# LONG TERM DISPOSAL OF SHORT LIVED NUCLEAR WASTE APPLICATION IN BELGIUM AND RUSSIA (Region of Moscow)

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## ABSTRACT

Surface disposal facilities have been studied in detail, first for Belgium and then for Russia but with different basic requirements. The paper underlines all basic design features.

***The Belgian Concept***

The principles of a safe disposal site are developed and summarised :

the *multi-barrier* concept including the criteria for siting (98 sites were initially selected);

the optimisation for the *long term safety* with regards to the containment of radionucleides and measures taken to delay contact with rain and ground water and their subsequent release in the biosphere;

the optimisation of the *short term safety* with regards to operational requirements;

the principles of an optimal and resistant *earth cap cover* and its two primary functions : the impervious lower layers and the upper "biological" layers designed for protection against natural aggression;

Several specific design aspects are tackled : the *container* principles, *settlements* problems, the *seismic* design, the choice of *durable concrete*, the position taken to account for direct airplane *impact*, the *monitoring*, the minimisation of the *maintenance*, some specific site amelioration to better identify the water *outlet*, *intrusion* scenario after the institutional period.

The study was made under a contract with ONDRAF/NIRAS.

***The Russian Concept***

Simultaneously, a similar basic engineering design has been performed for the Sergiev Posad storage and conditioning facility near Moscow. The study was performed in the frame of the TACIS Nuclear Safety Programme funded and managed by the European Commission.

The paper emphasises the differences in approaches between the two projects, such as the need to *strengthen* a less ideal site, the *retrievability* of all wastes, the need to *minimise initial investment* on civil works, the *handling* procedure, ...

## INTRODUCTION

Near surface facilities for short lived radioactive wastes must be based on basic safety requirements, from which all design features are assessed. They must provide *long term protection for local population, on site workers and the environment against uncontrolled release of radioactivity in every foreseeable circumstances*.

The system must also be designed in order to limit the burden to future generation by :

- selecting the waste in order to limit the time necessary for its radioactivity to decay below background levels. Acceptable time length is about 300 years. It fixes the life time of the engineered barriers and the institutional control period,
- choosing a relatively simple concept to limit maintenance requirements and to facilitate control and monitoring.

Quite recently, a new philosophy is being incorporated which is the possibility for future generation to choose for themselves and eventually *retrieve* the waste if and when more advanced technologies appear for treating them in a more efficient way.

Obviously the duration of the control period depends on both the acceptable dose limit for a critical individual and the half-lives of the waste distinctive constituents. More over, dose evaluation, hence the choice of construction phases and handling technologies must be conform to the ALARA principle (As Low As Reasonably Achievable).

The initial release of radionucleides mainly depends on *water transports*. It is necessary to delay waste contact with every possible source of water (rain, aquifer) including during the operational phase. Another vector for transport is long term gas release within the waste. Finally human intrusion must be studied after site banalisation.

Foreseeable circumstances means that a thorough risk analysis must be made on all possible *degradation* mechanisms likely to weaken the original confinement system :

- in a *normal evolution* situation, i.e. for every events with a occurrence probability of 1 (ageing of constituents, chemical aggression, erosion,….)
- in *accidental circumstances* such as aeroplane impact , seism,…

Corrective measures must be taken at the design level in order to lessen their consequences for the radionucleides release to the biosphere.

Near surface disposal have been successfully implemented in France (Soulaines) and El Cabril (Spain).

## DESIGN PRINCIPLES

In order to meet these basic requirements, it is generally accepted to install a *multi-barrier system* which is mainly design to :

- delay contact with water by placing preventive barriers,

- avoid intrusive water to leave the system in uncontrolled ways by placing curative barriers.

The multi-barrier system is made up of three different levels :

- the waste itself in its conditioned package
- the engineered structures to isolate the waste from water
- the site itself as an ultimate natural barrier against unforeseeable events and after closure.

