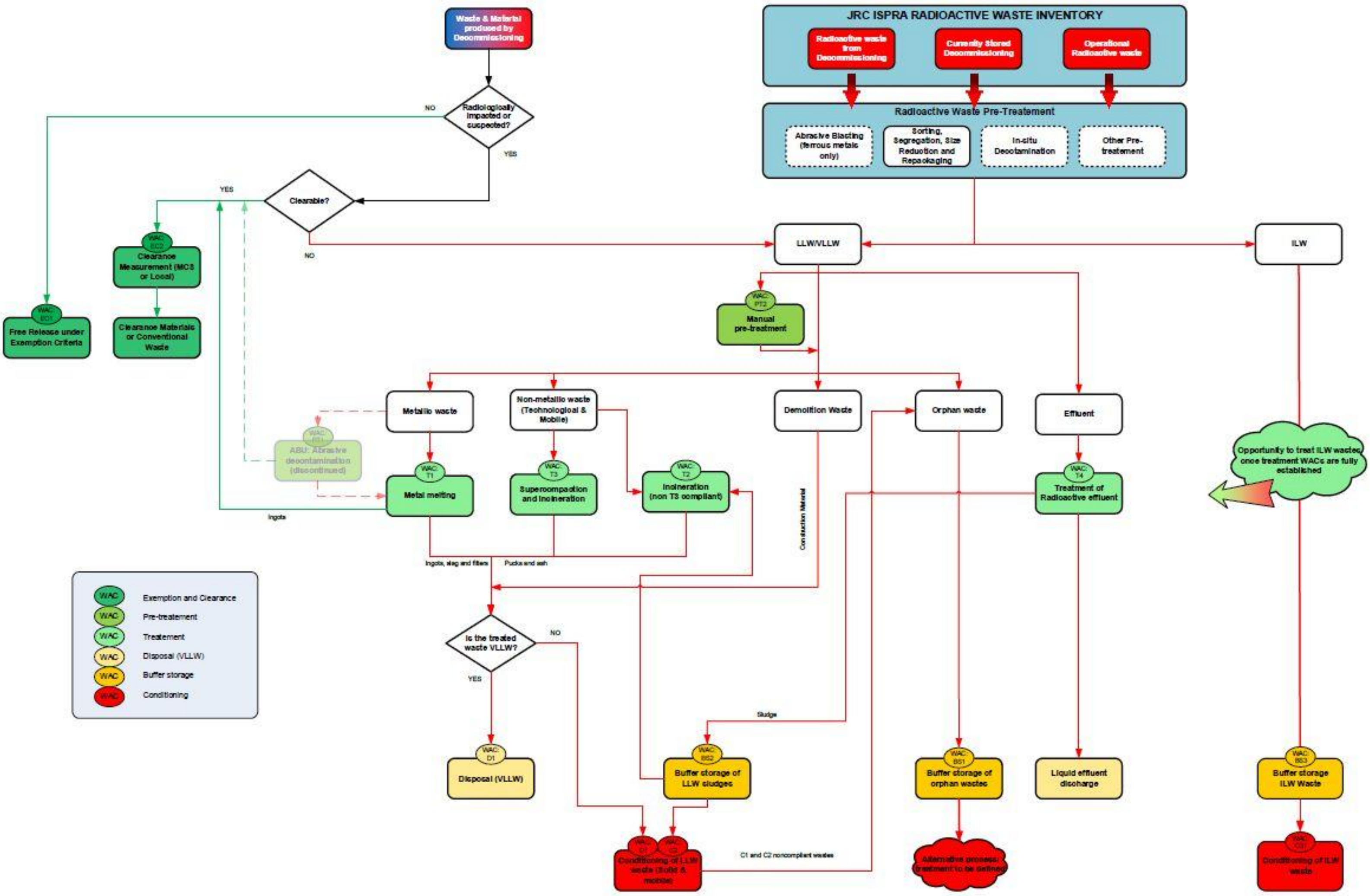

MATERIAL CLEARANCE FOR REUSE, RECYCLING AND DISPOSAL AT THE JRC´S ISPRA SITE

CASE STUDY

KP-JRC-017

17/11/2025

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Foreword

In 2021, the European Commission (EC) adopted a new proposal for a Council Regulation[1] establishing a dedicated financial programme for decommissioning nuclear facilities and managing radioactive waste. This instrument covers the co-funding of the decommissioning programmes of Bulgaria, Slovakia, and the decommissioning of the Joint Research Centre (JRC). A separate Council Regulation[2] was adopted for the decommissioning programme of Lithuania.

The EC JRC is mandated to foster the spread of decommissioning knowledge across all the European Union Member States and facilitate knowledge sharing arising from implementing the above-mentioned decommissioning programmes, funded by the Nuclear Decommissioning Assistance Programme (NDAP).

The decommissioning operators from the NDAP (NDAP Operators) implemented and tested a knowledge management methodology in 2021 through Project ENER/D2/2020-273. Using this methodology, the NDAP Operators can develop Knowledge Products that are currently available to share with other European stakeholders. In addition, this methodology is being implemented by the JRC Nuclear Decommissioning and Waste Management Directorate (NDWMD), which has become a knowledge generator extracting the knowledge from the ongoing decommissioning activities across the JRC´s four different sites (Geel, Ispra, Karlsruhe and Petten).

The JRC´s NDWMD aims to become a Centre of Excellence in nuclear decommissioning knowledge management and to develop a decommissioning knowledge platform which allows exchanging information building on EU best practices through executing the multi-annual financial framework (2021 – 2027) strategy. The operational phase of the project started in 2024 with the objectives to: develop ties and exchanges among EU stakeholders, document explicit knowledge and make it available through multi-lateral knowledge transfers on decommissioning and waste management governance issues, managerial best practices, technological challenges, and decommissioning processes at both operational and organisational level, as well as to develop potential EU synergies.

This is a Knowledge Product prepared by JRC for the Nuclear Decommissioning and Waste Management Directorate (NDWMD) – Directorate J of the Joint Research Centre.

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[1] Council Regulation (Euratom) 2021/100 of 25 January 2021 establishing a dedicated financial program for the decommissioning of nuclear facilities and the management of radioactive waste, and repealing Regulation (Euratom) No 1368/2013

[2] Council Regulation (EU) 2021/101 of 25 January 2021 establishing the nuclear decommissioning assistance programme of the Ignalina NPP in Lithuania and repealing Regulation (EU) No 1369/2013

PRODUCT DESCRIPTION

This KP describes the waste acceptance criteria (WAC) applicable to radioactive and potentially radioactive materials routed to clearance from regulatory control and destined for reuse, recycling or disposal. It is based on information gained from a series of waste compliance documents that provide advice and directions to waste producers on the range of waste management options available for specific types of waste (radioactive and conventional) in the context of the JRC Ispra site´s nuclear decommissioning and waste management (NDWM) programme. It also provides information to represent a holistic view of the JRC Ispra site´s material clearance programme and how it reflects internationally recognised sustainability principles and development goals.

ABSTRACT

This KP documents the application of material clearance procedures at the JRC Ispra site within the NDWM programme. It provides a comprehensive overview of WAC for releasing radioactive and potentially radioactive materials from regulatory control for reuse, recycling or disposal. It draws on operational experience, notably the full decommissioning of the Radio-Chemistry Hot Laboratory (RCHL), to illustrate best practices and compliance requirements. Key takeaways are recorded at the end of the document.

