EPJ Nuclear Sci. Technol. **9**, 9 (2023)

https://doi.org/10.1051/epjn/2022054

EPJ Nuclear Sciences & Technologies

Available online at:
https://www.epj-n.org

Euratom Research and Training in 2022: the Awards collection, Roger Garbil, Seif Ben Hadj Hassine, Patrick Blaise and Cécile Ferry (Guest editors)

REGULAR ARTICLE

OPEN ACCESS

CHICADE nuclear facility: a collaborative technological platform, dedicated to the expertise and characterisation of nuclear wastes

Olivier David[1,*], Dominique Carre[2], Mathieu Genin[3], and Olivier Vigneau[4]

[1] Head of CEA/DES/DDSD/DFDE/SECC, CEA Cadarache – DFDE/SECC, Bât 326, 13 108 Saint Paul lez durance cédex, France
[2] Deputy Head of DFDE/SECC, CEA Cadarache – DFDE/SECC, Bât 326, 13 108 Saint Paul lez durance cédex, France
[3] HEAD OF CEA/DES/DDSD/DFDE/SECC/LEC, CEA Cadarache – DFDE/SECC, Bât 326, 13 108 Saint Paul lez durance cédex, France
[4] Head of DFDE/SECC/LECD, CEA Cadarache – DFDE/SECC, Bât 326, 13 108 Saint Paul lez durance cédex, France

Received: 22 July 2022 / Received in final form: 2 December 2022 / Accepted: 15 December 2022

Abstract. CHICADE (CHimie CAractérisation DEchets – Chemistry CAracterization Wastes) is one of the nuclear facilities of the Energy Division of the French Alternative Energies and Atomic Energy Commission (CEA/DES). The CEA/DES is responsible for structuring and piloting the research programmes on energy at CEA. It involves its own institutes of research and those of other divisions. CHICADE is part of the Directorate for Nuclear Dismantling, Services and Waste Management. The Laboratory of Expertise and Destructive characterization is set up in the Basic Nuclear Facility – N° 156 called "CHICADE" where heavy equipment is used. The laboratory brings together both skills and means of characterization, using destructive methods on nuclear waste packages. It also carries out measurements on the whole waste package (gas release measurements, leaching tests). After a short presentation of the CEA and the Cadarache Centre, this publication aims to present the CHICADE facility and present the types of expertise on nuclear waste that are conducted there, i.e., measurement of the diffusion coefficient, inventories, leaching test, permeability measurement, gas measurements, radiochemistry, imaging. In conclusion, CHICADE is a nuclear facility with unique equipment, allowing exhaustive expertise to be carried out in a single location, benefiting from cross and complementary methods.

1 Introduction

The CHICADE facility is located in the CEA centre of Cadarache (Cf. Fig. 1), which is one of the CEA's historic centres as it is celebrating its 63rd anniversary. This centre was home to the first experimental fission reactors for electricity production and also for naval propulsion, but Cadarache is also a platform for fusion, solar energy and life sciences.

The CEA is made up of several directorates: the Directorate of Military Applications, the Directorate of Fundamental Research, the Directorate of Technological Research, and the Directorate of Energies (DES), of which the CHICADE installation is a part.

The DES is responsible for the production of low-carbon energy, resource management, global system performance, the functioning of the energy system and, the main topic of CHICADE, which is nuclear decommissioning and dismantling (D&D), including project management for D&D and operation of nuclear service facilities, innovation and advanced R&D in support of this and waste management.

CHICADE (Cf. Fig. 2) is involved in R&D and technological development in the field of nuclear waste. It is part of the CEA Directorate of Energies and Directorate for Dismantling, Nuclear Service and Waste Management Projects which, overall, generate annually 25 000 m^3 of waste through its dismantling sites; this flow, therefore, requires support in terms of expertise and technology development, which is provided by CHICADE and made available to other producers.

2 Presentation of the CHICADE facility

CHICADE is a Nuclear Facility of more than 6000 m^2, including 4000 m^2 of hot surfaces, with a wide range of equipment from the bench to the fume cupboards (Cf. Fig. 4), to the glove box, and even to the shielded cells (Cf. Fig. 5) and measurement casemates (Cf. Fig. 3).

* e-mail: olivier.david@cea.fr

Fig. 1. CEA Cadarache center.

Fig. 2. The CHICADE facility.

Fig. 3. A measurement casemates.

Fig. 4. Fume cupboards.

Fig. 5. The Cadecol shielded cell.

Fig. 6. Fission chamber.

