Decommissioning the Romanian Water-Cooled Water-Moderated Research Reactor: New Environmental Perspective on the Management of Radioactive Waste

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ABSTRACT

Pre-feasibility and feasibility studies were performed for decommissioning of the water-cooled water-moderated research reactor (WWER) located in Bucharest - Magurele, Romania. Using these studies as a starting point, the preferred safe management strategy for radioactive wastes produced by reactor decommissioning is outlined. The strategy must account for reactor decommissioning, as well as for the rehabilitation of the existing Radioactive Waste Treatment Plant and for the upgrade of the Radioactive Waste Disposal Facility at Baita-Bihor. Furthermore, the final rehabilitation of the laboratories and ecological reconstruction of the grounds need to be provided for, in accordance with national and international regulations.

In accordance with IAEA recommendations at the time, the pre-feasibility study proposed three stages of decommissioning. However, since then new ideas have surfaced with regard to decommissioning. Thus, taking into account the current IAEA ideology, the feasibility study proposes that decommissioning of the WWER be done in one stage to an unrestricted clearance level of the reactor building in an Immediate Dismantling option.

Different options and the corresponding derived preferred option for waste management are discussed taking into account safety measures, but also considering technical, logistical and economic factors. For this purpose, possible types of waste created during each decommissioning stage are reviewed. An approximate inventory of each type of radioactive waste is presented. The proposed waste management strategy is selected in accordance with the recommended international basic safety standards identified in the previous phase of the project.

The existing Radioactive Waste Treatment Plant (RWTP) from the Horia Hulubei Institute for Nuclear Physics and Engineering (IFIN-HH), which has been in service with no significant upgrade since 1974, will need refurbishing due to deterioration, as well as upgrading in order to ensure the plant complies with current safety standards. This plant will also need to be adapted to treat wastes generated by WWER dismantling.

The Baita-Bihor National Radioactive Waste Disposal Facility consists of two galleries in an abandoned uranium mine located in the central-western part of the Bihor Mountains in Transylvania. The galleries lie at a depth of 840 m. The facility requires a considerable overhaul. Several steps recommended for the upgrade of the facility are explored.

Environmental concerns have lately become a crucial part of the radioactive waste management strategy. As such, all decisions must be made with great regard for land utilization around nuclear objectives.

INTRODUCTION

The water-cooled water-moderated reactor (WWER) of Bucharest, Romania is a tank-type research reactor of 2 MW nominal thermal power and a maximum thermal neutron flux of 2 x 10^{13} n/cm^2/s. It is Russian-designed and manufactured and has operated continuously since July 27, 1957, with no major mishaps and no significant refurbishments.

The reactor was shut down in 1996 in order for the National Commission for the Control of Nuclear Activities (CNCAN) to conduct a safety review. Subsequently, the reactor resumed operations and continued to function until its final shutdown in December 1997. Decommissioning works are currently under way.

Decontamination and decommissioning activities create radioactive waste that needs to be managed appropriately so that the public is protected from the associated radiation hazard. According to the International Action Plan on the Decommissioning of Nuclear Facilities, decommissioning actions must be carried out in a manner that ensures the protection of the personnel and the long-term protection of the general public and the environment. These actions will typically include reduction levels in residual radionuclides so that buildings and materials can be safely released or reused.

In accordance with IAEA recommendations at the time, the pre-feasibility study proposed three stages of decommissioning. The first decommissioning stage would involve emptying and drying of process systems. The second stage would consist of decontamination and clean-up of the former nuclear plant. The third stage of decommissioning would involve the removal of parts with significant activity levels. However, recently new ideas have surfaced with regard to decommissioning. Thus, taking into account the current IAEA ideology and German experience, the feasibility study proposes that decommissioning of the WWER be done in one stage to the clearance level of the reactor building. The technical solution of a safe enclosure with surveillance was thus abandoned. This is due to the fact that, in international experiences, this has proven to be a costly solution that also bequeaths an undue burden upon future generations. Currently, the operational staff is in the process of removing fuel, draining systems, conditioning operational waste, cleaning and decontamination of equipment and structures. During this decommissioning transition phase, some radioactive materials from the initial inventory were further characterized. These materials were not previously identified as auxiliary devices. Their list is given in Table I.

