of joint efforts of Russia and France. Italy had started manufacturing ten TUK-143 shipping casks for the storage and transportation of spent reactor cores with liquid metal coolant (Alfa-class submarines) to be delivered to Russia in 2014. The United States was funding upgrades on TUK-108 shipping casks to be used for accommodation of SNF from spent reactor cores and its transportation from Gremikha to PA Mayak. Construction of the Regional Center for Conditioning and Long-Term Storage of Radioactive Waste in Sayda Bay, funded by Germany, was nearing completion. In a completing stage as well was the manufacturing of special process equipment for caissons for radioactive waste management, including cutting equipment, equipment for the conditioning facility, decontamination, and final radiation control. The project is to be completed by end 2014 [52].

In 2014, the third stage of LTSS RC construction is being completed in Sayda Bay. In 2016, following the commissioning of the radioactive waste storage facility, shipments of all regional solid radioactive waste will also be directed here [53].
Status in the first quarter of 2014

As was stated with regard to the complex in Sayda Bay at the Murmansk March 20, 2014 international seminar on nuclear and radiation safety in Northwest Russia, the creation of the necessary infrastructure in Sayda Bay made it possible to solve issues of safe storage of reactor compartments. Construction of the first and second stages of the LTSS RC has been completed in Sayda Bay, and construction of the third stage is being completed. Sixty-one reactor compartment units have been placed in temporary storage. Delivery technology has been tested, and the process practiced of accepting for temporary storage of solid radioactive waste from vessels and vehicles. Plans include completing construction of the Regional Center for Conditioning and Long-Term Storage of Radioactive Waste, setting up reception of radioactive waste, its reprocessing and storage, as well as placement in storage of compartments of dismantled icebreakers and nuclear service ships. By 2014, all submarines taken out of service at the Northern Fleet had been dismantled, 70 special-purpose trains’ worth of spent nuclear fuel had been sent off for reprocessing, and more than a half of cut-out reactor compartments had been placed in safe storage. Conditions have been created for SNF management and safe reprocessing of SRW, as well as transport means and casks for shipments of spent fuel and radioactive waste. As a result, environmental conditions in the region have improved considerably [20].
Conclusion

The creation of the LTSS RC in Sayda Bay may be considered the most successful, if the most expensive, project, which is being implemented almost entirely with funding provided by donor countries. Today, a storage facility has been built at the site for 180 storage spaces that allows for long-term storage (approximately 70 years) of reactor compartments of all submarines dismantled in Russia’s Northwest, reactor compartments of nuclear-powered icebreakers, and compartments of nuclear service ships. The regional center for conditioning and storage of solid radioactive waste, with a capacity of 100,000 cubic meters, is being completed. The total cost of the project, as of early 2014, is over €700 million.
CONCLUDING REMARKS

In this report we attempted to summarize the results of international cooperation projects aimed at cleaning up nuclear and radiation legacy sites in Russia’s Northwest. These sites and facilities, which are, mostly, part of the nuclear legacy inherited by Russia from the Soviet Union, were of serious concern for the governments of many countries. The work that has transpired is perhaps the first and only example in the world when many nations, acting on the understanding of the huge threat that nuclear and radiation legacy sites pose for all life on the planet, have agreed to give Russia hundreds of millions of dollars to eliminate these risks.

The combined spending required by the effort to clean up the nuclear and radiation legacies of the Russian Northwest that have been discussed in this report, and to remediate these territories by the international community and Russia, is expected to total around €2 billion. (A roundup of the main figures describing the contributions made by different countries toward the elimination of nuclear and radiation risks in the Russian Northwest is given in the Appendix to this report).

Many nations, in addition to providing financial support, also shared technologies with State Corporation Rosatom, and supplied unique equipment. Very importantly, Rosatom, for its part, created a favorable environment for this cooperation, providing its project partners with all the data, documentation etc. needed for the work. Implementation of these projects would have been impossible without openness, frankness, and transparency.

