ALPHA WASTE MINIMIZATION
IN TERMS OF VOLUME AND RADIOACTIVITY
AT COGEMA’S MELOX AND LA HAGUE PLANTS

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ABSTRACT

This paper describes the management of alpha waste that cannot be stored in surface repositories under current French regulations. The aim of the paper is to provide an overview of COGEMA’s Integrated Waste Management Strategy. The topics discussed include primary waste minimization, from facility design to operating feedback; primary waste management by the plant operator, including waste characterization; waste treatment options that led to building waste treatment industrial facilities for plutonium decontamination, compaction and cement solidification; and optimization of industrial tools, which is strongly influenced by safety and financial considerations.

WASTE MANAGEMENT’S CONTRIBUTION TO SUSTAINABLE DEVELOPMENT

The main industrial facilities involved in closing the back end of the nuclear fuel cycle in France are the La Hague reprocessing plants, in which recyclable materials (U, Pu) are recovered and purified, and the MOX plants (Melox and Cadarache), where recovered plutonium is used to fabricate MOX fuel. These facilities are operated by COGEMA. With a reprocessing capacity of 1,700 tU/year, the La Hague site accounts for some two-thirds of the commercial capacity offered worldwide (LWR fuel), while COGEMA’s MOX plants produce 145 tHM of MOX per year.

COGEMA’s commitment to sustainable development is a key component of its industrial strategy, emphasizing ongoing initiatives to protect the environment while reducing the amount of unavoidably generated waste to be disposed of. The final disposal of waste, in particular in deep underground repositories, has become a major challenge for the nuclear industry, in terms of technological and financial criteria, not to mention public acceptance.
The amount and radiotoxicity of final waste to be stored in surface or deep repositories have been considerably reduced, thanks to efficient plant performance, in particular in U-Pu separation cycles, and continuously improved waste management programs. Considerable work has been carried out to select the best treatment option for waste on the basis of its properties, in order to guarantee the long-term stability of waste conditioned in the appropriate matrix, after volume reduction, while complying with conventional safety criteria for nuclear facilities.

The application of sustainable development principles to waste management strategy has resulted in a comprehensive approach that takes into account all waste streams and all stages of the process, from waste generation to the final repository. For plutonium-bearing waste, implementation of this strategy is based on:

- **Primary waste management key principles:**
  - Minimizing volume and plutonium content at source.
  - Sorting at source, according to waste type, activity and suitability for subsequent treatment options.
  - Optimizing waste separation to minimize the proportion incompatible with disposal in surface repositories, using appropriate non-destructive nuclear measurement.

- Creating waste treatment options that led to the building of highly flexible industrial facilities:
  - Decontamination in the Centralized Decontamination Unit (called UCD unit), using the electrogenerated silver II dissolution process.
  - Compaction in the Hulls Compacting Facility (called ACC facility).
  - Cement solidification in the Waste Facility (called AD2 facility).

- Optimizing the strategy, which is closely linked to safety and financial criteria.

**PRIMARY WASTE MANAGEMENT KEY PRINCIPLES**

**Primary waste minimization during plant design**

Waste management was carefully considered in the early stages of design. Equipment was specifically designed to be removable and modular to facilitate remote maintenance through replacing complete subassemblies. Particular care was taken to facilitate access to subassemblies considered replaceable (motors, monitoring devices) and to locate these components, whenever possible, outside radioactive areas for direct maintenance. Waste from maintenance operations can therefore be limited to discarded equipment, considerably reducing the corresponding volumes.

**Efficient primary waste management in the plant - Key role of operators**

The deep involvement of operators, through enhanced awareness and training, is of major importance for technological waste management at source. The operators are specifically in charge of:

- The policy of control and, where possible, minimizing consumables entering controlled areas and liable to become waste.
- The zoning of facilities according to the type of waste potentially generated in nuclear facilities. Two types of zones are defined, one comprising areas in which conventional, i.e. inactive, waste is generated and another covering areas that generate nuclear waste. Facility zoning, coupled with optimization of control measures, reduces the amount of nuclear waste.
- Waste sorting at source, according to type, activity and suitability for the subsequent treatment option (decontamination, compacting, cement solidification).
In MELOX plant, primary waste management is continuously optimized across plant operations. A standing Operator Working Group is in charge of implementing global actions to reduce primary waste generation. An example is the minimization of waste drums, obtained by:

- Implementing appropriate drumming for empty PuO$_2$ cans.
- Densifying waste in drums, especially organic waste.
- Dismantling first-generation filters before conditioning, to mechanically reduce the amount of Pu in the waste and to reduce waste volumes by optimizing drum filling.

