Soil Radiological Characterization and Remediation at CIEMAT

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Located in Madrid, CIEMAT is the Spanish Centre for Energy-Related, Environmental and Technological Research. It used to have more than 60 facilities in operation that allowed a wide range of activities in the nuclear field and in the application of ionising radiations.

At present, the centre includes several facilities; some of them are now obsolete, shut down and in dismantling phases. In 2000 CIEMAT started the "Integrated plan for the improvement of CIEMAT facilities (PIMIC)", which includes activities for the decontamination, dismantling, rehabilitation of obsolete installations and soil remediation activities.

A small contaminated area named with the Spanish word "Lenteja" (Lentil), has had to be remediate and restored. In the 70's, an incidental leakage of radioactive liquid occurred during a transference operation from the Reprocessing Plant to the Liquid Treatment Installation, and contaminated about 1000 m3 of soil.

Remediation activities in this area started with an exhaustive radiological characterisation of the soil, including surface samples and up to 16 meters boreholes, and the development of a comprehensive radiological characterization methodology for pre-classification of materials. Once the framework was defined the following tasks were being carried out: preparation of the area, soil removal activities and final radiological characterisation for release purposes. Next step will be the refilling of the excavation from the removal soil activities.

This paper will describe the soil radiological characterization and remediation activities at the Lentil Zone in Ciemat Research Centre.

1.- Introduction

In the 70's, an incidental leakage of radioactive liquid occurred during a transference operation from the Reprocessing Plant to the Liquid Treatment Facility, and contaminated about 1,000 m^3 of soil. The contaminated area is called "Lenteja", which means lentil in Spanish, because of its initial shape.

At that time, part of the soil was removed, the excavation filled with clean soil and covered with a concrete slab. However, there remained variable concentrations of activity in the earth. The final affected area was 450 m^2 and up to 8 meters deep.

Remediation activities began in 2010 after an exhaustive radiological characterization of the soil. Old campaigns and historical data were analysed and three borehole surveys were performed, in order to know the scope of the contamination and the isotopic distribution in the affected area. Boreholes were performed up to16 meters deep.

Subsequently work to extract the contaminated soil was planned and implemented. This was followed by the radiological characterization of the excavation, which has been refilled on March 2012.

2.- Initial radiological characterization of the ground

Three sampling surveys were implemented, by drilling boreholes 16 meters deep, providing a total of 277 samples. The sampling surveys were carried out approximately concentric to the leakage point (Fig. 1):

- Central area of the origin of the leakage (campaign 9)
- Concentric area to the first (campaign 7)
- Peripheral area to the first two (campaign 8)

