8th edition of the International Summer School on Nuclear Decommissioning and Waste Management

Storage and disposal of radioactive waste in Italy
GENERATION OF RADIOACTIVE WASTE

Many socially beneficial activities use radioactive materials, generating radioactive waste as an unavoidable by product:

- Nuclear energy production (both in the operations and in the decommissioning phase)
- Medicine (diagnosis and treatment of diseases, medical research, testing of new pharmaceuticals)
- Industrial activities (non destructive testing, smoke detectors, food preservation)
- Research activities (research reactors, accelerators, testing of materials)
- Processing of raw materials containing naturally occurring radionuclides (NORM)
TYPICAL RADIOACTIVE WASTE

- Source
- Medical waste
- Ion exchange resins
- Metallic scraps
- Protection clothes
WASTE FROM FUEL REPROCESSING

- Fuel reprocessing separates reusable fissile materials (Uranium and Plutonium) from fission products which are the residues of the process.

- After reprocessing the residues will be sent back to Italy; they are composed by waste conditioned in a glass matrix inserted into a stainless steel container and by metallic waste (the structural parts of the fuel bundles) compacted in similar containers.

- The small quantities of such residues (few tens of m3) can be transported and temporarily stored into the National Repository in special shielding high integrity containers (casks).
RADIOACTIVE DECAY

• A nucleus of an unstable atom usually ‘decays’ emitting radiations and transforming to a more stable atom
• ‘Half life’ is the period of time typical of a radionuclide during which half of the initial number of atoms transforms
• Radioactivity therefore progressively reduces, in short or longer times, down to negligible levels

The radioactivity of radioactive wastes naturally decays and has a finite radiotoxic lifetime. This particular feature, compared to other industrial wastes (e.g. heavy metals such as cadmium and mercury) which remain hazardous indefinitely, helps in safely disposing of the wastes
WASTE MANAGEMENT STRATEGY

DELAY AND DECAY
Storage/disposal of the waste in order to guarantee isolation and let the radioactivity naturally decay down to acceptable levels

CONCENTRATE AND RETAIN
Volume reduction and confinement of the waste through qualified conditioning process; isolation from the biosphere to prevent dispersion into the environment

DILUTE AND DISPERSER
Dispersion of the waste into the environment in order to let the natural environmental conditions and processes reduce the concentrations down to acceptable levels
HOW TO CONCENTRATE AND RETAIN?

Processing the waste (both liquid and solid):

• Pretreatment/treatment
  Liquid waste: evaporation/drying, filtration, wet oxidation
  Solid waste: compaction/supercompaction, combustion, thermal decomposition (e.g. plasma), ...

• Conditioning
  Liquid waste: immobilisation of the radioactivity in a matrix (cement, bitumen polymer, glass) at a microscopic level
  Solid waste: contaminated or activated parts and objects embedded within cement matrix.

In this way the waste is converted into a solid waste form, enclosed in containers. The waste form is the first ‘barrier’ of a series of barriers of a disposal repository designed to ensure that the radioactivity is retained (confined) for the required time period.
WASTE CLASSIFICATION

IAEA classifies radioactive waste according to the disposal solutions suitable to safely store the different waste categories:

- **VLLW**: Waste which can be safely disposed of in surface repositories because they contain mainly short-lived isotopes (i.e. \( T/2 \leq 30\text{y} \); typically Sr-90 and Cs-137)
- **LLW**: Waste which can be safely disposed of in deep repositories because they contain longer lived isotopes
- **HLW**: High Level Waste can be safely disposed of only in deep geological repositories because they contain significant amount of long-lived isotopes, i.e. with half-lives up to several thousands of years

**NOTE**: Italy has recently adopted a RAW classification in line with IAEA
‘Storage’ refers to the retention of radioactive waste in a facility or a location **up to several tens of years** with the intention of retrieving the waste.

Temporary storage allows for the decay of Low and Intermediate Level Waste and the cooling down of High Level Waste (in particular irradiated fuel) and hence simplifies their management.

‘Disposal’ is the emplacement of radioactive waste into a facility or a location with no intention of retrieving the waste.

Disposing of waste requires **containing and isolating** waste from the accessible biosphere until they represent a hazard for man and environment (**several centuries up to hundreds of thousands years**).

Difference between storage and disposal: storage can represent a suitable strategy before localizing and realizing a disposal repository but it is a **temporary measure and not an alternative to disposal** (European Directive 2011/70).
CONTAINMENT AND ISOLATION

- Containment and isolation of the waste is assured by a combination of engineered barriers in series and the natural geologic characteristics of the site.

- The engineered barriers shall be designed and the host environment shall be selected, so as to provide containment of the radionuclides until radioactive decay has significantly reduced the hazard posed by the waste.

- Water is the main agent which can mobilize waste; the barriers prevent water from getting in touch with waste.
SURFACE DISPOSAL – BASIC CONCEPTS

- Waste to be disposed in surface is mainly ‘short lived’ waste (T/2 < 30 years; typically Cs-137 and Sr-90) with small quantities of ‘long lived’ RN (α emitters < 370 Bq/g)
- Engineered barriers qualified for > 300 years durability
- Institutional control period of 300 years for assuring isolation of waste
- 300 years = 10 half lives → $1/2^{10} \approx 1/1000$ of the initial activity of ‘short lived’ RN

**NATURAL BARRIER (SITE GEOLOGY)**

**ENGINEERED BARRIERS**
(DURABILITY > 300 years)

**BIOSPHERE**

Delayed migration of the residual radionuclides

**WASTE**

**RADIOACTIVITY OF THE SHORT LIVED RADIONUCLIDES**
DISPOSAL OPTIONS

SHORT LIVED WASTE
(≈ 95% of overall volume)

LONG LIVED WASTE
(≈ 5% of overall volume)

CONTAINMENT & ISOLATION
≈ 300 y

BARRIERS
Man-made

DISPOSAL
Near surface repositories

Hundreds of thousands y

Stable geologic formations

Deep underground repositories
DISPOSAL OF SHORT LIVED WASTE

• A ‘near surface’ repository for short lived waste must fully rely upon the Engineered Barrier System for isolation and containment of the radioactive waste for the required period.