The first few years of MELOX plant operations revealed that filters from grinding dust recovery systems, including cyclones, accounted for a significant proportion of generated waste, thus resulting in optimization actions. In addition, since dust generated by MOX fuel pellet grinding represented a major source of scrap, extensive work was carried out to optimize the containment and removal of grinding dust inside the glove box and to ensure it was recycled in the process. A specific filtration system was developed, supported by a complete R&D program, and deployed in the grinding glove box. It includes:

- Pulsed jet self-cleaning filters (second-generation filters).
- Mechanically decloggable pre-filters upstream from the HEPA filters.

Another optimization approach relates to improving the gloves used in the glove boxes. New gloves were developed that offered improved mechanical performance, longer lifetime (reducing replacement frequency) and increased ease of use (better touch sensation).

**Primary waste characterization**

All waste generated needs to be characterized, first to optimize waste separation in order to minimize the proportion incompatible with disposal in surface repositories, second to proceed with further application of the most appropriate treatment process.

Waste characterization is initially performed at the generating facility outlet. At this point, primary waste packages are characterized by:

- Generating facility.
- Type (organic, metal, etc.).
- Expected radionuclide composition, based on a reference spectrum. The plant’s various facilities are divided into process areas. Waste generated in the same step of the process has the same chemical composition, so its radionuclide composition depends only on the plutonium's isotopic composition. The reference spectrum is associated with one (or several) of these areas.
- Plutonium mass (required for transfer operations).
- Drum surface external contamination (required for transfer operations).

Prior to treatment, radioactivity is generally measured in a centralized unit. For solid waste, nondestructive examination coupled with the expected radionuclide composition is the only way to comply with industrial requirements. Special measurement devices have been developed to ensure that all waste is properly characterized.
In MELOX plant, waste is thus measured at:
- The outlet of MELOX facility, in stations able to detect Pu content in drums as low as 0.1 mg of Pu per 120-liter drum. This high level of accuracy is quite sufficient in order to separate the waste into waste compatible with disposal in surface repositories and waste that is incompatible.
- The inlet of the treatment unit. For example, in the UCD Pu decontamination unit, the activity is measured to confirm Pu content in the waste drum received. Measurement is obtained by gamma spectrometry coupled with neutron.

**DESCRIPTION OF PLUTONIUM BEARING WASTE**

Main part of alpha waste are generated by MELOX operation, the contribution of plutonium bearing waste from La Hague UP2-800 and UP3 plants being relatively low.

Waste from the operation and maintenance of MOX fuel fabrication plants comprises:
- Organic waste such as vinyl sleeves and gloves made of neoprene, PVC, polyethylene, polypropylene, and polyurethane.
- Empty PuO2 cans and stainless steel metal waste.
- Filters, composed of metal frames, sintered stainless steel media or glass fiber media.
- Miscellaneous waste (various tools).

The main feedback showed that less waste was generated than the expected design value due to the high level of plant automation. Additional feedback revealed that the plutonium content of the waste was mainly related to filter waste. As illustrated in Figure 1, the volume of organic waste generated by the MELOX plant was ten times lower than expected design values.
Figure 1: Pu-bearing waste generated by MELOX, 2000 results versus design values

Moreover, since the MELOX plant began operations, a sustained effort to minimize the volume and radioactivity of alpha waste has been conducted, as illustrated in Figure 2. As explained in the section on “Primary Waste Management Key Principles,” optimizing filter design resulted in a drastic decrease in the corresponding waste.

