A French Industrial Management Plan for Very Low Level Radioactive Wastes (VLLW) at the CIRES Facility - 17012

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ABSTRACT

Since 2003, very-low-level waste has been disposed of at the Andra CIRES disposal facility, the first disposal facility in the world for this type. It is now the main route in terms of volumes for the management of French radioactive waste.

The 2015 national inventory has identified 1.1 million m^3 of VLLW to be produced until 2030. Several waste management scenarios were then analyzed, including issues associated with the flow reduction of the waste to be stored.
The key avenues to reduce the volumes of waste, technical and economic viability of which still needing to be challenged, are at this stage:

- Favor the reuse of large amounts of metallic VLLW to be produced within the next decade.
- To service the recycling of metals, different opportunities for reuse should be considered –including within the non-nuclear sector.
- 30% to 50% of VLLW produced in the so-called "nuclear waste" areas probably have zero or non-detectable radioactivity levels and questions about the introduction of a clearance level.
- A disposal route based on a concept derived from waste storage facility for non-nuclear and non-hazardous wastes could be an alternative to the clearance level for the least active inert waste.

Therefore volumetric optimizations appear possible, even if the waste management costs will be higher than the current route. Furthermore, efficiency gains and progresses in operating modes would increase the technical capacity of the CIRES of about 250 000 m^3.
In all cases studied, it appears essential to create around 2030 a new VLLW disposal facility, particularly for the dismantling of the current fleet of reactors. According to the proposed optimizations, the necessary capacity for a second VLLW disposal facility would range between 600 000 m^3 and 1.2 million m^3.

INTRODUCTION

The VLLW category is often considered specific to France. French regulation does indeed prohibit the definition of clearance levels, i.e. a level of radioactivity below which the waste can be considered "non-radioactive." This threshold, applied in other countries, is generally around 1 Bq/g. Consequently, in France, waste is classified as radioactive according to the zone where it was generated (classified as a nuclear waste zone) so as to limit the risk that any waste presenting a contamination hazard would leave the nuclear industry. The flip side of this rule is that waste presenting no measurable traces of contamination is grouped under the VLLW waste management solution. It is estimated that this concerns 30 to 50% of VLLW volumes.

It is also estimated that by 2030, the dismantling of French nuclear installations will have generated more than 700,000 $m^3$of radioactive waste. For the most part, it will be VLL waste that will saturate the current facility.

To ensure dismantling is carried out correctly, it became important to plan, long-term, the changes necessary for this waste management solution through an industrial plan.

THE INDUSTRIAL FACILITY FOR GROUPING STORAGE AND DISPOSAL (CIRES)

The Cires facility is located in the Northeast part of the Aube department in France, on land belonging to the Morvilliers and La Chaise municipalities. Cires started operating in 2003 and was classified as an ICPE (environmentally regulated facility).

Figure 1: Radioactive waste management, interim storage and disposal facility in Aube, France - Photo credit: P. Masson.

With a total surface area of about 46 hectares, the Cires facility is essentially made up of the following zones:

- **The disposal area** for very low level waste (VLLW) measuring about 18 hectares. Currently, only the southernmost part (called phase 1) of this area contains waste. It comprises 14 closed disposal cells - i.e. cells containing radioactive waste and covered with various materials - and one cell currently in operation. Cell No. 15 is no longer in operation and will be covered in 2016. Cell No. 16 is currently in operation.

- **A receiving area** dedicated to the various buildings of the facility, measuring about nine hectares. This area includes:
    - A logistics building for unloading of waste and interim storage before transfer to disposal cells.
    - **A treatment building for compacting** low-density metallic or plastic waste, solidification, stabilisation and inerting of dangerous waste with a cementitious material; non-destructive tests (weighing, dose rate measurement, etc.) and destructive tests (physical inventory, waste sampling for analysis, etc.) of waste packages; 2000 to 3000 m^3 of plastic waste is compacted by a baling press annually. A reduction rate of 3 is achieved. About 1000 m^3 of light scrap metal is compacted annually with a reduction rate of up to 8.