The document outlines the structured approach adopted by the JRC, including early planning, rigorous radiological and physical characterisation, strict adherence to Italian and EU regulations and the integration of international standards such as IAEA GSG-18. It highlights the role of the Waste Management Hierarchy (WMH) in prioritising clearance as the most sustainable option, reducing waste inventories and supporting circular economy principles. Key technical elements include monitoring and traceability through the Waste Information and Tracking System (WITS), quality control aligned with ISO 9001 and the management of primary and secondary waste streams.

Results from the RCHL case study demonstrate measurable benefits: a 27% reduction in projected waste volumes through efficient decontamination, production of 220 tonnes of clearable material and successful release of facilities without radiological constraints. The kay takeaways emphasise the importance of robust scoping, continuous leadership and avoiding rebound effects that could undermine sustainability objectives as well as efficient execution of clearance activities.

By bearing cognisance of the United Nations Sustainable Development Goals (UN SDGs) during the execution of clearance activities, notably goals 9 (industry, innovation and infrastructure), 12 (responsible consumption and production) and 17 (partnerships for the goals); the JRC reinforces its commitment to sustainable development. This KP serves as a practical reference for operators, contractors and regulators, as well as other entities with a vested interest in clearance programmes, seeking inspiration on how to optimise clearance strategies, enhance compliance and embed sustainability in nuclear decommissioning projects.

OBJECTIVE

This Knowledge Product aims to record, convey and explain the knowledge gained through applying the JRC´s clearance programme at the Ispra site.

APPROACH

This KP was developed through referring to the following knowledge inputs: the “WAC EC2: material clearance for reuse, recycling, disposal” document [1] and ¨Decommissioning RCHL, NE.80.2625.A.027, Waste Acceptance Criteria: overview document¨ [2], in addition to additional relevant references cited throughout the document, as a contribution to the JRC's Nuclear Decommissioning Knowledge Management (NDKM) Initiative.

This KP addresses the following main points:

- applicability of the clearance procedures employed at the JRC´s Ispra site,
- WAC, data and quality control requirements involved in the successful clearance activities,
- management structure and roles (responsible entities),
- alignment with sustainability principles and sustainable development goals,
- key takeaways.

RESULTS, FINDINGS AND INSIGHTS

Supporting data, such as technical diagrams, especially those illustrating the procedures of the clearance programme, are provided throughout the document. Together, they highlight key results and proven success of the JRC's clearance and materials management practices. These elements are summarised in the key takeaways section at the end of this document, providing practical insight for similar large-scale decommissioning projects across the EU. This includes findings from the only facility at the JRC's Ispra site that has been decommissioned to date (the RCHL).

TARGET USERS

This KP is a contribution to all entities involved in clearance programmes, primarily decommissioning operators, contractors and regulators, as well as other entities with a vested interest in clearance programmes such as waste producers and radioactive waste (RAW) management organisations.

APPLICATION, VALUE AND USE

The concept of clearance applies to nuclear or radiological installations and has received increased attention in recent years, in line with the pursuit of circular economy principles and initiatives driving sustainability, such as the UN SDGs. Moreover, there are waste inventories worldwide that contain material that could be reused, recycled or disposed of more efficiently.

For example, in the case of concrete RAW management, there is a tendency for significant proportions of storage inventories to be mischaracterised and misplaced. Therefore, specifically curated and implemented clearance programmes would reduce the loads on inventories and, if employed consistently, could result in measurable benefits such as lower capital and operating costs.

In terms of explicit value, the proposed KP will be particularly useful to decommissioning operators, contractors, regulators, and other entities such as future waste producers and RAW management organisations, involved in the clearance of material stemming from decommissioning projects. For example, it would allow them to learn what the WAC of a successfully executed clearance programme entails. This KP also offers said entities the opportunity to benchmark their procedures or improve their practices based on the KP´s findings.

KEYWORDS

Clearance, decommissioning, management of materials, waste management, exemption

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ACRONYMS

ALARA	As Low As Reasonably Achievable
DTI	Direttore Tecnico di Impianto (Technical Plant Director)
EC	European Commission
ENER	Energy Directorate Project Code
EU	European Union
HLW	High Level Waste
JRC	Joint Research Centre (of the European Commission)
KP	Knowledge Product
LLW	Low Level Radioactive Waste
MIRADIS	Misure Radiologiche Ispra (Radiological Measurements Ispra)
NDAP	Nuclear Decommissioning Assistance Programme
NDKM	Nuclear Decommissioning Knowledge Management
NDWM	Nuclear Decommissioning and Waste Management
NDWMD	Nuclear Decommissioning and Waste Management Directorate
RA	Responsabile dell'Allontanamento (Removal Officer)
RAW	Radioactive Waste
RCHL	Radio-Chemistry Hot Laboratory (Nuclear Facility)
UN SDGs	United Nations Sustainable Development Goals
VLLW	Very Low-Level Radioactive Waste
WAC	Waste Acceptance Criteria
WITS	Waste Information and Tracking System
WMH	Waste Management Hierarchy
WMP	Waste Management Plan

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1. INTRODUCTION

1.1. Background and context

The **Nuclear Decommissioning and Waste Management Directorate** (**NDWMD**) of the JRC is running the Nuclear Decommissioning and Waste Management (NDWM) Programme for the nuclear sites of the European Commission (**EC**), with most activities currently focused on dormant facilities situated on the Ispra site in northern Italy[3].

In 2020 the Council of the EU issued **Council Regulations 100** and **101** in which they provided **co-funding to the decommissioning programmes in three EU Member States** (Slovakia, Bulgaria and Lithuania), and full funding to the EC's internal **NDWM Programme**, **run by the JRC**. This initiative is commonly known as the **Nuclear Decommissioning Assistance Programme** (**NDAP**).

The same regulations also mandated the JRC to initiate a knowledge management project on NDWM, based on the experience and lessons learnt during the implementation of the JRC and NDAP programmes. The primary products of the KM project, referred to as KPs, will be disseminated to European stakeholders to support new operators entering NDWM activities, enabling them to benefit from knowledge gained through previous experience and programmes. This KP builds on previous contributions on the **topic of material management** by focusing on the **WAC requirements for material clearance** at the JRC´s Ispra site, as well as relevant interdependencies with **material management**, as well as **sustainability** principles and goals.

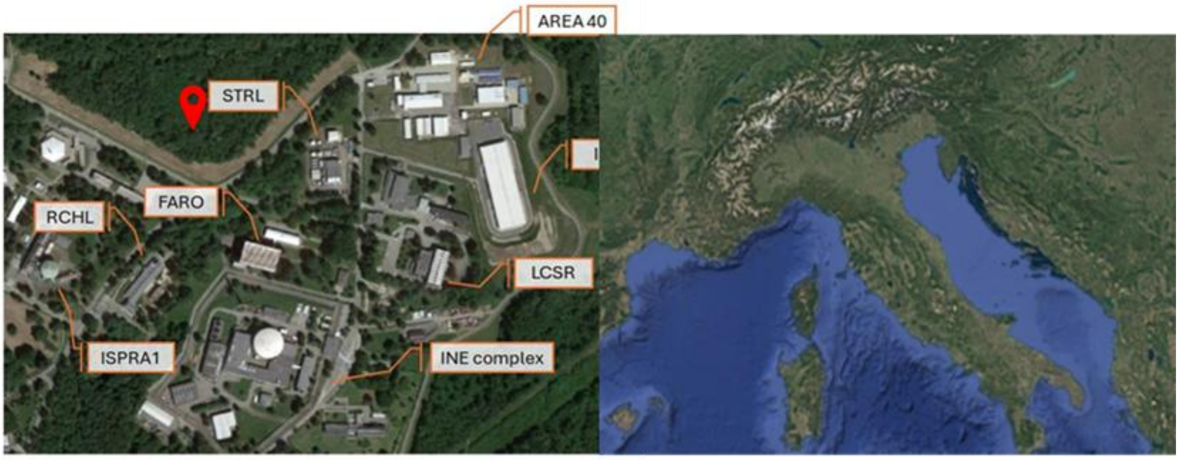

Figure 1. Aerial photo of JRC-Ispra nuclear installations

There are numerous nuclear installations on the JRC´s Ispra site that are currently "in shutdown", i.e., in a state of safe conservation. These include: experimental reactors, hot cells and radiochemical facilities, and waste handling and storage facilities. **The main installations of note are listed below**:

