ENGINEERING AND PUBLIC ACCEPTANCE PROBLEMS TO THE LOW / INTERMEDIATE LEVEL RADIOACTIVE WASTE REPOSITORY NEAR THE CERNAVODA NUCLEAR POWER PLANT

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ABSTRACT

This paper presents some specific problems and their solutions with regard to the final disposal of radioactive wastes generated by the Cernavoda Nuclear Power Plant (NPP). In order to provide for the disposal of the operating radioactive wastes (radwastes), a new repository will be erected in the vicinity of the Cernavoda NPP.

The Low/Intermediate Level Waste (L/ILW) Final Repository is designed to accomplish the main performance objectives as set by the International Atomic Energy Association (IAEA) and in accordance with United States Code of Federal Regulations 10 (US CFR 10) recommendations.

At the same time the basis of this objective took into account the prior Romanian and international experience in the field of radwaste management.

For the design of the L/IL Radwaste Repository the following issues were taken into account:

1) The Cernavoda NPP will ultimately be equipped with five Canadian Deuterium-Uranium (CANDU) 6 units;
2) National legislation in the field of radwaste management will be reviewed and/or completed in a manner consistent with the IAEA series of standards as well as the provisions of the US 10 CFR. The erection of this new repository creates the problem of disposal of other radwaste, like that of institutional radwastes and those from nuclear installation decommissioning. In this situation the repository will become a New National L/I Level Radioactive Waste Repository beside the existing Baita-Bihor Repository. The schedule of this objective provides for the erection of this new repository by 2011.

INTRODUCTION

The CANDU operating radwastes that will be disposed of present the following characteristics:

Low and intermediate level solid radwaste generated by a nuclear- power plant include a variety of types generated in the operational period. They may be categorized as follows:

- compactable waste
- noncompactable waste
- spent filtering cartridges
- spent ion-exchange resins
- organic fluids.

According to modern concept regarding radwaste management at the Cernavoda NPP-Unit 1 (U1), the only solid radwaste treatment method consists in compacting the compressible wastes into 200L standard drums which, after sealing, will be transferred to an intermediate storage facility. All other categories of solid wastes, except for filters from the ventilation system (non-radioactive after a short period of decay), filtering cartridges in the process of purification system and ion-exchange resins, will also be packed into 200L standard steel drums with no preliminary processing and then sealed and transferred to the intermediate storage facility.

The assessment of quantities and activities of solid L/ILW resulted from a NPP Unit per year, are those indicated by the Atomic Energy of Canada Limited (AECL) in the Final Safety Report:

- 31 m^3 general radwastes. Out of this quantity, 22 m^3 is represented by compactible radwastes, precompacted by slight pressing into 200L steel drums in order to obtain about 50% reduction by volume and 9 m^3 non-compactible wastes (including unusual wastes), with a total activity of 26 x 10^{-3} TBq;
- 7 m^3 spent ion-exchange resins with a total activity of 18.5 TBq;
- 2 m^3 spent filtering cartridges (15 pieces) with a total activity of 7.4 x 10^{-2} TBq.
- 1-2 m^3 organic fluids with a total activity of 3.7 x 10^{-2} TBq;

After eight years of operation, the quantities of radwastes are three times lower than expected, but no significant abnormal operation or periodic circuits' decontamination has taken place during this period.

The IAEA recommendations were taken into account in order to ensure appropriate conditions for the Romanian Repository. As such, the disposal concept will have characteristics that will comply with international conventions. After numerous studies for conceptual design development, the shallow burial site option was selected. Two sites in the vicinity of the Cernavoda NPP were nominated following an extensive site selection program. The Saligny site was ultimately preferred.

THE SELECTION OF TECHNOLOGIES

Starting from the IAEA and European Community general requirements, design data for the repository and treatment-conditioning technologies described below were established.