Figure 2: Compacted waste - Photo credit: DR

- Support building, notably for maintenance
- **Two areas of about 13 hectares dedicated to excavation piles** from cell excavation work.
- **A pool area** of about 3 hectares

The Cires facility is licensed to dispose of 650,000 m^3 of VLL waste. As of end-2015, 47 % of this total licensed disposal capacity had been used.

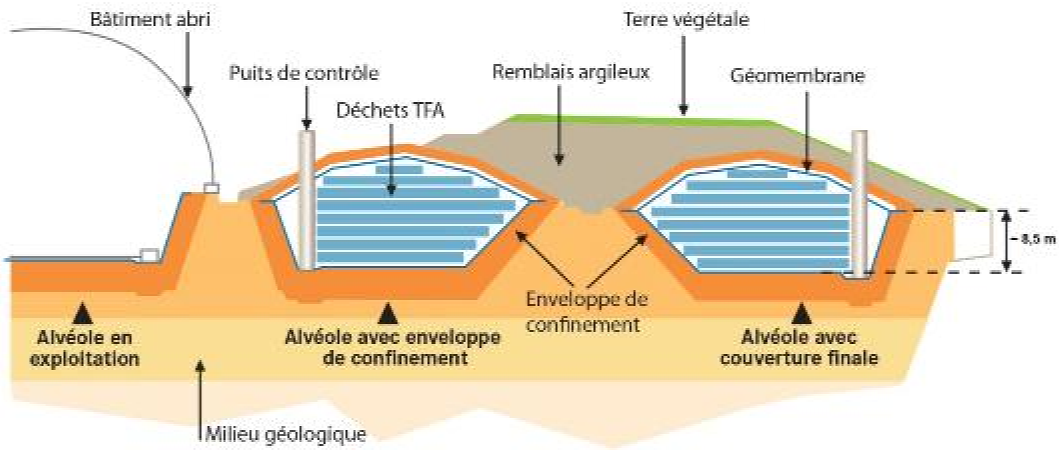

Figure 3: schematic cross-section of a disposal cell -

Currently, the VLL waste is disposed of in cells measuring about 176 metres long by 26 metres wide, excavated in a clay layer to a depth of about eight metres. The design of these disposal structures is similar to that of conventional waste disposal installations (Figure 3).

The waste at Cires is exclusively produced on French territory and mainly comprises rubble, earth and scrap metal with very low levels of contamination. It results from the dismantling or operation of nuclear facilities or from conventional industries that use naturally-occurring radioactive materials. VLL waste is also generated in cleanup and rehabilitation of formerly polluted sites.

HISTORY OF WASTE FLOWS DISPOSED OF AT CIRES

The histogram in Figure 4 presents the changing volumes disposed of at Cires. 25 to 30,000 m^3 of additional VLL waste is disposed of at Cires each year. At this rate, and despite the efforts to use disposal space more efficiently (adaptation of cell design, adjustment of the filling method, densification efforts, potential extension of the disposal footprint, etc.), the Cires facility will reach its maximum disposal capacity (650,000 m^3) by 2025-2030.

Also, according to the national inventory of radioactive materials and waste, published by Andra in July 2015, the dismantling of nuclear facilities is going to generate an increasing volume of VLL radioactive waste in the coming years. (Figure 5) It is estimated that this waste will represent a volume of over two million m^3 when all is said and done. Therefore, even if a second disposal facility for VLL waste is built, the question of overall management of this waste must be examined. As far as a large part waste is hardly radioactive or not, disposal may not be the best solution. Other alternatives may enable more appropriate use of resources with regard to the risk that this waste actually poses.

Figure 4: Volumes disposed of at Cires over time.

