# ARGENTINE EXPERIENCE RELATED TO THE FINAL DISPOSAL OF LOW LEVEL WASTES

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## ABSTRACT

Nuclear activities in Argentina Republic have begun in 1950 with the National Atomic Energy Commission (CNEA) creation. This institution have developed, practically, all the pacific applications on nuclear energy, including the energy generation and the control of fuel cycle.

All these activities and those from hospitals, universities, research centers, industries and other radioactive materials users, generate important volumes of wastes of different characteristics and the overall strategy of argentine program is to plan, develop and implement the technology and provide the facilities for the permanent isolation of the generated wastes, with the aim that not compromise the health and safety of general public.

To implement all of these activities, CNEA has established the Waste Management Program (WMP).

In this paper the argentine experience is described concerning to the collection, classification, characterization, treatment, conditioning, intermediate storage and final disposal of low level wastes (LLW).

Also, the paper provides details on the methodologies developed, the means for the effective implementation, the documentation required to verify that each task has been satisfactorily performed, as well as design, construction, operation, performance, closure and control of the trenches for the final disposal of low level wastes.

## INTRODUCTION

Argentina has in operation two nuclear power plants, the 380 MW(e) pressure vessel (PHWR) Atucha I and the 640 MW(e) pressure tube type Embalse. Both, of natural uranium and heavy water, represent more than 17% of the total electricity generated. There are a third pressure vessel type nuclear power plant under construction (70% completed) Atucha II of 720 MW(e) and a fourth one is under study.

In order to supply the fuel elements to the nuclear power plants mentioned before, CNEA has implemented the front part of the Fuel Cycle.

Complementing the nuclear plants needs, the operation of an industrial plant for heavy water production with a capacity of 250 ton/year is nearing to start.

Regarding the back-end of the Fuel Cycle the actual policy of our country concerning to the spent fuel elements, is to storage them in pools or in concrete silos waiting for further decision.

Together with these activities, the CNEA has developed all the peaceful applications of nuclear energy; it produces over 90% of the radionuclides consumed in the country, and an uranium enrichment plant was developed and commissioned in order to supply the fuel to be used in experimental and research reactors and on the other hand, to attain light enrichment in the fuels to be used in nuclear power plants to improve the "burn up".

All of these tasks, distributed over the country, generate important volumes of radioactive wastes of different characteristics, that must be taking in account to manage them in adequate way. For that purpose the CNEA has established since 1986 the "Waste Management Program" (WMP) which objectives are to deal with the treatment, conditioning intermediate storage, transport and final disposal of low, medium and high level radioactive waste and develop and to implement all the mechanisms required in order to attain these objectives.

WMP have overall responsibility for the safe operation of waste management systems and components, as well as the optimization with the wastes generators, of the operations related to the wastes production in order to minimize as low as possible the amount of wastes generated. Nevertheless it also can delegate to wastes generators, operations such as treatment and conditioning in a safe manner, in accordance with the procedures operational limits and conditions set out by the WMP. The objectives are that the waste form and the waste package meet the acceptance criteria established for the final disposal.

In this paper the argentine experience is described concerning the treatment, conditioning and final disposal of low level wastes.

## LOW LEVEL WASTES (LLW)

More than 90% of the low level wastes are produced in the operation of nuclear power plants and the additional waste arisings are produced from activities in the atomic research centers, radioisotope productions, universities, hospitals, industries, etc.

Low level wastes, depending of its sources, consist of aqueous effluents as evaporate concentrates, washing effluents, decontamination solutions, tracer solutions etc, and a wide range of solid waste as clothing, gloves, rags, papers, disposable materials, replaced components, small sources of short half-lives (usually $< 5$ yrs.), etc.

Once that these wastes are treated and conditioned they are finally disposed in trenches.

At present, there are 1023 $m^3$ of low level wastes treated and conditioned into 5160 drums of 0.2 $m^3$ according to specifications and procedures defined in each case. From these drums, 3500 has been disposed in the Trench N°1 for low level solid wastes. At present this trench is completed and closured. The remainder 1660 drums are disposed in the Trench N°2. This trench can accommodate up to 5600 drums.

