Radioactive Waste Management in Serbia, 2002-2010

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ABSTRACT

Heavy water moderated and cooled RA research reactor located at the Vinca Institute of Nuclear Sciences near Belgrade in Serbia, was in operation from 1959 until 1984. In 2002, the Serbian government decided to decommission the RA reactor and its ancillary facilities, and set up for that purpose the Vinca Institute Nuclear Decommissioning (VIND) programme. According to the decommissioning plan for the RA reactor, the first activity was the removal of fresh and spent reactor fuel. The fresh fuel, containing 48kg of highly enriched uranium in about 5000 fuel elements, was repatriated to the Russian Federation in 2002 as a result of a joint project between the Serbian government, the USA, the Russian Federation and the International Atomic Energy Agency (IAEA). The removal of about 2500kg of spent fuel is currently ongoing and comprises a number of coherent actions starting from the removal of spent fuel from spent fuel storage facility and reactor core, the packaging into proper shielding and transport containers and the final repatriation to the Russian Federation. Vinča Institute of Nuclear Sciences served for many years as the main radioactive waste management facility in former Yugoslavia, being a national storage facility for the radioactive waste from different institutional activities (medical, military, etc.) as well as the center for research and waste solidification technology development. The main fraction of the low and intermediate level waste (LILW) is stored in two metallic hangars, but several other storage facilities were situated at the Vinča Institute site, historically at different places (open repository, shallow repository). The situation of the interim storage facilities was not satisfactory from the safety and security point of view for a long time. On the other side, current spent fuel repackaging and future reactor decommissioning will generate significant amount of new radioactive waste. In addition, long-term solutions cannot be addressed at the moment, because national plans for final disposal of radioactive waste don’t yet exist. Consequently, waste management can only address an interim solution, which is the design and construction of new facilities: hangar for radwaste (hangar H3) and secure storage for strong sealed sources, as well as waste treatment facility.

Key words: radioactive waste, spent fuel, reactor, decommission, solidification, hangar,
1 INTRODUCTION

1.1 Radioactive waste inventory

Two light construction metal-sided hangars, Hangar-1 (H-1) and Hangar-2 (H-2), were commissioned in 1968 and 1982 respectively to temporarily store the waste. Figure 1.

Figure 1. Hangar-1 (H-1) and Hangar-2 (H-2),

H-1 is now full but is not leak-tight or isolated from the environment. The construction is corroded and in some places mechanically damaged, and the inner space is very probably contaminated by the radioactivity released from the stored waste packages. This hangar contains almost 800m$^3$ of packaged and non-packaged waste and in particular (3):

- About 1500 pieces of 200L metal (carbon steel) drums;
- About 300 pieces of 30L plastic containers;
- About 300 pieces disused sealed sources (Co-60 and Cs-137) in lead containers;
- An unknown inventory of different kinds of radioactive waste in the drums, as well as some contaminated free loaded wastes and materials.

H-2 contains more than 1000m$^3$ of fully containerized waste and shielded sealed sources, in particular (4):

- About 1000 standard 200L drums with repacked (compacted) waste former open pitch repository (the average activity is about 185 MBq/drum);
- About 300 standard 200L drums with very low activity air filters gathered after the Chernobyl accident;
- About 450 standard 200L drums with waste from various users;
- 31 pieces of 200L drums with cemented sludge (of 1996) from the reactor spent fuel storage pool (with an average activity about 150 MBq/drum);
- Almost 1000 spent sealed sources (the total activity inside the containers is 22.2TBq); Figure 2.
H-2 is, in general, in better conditions, and safe manipulation of the waste is still possible. Although all of the waste is poorly characterized, the records for principal categories of the waste are available. Figure 3.

2 RADIOACTIVE WASTE PROCESSING/SLUDGE CONDITIONING AND STORAGE

Ten Years ago We treat radioactive sludge from RA Research reactor. Total quantity of sludge on the bottom of the RA research reactor spent fuel storage pool was estimated to be about 3 m$^3$. Estimation was made on the basis of the average sludge height on the bottom of the pool and pool surface. The sludge color has been a dark red - brown, like an iron oxide corrosion products. Gamma spectrometry analysis showed that the specific activity of the sludge is about $1.8 \pm 0.2$ MBq/L from $^{137}\text{Cs}$ nuclide and about 15 kBq/L from $^{60}\text{Co}$ nuclide. Based on the previous experience a technology was developed for sludge immobilization and conditioning in a cement matrix, inside casks, produced using the standard 200 L metal barrels which have lids supplied with screws. Casks have been produced as concrete shielded containers in standard metal barrels. Thickness of the concrete walls is from 6 to 7 cm. Entire inner side of the cylindrical concrete wall is covered by plastic tube with wall thickness of 1 cm, which has been used as a model in forming cylindrical concrete wall. This plastic tube serves as a first barrier in preventing radionuclides leaching from radioactive sludge immobilized in a cement.
matrix. The bottom cask concrete wall is also 6 – 7 cm thick. In order to prevent or reduce radionuclide leaching, this wall has been covered with epoxy resin. The useful volume of such designed cask is about 75 L.