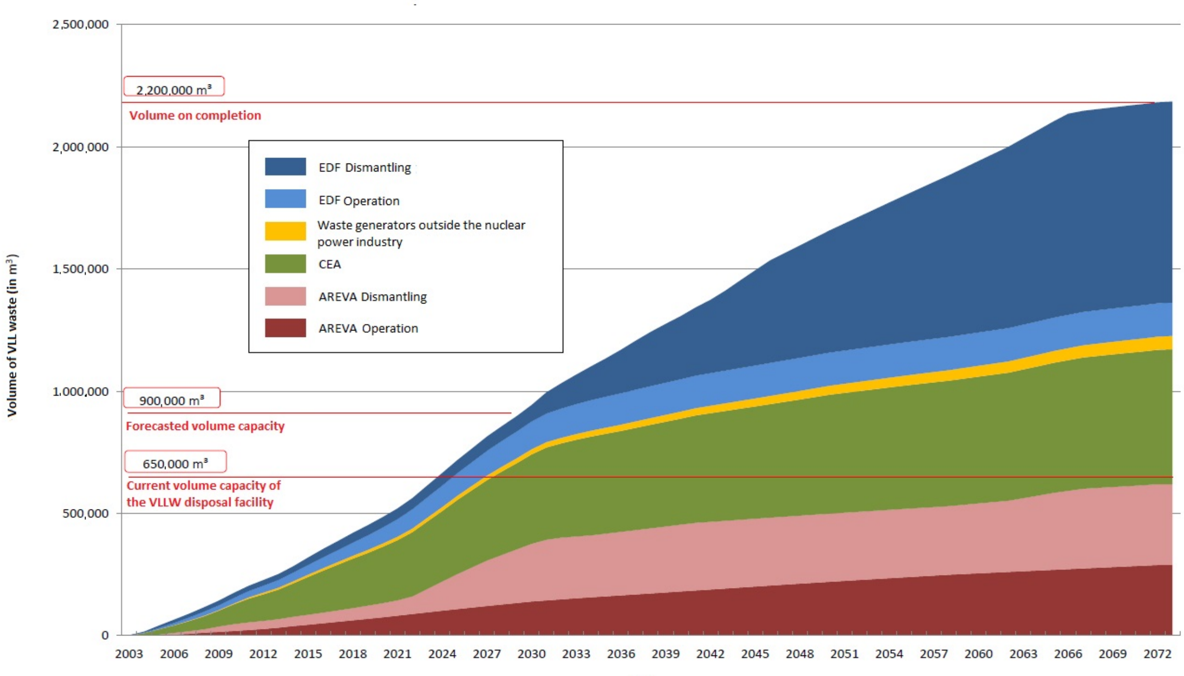

Figure 5: Changes in VLL waste volumes since 2003 and final forecast for dismantling of the current fleet - Source: Andra.

The VLL industrial plan therefore identified the main issues for the VLL waste management solution. Considering these issues, it proposes alternative solutions to the current management method.

ESSENTIAL ISSUES IN TERMS OF VOLUME

The main issue concerning the VLLW solution is volume because the levels of radioactivity received are generally much lower than the levels authorised at Cires. The authorised capacity is 650,000 m^3 of which 300,000 m^3 were already used at the end of 2015. Considering the waste flows to be produced by dismantling operations in the coming years (20,000 to 35,000 m^3/year), this will lead to saturation of the regulatory capacity by 2025. Technical optimisation of disposal cells may delay this saturation to 2030, if an administrative licence is obtained. Thus the volume of each disposal cell (about 30,000 m^3 per cell) will have been progressively increased (Figure 6) for an equivalent footprint area (depth, length and height increased). It is estimated that the capacity of the current centre could be increased to more than 900,000 m^3 without extending its surface area.