There are 100 $m^3$ of biological wastes treated and cemented in a concrete pit "ad hoc".

It was estimated that about 40,000 drums of 0.2$m^3$ of LLW will be produced in the next thirty years taking into account the operations of four nuclear power plants.

## GENERAL CONSIDERATIONS

In order to consider the treatment and final disposal of the low level wastes produced in the country, it is necessary to establish previously safety criteria.

Radiation safety criteria adopted for normal situations are consistent with ICRP recommendations.

The authority considered as upper bound resulting for an ideal critical group from the disposal of waste in the repository under consideration, 0.1 mSv in one year.

Concerning potential disruptive events in a repository, the maximum individual risk for a member of the public must not exceed the risk due to normal radioactive releases.

The degree of isolation of waste depends on performance of the various barriers.

The first barrier is the immobilized waste where suitable technologies and special knowledge are required.

Relevant properties have to be assessed for each management stage. Quality of the waste packages to ensure compliance with the waste acceptance criteria must be checked previously to the final disposal.

Procedures, quality control and quality assurance systems applied to the process, waste form and its container are being established.

With the aim to guarantee the behavior of the waste form product, that is the first barrier, in the short and in the long term, modelling and experimental studies were considered in each case.

The second type of barrier would be a repository, wherein a series of complex engineering and geological elements must be established so as to assure complete isolation.

The strategy is based on a near surface disposal of low level waste. As it will be described further on, trenches system is being used.

## TREATMENT AND CONDITIONING

At Atucha power plant (CNAI) all the aqueous effluents from controlled area are collected and treated for volume reduction in an evaporator.

The liquid wastes storage system consists of 2 tanks (TT11 and TT12) of 10 $m^3$ each.

Evaporator concentrates produced during normal operation are stored in tank TT12. Decontamination liquid wastes are stored in tank TT11.

In the past, a polyethylene matrix (Alkatene), was used as a solidification agent employing a screw extruder. As a result of troubled extruder operation, finally it was abandoned.

At present, the evaporator concentrates are immobilized by cementation. A cementitious matrix containing blast furnace slag is being used. The process is carried out with remote control and the product is conditioned in drums of 0.2 $m^3$. These drums have an internal coating of concrete 0.07 m thickness, according with specifications. This coatings acts as biological shielding and as additional physical barrier.

The solid wastes are classificated into compactable and non compactable. Compactable wastes are compacted with 1:3 to 1:5 ratio in its own drum. Non compactable wastes are immobilized with a cement grout.

The LLW produced in Embalse nuclear power plant (CNE), consist of solid wastes, since all the aqueous effluents generated into the controlled area, are decontaminated by ion exchange resins. The spent resins are medium level wastes.

The low level solid wastes are treated and conditioned as already mentioned.

Wastes from the reminder waste generators, (agriculture, research, medicine and industry) are collected, segregated, treated and conditioned by the WMP in Ezeiza Atomic Center( CAE).

For incinerable wastes an incinerator is available with 1$m^3$ capacity, incineration rate of 34 $m^3$/h, and working temperature of 970-1070°K. The ashes are incorporated into bitumen by mechanical agitation in the proportion of 1:2 in weight, at 453°K. The mixture is loaded into drums.

Non compactable wastes are put directly into drums with cement grout.

To immobilize low level liquid wastes by cementation a remotized mixer equipment is used.

## GENERAL REQUIREMENTS

General requirements for low level wastes to be accepted for final disposal are described.

Changes have been considered since 1986 to improve low level waste management practices in order to be disposed in trenches. These improvements are: characterization of the wastes generated and waste forms, selection of materials to be used (as drums, concrete, etc.), optimization of the cementation plants, selection of adequate formulations, a better design of trenches, minimization of water infiltration, better drainage, use of a severe quality assurance programs, etc.