Table I. Quantities of Previously Undetailed Radioactive Waste Generated by WWER Decommissioning in transition period.

Type	Mass (t)
• Metals: Aluminum, Cast Iron, Stainless Steel, Copper	~ 19
• Plastics	~ 7
• Wood	0.6
• Graphite	0.8

• Rubber	0.1
• Glass	0.1
• Textiles	0.15
• Resins	0.017

Additionally, there are 800 drums filled with historical waste.

The Decommissioning Plan provides for the following activities, after the transition stage:

- reactor block decommissioning
- primary circuit decommissioning
- hot rooms decommissioning
- removal of parts in which activity level remains significant.

The plan also provides for the final rehabilitation of the laboratories and ecological reconstruction of the grounds. Cleaning the main building will allow it to be used for research activities. Currently, a Waste Management Plan related to the Decommissioning Plan is being drafted, and should be available soon (April 2006).

Studying past international experiences in the nuclear field, one can conclude that decontamination is a key part of nuclear facility decommissioning. Using decontamination techniques, it is possible to reduce the amounts of radioactive waste and to reuse valuable materials.

DECOMMISSIONING THE ROMANIAN WWER – SPECIFIC FEATURES

The decommissioning strategy involves the following costs:

- reactor decommissioning costs
- Radioactive Waste Treatment Plant rehabilitation costs
- Baita-Bihor Radioactive Waste Disposal Facility rehabilitation cost.

Specific for Romanian WWER reactor is the necessity for rehabilitating the existing Radioactive Waste Treatment Plant (located near the WWER) and the existing National Radioactive Waste Disposal Facility, located at Baita-Bihor, 600 km away from Bucharest.

These facilities do not comply with the current requirements for nuclear facilities and need major improvements.

CHARACTERISTICS AND INVENTORY OF RADIOACTIVE WASTE GENERATED BY WWER DECOMMISSIONING

Radioactive waste generated during WWER decommissioning is classified as follows:

1. Activated radioactive wastes (internal, horizontal channels and thermal column, biological shielding).
2. Radioactive contaminated wastes (primary circuit non-activated components, some technological rooms as main hall, pumps room, radioactive material transfer areas, ventilation building and stock).
3. Contaminated materials, identified during the transition stage, from the reactor and ventilation buildings after 40 years of nuclear research activities.
4. Secondary wastes resulted from decommissioning works.

The types of radioactive waste that will be generated by the decommissioning operations soon to be performed at Romanian WWER are outlined in Table II.

Table II. Quantities of Radioactive Waste Generated by WWER Decommissioning

Type	Phase	Level of Contamination	Quantity
Decontamination solutions	Liquid	Very low	500 m^3
Decontamination solutions	Liquid	Low	750 m^3
Decontamination solutions	Liquid	Intermediate	360 m^3
Organic Solvents	Liquid	Low	1 m^3
Misc. Materials	Solid	Intermediate	150 m^3
Misc. Materials	Solid	Low	500 m^3
Thermoplastics	Solid	Low	60 m^3
Spent Ion Exchangers	Solid	Intermediate	5 m^3
Air Filters	Solid	Low	50 items
Misc. Metallic Waste	Solid	Low	25 m^3
Aluminum	Solid	High	10 Kg
Steel	Solid	High	900 Kg
Aluminum	Solid	Intermediate	2300 Kg
Steel	Solid	Intermediate	77000 Kg
Concrete	Solid	Intermediate	12000 Kg
Graphite	Solid	Intermediate	1200 Kg
Aluminum	Solid	Low	1250 Kg
Steel	Solid	Low	6650 Kg
Concrete	Solid	Low	48000 Kg
Graphite	Solid	Low	2770 Kg
Steel	Solid	Low + Intermediate	135000 Kg
Concrete	Solid	Low + Intermediate	1500000 Kg
Aluminum	Solid	Low + Intermediate	3850000 Kg
Graphite	Solid	Low + Intermediate	2000 Kg
Paraffin	Solid	Low + Intermediate	5000 Kg
Plastics	Solid	Low + Intermediate	1600 Kg
Radioprotection materials	Solid	Low + Intermediate	10000 Kg
Electrical Cables	Solid	Low + Intermediate	7000 Kg
Equipment and Tools	Solid	Low + Intermediate	15000 Kg
Organic Materials	Liquid	Low + Intermediate	5 m^3
Plastics	Solid	Low + Intermediate	100 m^3
Abrasive Material	Solid	Low + Intermediate	5 m^3