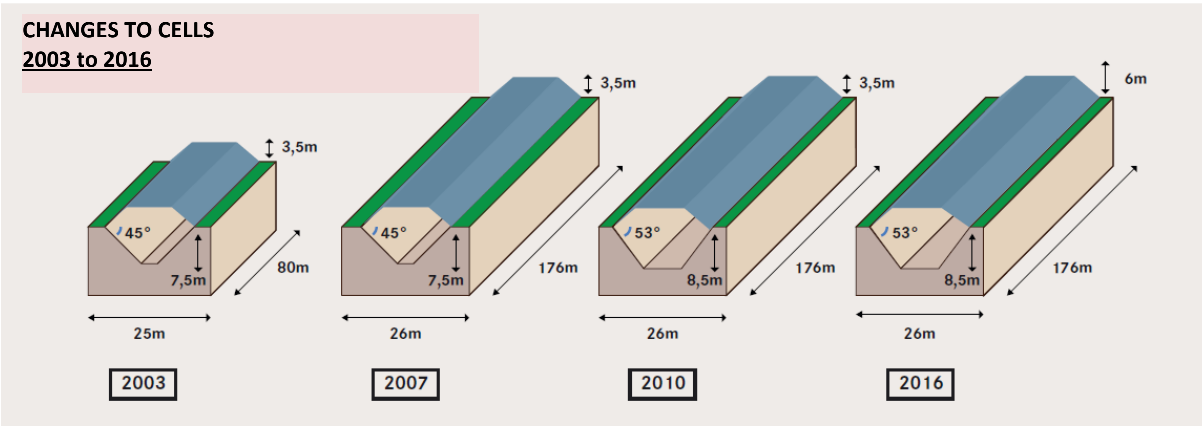

Figure 6: Changes to disposal cell design

After 2030, a new disposal facility will need to be built. This installation will be in large part dedicated to the dismantling of the EDF reactor fleet, currently in operation. It is estimated that the dismantling of each reactor will produce about 10,000 m^3 of VLL waste.

Figure 7: Photo of a Cires cell - Photo credit: Andra

The main options examined for reducing the necessary VLLW volume capacities are:

- **Densification**. Compaction presses are currently used, but they only provide a modest amount of power. Larger investments could be made, as long as the final densities would be high. For metals, melting would provide significant gains (a factor of 5), but the level of investment would be high. Finally, incineration would reduce the final volume by a factor of 10, but the current cost of the only French incinerator (Centraco) is not competitive in comparison with direct disposal of VLL waste.
- **Recycling**. This point is described in a later chapter.
- **Reduction at the source**: zoning changes throughout the life of the nuclear installation would make it possible to avoid over classification of conventional waste as VLLW. More flexible procedures are planned to allow such changes.
- **Installation of "alternative" disposal methods:** for large quantities and for minimal activity levels (for natural radioactivity), disposal facilities similar to conventional waste disposal installations could be economically advantageous. The economic advantage would be reinforced if these disposal facilities could be located near dismantling sites, geological conditions permitting.

The published industrial plan sets out objectives in terms of cost per m^3 of waste kept out of disposal. These cost objectives are currently between € 500/ m^3 and € 1500/ m^3, depending on gains in terms of conditioning, provided by alternatives to disposal. These costs do not currently take into consideration the finite nature of the resource that is VLLW disposal capacity.

The industrial plan therefore provided several alternative scenarios to the "business as usual" option. According to the optimisation possible upstream of disposal, the capacity necessary for a new VLLW facility would be between 600,000 and 1,200,000 m^3.

RADIOLOGICAL ISSUES FOR CERTAIN RADIONUCLIDES

The total quantities of radioactivity authorised at Cires are much lower than those authorised for the VLLW management solution. Beyond confinement requirements, which are lower, the monitoring and therefore decay period will be 30 years as opposed to 300 years for VLLW disposal. This is the same amount of time as for conventional waste disposal installations. In practice, total limits are set for radionuclides with a long half-life (> 30 years). For example, this limit is 1.2×10^{12} Bq for plutonium 239 or 6.4×10^{10} Bq for chlorine 36. For radionuclides with a short half-life, it's the concentration that is limited (for example, 10 Bq/g on average for cobalt 60).

For tritium (3H), mobile in the environment, a total maximum activity of 15 TBq is defined, related to the objective to prevent radiological marking of the environment.

These limits do not currently constrain operation or dismantling of nuclear installations. However, the flows coming from certain installations are going to reduce the available margins. This will be the case for the ITER project which will produce tritiated VLL waste, or the Malvesi site that is to send out for disposal up to 7000 m3 of waste marked with 99Tc per year.

A goal of the VLLW industrial plan is therefore to anticipate such margin reductions to carry out studies that can re-evaluate the safety demonstrations or develop alternative solutions at a reasonable cost, proportionate to the safety risks.

Also, waste generator reporting methods highly overestimate the actual levels of activity disposed of. These conservative evaluation methods are due to an accumulation of safety margins, but also to the difficulty of measuring radiological activity at such extremely low levels.

PHYSICAL-CHEMICAL ISSUES

Beyond the radioactivity, which is extremely low, the physical-chemical composition of the waste is to be monitored as well. This non-radiological impact may be the main impact on the environment, long-term.