It seemed at times that the cleanup effort was not proceeding fast enough, but one should take into account that nowhere in the world have projects of this nature or this scope been attempted before, and in many projects, emphasis was placed on achieving maximum safety rather than speed of implementation. The experience gained remediating the territories of the Navy’s former onshore maintenance bases in Northwest Russia will undoubtedly help in the Far East, where similar work is just starting to unfold.

Besides the projects described above, a mention must be given to the fruitful international cooperation achieved in the removal of RTGs that were deployed along the coasts of the Barents, Kara, White, and Baltic Seas. Cooperation also
continues in the field of identifying and examining the nuclear and radiation legacies submerged in the Arctic seas.

Furthermore, the experience acquired by the participating countries in the collaborative effort of eliminating the nuclear- and radiation-hazardous sites in the Russian Northwest can be used to address the problem of the hundreds of thousands of tons of chemical warfare agents dumped in the Baltic Sea, which pose a real threat to all living beings.

Hopefully, the turbulent political times will have no bearing on further cooperation between Russia and its international partners in projects committed to reducing nuclear and radiation threats in the Arctic and adjacent regions.
REFERENCES

1. Королев А. В., Казеннов А. Ю., Кикнадзе О. Е. Презентация НИЦ КИ. Мурманск, 2014.
2. Кудрик И. «Курск» без ядерного топлива отправится на кладбище кораблей. 11.03.2003 (http://www.bellona.ru/russian_import_area/international/russia/...). 11.03.2003 (http://www.bellona.ru/russian_import_area/international/russia/...).
3. Узник Новой Земли. 01.11.2002 (http://bellona.ru/russian_import_area/international/...).


14. Киреева А. Реабилитация ядерных и радиационных объектов на Кольском полуострове затягивается. 23.05.2008 (http://bellona.ru/articles_ru/articles_2008/master_plan_murmansk).


25. Франция профинансирует строительство дезактивационных комплексов в Гремихе. 02.06.2005 (http://bellona.ru/russian_import_area/international/russia/navy/co-operation/38300).


43. Киреева А. Общественникам и журналистам показали объект в Сайда-губе. 09.08.2010 (http://www.bellona.ru/articles_ru/articles_2010/1281340506.42).


55. Павлов А. Норвегия не жалеет денег на губу Андреева. 09.06.2012 (http://bellona.ru/articles_ru/articles_2012/1339236263.06).

56. Денисон Мик (Dennison Mick). Создание системы обращения с ОЯТ и его транспортировки в губе Андреева. Ход выполнения проекта ИСГ 007В. Презентация. Мурманск, 2014.
APPENDIX

A brief summarizing note on financial contributions provided by donor countries to nuclear legacy cleanup projects in Russia’s Northwest

As per expenditure plans approved in 2005 in accordance with the Strategic Master Plan, up to €2 billion was expected to be spent jointly by Russia and the international community before 2025 on nuclear- and radiation-hazardous sites cleanup and area remediation efforts in Russia’s Northwest, including on the following projects:

- dismantlement of all nuclear-powered submarines, reactor compartments at the Long-Term Storage Facility in Sayda Bay: €550 million;
- dismantlement of nuclear-powered surface vessels, reactor compartments at the Long-Term Storage Facility in Sayda Bay: €50 million;
- dismantlement of the nuclear service vessel Lepse: €40 million;
- dismantlement of other nuclear service vessels: €15 million;
- removal of spent nuclear fuel from the territory of the former naval base in Andreyeva Bay and area remediation: €550 млн;
- removal of spent nuclear fuel from Gremikha and area remediation: €200 million;
- building the Long-Term Storage Facility for reactor compartments in Sayda Bay: €200 million;
- building the Regional Center for Conditioning and Long-Term Storage of Radioactive Waste in Sayda Bay: €270 million [12].

However, as follows from information reported on the website of the Russian Atomic Society [24], as of end 2012, the overall amount contributed to the various projects related to nuclear submarine decommissioning totaled already €600 million, and contributions into setting up physical security systems at nuclear sites totaled €170 million.