The treatment and conditioning of these wastes will involve some options presented in the next chapters.

WASTE MANAGEMENT

Although at this stage a Waste Management Plan does not exist, it was substituted with measures for waste treatment and disposal improvements. Waste Management Plan is currently being drafted, based on the aforementioned waste treatment methods and taking into account the requirements of the Decommissioning Plan. This Waste Management Plan should be available by April 2006.

In order to obtain maximum benefits it is necessary to improve the current Radioactive Waste Management National System in the following aspects:

- Implementation of EU legislation and IAEA recommendations in order to achieve a safer and more efficient waste management.
- Creation of a National Exemption Policy, which would establish clearance levels and the characterisation system to be applied. This is currently in its final stages of approval.
- Technical and administrative cooperation with other countries interested in experience exchange.

Recently, a Waste Management Agency, ANDRAD[1], was created in order to separate the three responsibilities: Waste Producers, Regulatory Body and Waste Management Agency.

Presently, in Romania, IFIN-HH[2] is responsible for radioactive waste management produced by the non-nuclear fuel cycle and SCN-Pitesti[3] is responsible for radioactive waste management arising from nuclear fuel cycle, while the newly created ANDRAD coordinates all activities. The operation of the National Disposal Facility from Baita - Bihor is also the responsibility of IFIN-HH. The nuclear activity regulatory body is CNCAN[4].

The existing Radioactive Waste Treatment Plant (RWTP) from IFIN-HH includes:

- The collection of liquid effluents into two 300 m^3 reception tanks.
- The liquid effluent treatment is carried out by means of chemical treatment (flocculation), evaporation and passing the distillate through an ion exchange resin column.
- The concentrate from the evaporator is removed for mixing with cement and placement into drums. This installation will be decommissioned and a modern facility will be built to replace it.
- Low level solid wastes are treated by incineration, shredding and compaction followed by cementation.
- Intermediate level solids are conditioned by direct cementation.

Because the Radioactive Waste Treatment Plant has operated without significant modification from 1974 some of the installed equipment at RWTP need to be replaced due to deterioration. Also, the overall level of safe guards and safety within the facility is not up to present standards in the western countries. In order to be able to treat radioactive waste generated by decommissioning works as well as, other radioactive waste coming to the RWTP from other sources, the following minimum requirements:

- Updating and adapting the existing installations to bring the plant up to modern standards and fully operational status.
- Modification and improvements brought to the existing installations in order to be able to treat wastes generated by WWER decommissioning.

The existing waste treatment facility was designed for the following capacities:

- Liquid wastes (3300 m^3/year);

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1 National Agency for Radioactive Waste
2 Institute for Physics and Nuclear Engineering – Horia Hulubei
3 Nuclear Research Institute - Subsidiary of Romanian Authority for Nuclear Activity
4 National Commission for the Control of Nuclear Activities

  - Very low radioactive liquid: 2100 m^3/year ($A<10^{-6}$ Ci/m^3);
  - Low radioactive liquid: 1000 m^3/year ($A<10^{-3}$ Ci/m^3);
  - Intermediate radioactive liquid: 200 m^3/year ($A<10^{-3}$ Ci/m^3);
- Solid wastes:
  - Combustible: 10 m^3/year;
  - Compactible: 50 m^3/year;
  - Noncombustible - noncompactible: 10 m^3/year;
  - Shreddable: 10 m^3/year;
  - Intermediate radioactive waste: max. 150 drums with concrete shielding.