- Radio-Chemical Hot Laboratory (**RCHL**), already **fully decommissioning and released**,
- Fuel Melting Experimental Facility (**FARO**),
- Laboratory for Hot Studies and Research (**LCSR**),
- Liquid Radioactive Waste Treatment Station (**STRRL**), currently no longer in use because it was **replaced by the Liquid Effluent Treatment Station** (**STEL**),
- **Cyclotron**,
- **Waste management area and facilities** (including the Interim Storage Facility (**ISF**), Radioactive Waste Management Station (**SGRR**) and **STEL**),
- **ISPRA 1** (note: as of the 26th of September 2019, it has been **managed by SO.G.I.N. S.p.A.**),
- **INE Complex** (**ESSOR reactor** and associated buildings / laboratories).

[3] *The JRC-Ispra is located in the province of Varese, on the eastern shore of Lake Maggiore at the foot of the Lombard Prealps; it is situated between 8° 37' 10" and 8° 38' 40" eastern longitude (Greenwich) and between 45° 48' 05" and 45° 48' 55" northern latitude and is about 22 km from the nearest border of Switzerland.*

One point of interest in relation to the above list of installations is the RCHL, a former radio-chemistry laboratory, which was located in Building 46 and its adjacent buildings. To date, the **RCHL is the only installation on the JRC's Ispra site that has been fully decommissioned and released**. Therefore, a complete material clearance lifecycle, has so far only been completed for the RCHL. Consequently, it acts as the best example to demonstrate the JRC's effective material clearance programme and material management practices.

The RCHL was constructed in the early 1960s. The laboratory activities started in 1964 and the main building (Building 46) was completed in 1966. In 1976 an annex to Building 46 was built (Building 46d) and in 1978 a new area of laboratories named Building 32b "Stabularium" was completed. This was used for research activities with radioactive sources of various types.

In the framework of the NDWM Programme, the goal of the RCHL decommissioning project was to be **decommissioned up to what is referred to as "brown field" status**, i.e. buildings release without any radiological constraints (**IAEA Stage 3**), **including delicensing**.

The following activities were required during the RCHL's decommissioning:

- to perform the **physical** and **radiological characterisation** of the whole RCHL,
- to perform the **dismantling activities**,
- to plan and perform **suitable remediation activities**,
- to plan and perform the **final survey** and issue the **final decommissioning documentation** with the **Qualified Expert** (**QE**) **assessment certifying absence of radiological constraints**.

Subsection 2.2.2 and section 3 present an example based on the activities performed and results obtained from the RCHL decommissioning project, as well as general key takeaways, respectively.

1.2. Scope and objectives of the case study

This document applies solely with respect to the clearance of materials arising from waste management, **decommissioning**, **maintenance** and **safe conservation activities** performed under the JRC Ispra site´s NDWM programme [3]. It also takes into account the interconnections with the general material management procedures employed on site and sustainability principles observed.

A **Waste Management Plan** (**WMP**) must be generated for any nuclear construction, maintenance, dismantling and decommissioning project of a nuclear nature at the JRC-Ispra site that will result in the generation of waste or material for reuse.

Before the WMP is developed relevant information from **the following sources must be evaluated**:

- the **Waste Inventory** and **Tracking System** (**WITS**),
- Radiological Measurements (Misure Radiologiche Ispra, **MIRADIS**) [13],
- **WAC suite**,
- **Characterisation plans**,
- any **As Low As Reasonably Achievable** (**ALARA**) must be evaluated.

The WMP's purpose is, **prior to waste generation**, **to**:

a) **estimate the potential waste arising**,
b) **demonstrate adequate consideration of and application to the WMH** (minimisation, reuse, recycling etc.),
c) **specify any pre-treatments**,
d) **specify packaging** and **materials management requirements**,
e) **identify the final disposal routes**.

Specific constraints are applied to the process undertaken across all stages of the waste management lifecycle. Such constraints effectively **form a set of compliance requirements with which waste producers and managers are obliged to comply** with. A waste compliance led approach is implemented through the application of specific WAC documents (as part of the waste management compliance documentation [3]). The **suite of compliance documentation** assists waste producers in developing their decommissioning and WMPs (see Figure 2). **The documentation is organised into three tiers**:

1) **Overview documents** that provide a general introduction to the suite and assist waste producers in identifying the correct documents for developing their WMPs and associated quality plans.
2) **Guidance documents** on available options for specific waste (metallic, demolition, technological, mobile, orphan etc.).
3) **WAC documents** on specific requirements for each distinct waste process.

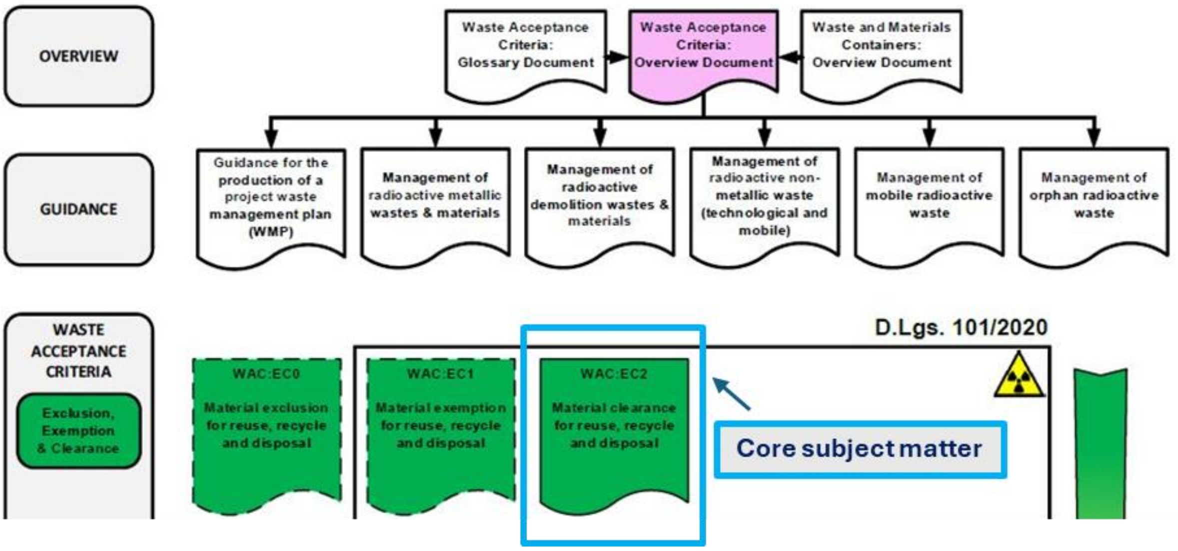

Figure 2. Partial hierarchical structure of waste compliance documentation (adapted from fig.4 in [3])

The Management of **excluded material**[4] and **exempted material**[5] **are outside the scope of the WAC** currently in force at the JRC's Ispra site. These materials must be handled according to specific waste criteria [3] and procedures [4] and [5].