The existing pilot cement mixer was reconstructed to enable placing a barrel containing the planned quantity of sludge on its platform without a risk of spilling. About 60 – 65 l of sludge are poured at a time from the sedimentation vessel into a previously prepared cask. As soon as a cask is filled up, it is hermetically covered with a lid supplied with screw and transported to the laboratory for sludge conditioning. There, additional settling of sludge is allowed. Separated water is pumped into a plastic can and taken back to the RA reactor spent fuel storage pool. Through the second stage of the sludge settling, volume of the sludge in the cask has been reduced to about 40 l. Figure 4.

![Image](image.png)

**Figure 4. Apparatus for sludge settling and Modified pilot mixer with concrete container made in metal barrel**

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When the cask with the settled sludge is placed on the platform of the mixer for further conditioning, the necessary amount of cement (PC-45 MPa), according to the established formula of cement matrix and the cement-sludge ratio, are poured into the cask. The formula of cement matrix and the cement to sludge ratio, are defined in accordance with previous experience and experimental investigations on radwaste cementation and and experiments made with this sludge. The best sludge to cement mass ratio for appropriate mechanical strength was approximately 1:1.8 Practically, Reduction Factor, RF, was about 33 ( 200m3 of liquid radioactive waste from RA basins, we transferred in 31 concrete casks in metal barrels, approximately 6 m3 of solidified sludge with concrete. Figure 5
3. **VIND Program**

Serbia, it referred primarily to the Institute of Nuclear Sciences "Vinca", together with Public Companie Nuclear Facilities of Serbia, which has already begun to solve the problems of final disposal, in terms theoretical and research in the field of procedures for the immobilization of low and medium radioactive waste by cement process (based on mortar and concrete), as well as define the conceptual design of Engineered near-surface disposal facilities.

Based on the Republic of Serbia Government's decisions made in July 2002 & February 2004, VIND PROGRAM (Vinca Institute Nuclear Decommissioning), starts with three Projects:

1. Spent Fuel Transport
2. Radioactive Waste Management at the Vinca site, and
3. Decommissioning of RA Reactor

3.1 Spent Fuel Transport

The first project was successfully completed in the year 2010. On 7 April 2010, Serbian officials announced that the last of the spent nuclear fuel (around 8,000 fuel elements), at the Vinca Institute of Nuclear Sciences in Belgrade would be transferred to the Russian Federation. In an operation coordinated by the IAEA, the material left the Vinca Institute on 18 November 2010 and was transported through Serbia, Hungary, and Slovenia under heavy security before arriving at the Slovenian port of Koper on 21 November. There, it was loaded onto a cargo ship and sent to Murmansk, Russia. From Murmansk, the spent fuel was transferred by train to the Mayak reprocessing facility in Ozersk, Russia, where the fuel will be reprocessed and the waste will be stored. On 22 December 2010, 2.5 tons of spent nuclear fuel arrived at the secure nuclear facility in Ozersk. This event marked both the complete removal of spent nuclear fuel from the Vinca Institute and the largest single shipment of spent nuclear fuel under an international program. No further spent fuel or weapons-grade materials remain on the territories of the states that previously comprised the country of Yugoslavia.
3.2 Radioactive Waste Management at the Vinca site

The radioactive waste management project, which includes the construction of new storage and waste processing facilities, was completed in 2010. For more than 40 years, the Vinca Institute collected radioactive waste from the Former Yugoslavia and subsequently, the Republic of Serbia. Two dilapidated storage facilities held more than 4,000 sealed and unsealed radioactive sources along with transuranic wastes and depleted uranium. Construction of the new storage facility (Hangar 3), cost 2.4 million Euros and was completed in November 2010. Currently 1700m³ of radioactive waste can be stored there. The facility will reportedly store more than 6,000 “disused sealed radioactive sources” and over 40,000 category 5 smoke detectors. A waste processing facility was constructed at this site in the 1980s, but was never commissioned. It was fully upgraded in November 2010 in order to be able to treat low and intermediate level radioactive waste. Improving the waste processing facility required an investment of 1 million Euros, including the equipment costs.

Establishing a proper and well-equipped radioactive waste processing facility became one of the highest priorities of the VIND programme, considering the existing and foreseen waste inventory. Thanks to the financial support given by the Ministry of Science and Technological Development of the Republic of Serbia and a number of donor countries and international organisations, one of the existing buildings at the Vinca site was refurbished and transformed to a Waste Processing Facility (WPF). This new facility will become operational early in 2010 and will be equipped with simple and proven technologies, tailored to processing of existing and foreseen solid and liquid radioactive waste existing at the site. Fig.5

Fig.5 Waste Processing Facility (WPF)

Functions performed will include:
- Sorting of radioactive waste.
- Fragmentation of solid radioactive waste.
- Packaging of sorted radioactive waste.
- Compaction (at medium pressure) of solid radioactive waste.
- Cementation (in drum or with external cement mixer - not yet decided).

Fig. 6

Fig.6 Shematic view of Waste Processing Facility (WPF)

- Extensive radioactive waste control and characterization.

The WPF will provide for reprocessing and if necessary for the repackaging of all the historical waste from H-1 and H-2 and will be also able to fully process all expected kinds of decommissioning radioactive waste generated during SNF shipment and RA and H1 decommissioning.

3.3 The project will continue in 2012 and 2013. with "Reactor Decommissioning of RA"

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4. REFERENCES