Specific CANDU radwastes contain higher quantities of tritium and radiocarbon than other types of nuclear reactors, which require special treatment and supplementary barriers. It is therefore necessary to demonstrate that any radionuclide migration would result in exposures that are as low as possible, and in any case lower than those allowed by the regulations in effect for the general public.

All categories of solid wastes generated by a NPP, with the exceptions of unusual wastes (contaminated large pieces and equipment parts) and spent filtering cartridges, will be transferred to the Repository (formed of the Treatment & Conditioning Plant and the Repository's cell or the proper Repository) packed in 200 L standard capacity carbon steel drums (for a 90% fill-in factor). Prior to their transfer to the repository, the spent filtering cartridges will be stored in the NPP Intermediate Storage Facility packaged in steel cases. Large - sized unusual wastes will be transferred to the Repository using special transfer containers having adequate capacities. Compactable radwastes will be treated in the Cernavoda plant by slight pressing into standard drums resulting in a 50% reduction of the initial volume.

The Repository's concept is based on the guarantee of treatment and conditioning of radioactive wastes in the in the Treatment and Conditioning Plant as follows:

- the super compaction of compactable wastes;
- the cementation of used filters;
- the cementation in concrete modules of drums with noncompactable wastes and with the pellets results from supercompaction;
- the mineralization and cementation of liquid organic wastes;
- the cementation of spent ionic resins;

At the Treatment & Conditioning Plant near the Repository's cell, the drums containing compactable wastes will be further over-compacted by a 3,000 t press, obtaining a minimum of two times further reduction of the volume. The resulting pellets will be loaded into the storage modules and conditioned by cement pouring. All the operations (including over-compaction) will be carried-out in the Treatment & Conditioning Plant.

Non-compactable radwastes will be taken to the Plant directly packed into standard drums.

The drums will be loaded into disposal modules and conditioned by cement pouring. Spent resins, discharged from the storage pools will be conditioned on-site at the NPP by encasement in cement and mixing into standard 200L capacity carbon steel drums by means of a mobile facility. All the other operations will be carried out in the Treatment & Conditioning Plant.

The resins are to be transferred to the Treatment & Conditioning Plant and after cementation loaded into the storage modules. The empty interspace among the drums will be filled in with cement mortar.

The steel cases containing the spent filtering cartridges will be cut and the wastes will be conditioned as non-compactible wastes. The unusual wastes, loaded in transfer containers are carried to the Treatment & Conditioning Plant and discharged in storage modules directly. After fill up with wastes, the interspaces are filled with cement mortar

The disposal modules loaded with immobilized wastes will be shipped, by trucks, from the Treatment & Conditioning Station to one of the final disposal cells that will undergo the filling process. The outside dimensions of each storage cell are as follows: 15.90 x 29.40 x 8.50 m., the base slab and walls are 60 cm. thick. In each storage cell, 216 modules, disposed in 3 layers of 72 modules each, will be deposited. Disposal of these modules in the cells will be enabled by the fact that the dimensions of cells and modules have been selected in such a way as to make up central free areas (both longitudinally and transversally) aimed to overtake the possible discontinuities. These spaces will be filled in with gravel before casting the coverage plate.

At the Saligny Repository a multibarrier system with the following components will be achieved:

- The First System comprises of the waste immobilization matrix which, even if the packages were to be submerged in water, minimizes the radionuclide release rate, the metallic drum and disposal concrete container isolating them. This system contains therefore three engineered barriers.
- The Second System, formed by disposal vaults, cap and Infiltration Control Network, limits the water seepage. The necessary design of the disposal cap means in fact 3 barriers systems:
  - A bioengineering barrier
  - Conductive layers which alternate resistive barriers, and
  - Resistive layers.

  The special characteristics of Saligny site imposed the necessity of improving the soil resistance by special treatment. This treatment, consisting of compaction in certain conditions and by addition of some compounds, improves at the same time the radionuclide absorbency capacity, being in fact an engineered barrier;
- The Third, the geological barrier system, is the surrounding land. This could limit the impact of a possible release in the event of an accident or in the hypothesis of a total degradation of the first two barrier systems, as adopted for the free use phase.