Figure 2: Pu-bearing waste generated by MELOX

WASTE TREATMENT OPTIONS

In France, the choice of waste treatment options has been driven by the following objectives, directly related to the ALARA principle:

- Whenever possible, downgrade waste to make it compatible with disposal in a surface repository.
- Minimize the volume of waste to be disposed of.
- Recycle as much plutonium as possible in the reprocessing plants.

Each of these objectives can be associated with a specific indicator:

- Downgrading.
- Decontamination.
- Volume minimization.
- Recycling.

The resulting waste treatment options set up in France are shown in Table I, with the corresponding compliance/non-compliance with the relevant indicators.
Table I: Waste treatment options and corresponding indicators

<table>
<thead>
<tr>
<th></th>
<th>Downgrading</th>
<th>Decontamination</th>
<th>Volume minimization</th>
<th>Pu recycling</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pu decontamination in the UCD unit</td>
<td>yes</td>
<td>yes</td>
<td>no</td>
<td>yes</td>
</tr>
<tr>
<td>Compaction in the ACC facility</td>
<td>no</td>
<td>no</td>
<td>yes</td>
<td>no</td>
</tr>
<tr>
<td>Conditioning in the AD2 facility</td>
<td>no</td>
<td>no</td>
<td>no</td>
<td>no</td>
</tr>
<tr>
<td>Pu decontamination in the UCD unit + compaction in the ACC facility</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>Pu decontamination in the UCD unit + conditioning in the AD2 facility</td>
<td>yes</td>
<td>yes</td>
<td>no</td>
<td>yes</td>
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</table>

**Plutonium-bearing waste decontamination in the UCD unit**

After extensive process development in the CEA laboratories, which began in the early 1980s, COGEMA decided to equip the La Hague site with facilities to decontaminate plutonium-bearing waste. The UCD unit has been designed to treat such waste from the La Hague reprocessing plants and the MOX fuel fabrication facilities [1]. The process implemented is based on PuO₂ dissolution by electrogenerated silver II ions, which was selected for its strong oxidizing properties.

The sequence of operations performed in the UCD unit is shown in Figure 3.
Figure 3: Description of process implemented in UCD unit

Waste received in the UCD unit is first checked in nuclear measurement stations. Waste drums are then opened in a large glove box called the sorting center:

- The wrapping vinyl bags are isolated for conditioning in the AD2 facility prior to being transferred to the surface disposal facility.
- Non-leachable waste (cellulose waste, metal parts with poor corrosion resistance in the leaching solution) is removed for direct conditioning.
- Waste suitable for leaching is decontaminated by silver leaching.

Prior to leaching, waste is mechanically pre-treated. Plastic waste is crushed, metal waste is cut up.

Silver leaching consists of washing the waste in an acidic solution in which the Ag\(^{2+}\) ion has been electrogenerated. The ion oxidizes the plutonium, making it readily soluble. Once decontaminated, the waste is rinsed, dried, conditioned in 120-liter drums, checked by gamma measurement and directed to the appropriate conditioning facility.

The UCD unit came on stream in February 1997. Since then, about 2,500 drums of waste have been treated. On average, approximately 60% of the treated waste has been made compatible with surface repository requirements, after compacting when possible. For certain types of waste, such as metal parts with simple geometry, a downgrading rate of up to 80% has been obtained.

Excellent UCD efficiency has resulted in the treated waste range and facility capacity being extended.
Cement solidification in the AD2 facility

Once sorted and/or treated in the UCD unit, waste is routed to the AD2 facility. Since 1989, all technological waste generated by reprocessing operations is conditioned in a cement matrix. These operations are performed in the centralized AD2 facility, in which:

- LLW technological waste is compacted and encapsulated in fiber-reinforced concrete containers, prior to surface disposal.
- ILW technological waste is encapsulated directly in fiber-reinforced concrete containers for interim storage awaiting final disposal.

These containers, which have been approved for surface disposal by the French National Agency for Radioactive Waste Management (ANDRA), were also approved by the US NRC in March 1995.

In the coming years, most ILW technological waste will be compacted in the ACC compaction facility, which came on stream in 2002.

