NEA Workshop on the Management of Non-Nuclear Radioactive Waste

Management Approaches to Minimise Non-Nuclear Waste

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1. Fundamental Principles
2. Definitions
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Origin of radioactive waste

- Nuclear fuel cycle
- Plants dismantling

- Research, medicine
  - Hospitals
  - Pharmaceutic industry
  - Research reactors

- Others
  - Smoke detectors
  - Lightning conductor
  - Combustion dustes
  - Derivated products of Th use

- Industry NORM/TENORM
  “Big” sources
  - Oil
  - Phosphate
  - Metallurgy
Origin of radioactive waste

• **Fuel cycle**
  Nuclear Power plant in operation
  Decommissioning and Dismantling of nuclear installation

• **D&D**
  Waste contaminated by Transuranic elements, fission and activation products
  Short and very long half life radionuclides
  Waste low, medium and high level of activity concentration

• **Biomedical**

• **Industry**

  Nuclear Medicine (Not sealed sources $^{99m}$Tc, $^{201}$Tl, $^{67}$Ga, $^{111}$In, $^{131}$I, $^{123}$I, $^{18}$F)
  Radiotherapy (sealed sources $^{192}$Ir, $^{137}$Cs, $^{125}$I...)
  High activity sources D. Lgs 52/07
  NORM and TENORM
CHARACTERISTICS OF BIOMEDICAL RADIOACTIVE WASTE

- Radioactive material is used in medicine for diagnosis, therapy and research, like:
  - *In vitro* radioassay for clinical diagnosis and research using unsealed sources containing radionuclides;
  - *In vivo* use of radiopharmaceuticals for clinical diagnosis, therapy and medical research using unsealed sources containing radionuclides;
- Radiotherapy using sealed sources which are either implanted into the patient or used in an external device.

**DIAGNOSTIC**

Investigation of body function using gamma camera imaging. Many in vivo radiopharmaceuticals are prepared by diluting a pharmaceutical with 99mTc, which is eluted from a 99mTc generator. Some radionuclides are also used to label human blood components to act as tracers for sites of blood loss or sites of infection. This typically involves removing a blood sample from the patient, radiolabelling the blood and re-injection.

**THERAPEUTIC**

Iodine-131 is widely used for treatment of thyrotoxicosis and for ablation of the thyroid tissue or metastases during cancer treatment. Venous injection of a sterile, undiluted solution of 89Sr or 32P. Strontium is typically used in therapy for the management of pain associated with bone metastases.

**RESEARCH**

The use of radionuclides such as 3H and 14C in GBq quantities for organic synthesis in pharmaceutical research.
Radwaste management

Research Institutes, Hospitals, Medicine and Biological Research Inst.

Nuclear and conventional Plants
- Foundry
- Oil Companies
- Research Nuclear Plants

Other Producers
- Lightening Rods
- Smoke Detectors

INTEGRATED SERVICE

Waste Treatment
Temporary Storage

Private Operators

Conditioned Waste

NUCLECO

National Repository

NUCLECO
Radwaste management principles

• Radioactive waste shall be managed in such a way as to secure an acceptable level of protection for human health.

• Radioactive waste shall be managed in such a way as to provide an acceptable level of protection of the environment.

• Generation of radioactive waste shall be kept to minimum practicable.
Waste Management principles

- **Avoid**: This means using the many opportunities to avoid the production of radioactive waste, for example, by limiting the spread of contamination and avoiding the introduction of tools, consumables and packaging into a contaminated areas.
- **Reduce**: Limiting the amount of waste that is produced.
- **Reuse**: Finding alternative uses for materials that would otherwise be considered as waste.
- **Recycle**: Extracting resources from waste that can be used again.
- **Treatment**: Reducing the volume of waste or conditioning waste to minimize the impact of the disposal of the waste.
- **Disposal**: Having followed the waste management hierarchy some waste will still require disposal in a fit-for-purpose facility that offers the level of environmental protection for the waste type.