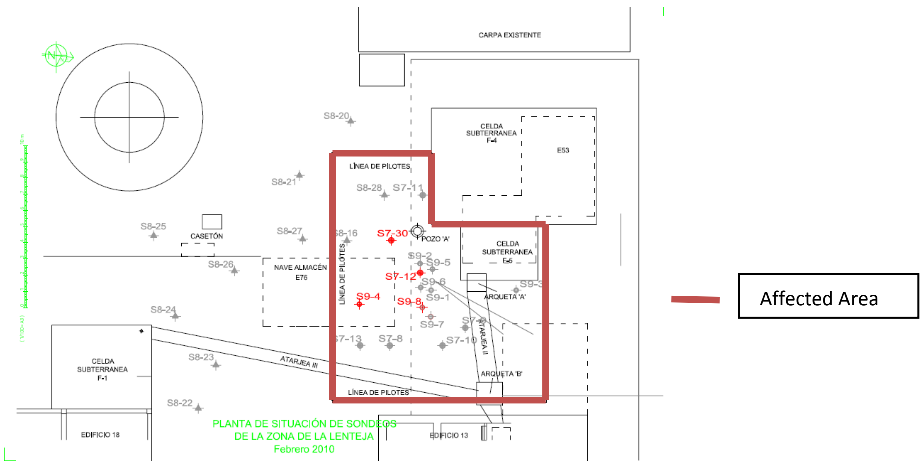


Fig. 1. Lenteja area. Location of the boreholes

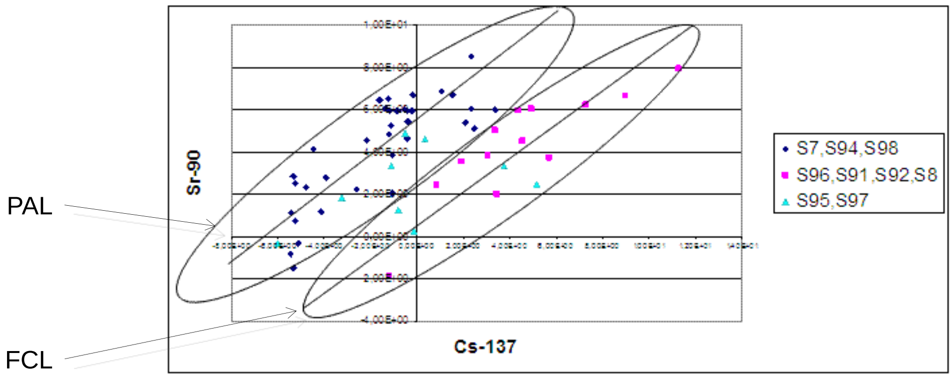
The predominant artificial isotopes were Cs-137 and Sr-90. After analysing the results it was concluded that the isotopes were distributed as follows:

- Cs-137: spreading vertically from the source of the leakage and to a lesser extent laterally.
- Sr-90: initially in the first two meters, it was spreading vertically, but from there the main diffusion process was sideways, to an area where it diffused vertically once again.

This fact resulted in the presentation of different relationships for the Sr-90/Cs-137 ratio. Statistical data analysis led to the conclusion that there were two clearly distinct relationships which were geographically distributed following the diffusion pattern described above.

The two isotope ratios were termed Lenteja Central Focus (*foco central de la lenteja - FCL*), which was where the leakage occurred in the 70's, and Lenteja Well A (*pozo A lenteja - PAL)*. The isotope ratios are:

Isotopic	Sr-90/Cs-137
PAL	310
FCL	0.8



The complete isotopic distribution was determined in each case:

to 01.01.07	FCL	PAL
ISOTOPE	**% TOTAL**	**% TOTAL**
Pu-238	0.1150%	0.0007%
Pu-239	0.3730%	0.0023%
Pu-241	2.2900%	0.0140%
Sr-90	44.3000%	99.7000%
U-234	0.1290%	0.0008%
U-235	0.0122%	0.0001%
U-236	0.0079%	0.0000%
U-238	0.0496%	0.0003%
Am-241	0.1920%	0.0012%
Cs-137	52.5000%	0.3190%

Figure 2 shows the geographical range or area of dominance of each spectrum. This figure shows that the predominant PAL area is small compared to the predominant FCL area.