Based on real necessities, the following technical solutions are selected at pre-feasibility phase:

- Build a new liquid treatment plant.
- Refurbish the solid treatment plant, improving compaction, incineration and cementation lines, and including decontamination and cutting systems;
- Build a new interim storage facility.

The feasibility study phase provides for the acquisition of a new liquid treatment installation that will be set up in the refurbished existing building.

Features of the New Liquid Treatment Plant

The existing liquid waste treatment facility will be decommissioned and replaced by a modern facility. The new liquid treatment plant, to be set up in an existing chamber, will have a capacity of 350 m^3/year. It will be equipped with a module for chemical treatment, an installation for slurry filtration, an evaporator for decontamination factor improvement and waste volume reduction, and an ionic exchange installation. After chemical treatment and precipitation the slurry will be directed to the filtration system with a story filter that will operate in vacuum. The supernatant resulted will be filtrated through ionic exchangers and then transferred to the intermediary tank. After the radiochemical analysis, this liquid will be released or transferred to the evaporation unit.

The general flow schematic for the management of radioactive waste generated by the decommissioning of the Bucharest-Magurele WWER is included in Figure 1.

THE MODERNIZATION OF THE NATIONAL DISPOSAL FACILITY

The National Disposal facility was adapted in a former uranium mine in the central-western part of the Bihor Mountains in Transylvania. Two galleries at a depth of 840 m were selected.

The operation of this disposal facility involves the following stages:

- the stage of disposal room preparation;
- the stage of operation;
- the stage of rooms closing;
- the stage of disposal facility closing;
- the stage of institutional surveillance.