- **Waste collection, characterization and segregation**: For the purpose of determining the waste properties and suitably grouping and separating waste types, if applicable, for further processing;
- **Waste treatment**: For the purpose of easing conditioning operations through volume reduction, removal of radionuclides from the waste and change of physical and/or chemical composition;
- **Waste conditioning**: For the purpose of producing packaged waste suitable for handling, transport, storage and disposal; it is achieved through the processes of solidification, embedding and/or encapsulation;
- **Storage**: To hold the waste during its processing (buffer storage), to hold unconditioned waste until it reaches clearance levels (decay storage), to temporarily hold waste prior to its transport to a disposal facility or to hold waste until a final waste repository becomes available.
### Waste Classification

**D.LGS. N° 45/2015**  
Implementation of the Directive 2011/70/Euratom

<table>
<thead>
<tr>
<th>Categoria</th>
<th>Condizioni e/o Concentrazioni di attività</th>
<th>Destinazione finale</th>
</tr>
</thead>
</table>
| **Esenti**         | • Art. 154 comma 2 del D.Lgs n. 230/1995  
• Art. 30 o art. 154 comma 3-bis del D.Lgs n. 230/1995                                                | Rispetto delle disposizioni del D.Lgs. n. 152/2006  |
| **A vita media molto breve** | • $T_1/2 < 100$ giorni  
Raggiungimento in 5 anni delle condizioni:  
• Art. 154 comma 2 del D.Igs n. 230/1995  
| **Attività molto bassa** | • $\leq 100$ Bq/g (di cui alfa $\leq 10$ Bq/g)  
Raggiungimento in $T \leq 10$ anni della condizione:  
• Art. 30 o art. 154 comma 3-bis del D.Lgs n. 230/1995 | Non raggiungimento in $T \leq 10$ anni della condizione:  
• Art. 30 o art. 154 comma 3-bis del D.Lgs n. 230/1995 |
| **Bassa attività** | • radionuclidi a vita breve $\leq 5$ MBq/g  
• $\text{Ni}_{59-63} \leq 40$ kBq/g  
• radionuclidi a lunga vita $\leq 400$ Bq/g | Impianti di smaltimento superficiali, o a piccola profondità, con barriere ingegneristiche (Deposito Nazionale D.Lgs n. 31/2010) |
| **Media attività** | • radionuclidi a vita breve $>5$ MBq/g  
• $\text{Ni}_{59-63} > 40$ kBq/g  
• radionuclidi a lunga vita $>400$ Bq/g  
• No produzione di calore | Radionuclidi in concentrazioni tali da non rispettare gli obiettivi di radioprotezione stabiliti per l’impianto di smaltimento superficiale. |
| **Alta attività**  | Produzione di calore o di elevate concentrazioni di radionuclidi a lunga vita, o di entrambe tali caratteristiche. | Impianto di immagazzinamento temporaneo del Deposito Nazionale (D.Lgs n.31/2010) in attesa di smaltimento in formazione geologica |
The application areas for the use of radioactive devices and sources may be broken into six groups:
- Medical uses
- Non-medical irradiation of products
- Gauging systems
- Imaging systems (radiography)
- Materials analysis
- Miscellaneous uses

<table>
<thead>
<tr>
<th>Category</th>
<th>Categorization of common practices</th>
<th>Activity ratio$^b$ (A/D)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Radioisotope thermoelectric generators (RTGs)</td>
<td>A/D ≥ 1000</td>
</tr>
<tr>
<td></td>
<td>Irradiators</td>
<td></td>
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<tr>
<td></td>
<td>Teletherapy</td>
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<td></td>
<td>Fixed, multi-beam teletherapy (gamma knife)</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Industrial gamma radiography</td>
<td>1000≥A/D ≥ 10</td>
</tr>
<tr>
<td></td>
<td>High/medium dose rate brachytherapy</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Fixed industrial gauges</td>
<td>10≥A/D ≥ 1</td>
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<tr>
<td></td>
<td>-level gauges</td>
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<td></td>
<td>-dredger gauges</td>
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<tr>
<td></td>
<td>-conveyor gauges containing high activity sources</td>
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<td></td>
<td>-spinning pipe gauges</td>
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<td></td>
<td>Well logging gauges</td>
<td></td>
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<tr>
<td>4</td>
<td>Low dose rate brachytherapy (except eye plaques and permanent implant sources)</td>
<td>1≥A/D ≥ 0.01</td>
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<td></td>
<td>Thickness/fill-level gauges</td>
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<td></td>
<td>Portable gauges (e.g. moisture/density gauges)</td>
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<tr>
<td></td>
<td>Bone densitometers</td>
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<td></td>
<td>Static eliminators</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Low dose rate brachytherapy eye plaques and permanent implant sources</td>
<td>0.01≥A/D ≥ Exempt$^c$/D</td>
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<tr>
<td></td>
<td>X-ray fluorescence devices</td>
<td></td>
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<td></td>
<td>Electron capture devices</td>
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<td></td>
<td>Mossbauer spectrometry</td>
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<td></td>
<td>Positron Emission Tomography (PET checking)</td>
<td></td>
</tr>
</tbody>
</table>
Radwaste management