Fig. 7. Logo of CHICADE.

Thus, it allows the assessment of waste, ranging from mg to several tons, from mBq to TBq!

The fifty or so CHICADE employees contribute to the activities of the six laboratories, each with its own field of expertise: operation, characterisation, radiochemistry, imaging, gamma spectrometry and also the manufacture of fission chambers.

These skills, both technical and human, give CHICADE the opportunity to carry out research and technological development activities enabling us to supervise the research work of PhD students, conduct teaching activities and meet the needs of other waste producers such as ITER, ONDRAF/NIRAS, Orano, EdF, etc.

The LECD, i.e., the Laboratory of Expertise and Destructive Characterization, is set up in the BNF (Basic Nuclear Facility – N° 156) called "CHICADE" where heavy equipment is used.

The laboratory brings together both skills and means of characterization, using destructive methods on nuclear waste packages. It also carries out measurements on the whole waste package (gas release measurements, leaching tests) and is associated with other experimental laboratories within the framework of the R&D programs of the DES.

It should also be noted that fission chambers are manufactured at CHICADE, in addition to the waste activities (Cf. Fig. 6).

The purpose of fission chambers is to measure the neutron flux in reactors. This measurement is important because it allows the heat flux to be regulated and the safety of reactor operation to be controlled.

3 Objectives of the assessments on nuclear wastes

The objectives of the assessments carried out at CHICADE (Cf. Fig. 7) are, therefore:

1. expertise in order to transport nuclear wastes to the appropriate waste stream,
2. development of waste conditioning methods,
3. sample controls of waste assigned to the existing waste stream.

CHICADE is, therefore, able to assess nuclear waste packages and answer certain questions, some of which are important for the safe storage of nuclear waste, such as:

- will the radionuclides contained in concrete waste packages remain in these packages after several hundred years and under severe conditions?
- Is the assessed waste assigned to the right waste outlet or is there a more suitable waste stream?
- Does the mechanical strength of the waste packaging comply with the storage requirements, in particular with regard to the stacking of waste packaging?
- For new waste, what are the methods for blocking the package to meet the storage requirements?
- ...

Fig. 8. Preparing an inventory.

Fig. 9. Remote manipulators.

4 Presentation of expertise capacities of CHICADE

The means of expertise available on CHICADE enables the actions described in the following paragraphs to be carried out.

4.1 Inventory of the nuclear waste package content

This is the most basic investigation performed but not the easiest (Cf. Fig. 8). The objective of these investigations is to ensure the conformity of the content of technological waste packages to the acceptance criteria. According to the type of radiological risk involved, these operations are carried out using various types of equipment: vinyl tents, alpha cells, shielded cells and protective clothing adapted to the radiological exposure risks of the operators.

The inventory includes the identification of the type of waste, its activity, its conditioning state, and its weight distribution...

4.2 Destructive sampling

CHICADE is equipped to the core and/or cut waste materials up to several tons and to take samples suitable for the expertise to be performed. CHICADE is able to cut through drums under water spray and to drill dry axially or radially through shells. For this purpose, CHICADE owns suitably equipped shielded cells.

These equipments are the 'Alceste' (Cf. Fig. 10) and 'Cadecol' shielded cells which can handle waste packages up to $2\,m^3$, 16 tons and up to 11.1 TBq of activity.

For α or β-type waste packages with irradiated contents, all operations are carried out by a remote manipulator(Cf. Fig. 9) beginning with the opening by coring to the closing of the cored package by filling it up and subsequent removal of the samples and waste induced.

The coring process (Cf. Fig. 11) allows researchers to penetrate and sample envelopes of the waste package

Fig. 10. The Alceste shielded cell.

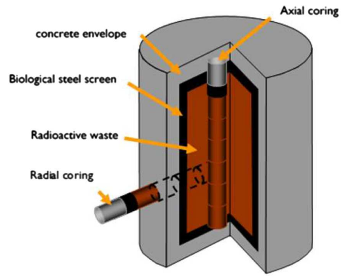

Fig. 11. Schematic diagram of core drilling.

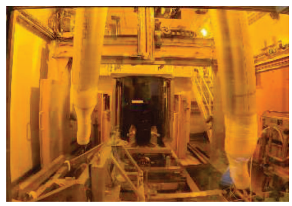

Fig. 12. Installation of an 870 l drum in CADECOL.

(mortar, concrete, possible biological steel screens and/or shielding) and to reach embedded waste in order to take samples.