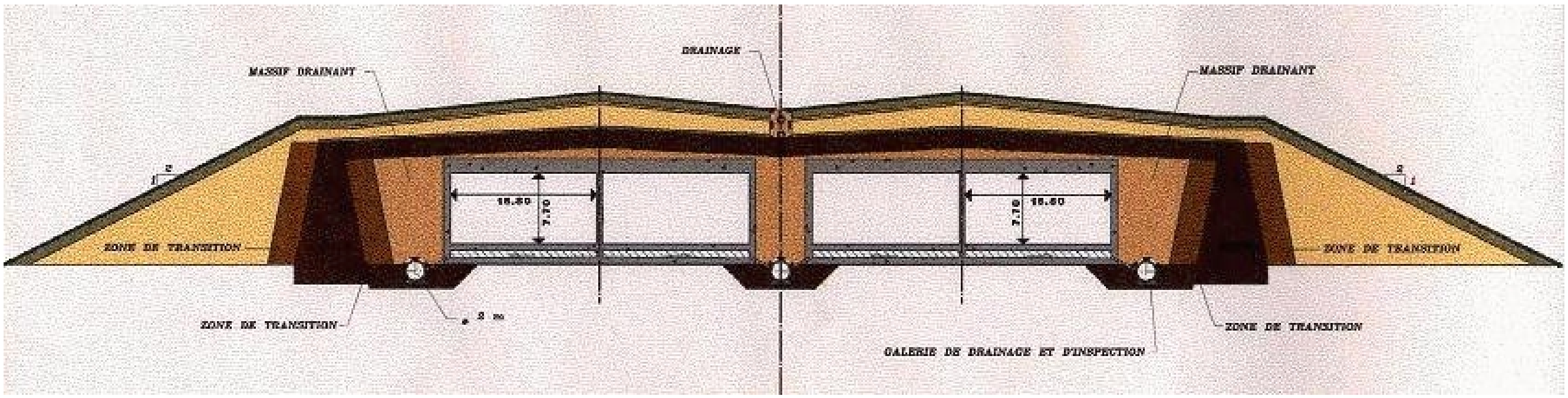
The waste must be labelled, sorted, stabilised in concrete, bitumen or resin and conditioned in containers for its safe transport and handling.

The engineered structures are made up of two different parts :

- the concrete structure as rational rigid storage boxes, known as module
- the impervious earth cap system providing long term protection against water ingress.

The site must be carefully chosen and/or adapted in order to maximise its capacity to act as a last curative retaining barrier. Any additional isolation properties such as good radioactive *containment properties*, add to the overall safety of the concept. At the same time, the site must be geotechnically and seismically stable.

An example is shown on the next figure.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## IMPLEMENTATION FOR BELGIUM

From 1960 to 1982, low radioactive waste has been disposed in the Atlantic ocean. Since then , the newly appointed organism ONDRAF (Organism National des Déchets Radioactifs et des Matières Fissiles Enrichies) has been in charge to seek land based solutions. Among them, a near surface facility remains one of the best economical and technical option but other alternatives are still being investigated such as deep disposal. No waste has been disposed of yet, pending a governmental decision.

This paper deals only with the near surface option and the study performed by BELGATOM.

In Belgium a first early screening has been made for the choice of eligible sites. Based on data's collected for these sites, a generic design study has been made.

### *Siting*

The first step of  a near surface facility safety assessment is the careful choice of the ultimate barrier, i.e. , the site itself. In Belgium, about 98 sites have been initially identified

- 68 on sites with sand layer on top of a sufficiently thick impervious clay layer
- 30 on schist-like formations

The choice is based on several technical and environmental criteria such as

- geographical location
- sub soil characterisation (nature and thickness)
- topography (slope)
- hydrogeology (drainage quality)
- existence of faults and discontinuities
- seismic intensity
- main joints (schist),…

Generally, the site should be above flooding levels, presents well identified water outlets, offers a simple and understandable hydrology for modelisation and should not possess potential natural resources.

Recent retrievability and controllability requirements have allowed to adapt the initial siting criteria; today, 4 sites still remains eligible for disposal by government decision, i.e. the existing nuclear areas.