According to November 2012 information by State Corporation Rosatom [54], France estimated its contribution to the Global Partnership program at $900 million (€670 million), the UK had its contribution pegged at $750 million (€560 million), Japan’s was $200 million (€149 million), and Norway’s $100 million (€74,5 million). The total financial assistance rendered by these countries to Russia thus amounted to $1.950 billion (€1.453 billion). Added as well to this amount should be the contributions of Italy, at €700 million, and the EBRD, at €166 million, as well as the contributions of the United States, Canada, Sweden, and other countries (see below). Altogether 24 countries are participants of the Global Partnership program. The total amount of contributions already exceeds €2.3 billion.
Over the ten years between 2002 and 2012, Russia’s spending as part of the Global Partnership program totaled RUR 27 billion (€554 million), and foreign states altogether contributed RUR 64 billion (€1.312 billion). **Overall, these funds amount to €1.866 billion**.

However, by 2014, target expenditures for many projects had already been exceeded. Thus, over €700 million contributed by Germany had been spent on projects in Sayda Bay instead of the planned €470 million.

**Norway.** Norway since 2002 annually contributed around €10 million into projects in Russia’s Northwest. Thus, by 2014, Norway had altogether contributed around €120 million (including, in particular, €39 million donated to build infrastructure, and €75 million to build a spent nuclear fuel and radioactive waste management complex). Additionally, Norway’s funding was used to decommission five nuclear submarines and 251 RTGs. Work continued in Andreyeva Bay that had been started in 1999: a comprehensive engineering and radiation survey at the stage of designing the SNF and radioactive waste management complexes, and the ongoing monitoring of objects buried in the Kara and Barents Seas. Additional infrastructure was being built at the Shiprepairing Yard Nerpa, etc. [55].

**Italy.** The containership *Rossita* was built, with an estimated cost of €177 million (other sources cite the vessel’s cost at €71.5 million). A radioactive waste management complex was built in Andreyeva Bay (two shelter buildings – Buildings No. 201 and No. 202 – at €5.66 million, as well as a radioactive waste reprocessing complex). Additional funding in the amount of €177 million was spent on equipment for the training center and the shelter buildings [24]. Italy’s funding was also used to dismantle six nuclear-powered submarines, supply submarine dismantlement equipment to the dismantlement site of the Shiprepairing Center Zvyozdochka, and build casks for the spent cores of liquid metal cooled reactors of Alfa-class submarines. The total cost of works carried out with participation of Italy in 2006 to 2012 was €360 million. In addition, €75 million is planned to be contributed to build floatation pontoons for the transportation of reactor units to Sayda Bay and for works in Andreyeva Bay. In total, Italy’s contribution amounts to over €435 million. As per information current for 2012, Italy was expected to contribute another €275 million to projects under the Global Partnership program before the end of 2013, including around $183 million (€136 million) for work with damaged submarines. The total funding already contributed by Italy to the project was estimated by Rosatom to be no less than $700 million (€522 million), and overall Italy was planning to spend around $1.2 billion (€895 million) on cleaning up the nuclear legacy inherited by Russia after the breakup of the USSR [54].

**France.** France has been a participant of Global Partnership projects since 2002. France’s main area of work is remediation projects at the former naval base...
in Gremikha (upgrading the infrastructure, manufacturing equipment for spent nuclear fuel and radioactive waste management, removal of defective SNF, work on rendering safe the damaged reactor compartment of the Alfa-class submarine No. 910, to which France contributed €45 million, and Russia over €50 million). France also helped upgrade equipment at a number of enterprises (the solid radioactive waste incineration facility at the Shiprepairing Center Zvyozdochka, equipment for dismantling spent liquid metal cooled reactor cores and a cell for handling defective fuel assembly canisters at Production Enterprise Mayak, a crane supplied to Atomflot). In addition, 16 RTGs were also dismantled with France’s help [24].

**Great Britain.** Great Britain contributed £3 million (€3.75 million) for the dismantlement of old buildings and structures; another £6 million (€7.50 million) was provided for other projects in Andreyeva Bay.