• Concrete is usually used for this type of barriers, both as construction material and as backfilling. Its mechanical, hydraulic and chemical properties make it an ideal material to assure both structural and isolation functions.

• Its behaviour is well known also over long time scale, as confirmed by studies of ancient analogue man-made structures.

Pantheon – 128 a.d.
44 m concrete dome with a 8 m oculus
DISPOSAL OF LONG LIVED WASTE

• In a deep repository for long lived waste, the long term isolation from the biosphere is provided by the natural characteristics of the host geological environment which must be confirmed to be stable over the required time scale

• The requirements for long time containment are met by sedimentary bedrocks like salt formations and clay or crystalline rocks like non-fractured granites

• Salt formations are formed during long evaporation processes of former oceans; their existence is a proof of absence of water for geological ages.

• Clay formations have equally favourable characteristics; in addition, they behave as a geochemical barrier, through sorption of radionuclides
### ITALIAN RADIOACTIVE WASTE INVENTORY

<table>
<thead>
<tr>
<th>Old classification (ISPRA GT26)</th>
<th>New classification (in line with IAEA)</th>
<th>Origin</th>
<th>FWP Gross volume (m³)</th>
<th>Destination</th>
</tr>
</thead>
<tbody>
<tr>
<td>II Category</td>
<td>VLLW - LLW</td>
<td>•Operations and decommissioning of NPP’s and Fuel Cycle facilities •Medicine, industry, research reactors</td>
<td><strong>75.000</strong></td>
<td>Surface disposal – National Repository</td>
</tr>
<tr>
<td>III category</td>
<td>ILW</td>
<td>•Operations and decommissioning of NPP’s and Fuel Cycle facilities</td>
<td><strong>15.000</strong></td>
<td>Interim storage before availability of a geologic repository</td>
</tr>
<tr>
<td>III category</td>
<td>HLW</td>
<td>•Residues from SNF reprocessing •Non reprocessable fuel</td>
<td><strong>1.000</strong>**</td>
<td>Interim storage before availability of a geologic repository</td>
</tr>
</tbody>
</table>

* *Includes the estimated production of medicine, industry, research waste in the next 50 years

** *Gross volume of the casks – assuming the return of only vitrified residues from UK reprocessing
Two broad categories of waste will be delivered to the National Repository:

**VLLW-LLW**  
SURFACE DISPOSAL

**ILW**  
LONG-TERM STORAGE

**HLW**
VLLW-LLW DISPOSAL REPOSITORY

Wastes are conditioned in metallic containers by the producers. Final Waste Package (FIRST BARRIER) are then transported to the National Repository.

The Modules are placed in reinforced concrete vaults 27m x 15,5 m x 10 m qualified for >300y life (THIRD BARRIER).

The Final Waste Packages are inserted in reinforced concrete Modules 3 m x 2 m x 1,7 m qualified for >300y life to be realised on site (SECOND BARRIER).
The Technology Park is a centre of excellence for advanced R&D on nuclear matters and possibly on sustainable development with structures dedicated to information and training. It will support the local communities bringing added value to the territory.

**Foreseen research laboratories and infrastructures:**

- New technologies for decommissioning and waste management activities
- Laboratories for Environmental Analyses
- Training School and visitors centre
- Additional research laboratories to be agreed with local authorities during the site selection phase

Two categories of criteria are defined:

- **Exclusion criteria**
  - In the first phase of the siting process and on a national scale they lead to the exclusion of areas whose characteristics do not comply with the IAEA principles.

- **Investigation criteria**
  - They can be applied to the not excluded areas by means of data on a local scale for further exclusion of unsuitable areas and/or for ranking the remaining areas on the basis of their suitability to host the repository (techno-economic aspects of realization).
SITING PROCESS

Sogin applied a procedure in two separate phases, as suggested by IAEA:

- Regional mapping phase: areas are excluded if the analysis of the available data shows their non-compliance with the Exclusion Criteria defined by ISPRA
- Site screening phase: areas are excluded or ranked according to more detailed data compared to the Investigation Criteria defined by ISPRA

The "potentially suitable areas" are areas, even vast, which have characteristics favorable to the identification of sites suitable for the localization of the LILW repository.
PUBLIC CONSULTATION

Phase 1  Information campaign - Online consultation process (about CNAPI and Preliminary Design)

Phase 2  National Workshop (to update CNAPI and Preliminary Design with qualified stakeholder positions)

Phase 3  Collection of expressions of interest to host the DNPT by the communities whose territories are included in the National Map of the Potentially Suitable Areas
BENEFITS FOR THE HOSTING COMMUNITIES

• Law N. 31 of 2010 foresees direct economic benefits for the local communities whose size and delivery procedure shall be proposed and agreed during the consultation phase

• Indirect benefits will derive by the occupational workforce during the various phases of the National Repository & Technology Park life-cycle: an average of more than 1500 jobs are expected during the 5 years of construction and around 700 employees for the operational phase

• Long-term social and economic added value for the hosting region will be represented by the Technology Park and the relevant projects and activities
Thank you!