### *Basic dimensional constraints*

The next design step is to evaluate realistic geometrical dimension for a single concrete module destined to receive a yearly amount of waste containers. These dimensional constraints depend on the following aspects :

> direct military *aircraft impacts* on the roof have first been studied in a deterministic way. In this approach and for roof span ranging from 10 to 20 m, a 2 m thick heavily reinforced concrete roof is necessary to avoid any permanent structural damages. Walls and bottom slab are also proportionally thick for adequate load transmission to the ground. The earth cap does not provide enough damping to lessen the impact. A

more realistic stochastic approach may finally be chosen by considering the amount of radioactivity discharge at impact (the roof is destroyed) and comparing it with admissible risk (dose * probability of impact).

The *bearing capacity* of the ground must be evaluated. The overall dimension of the module raft foundation induces a deep stress influence. It limits the number of containers layers for some sites.

The *settlements* analysis is even more important than soil capacity mainly in clayey soil were settlements evolve with time thus enhancing any existing heterogeneity in the soil. The consequence of differential settlements is unacceptable *cracking* of the concrete and the earth cap. Overall *slope reversals* may also appear in the drainage system, creating pools of water and excessive infiltration. For this study and due to the unusual life time of the structure, *secondary consolidation* have been taken into account; this effect could double the classical settlements values obtained for ordinary buildings and based on simple consolidation formula. This generic settlements analysis has provide crucial rules on minimal slope and maximal drainage length.

The *handling procedure* also gives dimensional indication; a top filling with overhead crane or lateral filling with lift-trucks will lead to different structural solutions. The choice of the handling procedure must be guided by safety concern for the personnel in charge : dose limitation in normal operation and risk limitation (accident or breakdown). At the same time, water ingress in the open cells must be avoided. In Belgium, due to normal handling practice and relatively mild weather condition, a *top filling* was chosen under the *protection of a temporary movable closed steel hall.*

The waste *container* itself is the basic building block leading to final dimensions. The Belgium study has evolved from a irreversible disposal with steel drums embedded in mortar to a more flexible solution with concrete monoliths stacked up without any immobilisation materials. It provides equal or better protection for direct doses and retrievability for future generation, if necessary.

***The earth cap concept***

The earth cap function is to provide watertightness against rainwater for the whole duration of the institutional period (300 years). This is usually guaranteed by an *impervious composite layer* of natural inert materials and synthetic sheets giving best durability.

The watertight section is mainly composed of two 90cm minimum thick compacted clay with a middle high density polyethylene membrane. Clay and membrane properties are complementary to assure watertightness :

- Clay is not sensitive to mechanical damage and its long term stability has been demonstrated but special measures must be taken to avoid premature drying.
- Membranes are not sensitive to drying but they are fragile and special care must be taken during placement.

On the other hand, polyethylene longevity is not proven beyond 30 years. Percolation will thus gradually increase with time if the system is not replaced. Only safety assessment will confirm the permissible flow.

The intrinsic stability of the clay is verified under the load of the biological layer (described hereafter), imposing a maximum slope to avoid creeping, slipping and overstresses.

This barrier must be protected by an overlaying *biological composite layer* to delay excessive percolation due to several degradation mechanisms :

- erosion
- drying
- frost and thaw effects
- root plants
- destruction by several small animals,…

The exact composition for this biological layer depends on local conditions. A detailed hydro-agronomical study has been performed to determine the optimal configuration. For example, the choice of top soil and covering vegetation must be compatible with natural site conditions. Top soil characteristics and thickness must be chosen in order to offer good retention potential and enough moisture reserves during dry seasons. The 10 % top slope, of 60 m length maximum ,is determined by iso-erodent maps for Belgium.

The performance of the whole earth cap system has been calculated by finite differences under various conditions (membrane disappearance, default, dry year conditions,…).

The ideal configuration leads to a cap of minimum 5 m in total thickness.

Nevertheless, such theoretical considerations will be confirmed by large scale in situ testing. The performances should be monitored for several years in order to cover different weather cycles.

***The concrete structure***

The concrete cells act as a rigid confinement box in order to

- transmit the load uniformly to the ground,
- resist stresses from ground pressure, differential settlements and seismic loading,
- act as a secondary barrier to delay water contact with the waste,
- impose a predetermine exit pathway for any infiltrated water that has been in contact with the waste,
- impose a preferential pathway for gas release created within the cells.

