

Decommissioning and Dismantling of Liquid Waste Storage and Liquid Waste Treatment Facility from Paldiski Nuclear Site, Estonia

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ABSTRACT

The Paldiski Nuclear Facility in Estonia, with two nuclear reactors was owned by the Soviet Navy and was used for training the navy personnel to operate submarine nuclear reactors. After collapse of Soviet Union the Facility was shut down and handed over to the Estonian government in 1995. In co-operation with the Paldiski International Expert Reference Group (PIERG) decommission strategy was worked out and started to implement. Conditioning of solid and liquid operational waste and dismantling of contaminated installations and buildings were among the key issues of the Strategy. Most of the liquid waste volume, remained at the Facility, was processed in the frames of an Estonian-Finnish co-operation project using a mobile wastewater purification unit NURES (IVO International OY) and water was discharged prior to the site take-over. In 1999-2002 ca 120 m³ of semi-liquid tank sediments (a mixture of ion exchange resins, sand filters, evaporator and flocculation slurry), remained after treatment of liquid waste were solidified in steel containers and stored into interim storage. The project was carried out under the Swedish - Estonian co-operation program on radiation protection and nuclear safety. Contaminated installations in buildings, used for treatment and storage of liquid waste (Liquid Waste Treatment Facility and Liquid Waste Storage) were then dismantled and the buildings demolished in 2001-2004.

INTRODUCTION

The Paldiski Nuclear Facility in North-East Estonia was constructed by the Soviet Navy and was used for training of navy personnel in the safe operation of the nuclear submarine propulsion systems. The hull sections of Delta and Echo class submarines, each housing a full-sized PWR type nuclear reactor were installed in the Main Technological Building at the site. These operating nuclear reactors of 70 and 90 MWth output, respectively, were commissioned in 1968 and 1982, while both were shut down in 1989. After collapse of Soviet Union and Estonia's re-proclamation of independence in 1991 the responsibility for the cleanup and decommissioning of the Paldiski site became a subject of negotiations between Russia and Estonia. The Russian military authorities maintained their control and management over the site until September 1995, when the Facility was handed over to the Estonian government.

Before the site takeover by Estonians, Russian operator started the decommissioning of the facility. The reactors were de-fuelled and the spent fuel was transported to Russia, the hull sections not related to reactor systems were dismantled. The hull sections housing



Fig. 1. An overview of Paldiski nuclear site in 1995

the reactor vessels with their primary systems were seal welded and enclosed within the reinforced concrete sarcophagi. The auxiliary facilities were mainly left intact.

By the time of taking over the Paldiski facilities neither national legal framework, regulating radiation protection and nuclear safety nor practical experiences in decommissioning and radioactive waste management existed in Estonia. At request of the government of Estonia, an international advisory group, Paldiski International Expert Reference Group (PIERG), was established in 1994. The main objective for founding PIERG was to promote safe and timely decommissioning of the Paldiski nuclear facilities by advising and assisting of the Estonian authorities and organizations participating in the decommissioning work in technical, legal, organizational, financial, waste management and radiation protection matters [1].

One of the first tasks of the PIERG was to assist the Estonian government in the planning of decommissioning activities of the Paldiski facilities. The prevention of the spread of radioactive, non-radioactive and hazardous material to the environment as well as the minimization of the waste volume has been considered as the highest priority of the decommissioning plan. The final goals of decommissioning are to remove all radioactive material from the site and to release the site (or most of its territory) for an unrestricted use [2].

The current presentation gives an overview about the decommissioning and dismantling of Liquid Waste Storage (LWS) and Liquid Waste Treatment Facility (LWTF) of the Site, as well as about handling of liquid and solid wastes, resulted from these decommissioning activities..

DESCRIPTION OF FACILITIES

Liquid Waste Treatment Facility (LWTF)

The purpose of LWTF was to receive and treat different types of contaminated liquid waste, produced in the site (primary water from the reactor systems, active floor drains and active laundry water, water from showers adjacent to radiological controlled areas etc). The building consisted of a five-storey building with two storeys below ground and a tank farm for storing of contaminated water before treatment or discharge of the free released liquids into the sewage system. Waste treatment systems included three lines of evaporators, one flocculation and sedimentation tank, two ion exchange columns, four sand filters and a number of receiving tanks. The tank farm included 5 tanks of 300 m³ and 3 tanks of 100 m³. All tanks were made of reinforced concrete and lined with discharge stainless steel except two of the 100 m³ tanks which were carbon steel lined and epoxy painted.