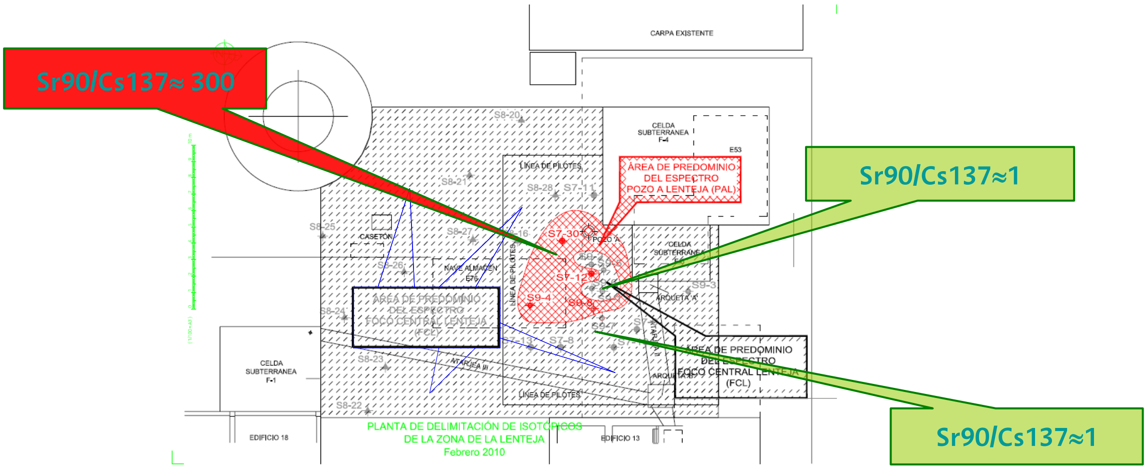


Fig. 2.- Spatial distribution per isotopic composition

In the PAL area, low Cs-137 activities imply that Sr-90 values are above the clearance levels. In the FCL area, in the centre of the *Lenteja*, the material was initially classified as radioactive waste, whilst in the area surrounding the PAL area in the most remote part, it could be classified initially as very low level waste or material to be released.

Most of the Cs-137 and Sr-90 activity was in the vicinity of Well A and in the central part where the isotope is FCL. With regard to the depth, from 5 m the soil activity significantly decreased, and in general at 9 m the values for Cs-137 and Sr-90 were less than 1 Bq/g.

3.- Radiological criteria

The following radiological criteria were taken into account during the soil remediation work:

- Clearance of the material removed: clearance levels derived from the Radiation Protection 122 document of the European Union.
- Release of the excavation:
    - Superficial Soil: release levels, in the top 15 cm of soil. These levels were obtained using the RESRAD code, taking into account following dose criteria:
        - 100 uSv per year for industrial scenario
        - 1 mSv per year in case of failure of the regulatory control.
    - Subsurface: there is no residual radioactivity (at the depth of greater than the top 15 cm)
    - Wall surfaces: clearance levels for re-use, derived from the European Union Radiation Protection 113 document.

4.- Planning and implementing the soil removal work

Taking into account the physical characteristics of the zone, and the limited space within the area for manoeuvring equipment, the over ground and underground structures were demolished. (Fig.3) and a storage area for waste was constructed.

Fig. 3: Demolition of over structure

Fig.4: Construction of underground piling wall

Before the soil removal activities, it was necessary to construct a pile containment wall that allowed the cleaning of contaminated site, and insulated it from other potentially contaminated areas. (Fig.4). Most of the soil extracted during the piling work was released.

The affected area and the temporary storage were then confined by a tent, as a measure of protection against water infiltration and to control airborne emissions. The tent was divided into two zones: the excavation area and a temporary storage area. (Fig. 5).

Fig.5: Soil excavation inside confinement tent

Excavation began in May 2010 and was implemented in grid, in accordance with the isotopic composition expected in each, with the two isotopic distributions coexisting in some areas. (Fig. 6).

