

# Andra Call for Projects with the support of the Investments for the Future Programme



## CYBER

Innovative recycling of VLLW concrete in radioactive environments



Project supported by Andra under the "Investments for the Future Programme" ("Investissement d'Avenir") - Selected under the Andra Call for Projects: "Optimisation of post-dismantling radioactive waste management", organised in cooperation with the French National Research Agency (ANR).

**Duration:** 36 months

**Project launch:**  
02/2017

**Total project cost:**  
€1.8 million

**Sum covered under the  
Investments for the Future  
Programme:** €900,000

**Type of financial support:** Subsidy  
with ROI guarantees for the State

**Locations:**

Changé,  
Orléans,  
Neuron

**Coordinating body:** Séché Énergies

**Partners:**

- Séché Énergies
- French Geological Survey (BRGM)
- Sairem

**Certification:** Nuclear Valley

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### BACKGROUND

Very low-level waste (VLLW) in France is currently disposed of at Andra's Industrial facility for grouping, storage and disposal (Cires). However, current forecasts show that this disposal facility will reach saturation between 2030 and 2035. Several solutions are being explored in order to optimise filling of the facility and increase its service life.

Concrete waste (rubble) is the second largest flow of VLLW. A solution has been developed to crush this rubble for reuse as disposal cell filling material at Cires. However, in order to avoid specific precautionary measures for rubble handling, this solution has only been studied for waste with activity below 1 Bq/g, which accounts for around 40% of VLLW concrete. Moreover, no recovery method has yet been proposed for the fine fraction (<2 mm) produced during concrete crushing. Concrete recycling has therefore yet to reach its full potential.

### OBJECTIVES

The CYBER project aims to develop an innovative process for treating rubble using microwave heating, in order to:

- selectively separate the components of concrete: coarse aggregates, sand and cement paste,
- decontaminate the coarse aggregates and sand,
- define and qualify uses for the separated components: in France, reuse in the nuclear industry (e.g. as a material used in disposal facilities) and, for the international market, recycling outside the nuclear sector, given differences in regulations outside France.

### PROJECT SEQUENCE

The project will involve laboratory-scale (few kg) processing tests on representative (but non-radioactive) concrete waste. The products of these tests will be characterised in order to demonstrate compliance for reuse. In particular, the capacity of cement paste to stabilise other radioactive waste will be explored.

The scheme developed in the laboratory will then be applied to the development of a pilot treatment facility to a scale of 100 kg/hr.

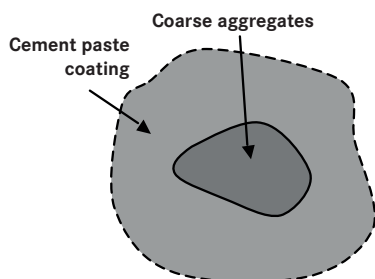
The experimental results obtained in the laboratory and those from the non-nuclear pilot will be supplemented by testing the process on concrete with radionuclide activity concentration representative of VLLW.

All these results will be used for economic and environmental assessment of the process. At the same time, the microwave oven equipment manufacturer, SAIREM, will be able to study the potential for expanding its market into the treatment of concrete waste from all sources.

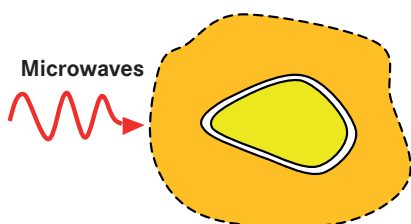


► Mockup of the CYBER project process

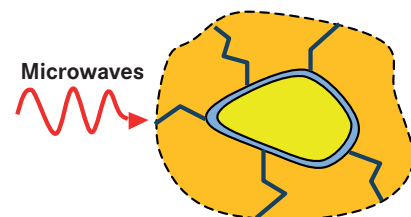
## CYBER: Innovative recycling of VLLW concrete in radioactive environments



- Cross-section of concrete with a piece of aggregate in its cement gangue



- The temperature increases and subsequent differential dilatation of the materials due to the effect of microwaves creates stresses and cracks at the interface 'cement paste/ aggregate'



- The microwaves vaporise the pore water, and the pressure of the vapour adds stress and cracks the cement paste, leading to a separation between the cement paste and aggregates



- Example of the use of a microwave oven for earth processing in a trailer on site (destruction of invasive plant seeds)

### EXPECTED RESULTS

#### Innovation

Unlike the standard process which involves mechanically crushing concrete, CYBER aims to separate out the raw components without degrading their characteristics. Moreover, reuse of cement paste as a stabilisation agent will be explored.

To this end, the process heats the rubble using microwaves, which selectively weaken the coarse aggregates/cement paste interface in order to separate them. The microwave treatment process involves two different phenomena: 1) generation of a water vapour flow within the material and 2) the differential responses of the components (cement paste versus aggregate) to the electromagnetic waves. These phenomena generate thermal expansion, which creates mechanical stresses in the material which tend to be located at the interfaces between the various material components.

Previous studies (see ANR COFRAGE project) have shown the high potential of microwaves for selectively weakening concrete.

#### Economic impact

The project aims to demonstrate the technical and economic feasibility of a radioactive rubble recycling solution in the nuclear industry.

The French market will strongly depend on the dismantling strategy adopted by nuclear operators (clean-up, followed by dismantling as a non-nuclear building, or direct dismantling). This strategy could be affected by the existence of this new recycling solution developed within the context of the CYBER project.

Assuming the favourable conditions created by a direct dismantling strategy, the market could represent over 20,000 m<sup>3</sup> of concrete waste per year, at a processing cost of around €250 per m<sup>3</sup>, significantly below the Cires direct disposal cost, representing a market of €5 million per year.

These amounts do not include foreign markets, especially in Belgium and the UK, where, unlike in France, regulations authorise the release from regulatory control of decontaminated radioactive waste and its treatment as conventional waste. For regulations outside France, the fact that radioactivity is concentrated in the cement paste is particularly interesting, because it means that sand and coarse aggregates can be decontaminated and cleared.

#### Impact on radioactive waste management

The industrialisation of CYBER could halve the cost to the nuclear industry of eliminating some of its VLLW by a factor of two from the current rate. Moreover, it would involve a "virtuous" recycling approach. Finally, the existence of this new waste management route would facilitate dismantling, and especially safety demonstrations associated with the decommissioning of what was initially a nuclear building into a non-nuclear building.

#### Social impact

Around thirty jobs will be created through the creation of a central unit for processing VLLW concrete for recycling.

### APPLICATION AND COMMERCIALISATION

In France, regulations authorise the reuse of radioactive waste only in the nuclear sector. The decontaminated coarse aggregates and sand from the CYBER process could be recycled in new construction projects or as a filler material in radioactive waste disposal cells, for example. The cement paste could be used to manufacture cement materials for stabilising radioactive waste.

Outside France, coarse aggregates and sand could be recycled as construction materials or new backfill.