The facility did not contain any solidification system. Liquid radioactive wastes remained at the LWTF after treatment, were pumped into the tanks in LWS. The waste included also sludge from flocculation and evaporator concentrates. Spent ion exchange resins were also pumped from LWTF to LWS. Purified water was collected in one of the 300 m³ tanks, and after free releasing, discharge into the Baltic Sea.

The measured dose rate and surface contamination levels in the rooms of LWTF were generally low ranging from background up to 10 µSv/h. Only the contact dose rates on pipes and components were higher in some rooms, the mean values were around 30 µSv/h and in one single room the contact dose rate reached 500 µSv/h.

Liquid Waste Storage (LWS)

The LWS was the central storage facility for liquid waste arisen during the operational period of Paldiski Training Facility. LWS consisted of a main building housing main hall, several auxiliary rooms containing necessary equipment and pipelines, annex with change rooms and different storage rooms and six tanks for storage of liquid waste. The tanks, 400 m³ each, were designed for final storage of processed/concentrated liquid radioactive waste. They were made of reinforced concrete and lined from inside with stainless steel. Two of tanks had engineered sand filter bottom and the surplus water from them were returned to LWTF for additional treatment.

Dose rate and surface contamination levels in most rooms of LWS (except of waste tanks) were in background level, only in a few rooms some contamination was found, corresponding with slightly elevated dose rate readings.

TREATMENT OF LIQUID AND SEMI-LIQUID WASTE

Treatment of liquid wastes prior to takeover of Paldiski Site

During the overall life-cycle of Paldiski Nuclear Site approximately 800-900 m³ of liquid radioactive wastes had been accumulated in the storage tanks of LWS prior transfer of the ownership the Site in 1995. The total activity of these wastes were estimated to be approximately 5 Ci (0,18 TBq), of which 10% was supposed to be in the liquid phase and 90% in the solid phase (ion exchange resins, corrosion products, sand filters, flocculation sludge etc) [3]. The radionuclide inventory of storage tanks in the beginning of 1995 is presented in Table I below.

Table I. The Radionuclide Inventory of Storage Tanks in the Beginning of 1995

Tank No	Volume of waste	Radionuclides in water and sediments				
		¹³⁷ Cs	⁶⁰ Co	⁹⁰ Sr	³ H	
1	Water	111	1,1 x 10 ⁴	3,7	200	1,5 x 10 ⁵
	Solid	ca 3	4 x 10 ⁵	3,2 x 10 ⁴	2 x 10 ⁶	
2	Water	19	5 x 10 ⁴	-	40	1,7 x 10 ⁵
	Solid	ca 1	3,8 x 10 ⁵	2 x 10 ⁴	4,9 x 10 ⁶	
3	Water	29	3,1 x 10 ⁴	-	60	1 x 10 ⁵
	Solid	ca 1	4,9 x 10 ⁵	1 x 10 ⁴	3 x 10 ⁶	
4	Water	24,5	2,3 x 10 ⁴	-	80	8,2 x 10 ⁴
	Solid	ca 1	4,3 x 10 ⁵	1,3 x 10 ⁴	1,5 x 10 ⁶	
5	Water	115	9,1 x 10 ³	20	230	2 x 10 ⁵
	Solid	ca 15-50	4 x 10 ⁶	7,4 x 10 ⁵	6,1 x 10 ⁵	
6	Water	125	3,9 x 10 ³	50	960	2 x 10 ⁵
	Solid	ca 30	2,1 x 10 ⁵	1,3 x 10 ⁶	6,1 x 10 ⁴	

In January – August 1995 most of existing radioactive liquids were purified and free released. This work was initiated under PIERG activities and financed by the Government of Finland. Purification was carried out by the Finnish company IVO International OY using their mobile wastewater purification unit NURES, equipped with selective ion exchange filters for different radionuclides. As Estonian legislation concerning radioactive waste management and effluent releases was almost absent at that time, temporary release limits, set up by authorities, were used. After these had been approved, it became clear, that NURES had to be equipped with filter for the separation of ¹³⁷Cs only.

As a result of purification, 760 m³ of purified water were discharged with total activity of 15 MBq for Cs-137, 296 MBq for Sr-90, 2 MBq for Co-60 and 75,36 GBq for H-3. Separated ¹³⁷Cs with total activity of ca 10 GBq, was collected in one filter column. The filter was then placed in a specially designed concrete container.

Solidification of semi-liquid tank sediments

After most of the liquid waste was treated and released, ca 120 m³ of tank sediments (a mixture of ion exchange resins, sand filter, evaporator and flocculation slurry) remained in two of the tanks of LWS, while other four tanks were emptied from both water and sediments and decontaminated. A thin liquid layer also remained in these two tanks, on the top of sediments, to prevent of drying them.

