Managing Research Accelerator Waste

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CERN:
~ 2500 staff
~ 800 associates
11000 users ~ 100 pays
~ 2500 contractors

Currently: 22 member states - Austria, Belgium, Bulgaria, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Italy, Israel, the Netherlands, Norway, Portugal, Poland, Romania, Slovakia, Spain, Sweden, Switzerland, the United Kingdom
+ Candidates to membership and Observers

An aerial view of CERN, located across the franco-swiss border, near Geneva

LHC: A tunnel of 27 km circumference, situated at ~100 metres below surface.
Some CERN Key Parameters

Radiation Areas:
- 45 km of accelerator tunnels
- RIB facility (ISOLDE)
- Spallation Source (n-TOF)
- Radioactive laboratories
- 60 access points
- 160 experiments
- 9300 radiation workers
- A few hundreds of m$^3$ radioactive waste/year
- more in long shutdowns
Induced radioactivity

Induced radioactivity depends on:
- type and energy of accelerated particles,
- beam intensity,
- chemical composition of the irradiated material

Induced radioactivity has consequences for
- the exposure of personnel during maintenance
- the maintenance of accelerator components, in particular the control of the spread of contamination during machining of radioactive components
- the administrative control of movement of radioactive items, e.g. during dismantling
- the disposal of waste
CERN’s radioactive waste

Radioactive waste produced at CERN has the following main characteristics:

- The radiotoxicity is very low to low. Only some cases of medium level activity waste (no high level waste)
- Limited quantities of activated or contaminated liquids
- Short to medium lived radionuclides (no long-lived radionuclides, apart from at very specific experiments)
- Inhomogeneity of the residual activity
- Wide range of activation channels (different beam energies and types of primary particles): Spallation, neutron capture, photonuclear reactions
- Large variety of radionuclide inventory
- Possible mixed waste (waste presenting a chemical hazard linked to the radiological hazard)

CERN needs to treat considerable amounts (several hundreds of m³ per year) on a regular basis.

A global approach was developed, taking into consideration the entire life-cycle of waste from the design phase of the facilities to the disposal of waste.
Origin of waste (CERN)

- Regular maintenance
- Repair
- Modifications and up-grades
- Dismantling projects

Examples:
- Massive objects (e.g. dumps, magnets, collimators, kickers,
- Targets, shielding blocks, detector parts,…
- Vacuum components (pumps, valves, vacuum tubes…)
- Cables
- Ventilation units and filters
- Concrete
- Burnable waste (gloves, overalls etc.)
- cooling and gas systems
  - …
Some more examples

- Pumps
- Cables
- Radiofrequency systems
- Magnets
Management of radioactive waste at CERN

In the installations:

Operational radiation protection
- Pre-treatment:
  - Dismounting and sorting of equipment and infrastructures
  - Decontamination, packaging (for internal transport)
  - Pre-characterization (RP officers)
- Transport:
  - Internal transport
- Reception:
  - Traceability
  - Sorting, dismounting, re-organization for safe storage
- Temporary storage:
  - Radiological decay
  - Accumulation of batches for treatment and disposal
- Treatment and characterization:
  - Treatment and packaging
  - Chemical and radiological characteristics
- Elimination:
  - Documentation
  - Transport (according to tripartite agreement)

Radiation protection (waste team)

In the waste treatment and storage center (RWTC):

Equipment owner

Transport service

Waste management service
Definitions and Responsibilities

Radioactive Material:
- radioactive components in use in accelerators or detectors or stored for reuse – It falls under the responsibility of the equipment owner (departments, experimental collaborations)

Radioactive Waste:
- former radioactive material, for which no further use is foreseen. After declaration as waste by the equipment owner, it falls under the responsibility of a centralised waste management unit, which is part of the radiation protection group.
Today's traceability at CERN

Software TREC
- InforEAM Oracle Database & Oracle Application Express (APEX)
- Functionality to create CERN electronic documents by TREC, avoiding entering the data twice.