SALIGNY SITE CHARACTERIZATION

From stratigraphic point of view Saligny area belongs to the Dobroudjan sector of the Moesic Platform, between two faults - Ovidiu-Capidava (north) and Intramoesic (south).

The main geological characteristic of South Dobroudjan Platform is the presence of a crystalline foundation in the deep, covered by sediments of 1500-2000 m thickness. A simplified stratigraphic column in Saligny area has:

- Greenshistes foundation below 1700 m depth;
- Precuaternary sedimentary deposits between 1700 and 35 m:
- Quaternary deposits
  - redclays 30-35 m in depth;
  - loess up to 30 in depth.

From geotechnical point of view, the average main geotechnical parameters have a good correlation with lithological separations. This zoning was confirmed by seismic or electrometric methods. The separation of these horizons extends to the entire perimeter between the Danube River (west), the Danube-Black Sea Channel (south) and the Cismeaua Valley (north). Four geological engineering horizons were separated:

- **A-horizon** - dusty loess - 0-20 m depth. The main granulometric fraction is the silty one - 70%. The porosity is characteristic for the same fields (40-45%).
- **B-horizon** - quaternary clayish loess - the base of loess with frequent calcareous concretion and clayey fossil soils. The clayey fraction is increasing to 30%. This porosity decreasing to 36-39%. This horizon is generally, 6-10 m in thickness.
- **C-horizon** - quaternary red clay. With some small exceptions (V. Cismelei is eroded), the horizon present in the entire area is 5 m thick. The granulometric fraction is a clayely one -

40-50% but its non-homogeneity is present, both, horizontally and vertically. The upper subhorizon is the silty one and lower has intergranular spaces filled with clayey material. The main mineralogical component is montmorillonit.
- **D-horizon** - precuaternary clays with sandy and limestone lentils. It appears above barremmian with a thickness of about 30-40 m. The main component is clay - marly in Lower Aptian, caolinitic in Aptian 2-3 or greenish in Sarmatian. The lentils are present in the entire interval with sandy or gravelly component.
- From a hydrogeological point of view, the main drain of the perimeter that includes Saligny site is Danube River at 10-11 m above the Black Sea level. Our site is 60 m above the Black Sea level. Water is present and there is no variation in time. Based on the underground water level, on the lithology observed in drillings and on the saturation ratio, a hydrogeological zoning was drawn.

In conclusion, the underground water from the Saligny site is supplied from 2 main sources: natural precipitations and the barremmian aquifer. The influence of precipitation water manifests itself down to 15-16 m. Deeper than that, the moisture content is constant to a depth of 25 m and then increases down to the red clay. The water from the barremmian aquifer has an upwards circulation favoured by direct contact with aptian sandy lentils.

The red clay is the main geological barrier, both for the upwards and downwards water circulation due to its very low permeability and great capacity of retaining the specific radionuclides. The main mineral component is the montmorillonitic ore (approx. 85%) which has a great potential for retaining the specific radionuclides.

CONCRETE CELL DESIGN FOR POOR SITE CHARACTERISTICS

The foundation layer is a macropore loessoid soil, moisture-sensitive, which is type B class loess. This kind of soil presents supplementary settling due to moisture, both under outer loads and under its own weight.

In the Saligny area, the loessoid horizon, being approx. 30 m in thickness, has been separated in two subhorizons, namely:

- dusty loess, 10-20 m thickness;
- clayish loess, 6-10 m thickness.

From a geotechnical point of view, decreased bearing capacity and high values for settlements characterize the natural soil. The erosion rate of loessoid soil is very high; during weathering ravines could occur, especially on large slopes.