Solidification of tank sediments was carried out under the Swedish - Estonian co-operation program on radiation protection and nuclear safety. The Swedish counterparts, SKB and Studsvik RadWaste, assisted the site operator in selection of the solidification technology and provided also remotely operated equipment for waste retrieval and solidification. For different solidification options cementation was selected. As a first step the recipe used for solidification was developed and tested with test samples from both tanks.

The project lasted from 1999 to 2002. Before solidification, the tank sediments were separated from water layer, covering sediments in from both tanks, by pumping the water into one of empty tanks of LWS. Part of this contaminated water was later utilized for solidification process. Then the solidification equipment was installed in the main hall of the LWS, consisted of the following components:

- Vacuum unit
- Cement mixer
- Receiving tank for waste
- Silos for sand and cement
- Conveyor unit
- Vibrator unit
- Weight modudes for mixer with terminal
- Air charger (compressor)
- Electric control unit

The waste was transported by vacuum from tanks of LWS to the receiving tank, mounted on the solidification unit. The vacuum nozzle, connected to suction hose, was moved inside the tank by a remotely operated and radio controlled manipulator crane, lifted down to the tank. The process was controlled with two TV cameras. One of the rooms of LWS was refurbished as a control room, containing monitors and unit controls. When the receiving tank was full of waste, the vacuum was evacuated and the bottom valve of the tank opened by compressed air and the waste was falling from tank into the mixer. As an additional support for emptying the waste tank a vibrating device was also mounted on tank. Sand, cement and necessary additives were also poured into the mixer. Emptying of the mixer was done by opening the bottom valve manually. The active grout was poured from mixer into in the 1,7 m³ cubic waste containers made of carbon steel. These containers have been stored into a new interim storage constructed inside the Main Technological Building at the Paldiski site.

After each mixing sequence a sample of concrete was taken before emptying the mixer. Based on the data of radiometric analysis from these samples, radionuclide inventory for each waste package was established. During the project 121 waste containers was produced with total

volume of 209 m³ and total activity of 17,9 GBq for Cs-137, 1,75 GBq for Sr-90 and 1,1 GBq for Co-60.

DISMANTLING OF LWTF AND LWS

In 1998, the European Commission (EC) PHARE financed a project called “Dismantling of the Liquid Waste Treatment Facility at Paldiski -Phase I” was carried out to gather all necessary information of the Facility, to make a dismantling plan and cost evaluations for different alternatives, which then should be the base for a decision of decommissioning options and the financing of the project [4]. A consortium of two companies – SKB (Sweden) and SGN (France) - was formed for this project.

The main conclusions of the study were as following:

1. It was strongly recommended to start the dismantling work as soon as possible, not using the deferred dismantling option, because of a quite bad condition of the building and already low activity levels of dominating radionuclides. Deferred dismantling option would cause high expenses for all necessary repair and maintenance
2. As the activity levels and the contamination of rooms and the process systems were generally quite low, all dismantling work could be done manually with normal hand tools and there is no need of using expensive remote handling techniques. Also, full system decontamination of the most active systems e.g. evaporator or the ion exchange columns, was not motivated before dismantling in order to reduce the dose burden to the workers.
3. It was recommended that the pipes and components would be dismantled in such a way that enables decontamination at a later stage. The decontamination options were not decided on the course of the study and would be depending on the conditions in the future.
4. The estimated volume of active waste was estimated in the order of 350 m³ and the weight in the order of 230 tons. The total activity content was found impossible to calculate on the basis of existing data.

As the existing documentation about the building and it's containments was of a quite poor quality and in some areas almost absent, 3D AutoCad drawings about the building and all technological systems in it, produced in the course of a project, were a valuable outcome of it and very helpful when planning and implementing of actual dismantling operations.

Following the guidelines and recommendations given in the project the dismantling work of the LWTF started in 1999 and was completed in late 2002. The work was broken down into the following steps:



Fig. 2. The Liquid Waste Treatment Facility (LWTF)

The overview of the facility and artistic impression of equipment installed in it (up), dismantling of process lines and decontamination of concrete surfaces (down)

1. Dismantling of conventional technological systems (heating, ventilation, conventional sewage, water supply, cables, etc.) outside the radiological control areas
2. Dismantling of conventional systems within radiological control areas
3. Dismantling of contaminated technological systems and storage tanks
4. Decontamination and declassification of the building
5. Demolition of the building.