Prior to disposal, radioactive waste package must meet the waste acceptance requirements. General requirements are the following:

- Wastes to be disposed shall be at solid state due to the immobilization of low level liquid wastes in a solidification matrix as well as to the treatment and/or embedded of low level solid wastes in a cement grout, in compliance with the specifications of WMP.
- Liquid wastes immobilized in a solidification matrix shall be homogeneously distributed and in inherently stable form.
- Waste forms shall not contain free liquid phase, liquids or gases in ampoules or other containers and concentration of complexing agents that promote the migration of radionuclides.
- Waste forms shall not contain any explosive, pyrophosphoric, self ignitable and combustible materials.
- Waste forms shall not contain mass concentration of fissionable material higher than those established by the Regulatory Authority.
- Waste forms shall not generate gases, toxic vapors or fumes that cause risks during the transport handling, or final disposal.
- Wastes containing pathogenic, infectious, or putrescible materials shall be previously treated in order to minimize potential risks.
- Waste packages shall undergo random checks. These checks involve visual inspection, non destructive

and/or destructive tests when WMP consider necessary to apply. If the evaluation of the tests results in waste packages with relevant faults, they shall be rejected and returned to the waste generator in order to carry out a corrective action and/or its reconditioning

- Waste packages considered as "special wastes" shall only be accepted for final disposal by mutual agreement between waste generators and the responsible of WMP, properly documented.
- Waste packages containing non radioactive material in accordance with the Regulatory Authority, shall not be accepted, so that, they shall be disposed as conventional wastes.
- Containers or drums to be used to contain compacted wastes, embedded wastes in cement grout or immobilized in cement matrices, must be in compliance with the specifications established by the WMP, concerning to the design, selection of the materials used for manufacture, construction and tests.
- Each waste package shall exhibit a clear and unique identification, perfectly legible.
- Waste packages must keep the correspondent documentation attached, detailing the activities and actions carried out, with the aim to make sure that the required conditions are fulfilled.
- Waste packages with dose rate at surface up to 1000 mR/h shall be accepted whenever the proportion of them do not exceed the 25% of the total transport. This value shall be modified only with a previous agreement with the WMP.
- Permissible limits of surface contamination expressed in $\mu Ci/cm^2$ shall be low than the following values:
  - For Beta-Gamma and alpha of low toxicity, $10^{-4}$ $\mu Ci/cm^2$
  - For Alpha of high toxicity, $10^{-1}$ $\mu Ci/cm^2$

With regard to the acceptance criteria established for the final disposal of LLW, these are:

- Mechanical stability: The waste form must be able to undergo stresses without unacceptable damages related to the capability to perform the correspondent function. Compressive strength is determined according to IRAM 1690 standard test and the required values must be $\geq$ 10 MPa.
- Durability: The waste form must exhibit the chemical durability to provide the required confinement of the radionuclides involved. Leach rate is carried out with ISO 6961 standard test. Required values must be < $5 \times 10^{-5}$ m/d. In addition, compressive strength is determined after 30 cycles of 24 hours (+333°K; -233°K) according to ASTM B553-79 standard test and compressive strength after 90 days of immersion at room temperature. Values, in both cases must be $\geq$ 10 MPa.
- Combustibility and fire resistance: The waste form must be resistant to fire so that their relevant properties should not be affected in order to keep the radionuclides confined. Fire resistance is determined with ASTM D63551 standard test. The waste form must be non combustible.
- Radiation stability and radiolytic gas evolution: The dose rate and total doses must not exceed the authorized limits so that radiation induced processes and the degradation of the waste form do not attain unacceptable values as well as the gas generation must not jeopardize the performing of the whole system. Compressive strength is determined after $10^6$ Gy of gamma radiation exposure. Values must be $\geq$ 10 MPa. With regard to the required values of radiolytic gas is still not determined.
- Free water content: Considerations on the free water content is required with the aim to avoid any contamination in the eventual case of container breaking as well as to avoid accelerated degradation of the whole system.It is required that waste packages must not contain any free water.
- Biological stability: Waste form must be capable to undergo a bacterial or fungal attack without unacceptable damage employing ASTM G21 and G22 standard tests. Compression strength is determined and required values must be $\geq$10 MPa.