**United States.** The U.S. is involved in Global Partnership projects in Russia and Ukraine and plans to continue to participate in the Global Partnership program between 2012 and 2022 as well. The total budget of the U.S. participation is $10 billion (€7.49 billion). The main areas of work and results are [24]:

- dismantlement work completed on 33 nuclear submarines (even prior to the start of the Global Partnership program) and 435 RTGs, an RTG storage facility built on the territory of DalRAO;
- upgrades for the physical security systems at 57 civil sites (including sites operated by Atomflot), upgrades for means of physical protection are planned at 19 sites as well as technical maintenance at 62 sites;
- delivery of 60 TUK-108/1 shipping casks for spent nuclear fuel and special-purpose railroad cars for SNF transportation, modernization of casks for the removal of dismantled liquid metal cooled reactor cores out of Gremikha.

**Sweden.** Main areas of work [24]:

- work in Andreyeva Bay (developing a technical and economic feasibility study for radioactive waste management, developing a justification of investment study for the construction of SNF and radioactive waste management infrastructure);
- work is being done jointly with Norway and Finland to decommission RTGs installed along the coastline of the Baltic Sea;
- supplies (jointly with Norway) of equipment for safety enhancements at Leningrad and Kola Nuclear Power Plants;
- training of Northwest Center SevRAO personnel;
- assistance for the establishment of the Atomic Energy Information Center in Murmansk.
Canada. Main areas of work [24]:
- dismantlement work completed on 15 submarines and 64 RTGs;
- 12 submarines transported to dismantlement sites;
- additional submarine dismantlement infrastructure created at the Shiprepairing Center Zvyozdochka.

EBRD. In 2002, the NDEP Support Fund was established, which is managed by the EBRD. The two programs carried out via the NDEP Support Fund are the so-called “Nuclear Window” and “Non-Nuclear Window.” The Nuclear Window budget is €166 million.

The Nuclear Window includes, among other projects [24]:
- developing (jointly with the Nuclear Safety Institute of the Russian Academy of Sciences) of the Strategic Master Plan;
- projects in Gremikha (2006 to 2009): improving the physical security systems, SNF and radioactive waste management studies etc.;
- work in Andreyeva Bay (construction of the TUK shipping cask accumulation pad, the interior survey of Building No. 5 etc.);
- developing project documentation for the decommissioning of the nuclear service vessel Lepse;
- developing the SNF removal project for defueling reactors of Papa-class submarines.

Andreyeva Bay. The overall cost of SNF and radioactive waste removal works in Andreyeva Bay is around €55 million; the work is being financed by the EBRD. Russia’s participation is estimated at €15 million. The environmental rehabilitation at the former naval base is scheduled to be completed by 2025. In Russia’s estimates, no less than €1.5 billion will be required over the next 15 years to convert Andreyeva Bay into a brownfield.

Gremikha. The overall funding allocated for projects in Gremikha between 2003 and 2013 totaled: around €70 million provided by the Russian Federation (State Corporation Rosatom) and around €70 million in individual contributions made by donor countries (mainly, France). The overall funding was around €140 million.

Nuclear service ship Lepse. This is an international project supported by the EBRD. The full cost of dismantling the Lepse is estimated at €75 million, of which around €53 million is funding provided to Russia from abroad.

Sayda Bay. The overall cost of the project as of early 2014 was over €700 million.

As is demonstrated by the data on the cost of projects in Russia’s Northwest cited both in this Appendix and in the more detailed project descriptions
throughout the report, significant discrepancies can be seen in certain cases that can be ascribed to different tallying systems as well as fluctuations of the currency exchange rates between 2000 and 2014. As the note to the reader states at the beginning of this report, because the exchange rates of the various currencies to the euro fluctuated considerably as this report was being prepared, the rates current as of August 10, 2014 were chosen to convert the cited amounts to the euro (where 1 Russian rouble was equal to €0.0205; 1 U.S. dollar was equal to €0.745, 1 British pound was equal to €1.2505, and 1 Norwegian krone was equal to €0.1194). Where the sources used for this report cited euro amounts, these were left unchanged. An additional difficulty that complicated estimations is that each project is financed from a variety of funding sources, and the specific contribution of each side is not always stated in media reports or other information sources. It thus appears that an exhaustively accurate assessment of the funds spent on each particular project cannot be fulfilled.