To prevent spreading of contamination, for cutting of contaminated systems and pipelines a low speed hacksaws were used. Large components were, with a few exceptions, evacuated in one pieces, without segmenting and, awaiting the decision about their further treatment options, stored temporarily in the specially designed storage area in the Main Technological Building at the Paldiski Site. Contaminated tank linings were decontaminated using sand blasting. Some spots, which were not possible to decontaminate, were removed using disk cutter and disposed as radioactive waste. Fixed contamination on the concrete contamination was found only in the limited areas, mostly in the cellar. Contaminated concrete was removed with a FLEX 1709 concrete shavers and ADAMAS balanced diamond discs. The concrete shaver was connected with vacuum unit consisted of industrial vacuum cleaner and a 200 l drum for collecting of concrete



Fig. 3. The Liquid Waste Storage (LWS)

The overview of the facility (up left) and equipment used for solidification of tank sediments (up right), dismantling of process lines and demolition of building (down)

powder. In some areas, where the floor surfaces were quite uneven or the contamination has penetrated deep into the concrete, there was necessary to use a jackhammer to remove the contaminated concrete layer. For surface contamination unconditional clearance levels of $0,4 \text{ Bq/cm}^2$ was adopted for loose and 1 Bq/cm^2 for fixed contamination, taken over an area of 300 cm^2 .

Dismantling of LWS was, in principal, done in the same way using similar tools and approaches as in the case of LWTF, but as the building was smaller and contained less complicated installations, dismantling work was shorter in time and cost less compared with LWTF. Dismantling of conventional and contaminated systems started in 1993, shortly after the solidification of tank sediments has been completed and equipment, used for solidification, removed from the building. At the end of year 2003 all building, except of three from six waste tanks was emptied from all equipment and pipes and cleaned from surface contamination.

The remaining three waste tanks of LWS were decontaminated up to summer 2004. One of these still contained contaminated surplus water, separated from tank sediments before starting the solidification project. This water had partly been utilized for making active grout during solidification, but later an additional volume, resulted from wet blasting of tanks in LWTF and

LWS, added, so the final volume was 177 m³. According to radiometric analyses of samples, taken from the tank, the activities of radionuclides were 5,75 GBq for H-3, 0,14 GBq for Cs-137 and 17,5 MBq for Sr-90. After getting permission from authority, the content of that tank was free released and discharged in April 2004. The building and waste tanks were, after declassifying, demolished during July-September 2004.

SUMMARY

Before transferring the ownership of Paldiski Nuclear Site to the Estonian Republic, approximately 1000 m³ of liquid and semi-liquid radioactive wastes had been accumulated in the storage tanks of LWS. Built in the mid-sixties, these tanks were designed for final storage of these wastes. But the condition of tanks was quite poor to withstand for a long-term storage period. Also the overall safety criteria had changed much since erecting LWS and final disposal of unconditioned (non-solidified) liquid waste is nowadays considered as non-acceptable option. Thus, high priority was given to the issues concerning treatment of existing at the site liquid wastes as well as dismantling of corresponding installations, in the initial decommissioning plan, worked out before Site takeover.

As a result of implementing several decommissioning and waste management projects at the Paldiski Nuclear Site, at the moment all the liquid and semi-liquid wastes are purified and free released, or properly conditioned, packaged and placed into interim storage. In brief, the following has been done:

- Altogether 937 m³ of slightly contaminated water was free released and discharged with total activity of 155 MBq for Cs-137, 313,5 MBq for Sr-90, 2 MBq for Co-60 and 81 GBq for H-3.
- Ca 10 GBq of Cs-137 was separated during filtering and solidified in one concrete container
- Conditioning of tank sediments resulted of 121 waste containers with total volume of 209 m³ and total activity of 17,9 GBq for Cs-137, 1,75 GBq for Sr-90 and 1,1 GBq for Co-60.

After conditioning of wastes, the buildings, constructed for storage and treatment of liquid waste, were decommissioned and demolished. Altogether ca 150 tons of contaminated metal, 1 ton of asbestos and 5 tons of concrete was accumulated as a result of dismantling the contaminated process systems, tanks and pipelines from LWTF and LWS and decontamination of buildings. The future of these wastes is not finally decided yet, hopefully the significant part of it will be further possible to decontaminate and free release.

All these works were carried out in quite unique situation. Transferring the ownership of the Paldiski Site from Russian Navy to the Government of Estonia was comparatively fast and technically insufficiently prepared process. As a result, in the beginning there was a great void in the necessary technical expertise and trained manpower necessary for decommissioning. Practically all qualified personnel from the Facility have left from Estonia and quite limited information remained from the previous to current operators. Also, a proper legislation, waste management and radiation protection infrastructure were almost absent in Estonia [5]. Nevertheless, within a few years the basic national infrastructure for radiation protection and radioactive waste management was established and with the notable help from international organizations and other countries, several decommissioning projects have been initiated and performed in the former Paldiski Nuclear Site.

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