The present WAC apply to both historic and new solid materials (generated during ongoing decommissioning, waste treatment and characterisation, maintenance and safe storage activities) within regulated practices (i.e. systems, structures and components of licensed nuclear installations). **The WAC does not cover liquids**. **Aqueous effluents are managed at the STEL facility** [6].

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[4] *Excluded materials are not considered radioactive.*
[5] *Exempt practices and sources within practices are still regulated. While still subject to regulatory control, exempt sources generally need to be cleared before disposal as conventional waste or material.*

Clearance of wastes is the administrative process that releases radioactive materials from regulatory control. Italian regulations [6] apply to the JRC's Ispra site, specifically the clearance levels published in Table I-1B of Appendix I of reference [6]. By following a successful clearance procedure, **materials originating from classified areas can be disposed of as conventional waste** or **reused** or **recycled** outside of a nuclear practice (thus mitigating against the generation of RAW).

Clearance is clearly the preferred management option according to the **Waste Management Hierarchy's** (**WMH's**) principles, and from the perspective of the optimal use of resources while fully satisfying environmental management good practices.

A flow diagram of the WMH can be seen below in Figure 3. It is a tool which informs decision-making and should be reviewed before reading the detailed case study in section 2.

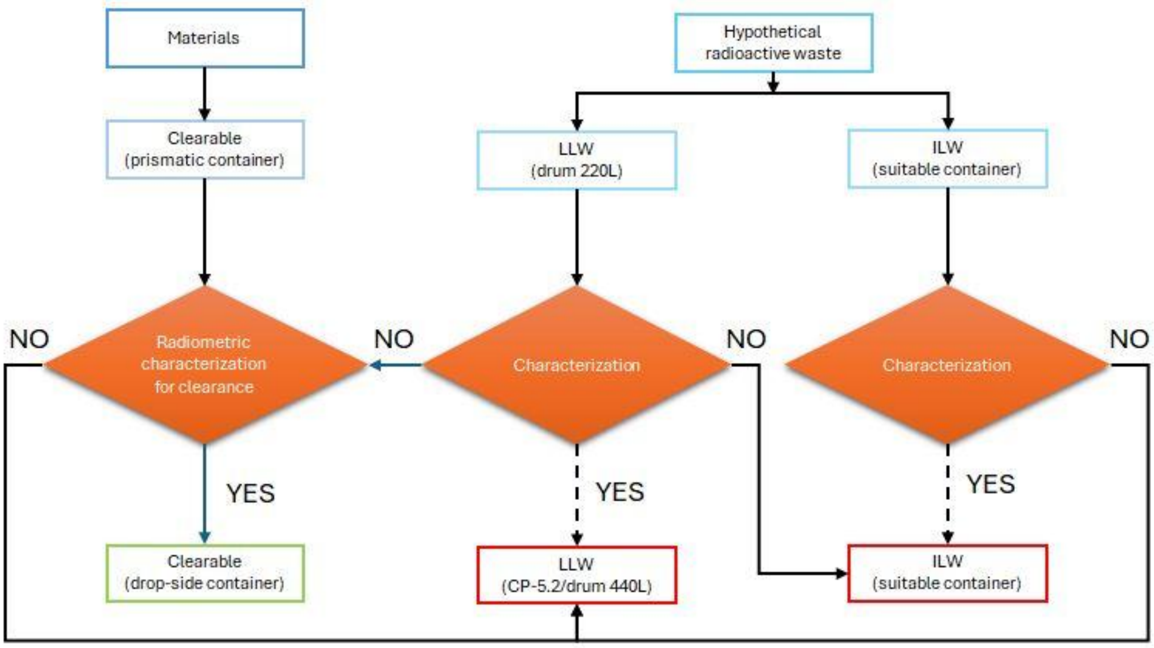

Figure 3. WMH flow diagram

2. CASE STUDY

2.1. General principles of an effective clearance programme

Effective material clearance is essential for ensuring the protection of human health, the environment, nuclear safety and the long-term sustainability of decommissioning and RAW management practices. This process **demands management that is regulated**, **technically accurate**, **transparent** and **in accordance with international standards**.

To achieve effective material clearance, **the JRC applies a structured set of principles for the** safe, efficient and fully compliant **management of clearable materials** generated at the Ispra site. **These principles** include: the aim to **minimise radiological risk**, **optimise logistics** and **costs** (i.e. minimise the production of waste), as well as **ensure traceability** and **environmental protection** throughout the entire material management lifecycle.

This case study first provides a holistic view of general RAW routes and then focuses on WAC (specifically WAC EC2); the latter of which are represented in Figure 4 below (sourced from and further elucidated in reference [3]). An orange box can be observed in the top left-hand corner of the green segment of the flow-diagram; it corresponds to the decision-making process for clearable material sourced from decommissioning activities already known to be or suspected to be radiologically impacted. The **potentially clearable material is first subject to a clearance measurement after which it is cleared or managed as conventional waste**.

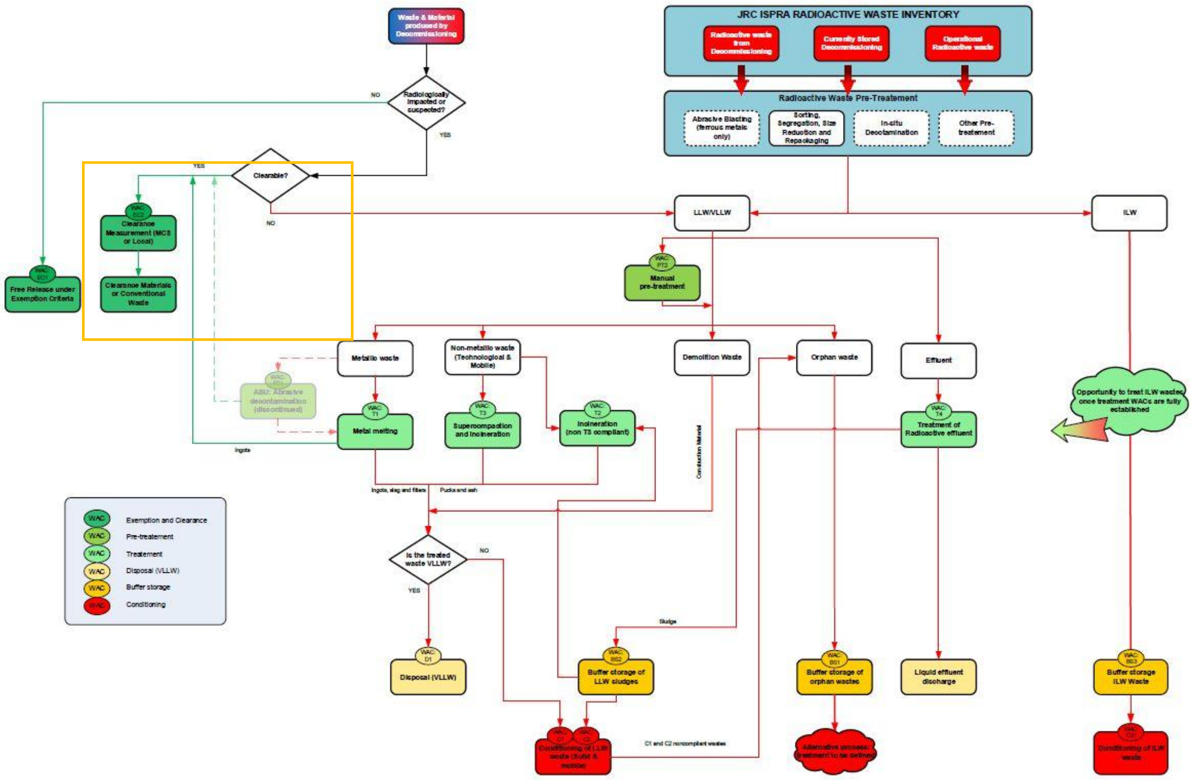

Figure 4. Overview of waste routes and acceptance criteria (WAC) applied at the JRC's Ispra site. On the top right a flow diagram related to this document.