For example, it must be guaranteed that heavy metals will not pollute the environment of the site. This is the purpose of leaching tests that can be performed before disposal. It is also an issue for disposal of electronic waste whose components are not currently recycled.

Degradation of waste over the years must also be estimated. Certain metals will be quickly corroded, thus producing hydrogen. It must be ensured that this hydrogen will be correctly evacuated from the disposal structures or absorbed by the geological medium.

ADAPTING VLL WASTE MANAGEMENT CONDITIONS TO DISMANTLING WASTE

Waste package management was developed for waste from the operation of nuclear installations, which is repetitive in nature. Standard packages were therefore developed and are compatible with the daily operation of numerous nuclear facilities. This is not the case for dismantling waste which requires "custom" solutions to be developed.

A major issue lies in exploiting the flexibility of the VLLW disposal facility to simplify dismantling and cutting operations on dismantling sites and thus reducing the radioactive doses, the costs and the timeline.

At Cires, Andra received and disposed of waste in conditions specifically adapted to the four steam generators of the Chooz A reactor. These components, with a volume of 100 m^3 and of about 100 t each, were disposed of in a cell, on a specially adapted slab. They were then injected with a cementitious material to ensure mechanical stability of the VLLW cells over time (Figure 8).

Figure 8: Disposal of a steam generator at Cires - Photo credit: Andra.

A special cell with heavy handling equipment will be set up at Cires in 2017 to facilitate management of such waste.

Other optimisation techniques will be explored, specifically concerning the VLLW solution. For example, it may be possible to use "big bags" with larger capacity than the packages currently used at Cires for managing contaminated soils.

Direct disposal without any packaging of VLL materials is also a possibility. Beyond the simplification of logistics (direct transport in large capacity skips), such a practice could limit the empty space and thus optimise disposal volumes. However, this type of disposal can only work for waste with very low or undetectable radiological activity, and with guaranteed homogeneity. The economic advantage of Cires lies in the simplicity of this concept, similar to what is done for conventional waste disposal installations. "Direct" disposal without packaging shall not generate radiation protection constraints that would cause operations to become costly.

RECYCLING VLL MATERIALS

To use the rare resource of disposal facilities as wisely as possible, waste recycling possibilities are studied.

40% of waste generated by dismantling will be metallic waste which comprises the most significant deposit to be studied with over 700,000 tons to be produced from now to the end of dismantling operations in about fifty years. While this waste is very easily recyclable in conventional industry, it is very rarely recycled in the nuclear industry (a few hundred tons, mainly in the Centraco treatment installation at Marcoule). These options are now authorised in the nuclear industry where the need is limited.

Packages made of recycled metal cast iron to replace concrete packages are currently being studied. But the economic balance of a foundry is difficult to reach compared to the disposal cost at Cires (around 500 Euros/ m^3), despite the compensation by reduction of the volume disposed of (use of metal instead of concrete makes it possible to "concentrate" activity and therefore volumes). Moreover, this substitution requires major developments at the facilities that produce the packages. Studies are still under way, both for shielding of low and intermediate level waste and for packages for geological disposal. One interesting option may come from dismantling of EDF steam generators (100,000 tons of metal over 30 years), which could enable production of packages over about 30 years.

Options outside the nuclear industry should be authorised if we want to be able to recycle a larger portion of this metallic waste. However, this waste must have residual activity levels similar to natural levels.

We estimate that more than 10,000 tons of VLL metallic waste from dismantling sites could be reused each year without radiological constraints (more than a third of the tonnage received), with the right treatment and/or control.

Specific licences should therefore be granted for clearly identified batches of metallic waste.

This is the case for dismantling of the gaseous diffusion enrichment installation Eurodif (Georges Besse plant), shut down since 2010. Dismantling is to produce 150,000 t of steel between 2025 and 2035 with residual uranium contamination around 10 Bq/g. While these levels appear too high for direct reuse, a melting operation should enable extraction of the majority of uranium. Tests are planned to better qualify the potential for decontamination.

The second major deposit of waste concerns cement-based construction materials, otherwise referred to as rubble, which will mainly be generated by the destruction of buildings. The volumes are estimated at more than 500,000 t. These volumes are to a large extent linked to the final radiological state of nuclear sites.

Currently, the French rule is to remove all traces of contamination, even tiny, which causes great uncertainty as to future volumes.