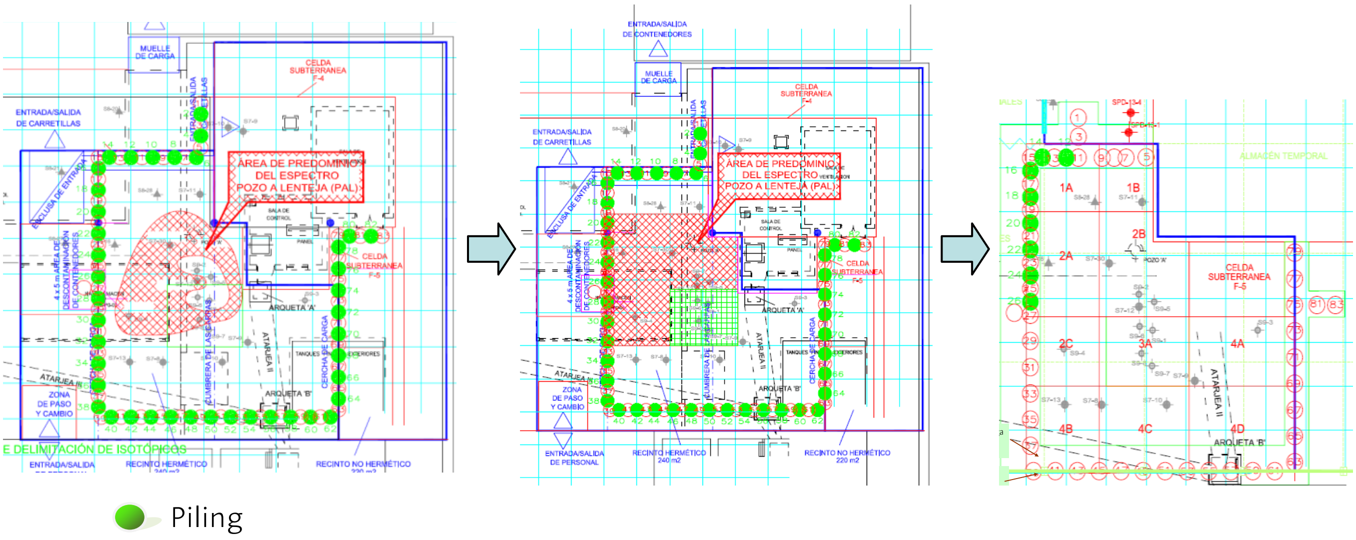


Fig. 6. Zoning inside the Lenteja excavation

Excavation was carried out slowly with a small backhoe, in order to permit the radiological control of materials and zones. The containers at the bottom of the excavation were loaded and lifted by crane anchored to the ground.

During the excavation, it was necessary to structurally reinforce the pillar wall using two perimeter beams. Finally, excavation stopped in 2011 at different heights, depending on the results of the samples. Most of the excavated area reached a depth of 7.1 meters where soil was clean, an “L-Shaped” area at a depth of 9.2 meters (Fig. 7).

Fig. 7. Levels reached in the lenteja excavation.

4.- Radiological characterization and material segregation

A key issue during the excavation was the classification and segregation of materials in-situ, in accordance with their radiological characteristics (isotopic and activity).

The soil could be classified as:

- Radioactive waste
    - Low and Intermediate Level waste of PAL or FCL isotopic composition.
    - Very Low Level waste of PAL or FCL isotopic composition.
- Material for release of FCL isotopic composition. Material with PAL isotopic composition was not classified as material for release due to the difficulty of measuring Cs-137 below 1/300 Bq/g. Clearance level for both Sr-90 and Cs-137 is 1 Bq/g.

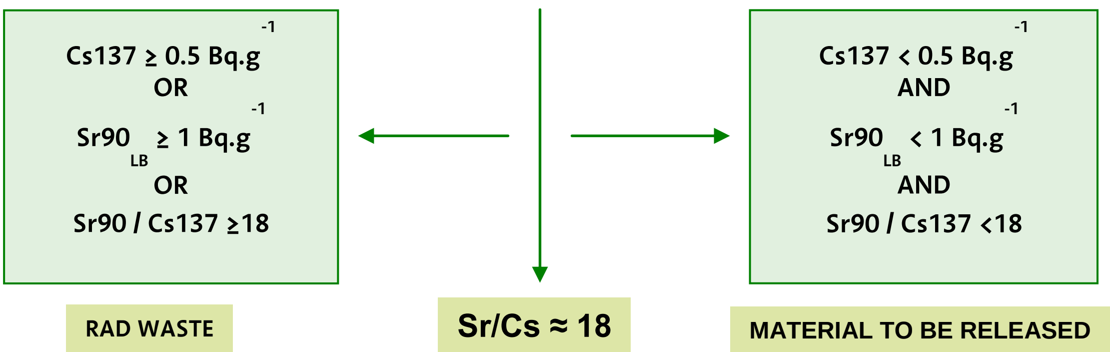
Radiation and contamination detectors were used for operational field measurements by performing a scan to make an initial assessment of whether the material was radioactive waste or a candidate for release.