It must be accepted that these large concrete structures will never be completely watertight (unless built according to the costly technology used for underwater precast road tunnels). So a reasonable approach is to recognise this fact and to provide control devices and close accesses in order to collect and analyse the water quality that has leaked through all the preventive barriers. Any leakage can therefore be immediately localised , remedial measures can then possibly be taken to correct it (earth cap repair or replacement, waste retrieval,….).

The concrete structure are thus equipped with a bottom drainage system connected to a network of lateral inspection galleries.

The effective watertightness function is thus provided by the earth cap alone.

Nevertheless, extensive studies have been performed to chose technological solution aimed at strengthening the concrete watertightness, such as

- simple structure and minimisation of construction joints,
- chose a durable concrete with a low e/c factor,
- minimise fissure (shrinkage, mechanical solicitations, age differences between concrete,..),
- limit the development of corrosion,…

Once the open cells are built and the steel hall installed, filling may proceed with an overhead crane. Monoliths are placed as close as possible in 4 to 6 layers. A top thin concrete slab is then poured on top of the last layer. To protect this structure against water before earth cap placement, layers of bituminous sheeting or epoxy coating are applied for short term imperviousness.

When the earth cap is finally installed, its load is entirely transmitted through the side walls and the monoliths themselves down to the ground.

The removal of a thin top slab is a relatively straightforward task providing retrievability of all waste at any time during the institutional control period

### *The drainage principle*

the drainage principle can be summarised as follows :

1. run off water and water infiltrated trough the biological layers are simply diverted off the site;

2. water percolating through the "impervious" clay layer is flowing laterally and collected in the inspection galleries. It gives an early warning of earth cap malfunction;

3. water infiltrated inside the cells are selectively drained on the bottom slab and lateral galleries were it is collected, send for analyse and possibly treated before release;

4. in the long term and without proper maintenance, water can by-pass the engineered barrier and mix with the aquifer. Retention properties of this third barrier with delay radionuclides propagation.

5. Before release outside the facility boundary and if a well known outlet has been identified, water can still be controlled. This outlet is thus an important part in the overall safety performance. It may be necessary to strengthen this feature by installation of artificial deep plastic cut -off walls surrounding the site and fitted with limited opening. It will narrow down the extent of a diffuse outlet.

### *Other design features*

The *hydrogeological modification* (flow and groundwater levels) brought by the construction of the engineered barrier have been computed: the presence of cut-off walls and the absence of infiltration over a large area could modify the overall water flow pattern.

The overall *geotechnical stability* have been checked against slope failure.

A *seismic design* was performed using a spectral analysis approach. This study provides the additional loads on the concrete structure as well as stress behaviour within the earth cap during earthquake loading . It is however accepted that under heavy earthquake, during the institutional period, the earth cap should be repaired but concrete must not be damaged. Calculation are now being made to take into account a thinner roof slab and direct loading on the monoliths.

For the safety assessment report to be performed by CEN/SCK, and in conformity with international regulations, several post closure *intrusion scenarios* were envisaged. The release of radioactivity is then not only driven by slow release in the groundwater but the consequence of direct contact with concentrated residual activity after 300 years. The basic hypothesis is that, at that time, the site is given back to the public without any restriction of use. Dose and risk are then computed based on contact duration during the intrusion process and its probability of occurrence. War, terrorism and sabotage are not envisaged.
Intrusion scenarios are single and multiple housing construction; road, rail and canal construction, water well boring. Commercial and military aircraft impacts are considered as well.

## IMPLEMENTATION FOR RUSSIA

MNPO RADON, , has, since 1968, an existing operational plant for radioactive waste treatment situated near Sergiev Posad some 100 km North of Moscow. The site provides different highly technological waste conditioning processes giving great flexibility for distinct types of waste (compaction, incineration, bitumization). The resulting products as well as other low active waste are stored in the nearby near surface disposal area. Since 1990, the government of Moscow has imposed RADON to provide conditions for new long term storage of conditioned waste with its further *retrievability* and transportation while final disposal sites are being investigated elsewhere (salt layers).

Nevertheless, in the absence of such external solution, the new concept could be used as final disposal and must therefore fill all the criteria assigned to it.