- Production
- Pre-treatment
- Characterization
- Treatment
- Conditioning
- Storage

- Fuel cycle
- D&D
- Research, medicine
- Industry

**Analogies**
- Principles
- Management strategies
- Treatment techniques

**Differences:** contaminants radionuclides

**Solutions**
- Avoid cross contamination
- Work batch
- Work for homogeneous lots

**About Sources:** Treatment (Cement conditioned waste packages) or Segregation (Securing homogeneous batches - Storage concrete vault)
NUCLECO : Radwaste management

- **Decommissioning and Site Remediation**
  - Waste treatment activities, storage and on site management
  - Work supervision
  - Remediation of contaminated industrial sites
  - Decontamination and dismantling operations on site

- **Health Physics and Radiological Characterization**
  - Chemical and Radiological Characterization (α, β, γ)
  - Radiological Monitoring
  - Health Physics

- **Radwaste Management**
  - Integrated Service
  - Solid and liquid radwaste treatment and conditioning
  - Large components dismantling
  - Storages management
  - Qualification and Process Development
Radiological Characterization
Radiological Characterization

Given the importance of the radiological characterisation for all the processes, its design is a very critical point. This is based essentially on:

- **Methodologies**
- **Techniques**
- **Goals**

Plant or waste characterisation is never performed by a single activity but always consists of several measurement activities with different goals that must be integrated.

The purpose of radiological characterisation is to detect and quantify the radionuclides contained in the waste. Generally the pre-characterisation measures are performed direct on the waste not packed, while characterisation measures are performed on the waste treated and packed.

The purpose of radiological characterisation is to define the quantitative and qualitative spectrum of the radionuclides contained in the waste and precisely in the final container not conditioned. In the characterisation phase are determined:

- Dose rate
- Radionuclides inventory: Not Destructive Evaluation techniques, Not Destructive Assay, Destructive Assay (sampling plan)

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Plant characterisation
- **Pre Decommissioning**
- **Decommissioning**

Waste characterization
- **Storage**
- **Treatment and conditioning**
- **Reuse**
- **Free release**
# Radiological Characterization

## NON Destructive Analysis

- Gamma Scanning & Spectrometry
- Active/passive neutronic spectrometry
- Computer codes
- X Radiography

## Destructive Analysis

- Gamma Spectrometry
- Liquid scintillation $\alpha$
- Liquid scintillation $\beta$
- $\alpha$ - $\beta/\gamma$ Counter

The destructive techniques consist of analysis of samples carried out in the laboratory with chemical methods. They are more accurate and precise than non-destructive techniques, but they need more time and require the samples to be analyzed are uniform and sufficiently representative of all material.

Non-destructive techniques consist of the measure of the intensity of the radiation nuclear, spontaneous or induced, for the qualitative and quantitative analysis of the nuclear material. They don’t alter the physical appearance and chemical composition of material, but are characterized by more modest accuracy and, often, they are conditioned by powerful effects of the matrix.

Characterization is an essential stage for the classification and control of waste in the different types according to the criteria for transport, treatment, conditioning and consequential storage.
Radioactive waste are pre-treated inside tight-cells for subsequent characterization, treatment and conditioning.

Large components are volume reduced inside tight cells, provided with heavy duty manipulators and cutting systems to allow the waste packing in 220 lt drums and the following supercompaction treatment.