After some tests performed by GEOTEC and Karlsruhe University, during some years, under SITON coordination, the following solution results in order to improve the soil characteristics: a 2.5 m thickness compacted soil layer should be performed, with an 0.5 m thickness upperlayer improved by 7% cement and 3% bentonite.

The main reinforced concrete structure, being for long-term period in contact with the geological medium, is the Repository's cell, made of special materials:

- Portland cement, having the compressive strength at 28 days >42.5 N/mm2;
- Siliceous aggregates dolomiteless;
- Concrete having the compressive strength at 28 days 350 daN/cm2 and the cement rate >400 kg/m3;
- Minimum concrete cover: 40 mm;
- Steel type B-500T for mesh reinforcement.

Damage, due to weathering and biological activity, will be stopped by means of an insulation roof made of alternating conductive and resistive layers, covering the cell groups (see Figure 1).

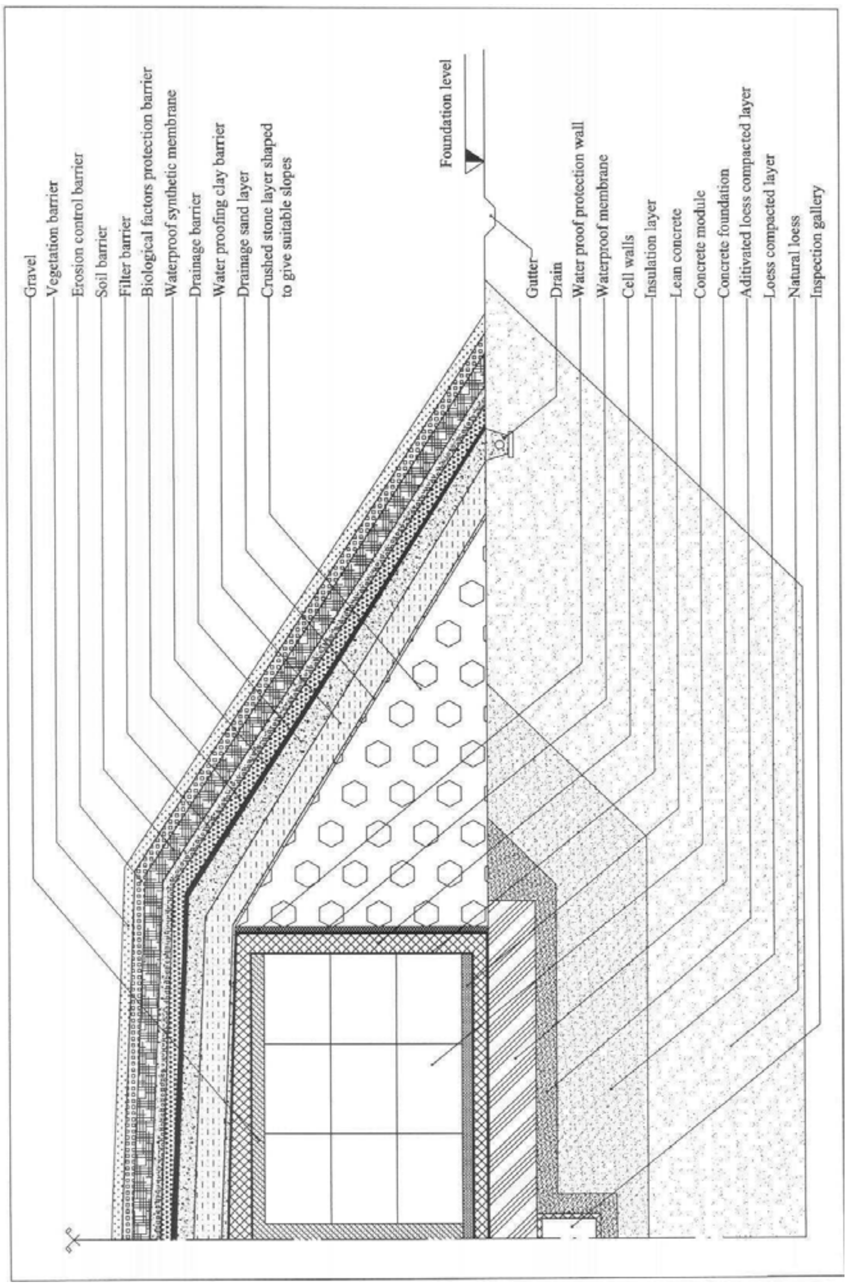

Fig. 1. The cover components of the cells

The isolation system includes the water proofing systems, water collecting systems and water release systems, in order to limit the hydrostatic pressure.

From the internal part of the cell, the following protection systems are provided:

- The liner of XYPEX type (Portland cement, fine sand and additives) with high adherence on concrete.
- The floor, concrete walls and the cap of the cell will be constructed from concrete of high quality B50 with maximum water proofing capacity.
- The thickness of both the floor and the walls will be of 60 cm, which assure the suitable shielding.
- Waterproof membrane of geomembrane type, being mode of high-density polyethylene and supported by the suitable walls.
- The drainage system of the cell with the access gallery.
- Underfloor with the thickness of 1 m of low concrete structure.
- Compacted loess with additives (7% concrete and 3% bentonite), 0.5 m;
- Compacted loess of 2.5 m.

The compacted loess with additives (cement and bentonite) layer assures, at the same time, a retardation of the tritium. The differences between the natural loess and the compacted-additivated.

Upon completion of the operating phase, and prior to the surveillance period, the disposal cells will be protected by means of a cover known as the long-term cover. The objective of this cover is to protect the disposal works against water and other agents, and especially against erosion and thermal variations, during the surveillance period, thus preventing deterioration of the cells and containers and the dispersion of radionuclides to the environment.