For this purpose, in the frame of the TACIS Nuclear Safety Programme funded and managed by the European Commission, a specific project was launched and assigned to a Consortium lead by Belgatom, with AEA Technology and SGN as western partners and with EAST CONSULT and GSPI as Russian partners; End 1998 this international Consortium has completed a complete basic design study including the production of a Preliminary Safety Analysis Report (PSAR). The objective is to demonstrate that the proposed facility is *licensable* and that its long term performance is satisfactory when compared with the Russian regulations and international standards. Assessment of *post-closure safety* was performed using latest available tools on which Russian beneficiary was trained for further calculation.

The study was essentially based on the same methodology used for the Belgium near surface alternative. The next aspects only emphasise the differences between the two concepts.

### *Siting*

The site is *existing* and was not selected according to classical criteria. The aim of the study was to identified all relevant hydrological and geotechnical characteristics in order to perform the long term safety assessment and to detect any weaknesses to be dealt for at the design stage. The ground consists of, from top, backfill (0-2m), clay with lenses of fine sand (2-6m), very soft clay layer (6-10m), very dense clayey sand layer (10-70m), fine sand down to 130 m. The area is covered by large amount of ditches and marshy ground and is located at the watershed of two rivers. Climate is characterised by warm summer and moderate cold winter with stable snow cover. Absolute minimum is -48°C, absolute maximum is + 36°C. It is considered as seismic quiet zone.

The natural site, as a third and ultimate barrier, should possibly be *strengthened* by artificial means. Such necessity will be assessed through additional investigations (boring, laboratory tests, in situ tests,…) :

- settlements may be reduced by soil improvement techniques on the upper soft clay layer. This may consist of a preloading of the whole area by means of a temporary backfill with presence of drains in order to evacuate water pressures. This preloading will also accelerate the settlement of the upper clay layer and will reduce the squeezing risk associate with it.

- a general backfill with peripheral ditches will raise the foundation level above normal flooding levels,

- the disposal site can be surrounded by deep cut-off walls in order to locally lower the water level for a better control of potentially contaminated water.

The natural outlet is however well identified and already included in the existing well-proven monitoring network.

***Waste containers***

A decision on the retrieval of waste is expected within 50 years after storage. In that case, standardisation of packaging is preferable for a rational disposal of waste from different region. The choice is a concrete container including 4 or 8 immobilised drums. The principle is identical for Spain or the Belgian concept but the handling procedure differs entirely (see handling)

***Concrete structure***

The harsh winter weather condition would impose very high performance for a large movable weather shield on top of an open structure during filling (wind, snow loading,…). For this reason essentially, it was decided upon a close roofed structure with only a lateral opening for access.

Due to the fact that waste may be recovered during the interim period and that this probability is very high compare to the final disposal option, it is necessary to distinguish two very different periods and purposes for the engineered barriers :

- *the interim period* (maximum 50 years);
- the *institutional period* (up to 300 years from the end of the interim period).

The interim period is defined as the elapsed time between the start of the operational period (filling) and the time a decision is made on the final purpose of the disposal.

The investment for each period should be minimised and only focused on the primary function of the engineered barriers during that period :

> During the interim period, the waste containers should be easily recovered and the barriers should remain impervious with current sealing systems available on the market. Maintenance of the waterproof system and control of any leaking or percolating water must be provided.
>
> During the institutional period , a more sophisticated long lasting earth cap must be installed based on principles followed for the Belgian concept. At that time an *additional reinforced roof slab* must be added to take this extra load which is not transmitted to the container

### *Handling*

The handling with overhead crane is not compatible with a closed structure. The handling system consists of a Diesel powered shielded forklift. The lifting capacity is more than 15 tons and is compatible with a height of four layers of containers.

The containers are installed in successive “walls” with direct contact between two adjacent piles. In the other direction the handling system requires a 35 cm spacing between the containers piles.

The placing of the top layer requires a free space of about 1.3 m between the bottom of the installed vaults roof and the top of the fourth containers layer. This free space can be used for lighting, ventilation and possibly definite filling for the disposal alternative.

The study has been successfully completed and approved by the Russian beneficiary at the end of 1998.

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