Solid Waste Treatment Plant «ICS42» reduce the drums volume by means of a fully automated hydraulic 1500 t press; reduced drums are piled up inside 380 l overpacks and embedded in a cement matrix for conditioning:

1. Reading of drum code and check out of the surface activity
2. Drum compaction
3. Compacted drum height measure and pellet positioning in overpack
4. Overpack Conditioned
**SOLID WASTE:** Volume reduction by different treatment

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Volume Reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Decontamination</td>
<td>Depending on surface contamination</td>
</tr>
<tr>
<td>Cutting</td>
<td>Depending on vacuum presence</td>
</tr>
<tr>
<td>Shredding</td>
<td>Depending on vacuum presence</td>
</tr>
<tr>
<td>Compaction</td>
<td>3 – 10</td>
</tr>
<tr>
<td>Incineration</td>
<td>80 – 120</td>
</tr>
<tr>
<td>Solid/liquid separation</td>
<td>Depending on sludge composition</td>
</tr>
<tr>
<td>Chemical precipitation</td>
<td>10 – 100 wet / 200 – 10 000 dry</td>
</tr>
<tr>
<td>Ion exchange/sorption</td>
<td>500 – 10 000</td>
</tr>
<tr>
<td>Evaporation</td>
<td>Depending on the salt in solution</td>
</tr>
<tr>
<td>Reverse osmosis</td>
<td>4 - 50</td>
</tr>
<tr>
<td>Distillation</td>
<td>3 – 4</td>
</tr>
</tbody>
</table>
LIQUID WASTE TREATMENT

The «ITLD22» Liquid Treatment Plant implements biological, chemical and physical treatment process. Clarified liquid is released in compliance with specific licenses issued by Competent Authority. Sludges are cement conditioned inside qualified overpacks.

Liquid waste treatment steps depend on the type of waste and the organic load transported. Indicatively, the treatment phases in the ITLD 22 Plant are:

- Pretreatment Process: Ozonization, Oxidation Treatment by Fenton Process, Heavy Metal Precipitation, Carbonation, Remotion of nitrogen substances by biological process;
- Clarification and floculation by addition of clay substances;
- Adsorption of dissolved organic matter on carbon matrix;
- Possible treatment of mud thickening by centrifugation;
- Possible reverse osmosis treatment on clarified liquid.

1. Chemical – Physical Treatment Flocculation section
2. Conditioning station
3. Plant control room
4. Overpack Conditioned
Transport (packagings and his qualification)

**Solids**
- metallic drum (60/200 lt) ONU certified;
- adsorbing spounge;
- plastic bag 0,20 mm thick;
- PVC bottle 30 lt with double plug
- metallic drum (60/200 lt) ONU certified;
- plastic bag 0,20 mm thick;

**Liquids**
- metallic drum (60/200 lt) ONU certified;
- adsorbing spounge;
- plastic bag 0,20 mm thick;
- PVC bottle 30 lt with double plug
- metallic drum (60/200 lt) ONU certified;
- plastic bag 0,20 mm thick;

**Packagings Qualification**
- Free drop test
- Temperature resistance test
- Penetration test
- Drop test at -40 °C
Cement Qualification laboratory

**Waste Simulation**
- Treatment simulation
- Pre-qualification
- Qualification

**COMPRESSIVE STRENGTH** – UNI EN 12390-3:2003
**TERMAL CYCLING** – UNI EN 11193:2006
**LEACHING RATE** – ANSI-ANS 16.1:2003 – Li ≥ 6 per Cs-137
**RADIATION RESISTANCE** – UNI EN 11193:2006
**HIGH TEMPERATURE RESISTANCE** – IAEA Safety Standard Series No. TS-R-1, § 728
**FIRE RESISTANCE** – ASTM 635-03
**WATER PERMEABILITY** – DIN 1048-1:1991
**BIODEGRADATION RESISTANCE** – ASTM G21-96 / G22-76
**GAS GENERATION** – UNI 11193:2006
**IMMERSION** – UNI 11193:2006
**FREE LIQUID** – ANSI-ANS 55.1:1992
STORAGE

Nucleco licensed areas for waste storage is about 4.000 mq in shelters and 1.000 mq in open space.

Treated and Conditioned Radioactive Waste stored in Casaccia site are about 7.500 mc