## DOCUMENTATION

All the waste packages for disposal in trenches at Ezeiza Atomic Center(CAE), must keep the documentation attached that verify the necessary assurance on their quality characteristics. This documentation must be fulfilled by the responsibilities of the different operations of treatment, packaging, handling and conditioning and will be assessed, supervised and endorsed by the authorized personnel of the WMP, who verifies that appropriate levels of control are applied to demonstrate the packaged wastes will comply with the requirements.

The documentation comprise procedures and a forms package, as part of a Procedures Manual Book that WMP are preparing.

An example of the documentation related to the waste packages containing low level liquid wastes (evaporator concentrate produced at CNA I) immobilized by cementation is as follows.

The documentation contains a description of the different stages from the collection of evaporator concentrates in tanks, to the monitoring of the waste packages to transport and final disposal.

The package forms contain the following information: sampling, physical and chemical analysis, radiochemical analysis, batch acceptation, materials reception, characterization and control of raw materials, control of internal concrete coatings of drums, authorization of the materials to use, processing of the batch, process control, drums record, characterization and control of the waste forms.

Sampling include the technical considerations to homogenize and taking samples. Physical and chemical analysis as well as the radiochemical analysis deal with the specifications which would be necessary to accept the batch to solidify. The former includes density, Ph, ionic strength, solid content and composition, soluble fractions and the latest, radionuclide inventory, total activity of beta/gamma emitters, specific activity and dose rate.

Batch acceptation verify that nature and composition are in the required range.

Material reception, characterization and control of raw materials include visual inspection, certifications, analysis and control to demonstrate compliance with the specifications.

Control of internal concrete coating of drums, contains the record and control of drums, concrete characteristics as well as the drums with internal concrete. Therefore according with the results, the material to be used is authorized.

Processing of the batch include batch characteristics, pretreatment, contents per drum and number of drums.

Process control involve control of formulation components dosage, control of mixing time and visual inspection. Control of the testing drums verify mixing, setting, free water content, exothermic peak and homogeneity.

Characterization and control of the waste form is considered at present as resulting of statistical taking samples from production chain and the properties tested are setting time, homogeneity, leaching rate, mechanical strength, etc.

Drums record comprise identification, total weight, waste content, dose rate at surface and at 1 m distance, surface contamination and total activity.

WMP has implemented a research program concerning with the performance of the waste form, containers and waste packages, to understand how is their behavior in the near field related to the disposal site in the short and long term. For example drum corrosion, leach tests using groundwater as leachant agent over a range of temperatures and comparison with the use of deionized water as leachant, effect of organic products arising from compacted low level solid wastes over the radionuclides migration (for example Co-60), gas radiolysis evolution, etc.

## FINAL DISPOSAL

Low level wastes once they are treated, conditioned and accomplished all the controls to assure that the waste package would be accepted for final disposal, are placed in trenches located at Ezeiza Atomic Center (CAE), Province of Buenos Aires.

The Trench No 1 has been closured and the other one, Trench No 2 is operating.

Studies of the soils in Ezeiza area with the aim to determine its ability of ions retention (the soil is loessian slime belonging to the quaternary period), has began in 1966, by evaluation of the performance of soil samples containing fission products.

Boreholes were driven and soil samples collected and tested porosity, grading and sorptive capacity for radionuclides. The site was surveyed accurately, the water table delineated and groundwater flow pattern deduced. The infiltration capacity was measured. Water supply and natural drainage was studied to evaluate possible migration paths for eventual radioactivity releases. The site was thus shown to be satisfactory and safe. It is probably one of the most suitable sites within the Commission's property.

Because of the high retention capacity of the soil it is anticipated that the radionuclides in solutions would be fixed or partially adsorbed on the soil.