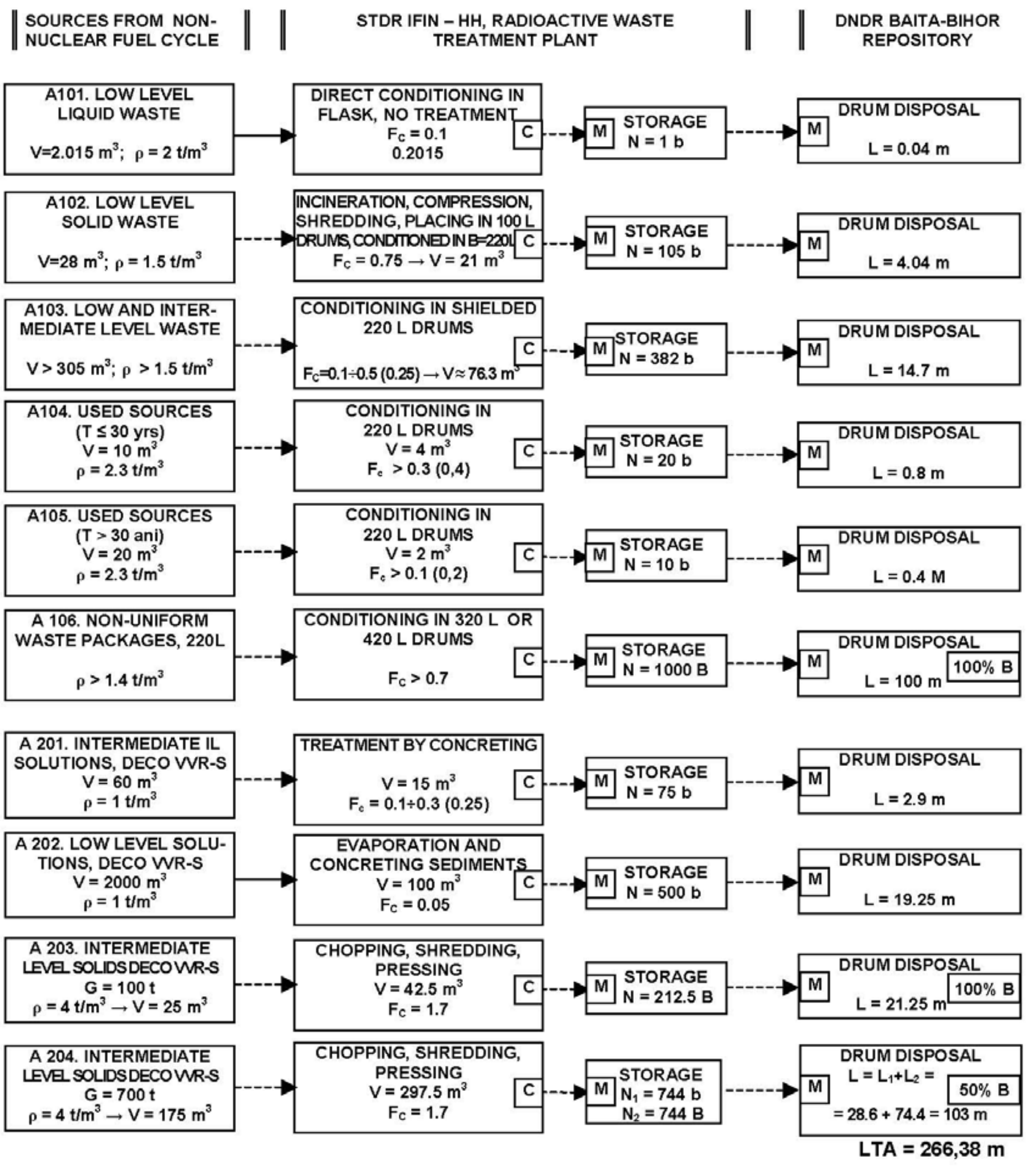

Fig. 1. The general flow sheet for the management of radioactive waste at IFIN-HH Bucharest

V = radioactive waste volume	T = half – life
N = number of drums	G = mass
b = 200 L drums	C = radioactive waste characterization
B = 400 L drums	L = length of the disposal gallery occupied by packages
M = radioactive waste monitoring	LTA = length of galleries required for IFIN-HH
ρ = apparent density	→ Transfer by pipe
F_C = conditioning factor	- - → Transfer by car

Length of the disposal galleries for IFIN-HH Bucharest LTA = **266,38** m

In order to improve the sealing of disposal rooms and the overall activity, it is necessary to achieve the following objectives:

a. The construction of a road to ensure year-round access of trucks to the disposal facility.
b. The construction of a technological building including a hangar for discharging drums.
c. Reconstruction of drainage channels.
d. The attainment of a physical protection system.
e. Waterproofing of 200 meters of main access gallery and supplementary works to disposal rooms.
f. Reconstructing the power supply.
g. Reconstructing the ventilation system.
h. Utilities supply for technological building.
i. The collection of the waters from decontamination.
j. Purchasing the necessary equipment (dosimetric equipments, transportation equipment, concrete mixer, etc.).
k. Developing new drum immobilization technology.

Access road

In order to ensure permanent access to the National Radioactive Waste Disposal Facility, an access road (~3 km) from the existing road in administration of National Uranium Company will be constructed. Presently, a provisional macadam road is in operation, one that renders access during snowy winters almost impossible.

Building characteristics

The technological building provided for by the prefeasibility study will have a ground floor and a technological basement. The ground floor will comprise of the following:

- an industrial hall provided with a lifting bridge and an electrical crane for drum discharging and transportation to storage facility. The drums are transported to disposal rooms by an electric car.
- the administrative building which will contain:
    - a control room for physical protection and surveillance of the disposal facility area.
    - the room for dosimetric instrumentation.
    - electrical room.
    - inactive ventilation room.
    - airlock (shower and sanitary group).
    - locker room.

The technological basement will comprise of the following:

- radioactive liquid tank room.
- potentially radioactive liquid tank room.
- radioactive ventilation room.

These improvements are not yet approved but necessary.