The flow diagram shown in Figure 4 above reinforces the fact that there are a specific set of compliance requirements (i.e. WAC) which must be fulfilled, as well as to guarantee adherence to the principles of the WMH (previously referred to in subsection 1.2). **The WMH is a prioritisation of management options, the preferred option being associated with the least environmental impact**.

The implementation of the JRC-Ispra NDWM programme's waste management strategy takes into account that WAC is strictly and solely applied to **final waste packages** (see subsection 2.1.2 and Table 1) which falls under the umbrella term known as "primary waste". A waste compliance led approach is implemented through the application of specific WAC documents. They are part of the suite of waste management compliance documentation as indicated in [3].

The WAC includes a few assumptions:

1) A limited number of **RAW types may arise** from operational and decommissioning activities **that do not conform to any of the currently planned waste treatment and conditioning processes** that support the JRC-Ispra NDWM Programme. **These waste types are treated as orphan wastes.** This means that, in the short term, they will be segregated, characterised and packaged for safe transport, then transferred **to the SGRR for buffer storage** while they await the development of appropriate processing methods.

2) Mobile waste (defined as **wastes of a granular or fluid form with a nominal particle size of 5 mm or less**) **are separately identified** if other treatment methods cannot be assigned, **because they may be unsuitable for conditioning by grout encapsulation**. They will require an alternative treatment or conditioning process such as solidification, incineration or evaporation.

3) Certain wastes are excluded from the overall suite of waste compliance documentation because discrete waste management processes are planned. **These wastes include items such as bituminised drums**, **roman pits**, **concrete blocks, among others**. **In these cases**, the defined **WAC will be specified in the appropriate project documentation**.

To provide further context, the section below elaborates on how material clearance falls within the framework of the wider RAW management system employed at the JRC's Ispra site.

2.1.1. Material clearance under the JRC's radioactive waste management procedures

The set of **processes identified by the JRC** for the **management, segregation, treatment** and **conditioning** of its RAW at the Ispra site **are arranged under six main headings**, each of which is assigned a code as follows:

1) **EC - Exemption and Clearance**
2) **PT - Pre-treatment**
3) **T- Treatment**
4) **D - Disposal**
5) **BS - Buffer Storage**
6) **C - Conditioning**

In addition to the primary waste and clearance approach provided above, **it is also important to acknowledge secondary waste**. Secondary waste consists of all new material generated that is not defined as primary waste. **Examples of secondary waste include** technological waste such as **personal protective equipment** (**PPE**) used by personnel during operations and **any equipment** (or parts of it) **that cannot be recovered because they are damaged or contaminated** [8].

Dismantling operations tend to **generate secondary technological waste** in limited quantities. **From the JRC's experience** of dismantling buildings 41, 41c and 41k; **this contribution was** conservatively **assumed to be about 5% of the total weight of the components** to be dismantled [8] **and of the material resulting from decommissioning**, based on previous operational experiences.

2.1.2. Early and thorough planning, preparation and comprehensive characterisation

The management of clearable materials should be based on thorough planning and preparation. This essential phase commences with the **identification of material types**, **quantities** and **locations of materials**, followed by comprehensive **radiological** and **physical characterisation**.

> Comprehensive characterisation is needed for accurate classification and routing, ultimately determining the optimal management strategy for each material stream, resource allocation and safe execution of activities. A critical step in this process is the **classification of materials according to their level of radioactivity**, given the diverse range of waste types with varying radioactivity generated at the Ispra site.

The Decree of the 7th of August 2015 [7] provides details on the **five RAW classes stipulated to strictly and solely apply to final waste packages**:

- **EW – exempt waste**: exempt waste and / or waste containing radionuclides with very short half-lives,
- **VLLW – very low-level waste**: waste containing radionuclides with very low-levels of activity,
- **LLW – low-level waste**: waste containing radionuclides with low levels of activity,
- **ILW – intermediate level waste**: waste containing radionuclides with intermediate levels of activity,
- **HLW – high level waste**: waste containing radionuclides with high levels of activity.

Due to different management options required for exemption, clearance, interim storage and final disposal, these classes act as key points of reference for establishing early, as well as comprehensive, planning, preparation and characterisation.

2.1.3. Strict application of legal and regulatory frameworks

All **material management activities carried out by the JRC are in strict accordance with applicable Italian and European legislation**. This ensures legal compliance, supports transparency and guarantees that all decisions related to material handling, treatment and disposal of materials are properly justified and traceable. Important **examples of items of legislation and international best practice are shown in the below list**:

1. **D.lgs. 31 luglio 2020, n. 101 s.m.i.** – **Italian regulation** [6]
2. **D.lgs. 152/2006 Norme in materia ambientale (Art.256)** [8]
3. **IAEA GSG 18 Application of the Concept of Clearance - IAEA Safety Standard Series** – **General Safety Guide** [9]
4. IAEA Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management, 1997

> In keeping with the relevant Italian, European and international guidance; the JRC NDWM programme's strategy is based on prompt decommissioning of its redundant nuclear facilities, **and the segregation of wastes at source**. In addition to this, **requirements for achieving compliance with waste disposal criteria** are provided in **IAEA TECDOC 864** [10]. This requires the adoption of waste compliance arrangements in the form of WACs.

The **classification of RAW in Italy** is **laid out in Decreto 191/2015** "Classificazione dei rifiuti radioattivi" (see Table 1 below) [7]. Previously wastes were categorised based on a now outdated technical guide. The **new limits align more closely with the IAEA's recommended waste classification scheme** detailed in **IAEA SSG-1**.

Table 1. RAW categories and their characteristics as described in the Art.5 D.Lgs. n.45 of the 4th of March 2014 for the JRC’s Ispra site (Ministero dell'Ambiente e della tutela del territorio e del mare e Ministero dello sviluppo Economico, 7th of August 2015)

Category	Condition and/or Activity concentrations		Final destination
Exempted	• Art. 154 comma 2 of D.Lgs. n. 230/1995 • Art. 30 or art. 154 comma *3-bis* of D.Lgs. n. 230/1995		In compliance with the disposition of D.Lgs. n. 152/2006
Very short lived waste	• $T_{1/2}$ <100 d Achieving into 5 years these conditions: • Art. 154 comma 2 of D.Lgs. n. 230/1995 • Art. 30 or art. 154 comma 3-bis of D.Lgs. n. 230/1995		Temporary storage (art.33 D.Lgs. n. 230/1995) and disposal in agreement with the dispositions (D.Lgs. n.152/2006)
Very low activity waste (VLLW)	• ≤100Bq/g (in which Alpha ≤10Bq/g)	Reaching in T ≤10 years of this condition: • Art. 30 or art. 154 comma *3-bis* of D.Lgs. n. 230/1995	
		Not reaching in T ≤10 years of this condition: • Art. 30 or art. 154 comma *3-bis* of D.Lgs. n. 230/1995	Surface storage facility, or at low depth, with engineering barriers (National Storage D.Lgs. n. 31/2010)
Low activity waste (LLW)	• radionuclides short lived ≤5MBq/g • Ni59-Ni63 ≤40kBq/g • radionuclides long lived ≤400Bq/g		
Medium activity (ILW)	• Short lived radionuclides >5MBq/g • Ni59-Ni63 >40Bq/g • long lived radionuclides >400Bq/g • no heat released	Radionuclidi alfa emettitori ≤400Bq/g and beta-gamma nuclides in concentration that respect the radioprotection limits established for the superficial storage facility	
		Radionuclides in concentration that do not respect the radioprotection limits established for the superficial storage facility	Temporary storage facility of the National Storage (D.Lgs. n.31/2010) for the final geological disposal
High activity	Released of heat or high concentration level of long lived radionuclides, or both conditions		

By consistently adhering to these regulatory requirements, the JRC ensures that its material clearance programme is technically robust, fully traceable and complies with both national and EU standards.