To have an experience at full scale about the retention capacity of the soil of the Ezeiza area, it was decided in 1971, the construction of a low level wastes semicontention system, which includes three liquids injection units.

It was made an excavation of 10 x 30 m and 3 m depth and soil was removed (Clayish slime with good exchange capability) and blended with sand in the same proportion.

A masonry wall contention was built on the perimeter and the mixture of soil and sand above mentioned, was placed (2.20 m thickness). It was covered with 0.4 m of crushed stone and distribution pipes of liquid wastes were placed.

The following layers were 0.4 m of crushed stone up to level soil, compacted soil in a vaulted arrangement, an asphaltic priming, sand, a polyethylene membrane 250 m thickness and finally 0.1 m of humus were grass sowed.

The vaulted arrangements and the water tight layers supply the lathered dripping of rainwater.

The radioactive liquids were introduced to the system by pumping.

Samples from piezometers next to the semicontention systems are taken off and measured by WMP, those samples from piezometers at perimetral area are taken off and measured by the Regulatory Authority. The whole values are below the detection limits which corroborates the former studies on the soils behavior in Ezeiza.

It was decided, with the experience gained, to construct the first trench for low level solid waste. This trench was build in 1975. It was made an excavation under the open sky and it was removed all traces of plants up to reach a reddish soil (0.4 m depth). The size is 20 m width and 130 m length.

This trench has been operating until 1988 (it was completed with 3500 drums) so it was covered and closured.

Sealing was carry out first of all by a backfilling with sand in the spaces between drums until covered them. Later was refilled, covered and compacted with selected soil in order to form a vault in longitudinal direction, of 0.5 m height at the edge and 1 m at the center, over the drums, with the aim to guarantee and adequate biological shielding and a running off profile.

Soil characteristics had to meet the specifications, for example the moisture content at which the material will be placed.

Each soil layer of the maximum 0.3 m thickness was compacted to get the specified density according to the maximum established by the VN-E-5-67 standard test (soils compactation).

Soil layers places below the last 0.3 m were compacted at 95% (minimum) from maximum density. The last 0.3m layer was compacted at 98%.

Over the compacted soil an asphaltic layer of 2 kg per $m^2$ with EM-1 material of road type was applied while hot, attaining 0.002 m mean thickness pores free. Over the asphaltic layer dry and fine sand was placed; afterwards a black film of polyethylene 250 $\mu$m thickness was placed on transversal direction respect to the trench axis, and the edge were brought together by welding.

Finally a tosca layer was placed over the polyethylene, free of lumps and without compactation, followed by a black layer soil of 0.15 m thickness and grass over it.

The maximum detected dose in contact with the soil is 0.75 mR/h and from 1 m distance is 0.10 mR/h. Average doses are 0.05 mR/h in contact.

Surrounding the trench, piezometers were placed in order to take off samples from the water table. Until now measurement date are below detection limits.

Taking into account the experience gained it was designed and constructed the Trench N° 2.

This installation 120 m long, 20 m wide 1.20 m deep is enclosed by perimetral batter supported by walls of concrete with their respectively drainages. Its base is 0.6 m thick bed of compacted caliche, plus a 0.1 m thick layer of soil concrete and upper layer of 0.07 m of granitic stone with a slope from 2 to 5%.

This selected soil is to attain a good hydraulic gradient and a good mechanical resistance. Concerning to the soil classification, the Highway Research Board System (HRB) AASHO-145 method, was employed; the liquid limit and the plasticity limit were determined by AASHO-T89 and T-90 method and the maximal capacity by the modified PROCTOR test.

The trench can accommodate up to 5600 drums of 0.2 $m^3$ each or its equivalent. When an amount of 600 drums is accumulated a partial closure of the trench is carry out. First of all is made a contention wall of 1 m thickness composed by polypropylene bags containing coarse sand. This wall will be of 1 m height at the center, over the drums on the central line and 0.5 m thickness on the edges. Therefore the trench is covered like the trench N° 1.The results show us that the whole system meet satisfactorily the requirements established by the Regulatory Authority.