A representative sample was taken for each container, composed of sub-samples of soil removed using the small backhoe until the container was filled. Also each container was assigned X, Y and Z coordinates.

A measurement method was developed to assign the isotopic composition using portable NaI (Tl) equipment. This determined the Cs-137 activity concentration, and the Sr-90 activity was estimated. The isotope was assigned taking into account the geographical origin and based on the Sr-90/Cs-137 ratio. As a function of the assigned isotope and the value obtained for Cs-137, the pre-classification of the material was confirmed either as radioactive waste or as material to be released.

In addition, a method was developed to measure Sr-90 using a proportional counter, which enabled the activity estimated by the INa detector to be fine-tuned. This method was used in the case of classified containers with material to be released and when the estimated Sr-90 activity was less than 3 Bq/g.

The classification criteria used to differentiate between radioactive waste and material to be released were:



The ratio cut-off value Sr/Cs = 18 was obtained from the statistical treatment of the data taking into account the two populations of isotopic data and the end values of the confidence interval of the data sampled.

Material classified as a candidate to be released, was sent for final measurement using a gamma spectrometer with four semiconductor detectors (Box-Counter equipment). If the results met the clearance criteria, the material was released from regulatory control.

Further, the following determinations were carried out at an external laboratory:

- 5% of containers for release: Sr-90 radiochemical determination.
- 1% of containers for release: gamma spectrometry, gross alpha and gross beta activity.

The segregation results indicated the following amounts of materials:

- Medium and low activity waste: 7 tons
- Very low activity radioactive waste: 961 tons
- Released material: 1,878 tons

5.- Final radiological survey

The final status radiological survey included direct measurements using portable INa detectors, proportional counters, surveys and sampling of the area at different points. Subsequently, piling wall was insulated using a system of shotcrete or gunite (Fig. 8).

Fig. 8. Piling wall insulation

The aim of the final radiological survey was to demonstrate that the radiological criteria detailed in paragraph 2 had been complied with. The extent of the radiological characterization was:

- Soil and subsurface: direct measurements were made using the MARSSIM methodology, and taking samples for the first 15 cm on the resulting grid and other deep judgment boreholes. In summary, the measurements were:

  Checking the top 15 cm (MARSSIM methodology)

  - 120 s dynamic measurement of 1 x 1 m2 grids using scintillation counters. Scan and static measurements using INa covering the entire surface.

- Static measurements in 15 points using INa spectrometry equipment.

  Depth checking (subsurface):

  - 15 boreholes at 2 m depth from ground level in the static measuring points, to rule out contamination in the subsurface.
  - 6 judgmental boreholes at 15 m depth from the initial ground level (between 6 and 8 m from ground level).
  - 3 samples were extracted from each borehole.

- Walls: direct measurements were taken using non-spectromatic portable equipment on the wall surfaces (consisting of piling, earth and brick) using the MARSSIM methodology. Two survey units were defined. Samples had previously been taken from the earth between adjacent piles and samples of concrete of the piles for characterization. In summary the measurements were:

  - 120 s scan measurements on each 1 x 1 m2 square grid using the scintillation counter for measuring surface contamination.
  - Static measurements: 13 for each monitoring unit.

The radiological characterization results were as follows:

- Soil and subsurface: activity levels were below release levels in the monitoring unit for the top 15 cm and no residual activity at depth was presented.

- Walls: In the two survey units, residual activity levels were below the clearance levels for reuse.

- All the survey units analysed that form the interior excavation of the *Lenteja* were released from radiological controls. Operations to fill the *Lenteja* excavation were scheduled for March 2012 and were performed as conventional work.

6.- Conclusions.

Restoration of the area called the *Lenteja* has comprised three radiological characterization processes:

1. Initial radiological characterization that provided information about the radiological characteristics of the soil in order to plan the scope of the work and management of the resulting materials.
2. In-situ radiological characterization that enabled segregation of the radioactive waste and the material to be released. Approximately 66% of the soil was released.
3. Final radiological survey which enabled verification that the radiological conditions of the resulting excavation and the subsurface met the regulatory requirements.