Supercompacting in the ACC facility

Following COGEMA’s decision to introduce a compacting process to reduce the final volume of hulls and end-pieces, the ACC supercompacting facility was commissioned in 2002 [2]. The ACC facility treats hulls, end-pieces and intermediate level technological waste from reprocessing operations. An R&D program is underway to assess the compaction of Pu-bearing waste in the ACC facility. Whenever appropriate, such waste will undergo Pu decontamination in the UCD unit to remove Pu prior to compaction.

In the ACC compaction facility, waste is inserted into casings prior to compaction in a 2,500-tonne press. The resulting compacted discs are then inserted into Universal Canisters which outer geometry is identical to that of the glass canister currently used for vitrified fission products.

Deploying this new conditioning technique yields an average volume reduction factor of five, compared with direct cement solidification. Moreover, with the use of Universal Canisters, standardization of the package facilitates handling and transportation and simplifies final disposal requirements.

Figure 4: The Universal Canister for compacted waste and vitrified fission products

OPTIMIZATION OF STRATEGY - SAFETY AND FINANCIAL CRITERIA
After few years of plant operation, COGEMA decided to incorporate operation feedback related to waste generation, into operation of waste treatment units in order to tailor the capacity and performance of the plants to real waste quantities and properties. This optimization was performed taking into account [3]:

- French safety authority requirements for disposal in deep repositories, including:
  - Compliance with the ALARA principle for reducing Pu in waste to be disposed of.
  - Minimizing the volume of Pu-bearing waste.
- Financial criteria, specifically minimizing the amount and volume of waste intended for deep repository disposal; lifecycle cost, including waste treatment plant operating cost; additional investment cost required for optimization; interim storage cost; and final disposal cost.

Based on the very good results of the Pu decontamination unit, this optimization resulted in the extensive use of the corresponding UCD unit. R&D was then conducted to extend the range of waste treated in the UCD unit, specifically to include media from glass fiber filters and organic waste. The R&D program investigated the behavior of waste during leaching, leaching efficiency (Pu recovery rate, waste downgrading), process parameters (leaching duration, stirring speed during leaching, drying conditions and duration). The results of the R&D program, performed on both inactive and active waste, concluded that the new type of waste could be introduced in the UCD process. The UCD unit was therefore modified in 2002 to extend its capacity.

In addition, R&D is currently underway on compacting plutonium-bearing waste in the ACC facility.

The optimized scheme for plutonium-bearing waste, referred to as the objective scheme to be fulfilled in the coming years, is shown in Figure 5.

![Diagram](image-url)

**Figure 5: Objective scheme for treatment of Pu-bearing waste in the coming years**
QUALITY ASSURANCE AND QUALITY CONTROL SYSTEM

Like any plant operator, COGEMA's major concern is to ensure that the quality of the final product complies with the specifications that guarantee the properties of the waste, especially since they are approved by French and foreign safety authorities. A quality assessment and control system is the principal reliable industrial means of demonstrating such compliance. COGEMA has thus implemented a Quality Assurance and Quality Control system known as QA/QC.

The QA requirements are defined on the basis of the ISO 9002 standards. COGEMA can demonstrate the quality of all waste, as well as control the conditioning process. The QC system comprises an organization and a series of controls performed by the operator and independent organizations. The following parameters are associated with the QA/QC: quality provisions of primary material and manufactured products, process control, and final product quality control.

In addition, within the framework of sustainable development initiatives, COGEMA facilities have committed to introduce environmental management systems to continuously improve management of their environmental impact.

Consequently, once the waste has been defined, specified and fully qualified, a high level of quality is achieved through the entire quality system in compliance with the ISO 9002 and ISO 14001 standards.

CONCLUSION

Through its nuclear fuel cycle activities, particularly in the fields of reprocessing and recycling, COGEMA has been consolidating knowledge and expertise by identifying and implementing processes to reduce the volume and radiotoxicity of waste.

This experience is the result of a dynamic step-by-step approach, covering all stages of waste management, from design to operating feedback, and conducted with the goal of continuous improvement. A wide range of units is now available to treat the plutonium-bearing waste, and further optimization is underway, taking into account safety and financial criteria.

COGEMA is committed to maintaining its involvement in the development of a nuclear industry that protects the environment, now and for future generations.

REFERENCES