Only reuse for VLLW disposal structures is currently being studied. It is estimated that 2,000 tons of crushed VLL concrete per year could replace some of the aggregate used to fill empty spaces in the cells at Cires. This would increase the quantity of waste contained inside the cells, especially with the filling of empty spaces inside the packages, because the fill materials would take up unused disposal capacity within the cell.

Longer term, it should be possible to reuse these cement-based materials as a base material for new cement-based materials, in particular for injection in radioactive waste packages or for building disposal structures.

Another option for managing cement-based materials could be reuse in a non-nuclear field; roadworks, for example. As for metals, such a project requires exemptions to be obtained, based in particular on the guarantee that there is no impact. This assumes the identification of large, homogeneous deposits (> 100,000 t) enabling implementation of industrial decontamination and/or inspection processes. Such deposits are not yet identified.

SECURING DISMANTLING SCENARIOS BY STRENGTHENING SYNERGY

Dismantling scenarios—and therefore, waste management options—are prepared well before the operations begin at the site. They involve investments in processing and conditioning tools, and structure the contracts between nuclear licensees and operators. These investments and contracts have to be secured by making the waste management and disposal conditions as stable as possible, or when this is not possible, by anticipating potential changes in order to find ways of adapting to them.

For disposal, as for dismantling operations in the field, studies concerning radioactive waste must be started as soon as dismantling projects begin. While acceptance specifications for current disposal facilities can provide a base for a dismantling project, it is necessary to keep in mind that new options may be implemented.

Andra has therefore studied the benefit of creating a VLLW disposal facility on a dismantling site in order to limit transport and even packaging. At this stage, the conclusions show that such solutions are only viable for very large volumes and when geological conditions are favourable. Such studies do serve to explore what is possible.

These studies require group involvement of the various actors (operators, dismantling, logistics and disposal contractors) on the main dismantling sites.

Mutual understanding in order to work together effectively is one of the keys to optimal collaboration throughout the dismantling process. In terms of disposal, Andra has set up training to educate those handling the conditioning of waste about the safety issues and priorities set out in the waste package acceptance specifications. In particular, these specifications are aimed at ensuring the quality of packages produced by the work sites.

The reality at work sites also shows that in spite of the preparatory work, unexpected types of waste can appear over the course of the operation, disrupting the organisation system and increasing costs. It is important to be able to react quickly in order to process this waste and send it to the proper outlet.

Andra is therefore working with large dismantling or cleanup projects (Eurodif, Malvesi, etc.) to collectively build the best solution from waste generation to disposal.

STIMULATING INNOVATION

Dismantling has become an activity that will continue to develop over decades to come, even if the schedules for the large sites have a tendency to be pushed back. Its only source of funding comes from reserves set aside during the operating life of the installations. Optimising the use of these funds is crucial. Innovation needs to prepare for the future.

To support the R&D efforts of all parties involved in dismantling, Andra has called on the academic community and the network of French SMEs to launch highly collaborative projects. Initiated in coordination with the French National Agency for Research (ANR), the request for proposals is aimed at transposing certain existing and emerging technologies or know-how from other areas of application into radioactive waste management. The RFP covers four main themes:

- Waste characterisation
- Waste treatment methods
- Innovative materials for disposal facilities
- And a human and social sciences component on innovation and society

Two series of projects were selected in 2015 and 2016. Some of the selected projects are of an industrial nature and can be applied for the VLLW solution (Eurodif dismantling site, recycling concrete or electrical cables). Other, more fundamental projects consist in longer term development. The total funding for this phase is around € 40 M.

CONCLUSIONS

With a technical capacity of 900 000 m3, the CIRES can ensure the continuity of the acceptance VLA wastes by requesting an extension of the regulatory capacity within the same geographical extent. Needs for additional storage capacity by 2030will range between 600,000 and 1,200,000 m3 according to the different scenarios studied

Several priorities have been identified and include a successful recycling of metallic waste, after fusion and the quantification of wastes whose activity level is extremely low and for which storage at CIRES can appear as an "oversized" solution. An on-going dialogue with waste producers on the appropriateness of the different options envisaged will contribute to the efficiency of the solutions to be developed.