2.1.4. Material classification and segregation at source

The ensuing section explains the general principles for the effective management of clearable material (free release) implemented at the JRC´s Ispra site.

All **the materials stemming from the NDWMD's installations** and activities that are planned for free release **are divided into three categories based on their origin**:

Category 1: materials originating outside the classified zone and have never transited through the classified zone.

Category 2: materials originating from the classified zone that may have come into contact with radioactive process fluids or may have been subjected to neutron irradiation.

Category 3: waste systematically produced from consumable materials and activities within classified zones, not originating from nuclear activities or ongoing radiological practices.

The JRC, specifically for the case of materials in category 2, also applies subdivisions referred to as **type A**, **B**, **C** and **D** materials**.** Type A, B, C and D materials, as defined in [11], **are parts of regulated practices** (i.e. **systems**, **structures** and **components of licensed nuclear installations**) and need to be cleared before release. **They are processed with a dedicated procedure** [4] and **in accordance with the present WAC**. Types A to D materials are defined as the following:

- **Type A**: **activated and contaminated materials,**
- **Type B**: **contaminated materials**,
- **Type C**: **activated materials**,
- **Type D**: **presumably neither activated nor contaminated**.

Potentially **clearable materials may be produced in continuous or discontinuous production activities**. The former are typically produced in routine safe conservation and maintenance activities, while the latter are generated in specific safe conservation or decommissioning projects.

2.1.4.1. Responsibility

Every waste producer (i.e. the entity responsible for the activity producing reusable, recyclable or disposable material) must ensure compliance with the relevant WAC.

During the generation of waste, the waste owner is the waste producer. The **waste owner is responsible for notifying the Clearance Coordinator that a material batch compliant with the clearance WAC is ready to be processed**. If the clearance requirements are fulfilled successfully, material ownership is transferred to the Responsabile dell'Allontanamento (RA, Release Officer [4]). For both historical and newly produced potentially clearable material, **the RA is by default the project leader of the waste producing project**.

Figure 5. Waste-clearance responsibility profiles

If the clearance requirements are not fulfilled, material ownership remains with the waste producer.

2.1.4.2. Radioactive waste separation, sorting and management of clearable materials

The following **main activities can be defined from the point of view of the generation of clearable materials** at the JRC´s Ispra site:

- the **separation of clearable material from RAW and conventional waste**,
- **sorting and management of clearable materials**,
- **exempting material and adhering to radiological and environmental limits**,
- **WAC compliance** (WAC documents define the specific requirements for each discrete waste process, the designated codes of which have been described previously in this document).

Materials regulated as radioactive in Italy must pass a clearance procedure before they can be released from regulatory control. As mentioned in the third paragraph at the beginning of subsection 2.1.4, Category 2 materials are also subdivided into the types A to D.

This subdivision serves the levels of release required by regulations for operation or decommissioning, which foresee different values of surface and mass concentration depending on the type described above, and in accordance with the recommendations of the European Commission, reported in the Radiation Protection series publications referred to in **Refs. European Commission Radiation Protection N.89, 113** and **122**. In particular with the **general clearance levels indicated in Legislative Decree 101/2020** [6]:

- The **clearance of metallic materials is subject to joint compliance with the levels of surface concentration** (**Bq/cm²**) and **mass concentration** (**Bq/g**) indicated in the technical specifications for each installation.
- The **clearance of concrete debris** resulting from the demolition of buildings and structures **is subject to joint compliance with the levels of surface concentration** (**Bq/cm²**) and **mass concentration** (**Bq/g**) indicated in the respective technical specifications for each installation.
- The **removal of other materials is subject to compliance with the levels of mass concentration** indicated in the respective technical specifications for each installation.

2.2. WAC, data and quality control requirements involved in carrying out successful clearance activities

To preserve it, all **historical information about materials must be recorded in the Waste Information and Tracking System** (**WITS**). The archival number of the WMP related to the material must be indicated in the ad hoc WITS field.

Where a WMP is not due, the checklist must be attached to the WITS generation process for the potentially clearable material as a document labelled with document type "checklist WAC:EC2" [14].

Annex 2 lists the options to describe materials in the WITS, indicating whether they are metallic, cementitious or of another type.

2.2.1. Monitoring, traceability and documentation

Digital and **physical documentation** is maintained in line with the JRC´s procedures and regulatory requirements, **ensuring full traceability** and **facilitating audits** or **post-project reviews**.

Every item or **batch of material** is uniquely **identified, monitored** and **tracked throughout its management lifecycle**. **Records include**, but are not limited to, **material ID**, **source project** or **component**, **classification result**, **radiological survey outcomes**, **packaging form** and **final destination** (release, disposal, storage, etc.).

The JRC applies a system to track all materials generated during decommissioning process. This ensures full traceability from the point of origin to final disposal, release or reuse. The **identification, monitoring** and **tracking of materials includes records of**:

- **Source**: where and how the material was generated (e.g. specific building, system, or activity).
- **Classification**: whether the material is considered radioactive (VLLW, LLW, etc.) or conventional waste, based on radiological characterisation and regulatory prescriptions.
- **Treatment history**: information on any decontamination or fragmentation processes applied (e.g. mechanical cutting, electrochemical treatment, abrasive blasting etc.).
- **Radiological monitoring**: measurement results from clearance monitoring of workplaces, including surface contamination, dose rate and radionuclide content.

The WITS is used to collate waste data at the JRC-Ispra site. Data concerning new waste must be mandatorily registered in the WITS. Other historical information, typically concerning exotic waste (such as the Roman pits, the bituminised drums and the cement blocks), may be stored in other forms.

Labelling of the waste items, drums and packages **allows all data associated with the waste to be tracked via a unique WITS code**. The unique code relates to a single 'WaMat' object. This information is stored electronically within the WITS system along with any waste characteristic data and records. The WITS has been designed to integrate with the downstream waste disposal requirements that are expected to be applicable.

In addition to the WITS, there is **another database** called **MIRADIS**, **where data relating to in-situ plant items** (pre dismantling) are stored. This **includes information such as location**, **the system to which the item belongs**, **estimates of dimensions**, **dose rate** etc. This historical information is recognised as valuable when characterising packaged and drummed wastes. Therefore, there are plans to ensure that the data stored within MIRADIS can be used in coincidence with WITS.

All data is recorded in the central documentation system in accordance with the JRC’s internal procedures and Italian nuclear legislation. **Measurement data is validated against clearance limits** and **release criteria before any material leaves regulatory control**. **Final documentation accompanies all material transferred** for storage, disposal or environmental release and **is available for inspection by regulatory bodies**.

This comprehensive approach to **documentation** and **traceability ensures safety**, **regulatory compliance** and **accountability** throughout the decommissioning process.

2.2.2. Quality control

ISO Standard 9001 may be used as reference for developing the **Quality Management System** which demonstrates compliance of the material with the current WAC document. **Documents must be produced**, **issued** and **archived according to the procedures** and **instructions within** the **NDWMD ISO 9001 Quality Management System**.