Protection against undetected intruders, temperature changes and erosion will be provided by the very constitution and thickness of the cover, as a result of the various superimposed layers. From the inside out, these layers will be as follows:

- Crushed stone layer shaped to give suitable slopes;
- Drainage sand layer;
- Water proofing clay barrier;
- Drainage barrier;
- Waterproof synthetic membrane;
- Biological factors protection barrier;
- Filter barrier;
- Soil barrier;
- Erosion control barrier;
- Vegetation barrier.

At the interfaces between this covering and the non-excavated terrain system will be installed to collect water from the draining layers, and where applicable rainwater collecting ditches will be dug on the surface, both systems draining to the surrounding terrain.

SAFETY CONSIDERATIONS

The special characteristics of Saligny site determined the necessity of improving the soil resistance by special treatment. This treatment, consisting of compaction in certain conditions and by addition of some compounds, improves at the same time the radionuclide absorbance capacity, being in fact the seventh engineered barrier.

The main design parameters of the Repository could be summarized as follows:

1) Each package will meet radionuclide specification that must be lower than the activity limits per package. These limits are presented in the Table I.

Table I. Activity Limits per Package (Bq/t)

RADIONUCLIDE	IAEA TECH. DOC.	NRC (USA)	PROPOSAL FOR SALIGNY, ROMANIA
C-14	1.0 E +12	1.5 E +11	2.0 E +11
Ni-59	-	4.1 E +12	6.3 E +10
Nb-94	9.0 E +07	3.7 E +09	1.2 E +08
Tc-99	8.0 E +11	5.6 E +10	1.0 E +09
I-129	7.0 E +19	1.5 E +09	4.6 E +07
Total Alpha	2.0 E +09	3.7 E +09	3.7 E +09
Nuclides < 5 years Life	-	1.3 E +13	-
H-3	-		1.0 E +12
Co-60	-		5.0 E +13
Ni-63	-	1.3 E +13	1.2 E +13
Sr-90	1.0 E +15	1.3 E +14	9.1 E +10
Cs-137	3.0 E +13	8.5 E +13	3.3 E +11
Ra-226	5.0 E +07	-	5.0 E +07

IAEA TECH. DOC. = International Atomic Energy Agency, Technical Documentation
NRC (USA) = Nuclear Regulatory Commission (United States of America)

2) Concerning total inventory of the radionuclides accepted in the repository, the figures presented in Table II are a result of the preliminary nuclear safety analysis.