Hardware
- Generic, unique, unambiguous traceability labels;
- Buffer zones equipped with a PC & 2D barcode reader;
- Mobile devices (iPad, smartphones)

Support available by centralised service

Minimization of activation at the origin

- Minimize the radionuclide inventory of components close to the beam through calculations and evaluation of alternatives in the choice of material
- Optimization already crucial during the design phase

**Safety benefit**
- Lower dose rates and committed doses

**Operational benefit**
- Reduced downtime due to faster access
- Less restrictions for manipulation & access

**End of life-cycle benefit**
- Smaller amount and less critical radioactive waste
- Smaller financial burden
Tools for minimization of waste

**Parameters responsible for material activation**

1. **Position** of the material with respect to the beam impact
2. **Energy** of the beam particles impacting on matter (influencing the intensity and characteristics of the radiation field seen by the equipment)
3. **Irradiation** and **cool down** pattern as a function of time
4. **Material composition**

A tool was developed: ACTIWIZ (*)

- **Nuclide inventory** & dominant isotopes
- **Safety relevant quantities** (activity, H*(10), radiotoxicity)

→ **optimize material selection during design**

Radioactive Inventory

- Aluminium: Na-22, Al-26, Co-60, H-3, C-14
- Steel: Ti-44, Mn-54, Co-57, Co-60, Zn-65, H-3, Fe-55, C-14, Cl-36, Ca-41
- Copper: Ti-44, Co-57, Co-60, Zn-65, H-3, Ni-63, Fe-55
- Cables: H-3, C-14, Na-22, Cl-36, Ti-44, Mn-54, Fe-55, Co-60, Zn-65, Ni-63, Rh-101, Ag-108m, Ag-110m, Sb-125, Ba-133, Bi-207

In the last few years CERN developed and implemented several tools to identify the chemical composition and the radioactive inventory of elements or compounds activated in any CERN facility or experiment (ActiWiz 3, activation techniques, chemical analysis, etc.)
Characterization

The characterization method for very low level waste is based on the establishment of **SCALING FACTORS** and validation by measurements.

**ETM:** easy to measure (γ and high energy X emitters)

**DTM:** difficult to measure (α and β emitters)

**ITM:** impossible to measure (low-level activity α and β emitters)

Key nuclide: principal ETM radionuclide

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*Courtesy of B. Zaffora, M. Magistris*
Quality controls: Systematic and random

Systematic controls
- Analytical vs experimental scaling factors
- Predicted vs identified γ-emitters
- Consistency between scaling factors and mean values of activity
- Pictures are taken during and after packaging

Random controls
- γ-spectroscopy analyses repeated by a different expert
- Additional in-situ γ-spectroscopy measurements (on 4 sides instead of 2)

Pictures taken during ... ... and after packaging.

In-situ gamma spectrometry.
Quantification of easy-to-measure radionuclides

ETM are measured in each single waste package, using:
- $\gamma$- spectrometry (laboratory or in-situ)
- Total gamma counters
Project RWTC

The Radioactive Waste Treatment Center (RWTC) project was launched in 2011.

Aim:
- Provide CERN with state-of-the-art facilities for treatment and packaging of waste according to the Host-States acceptance criteria in the final repositories.
- Centralize the activities linked to radioactive waste temporary storage and elimination in a unique location (former ISR tunnel).
Layout of the Radioactive Waste Treatment Center (RWTC)

Nominal throughput: 500 m³ per year after treatment
Some images of the treatment phases

- The shear-press is the main operational unit of the RWTC. It is installed and operational.

- The process line for very low-radioactive metallic waste is operational.
Commissioning: SHERPA

1. Characterization (sampling and calculations)
2. Treatment (sorting, cutting, compacting, packaging)
3. Validation (gamma spectrometry)

The process was documented, tested and is now operational. 1200 m3 of very low level waste were eliminated in 2016.

The characterization and validation steps are verified and accepted by the French final repository (ANDRA). They are based on:
- a high number of simulations of different irradiation scenarios,
- about 1000 measurements of in situ gamma spectrometry
- about 300 radiochemistry measurements
Some key points

Some key points in the management of radioactive waste from high-energy accelerators are:

- The management of waste shall be structured backwards, by starting from the requirements of the final repositories and from the prescriptions provided by the regulatory framework of the Country in which disposal will be performed.

- CERN develops a global approach which takes into consideration the entire life-cycle of waste from the design phase of the facilities to the disposal of waste.

- The wide range of radionuclide inventories and the inhomogeneity of the induced activity require tools for the characterization of potentially activated materials that take into consideration several possible activation scenarios.

- In large facilities like those at CERN, a reliable traceability system is essential during the dismantling and decommissioning in order to ensure sufficient information on waste origin and irradiation conditions.