The material is subject to **quality control** (**QC**) checks ensuring the correct application of the production procedure and the correctness of the collected data. The **QC checks are identified**, **described** and **recorded in either the WMP** or **in a waste QC Plan**.

2.3. Application of the WMH and clearance at the JRC´s Ispra site

This section builds on the aforementioned WMH and clearance procedures by providing **an example of how the procedures were applied to the RCHL**. It has already been noted that, at the time of writing, the RCHL is the only installation on the JRC’s Ispra site that has been fully decommissioned.

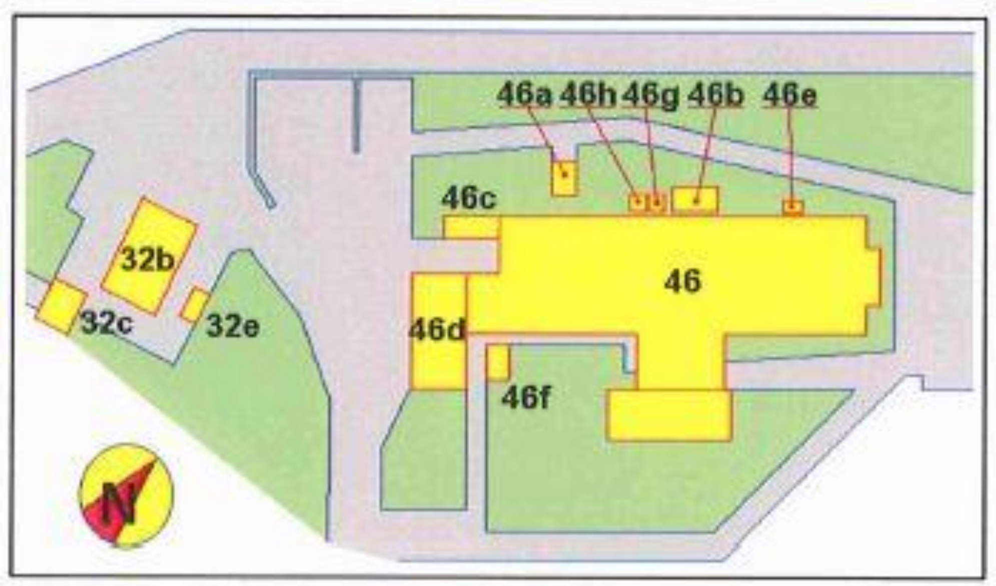

Figure 6. Map of RHCL facility before dismantling

To reiterate, the RCHL, displayed in Figure 6 as a map marked with all the buildings which underwent the decommissioning process, was constructed in the early 1960s. The main building (Building 46) was constructed in 1966. The laboratory activities started prior in 1964. In 1976 an annex to Building 46 was built (Building 46d) and in 1978 a new area of laboratories named Building 32b "Stabularium" was completed. In total the RCHL covered 1861m^2 and consisted of 8 buildings / structures.

In the frame of the NDWM programme, the RCHL decommissioning project’s goal was to be **decommissioned up to what is referred to as "brown field" status**, i.e. the release of buildings without any radiological constraints (**IAEA Stage 3**), **including delicensing**.

The following activities were required **during the RCHL’s decommissioning**:

- to perform the **physical** and **radiological characterisation** of the whole RCHL,
- to perform the **dismantling activities**,
- to plan and perform **suitable remediation activities**,
- to plan and perform the **final survey** and issue the **final decommissioning documentation** with the **Qualified Expert** (**QE**) **assessment certifying the absence of radiological constraints**.

The **final cost** of the operation was **achieved inside the term of the contract** with circa **4 years of working days**. The RCHL was **released without radiological constraints** [13]. A **decontamination activity reduced the amount of waste** estimated in the project plan **by 27%**.

2.4. Alignment with sustainability principles and development goals

Pioneered by the United Nations Brundtland Commission in 1987, **sustainability is defined as meeting the needs of the present without compromising the ability of future generations to meet their own needs** [14]. Nowadays, organisations look to the UN SDGs as a means of mapping their organisational processes against internationally recognised sustainability objectives.

Sustainability is integral to the JRC's clearance programme, ensuring environmental protection, cost efficiency and alignment with EU policy objectives. The JRC's material clearance programme actively supports sustainability by reducing waste volumes, promoting reuse and recycling and minimising environmental impact in line with the WMH. From looking at Figure 7, it can be observed that the JRC's practices directly contribute to the following UN SDGs:

- **Goal 9** (**industry, innovation and infrastructure**): Through the adoption of advanced clearance technologies and digital tracking systems (WITS), the JRC fosters innovation and infrastructure resilience.
- **Goal 12** (**responsible consumption and production**): Clearance enables responsible resource use by diverting materials from disposal to reuse or recycling, reducing raw material demand and landfill burden.
- **Goal 17** (**partnerships for the goals**): The JRC collaborates with EU stakeholders, sharing knowledge products and best practices to strengthen collective sustainability efforts.

Figure 7. United Nations Sustainable Development Goals (UN SDGs) [14]

Quantifiable results of the practices mentioned above, during RCHL decommissioning, include a 27% reduction in waste volumes and clearance of 220 tonnes of material for reuse or recycling. These achievements demonstrate alignment with circular economy principles and contribute to climate and environmental objectives under the European Green Deal.

An important aspect of sustainability is understanding that **reactionary actions** and **haphazardly defined strategies** could result in **rebound effects**. A rebound effect, within the field, can be described as an occurrence following the actioning of an idea that initially appeared well founded but resulted in unintended consequences, problems or undesirable affects [16]. Hence the need for proper planning and deliberative decision-making.

There are three key principles to sustainability in the context of international best practice, namely the three pillars (environmental, social and economic) which need to be considered during the implementation of sustainable practices in order to realise the UN SDGs. Through focusing on each principle, it can be seen how the JRC applies each one.

Environmental Pillar

- **Clearance reduces environmental impact** by diverting materials from RAW streams to reuse or recycling, minimising landfill use and conserving natural resources.
- Supports **circular economy principles** by extending material lifecycles and reducing raw material extraction.
- Incorporates **ALARA principles** and strict radiological controls to protect ecosystems and human health.

Social Pillar

- Promotes **health and safety** for workers and surrounding communities through rigorous compliance with EU and Italian regulations.
- Enhances **transparency and trust** by maintaining traceability (via WITS) and publishing lessons learnt.
- Knowledge sharing through KPs fosters **capacity building** among EU stakeholders, contributing to societal resilience and informed decision-making

Economic Pillar

- **Cost efficiency**: Clearance reduces storage and disposal costs, as demonstrated by the 27% waste reduction in the RCHL case.
- **Resource optimisation**: Reuse and recycling of materials lower procurement costs and support sustainable supply chains.
- Aligns with **European Green Deal** objectives, potentially unlocking funding and partnerships for sustainable innovation in the future.

It is with maintaining a holistic view of **the UN SDGs**, the **three pillars of sustainability** and **potential rebound effects** related to their activities, that the JRC constantly pursues continuous improvement and lessons learnt reviews, ensuring strategies remain adaptive and effective. Together these actions reinforce the JRC's commitment to sustainable development and growth mindset; ultimately ensuring that clearance activities are technically robust, socially responsible and economically viable.