Contrary to the wet process, the dry coring process, avoiding leaching of the samples, allows researchers to conduct leaching tests on samples (to measure the retention characteristics of radioelements in the matrix "waste").

These samples, obtained by dry coring of the waste package, are then prepared for the following analyses: permeability to gases, mechanical resistance, and radionuclide containment capacity... They can be evaluated by measurements taken on the whole waste package or on one of its components, concrete envelope, biological shielding steel screens or the waste itself.

In the latter case, those cores are then sliced into standardized sample shapes and sizes for experiments such as the determination of physical-chemical parameters (i.e., diffusion coefficients, leaching coefficients, compressive strength).

The cutting under water spray in CADECOL (Cf. Fig. 12) makes it possible to characterise and take samples. These assessments and characterisations aim to improve knowledge of the packages, optimise current and future characterisation methods and tools, and meet the storage requirements.

Fig. 13. Diffusion cells.

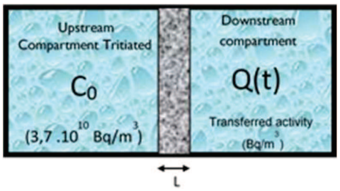

Fig. 14. Principle of measuring the diffusion coefficient.

Fig. 15. Permeability test.

4.3 Measurement of the diffusion coefficient

The capacity of the waste packages to contain the radionuclides in a saturated medium is an important characteristic for the safety of the storage.

The objective of the measurement of the diffusion coefficient is to answer the question: "Will the radionuclides contained in concrete waste packages remain in these packages after several hundred years and under severe conditions?"

This property is measured using a test of diffusion of tritiated water through a concrete sample (Cf. Fig. 13) that can have been cored in the envelope of the waste package (Cf. Fig. 14).

It is also possible to measure the diffusion coefficient of other materials, e.g., paints for containment purposes.

4.4 Permeability measurement

This expertise is to answer the question: "to which extent, a radioactive waste package is able to remove the gases produced by radiolysis (such as H_2, CO …)".

CHICADE conducts a permeability test using nitrogen on samples cored in the envelope and the active part of the waste package (Cf. Fig. 15).

Special equipment is used to apply a gas pressure on the side of a sample in order to measure the flow through it. A permeability coefficient is thus deduced and must correspond to an expected characteristic.

Fig. 16. Mechanical resistance measurements.

Fig. 17. 870 L FI setup in airtight enclosure (middle) and closed airflow circuit for accumulation data acquisition (right).

4.5 Mechanical resistance measurements to compression

In storage, the mechanical resistance of the waste packages is also an important property.

The stacking of the waste packages requires preliminary tests or measurements in order to determine the mechanical resistance of the components in the waste packages to compression.

The cores of embedded waste or concrete from the envelope are sliced into standardized samples. These "test-samples" are then subjected to compression tests using a 50 or 100-Ton press and placed in a glove box or shielded cell according to their activity level. The pressure of the load is increased gradually until fracture. The measured value must be higher than the limit of acceptability (Cf. Fig. 16).

4.6 Gas measurements of waste package gas release

The storage of many waste packages requires knowledge of the nature and quantities of the gases released. In order to carry out these measurements, CHICADE has specifically designed equipment adapted to the various types of existing waste packages.

These gas analyses are carried out either on individual packages or in storage wells.

The technique used is either gas air flush measurements or gas accumulation measurements.

With regard to the accumulation technique, the basic tool is an airtight container in which the released gases are accumulated and then sampled for identification and measurement (Cf. Fig. 17).

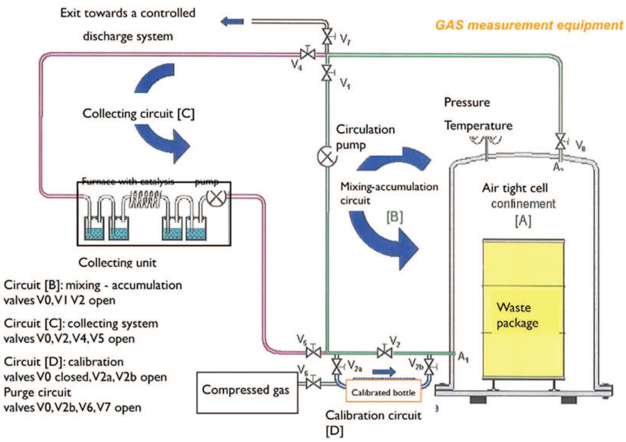

Fig. 18. Description of an accumulation measuring device.

Fig. 19. Leaching test.