Table II. Reference Inventory of the Saligny Repository (Bq)

Radionuclide	IAEA TECH.DOC. Clay soil/ temperate climate	Saligny repository
H-3	>1.0 E +20	1.0 E+16
C-14	>1.0 E +20	2.0 E +15
Ni-59	>1.0 E +20	2.0 E +14
Ni-63	>1.0 E +20	2.0 E +15
Co-60	>1.0 E +20	2.0 E +15
Sr-90	>1.0 E +20	1.0 E +15
Tc-99	>2.0 E +17	3.2 E +12
I-129	>6.0 E +14 / 3.0E +15	1.5 E +12
Cs-137	>1.0 E +20	1.0 E +15

Ra-226	>1.0 E +20	-
U-238	>2.0 E +16 / 2.0 E+17	2.7 E +13
Pu-241	>1.0 E +20	1.15 E +14

The Repository will be provided with safety systems selected by taking into account the best available practices in the world as follows:

- Filling of disposal structure under shelter of a movable building.
- Disposal vaults will be protected after closure by a waterproof cover consisting of a multibarrier layer including synthetic long life materials.
- Automation of disposal vault filling operation.
- Disposal vaults will be provided with safety drainage system.
- The water collection system will use a separative rainwater/seepage network.

The Repository will include provisions to perform the following functions:

- Isolate the waste from the environment for long time to prevent radionuclides spreading
- Prevent water intrusion.
- Maintain radiation exposures to site personnel, environment, and surrounding communities at very low level.
- Monitor the efficiency of the engineered barriers.
- Track the movement of individual waste packages.
- Close the individual modules and, ultimately, the site.
- Perform remedial actions on closed waste vaults if it is necessary.

The isolation reinforced concrete vault will have enough space and volume to accommodate wide variations of radioactive waste types in a safe manner. This intrinsic flexibility in the design of the waste vault will ensure that the disposal technology meets the changes in waste technology and regulatory philosophy.

PUBLIC ACCEPTANCE PROBLEMS AND THEIR SOLVING

There were some problems with local landowners, which limited the site selection possibilities. Even though it was proven that the Turk Hill at about 3 km distance from the NPP with 120 available hectares available was better, the Saligny site, at 0.5 km distance from NPP, with thirty available hectares, was preferred mainly due to local acceptance criteria.

If it were only for the Cernavoda NPP, the Saligny site would be acceptable as the lone National Repository. Since all radwastes produced in Romania must be accounted for, the Saligny site is simply not large enough.

Later, it was ascertained that local public does not look favorably upon the radwastes from other nuclear facilities. This problem will be solved within the radwaste management program, which will involve representatives the local public and the authorities.

CONCLUSIONS

The conception of a Repository, located near the Cernavoda NPP, based on interdisciplinary studies has been proposed taking into account the experience of other developed countries.

The treatment/conditioning of radwastes will be performed according to the best available practices, in order to assure the long-term stability of the containers and radwaste isolation. The disposal structure will be manufactured in accordance with specifications of proved procedures on the provisions of a rigorous Quality Assurance (QA)/ Quality Control (QC) Program. The best available Romanian materials within the frame of IAEA guidance will be utilized.

An important step in order to ensure the proper design of the Repository is the correct site characterization. At the same time the IAEA support and guidance will ensure the acquisition of the appropriate technologies.

The main problems, which must be solved in near future, are the following:

- The elaboration of a Feasibility Study for the Repository;
- The establishment of a Cooperation Agreement with an experienced organization, in order to obtain the necessary tactic and strategic support for finalizing the erection of the Repository.