Drainage channel

Presently, for infiltration water there exists a channel drainage system made of reinforced concrete and provided with drainage ducts. The secondary channels collect the infiltration water from the disposal rooms and takes it to storage basins. These basins are periodically emptied to the environment.

The drainage system will be improved by the construction of a new collection system, with local control pits at every disposal room, which will drain the infiltration water to radioactive waste tanks located in the technological basement of the new building. Other infiltration water will be collected in the potentially radioactive tanks also installed in the technological basement.

The existing storage basins will be reconstructed and designated for meteoric water and for non-radioactive liquid waste.

Physical protection system

The physical protection system will be designed to prevent sabotage and unauthorized intrusion. It will comprise of a protection fence and TV cameras. The system will be designed to cover the whole area, including the venting gallery.

Waterproofing

The main gallery designed for drum transport will be waterproofed along the first 200 meters from the entrance. The infiltrated water will be directed into existing storage basins. The disposal chambers will be waterproofed with a synthetic diaphragm. The infiltrated water outside the diaphragm will be directed to the potentially radioactive liquid waste tanks, located in the technological basement, and the infiltrated waste inside the diaphragm will be directed to radioactive waste tanks also in the technological basement. This improvement will reduce the capacity of the repository by 16%.

Radioactive liquid waste system

The system is designed to collect the radioactive liquid generated by decontamination of equipments and transportation means used in the technological process. Decontamination will be performed in the technological hall only after detection of contamination. The collected water will be stored in tanks for natural decay, controlled release or directed to the Waste Treatment Plant from IFIN-HH.

Utilities

The main utilities consist of clean water supply including fire fighting and decontamination water. For water drainage a septic tank will be constructed. Additionally, a new electrical supply line will be necessary.

The communications system

In order to ensure the safe and speedy transfer of information, a modern telephonic system that will provide outside and inside telephonic links will be installed.

Radioactive waste packages transportation

Trucks will perform the package transportation between IFIN-HH Bucharest and the National Radioactive Waste Disposal Facility, Băița – Bihor.

The following package types will be accepted for disposal:

- standard 220 L drums containing waste immobilized by concreting;
- 316 L drums containing immobilized degraded standard 220 L drums;
- standard 420 L drums containing immobilized waste.

It is also possible to dispose of other authorized packages with approval of competent authorities. The following will be provided for package transportation:

- two 19-ton lorries.
- an electric stacker, with a 3 ton available load.
- an electric car, available load 2 tons.
- two motorcars for personnel transport.

CONCLUSION

The Romanian WWER, in service since 1957, was taken out of service in 1997 and is currently undergoing a decommissioning process. Starting from actual IAEA defined options for decommissioning, during the feasibility study phase of WWER decommissioning the immediate dismantling option was preferred to the safe enclosure method, favored during the pre-feasibility phase and the earlier PHARE project. The immediate dismantling option does allow, however, for a transition period during which clean up and removal of auxiliary mobile radioactive devices is performed.

The decommissioning strategy must take into account costs for WWER decommissioning, as well as costs for much needed refurbishments to the radioactive waste treatment plant and the Baita-Bihor waste disposal repository. The quantities and composition of the radioactive waste generated by WWER dismantling were estimated. Several improvements to the Baita-Bihor repository and IFIN-HH waste treatment facility were proposed.

A Waste Management Plan is currently in the works. This plan needs to be applied in concordance with the Decommissioning Plan in order to achieve the highest efficiency. The development of the Waste Management Plan needs to take into account all technologies and

techniques developed and used internationally in this area. This plan will be completed by spring of 2006.
The estimated quantities of materials to be managed in the near future raise some issues that need to be solved swiftly, such as treatment of aluminum and lead and graphite management.

Since this is its first decommissioning project, Romania must take capitalize on valuable international experience in the fields of waste management and decommissioning. International experiences, such as the German decommissioning experience, and IAEA guidance constitute and invaluable fountain of knowledge. At the same time, the lessons learned from the deactivation of United States Department of Energy nuclear facilities must be studied and some efficient decontamination technologies may be implemented.

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