Gas chromatography is then carried out using a sample of the released gas in order to quantify it. The radionuclides produced in gas forms are collected in order to be measured by a bêta liquid scintillation method (Cf. Fig. 18). This makes it possible to quantify gases such as tritium, and carbon-14...

4.7 Leaching test

The capacity of containment in a saturated medium of a block of waste and its coating is one of the important characteristics taken into consideration for storage.

A complete immersion of the waste is carried out on an entire waste package or a sample. This is the leaching test (Cf. Fig. 19) lead in the most unfavourable conditions (complete immersion vs. partial immersion).

The sampling of the leaching water during immersion is done according to a precise timetable. These water samples enable the rate of radionuclide release to be measured.

Over very long periods, such as those involved in storage conditions, radionuclide release can be calculated.

4.8 Development of solid waste conditioning methods

Another objective of CHICADE is the technological development of new waste conditioning methods this is to say to define and qualify new formulations (e.g., hydraulic binder) and/or new conditioning technologies, in line with downstream requirements.

Fig. 20. Cementing of incinerator ash.

Fig. 21. Packaging of unused sealed sources.

These actions are carried out either in existing equipment (i.e., glove boxes) or in specific equipment designed and installed in CHICADE.

Two of our projects are presented below.

The first is the cementing of ashes originating from the incineration of radioactive wastes (Cf. Fig. 20). The formulation of the hydraulic binder was developed in cold conditions on dummy ashes and is currently being tested in hot conditions on the basis of aliquots of real ashes. The parameters studied are the incorporation rate and compliance with technical tests.

The second project under technological development is the packaging of unused sealed sources in 870-litre drums for the purpose of ILW-LL storage (Cf. Fig. 21). Once this process has been developed, it could be entrusted to an industrial company for packaging all the sources in the inventory.

4.9 Radiochemical analysis

The objective of the activities carried out in radiochemistry is to define and implement chemical and radiochemical analysis techniques, to develop analysis methods, to carry out expert assessments or characterisation and control operations, and to provide external support.

In the field of waste expertise, the challenges are to establish and update inventories, study the behaviour of radionuclides for storage, and characterisation of samples or structures.

4.10 Imagery

The objective of imaging is to obtain a non-destructive assessment of the waste. The associated challenge is to detect and interpret radiation on objects designed to reduce it to a minimum, for radiation protection purposes (Cf. Fig. 22).

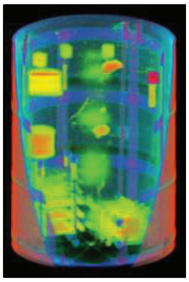

Fig. 22. Imagery of a nuclear waste.

Techniques developed and implemented at CHICADE are:

- physical characterization: X-rays and CT scans – HE.
- Radiological characterization: γ spectrometries – Passive and Active Neutron Measurements.
- Chemical characterisation: γ spectrometry after neutron/photon activation.

5 Conclusion

In conclusion, CHICADE is therefore a strategic facility for nuclear waste management, allowing:

- to carry out the necessary expert assessments on existing waste to assign it to an open outlet or to define a new waste stream,
- technological development of waste conditioning processes, to send them to an existing or future waste stream,
- to record, by sampling, the conformity of waste streams sent to open outlets.

To do this, CHICADE has a number of facilities ranging from the bench to the fume cupboards, to the glove box, and even to the shielded cells and measurement casemates that allow the assessment of waste, ranging from mg to several tons, from mBq to TBq!

CHICADE has an organisation that highlights the six areas of expertise (operation, characterisation, radiochemistry, imaging, gamma spectrometry and also the manufacture of fission chambers) necessary for its mission.

Finally, CHICADE has the human resources to fulfil its missions of expertise on nuclear waste, research and technological development, to supervise the work of PhD students, to carry out teaching activities and to respond to requests from partners.

In conclusion, CHICADE is a nuclear facility with unique equipment, allowing exhaustive expertise to be carried out in a single location, benefiting from the cross and complementary methods.

Conflict of interests

The authors declare that they have no competing interests to report.

Funding

This research was made possible thanks to CEA funding.

Data availability statement

This article has no associated data generated.

Author contribution statement

All the authors have equally contributed to this article.

Cite this article as: Olivier David, Dominique Carre, Mathieu Genin, and Olivier Vigneau. CHICADE nuclear facility: a collaborative technological platform, dedicated to the expertise and characterisation of nuclear wastes, EPJ Nuclear Sci. Technol. **9**, 9 (2023)