3. KEY TAKEAWAYS

The following main takeaways were recorded based on the RCHL decommissioning project:

- **220 t of clearable material was produced** and deposited in dedicated storage in preparation for eventually being transferred off site.
- **More clearable material was produced than initially planned** (~27%) **due to an efficient decontamination process**.
- **Release criteria are based on a radiological characterisation plan**.
    - According to this plan for the release of the buildings or areas, the RCHL's structures with radiological impact were subdivided into four parts of a homogeneous group (GO). This approach allowed operating, within the same GO, with the same measurement criteria with respect to the same radionuclides.
- **Dismantling operations generate secondary technological waste in limited quantities**. **From the JRC's experience** of dismantling buildings 41, 41c and 41k; **this contribution** was conservatively **assumed to be about 5% of the total weight** of the components to be dismantled and of the material resulting from decommissioning, based on previous operational experiences.

The number of homogenous groups should be chosen based on historical information and pre-characterisation results. Pre-characterisation activity was initially planned for a limited section of the laboratories and subsequently extended to all the RCHL area.

3.1. Negative outcomes avoided

Negative outcomes avoided as a result of a well-defined and properly functioning material clearance programme.

The JRC's effective procedures allowed for them, in the case of the RCHL decommissioning project example, to mitigate against many of the commonly experienced rebound effects and negative outcomes, which ultimately proved to be beneficial in the long run. Examples of such negative outcomes which were avoided are listed below.

Continued and uninterrupted leadership presence

Ensuring a dedicated project leader for the whole, or most of, the duration of a clearance project / activity removes the challenge of handovers of tasks which inevitably result in delays.

Scoping, waste inventories and characterisation

Poor definitions of the scope of works, as well as poorly defined waste inventories and characterisation of work areas, can result in unexpected problematic events.

Overlapping of tasks during project execution

During the execution of a project to sort and characterise old waste it was found that some infrastructure (such as the hard confinement) needed to be developed in tandem to the procedures needed to efficiently tackle the subject matter. This poses a challenge with respect to resource management and threatens schedule slippage in order to manage it.

Sampling

The destructive analysis sampling of potentially clearable material is often unnecessary or should not be aimed at the establishment of scaling factors.

3.2. Negative aspects of past work to inform future work

While not compromising and did not result in any major consequences, some aspects of the works executed as part of the RCHL decommissioning project were obstructed, as described below:

Obstructions

Delays to pre-characterisation activities and final surveys, as well as the required storage areas not always being available when needed, elongated the schedule of the RCHL decommissioning project and consequently will be considered during the planning and execution of future projects.

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ANNEX 1

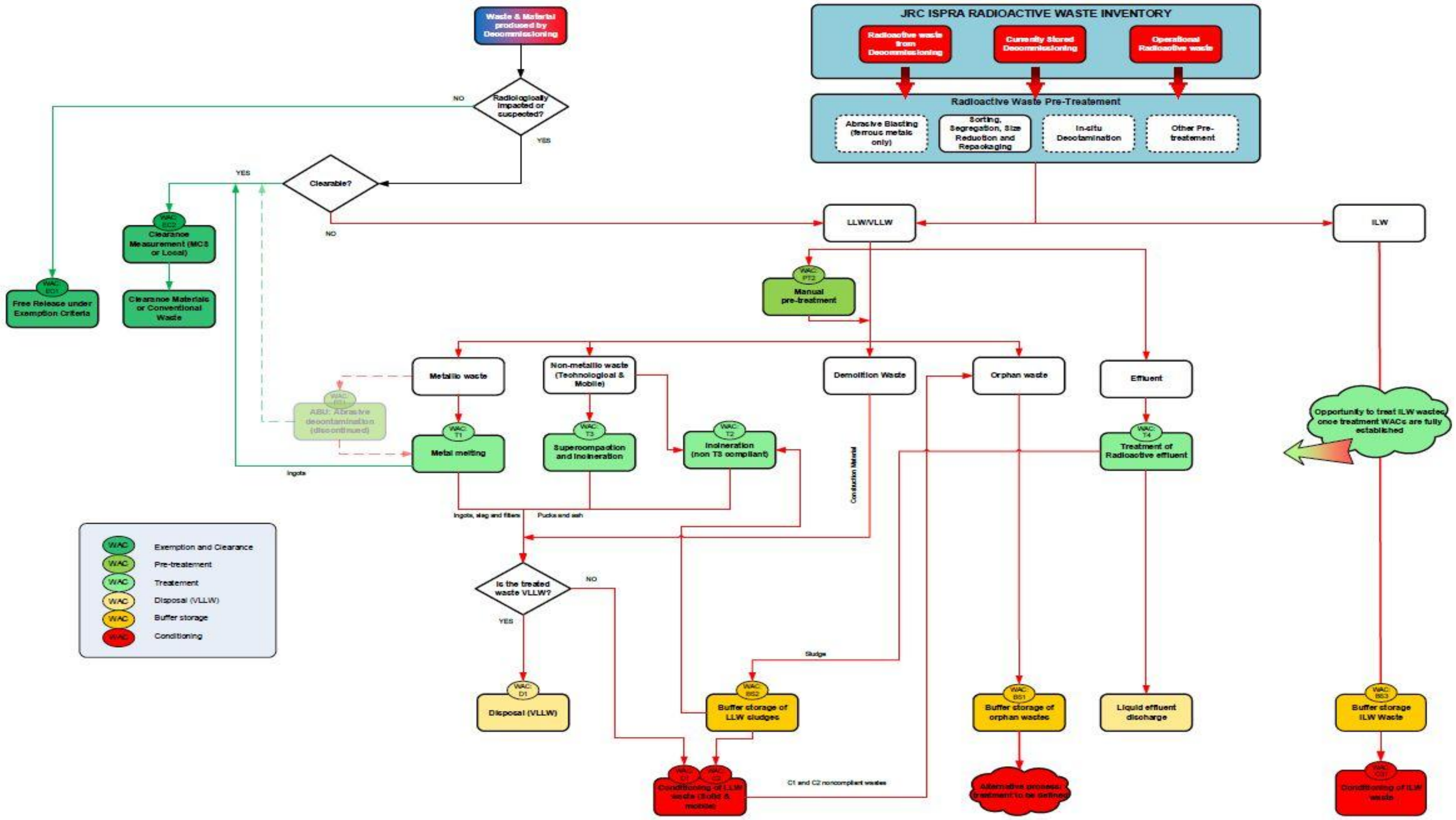

Figure 8. Overview of waste routes and acceptance criteria (WAC) application.

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ANNEX 2

Table 2. WAC EC2: WITS and Clearance materials, EWC (CER) codes

WITS MATERIAL	DESCRIPTION AND ALLOWED TYPES	CER	CLEARANCE MATERIAL
Absorbent Material	Filters and absorbent materials if not accompanied by analysis. Used PPE, rags, clothing, air filters	150202*	Other materials
Absorbent Material	Filters and other absorbent materials with SDS or non-hazardous analysis	150203	Other materials
Mixed electrical material	equipment with CFC, HCFC, HFC	160211*	Other materials
Mixed electrical material	Discarded equipment containing hazardous components such as old monitors and old smoke detectors	160213*	Other materials
Mixed electrical material	Boilers, buttons, keyboards, boards, keys, small electrical panels, mixed electrical and electronic material	180214	Other materials
Cement	Cement	170101	Cementitious
Bricks / brickwork	Clay bricks	170102	Cementitious
Ceramic	Ceramics, tiles, and ceramics	170103	Cementitious
Asphalt / bitumen	Bituminous sheaths, asphalt, bitumen	170302	Other materials
Asphalt / bitumen	Non-hazardous asphalt/bitumen mixture	170301	Other materials
Copper (alloys of)	Copper, bronze, brass	170401	Metallic
Aluminium	Aluminium	170402	Metallic
Lead	Lead	170403	Metallic
Mixed ferrous metals	Iron, steel, cast iron, iron and steel furniture and cabinets	170405	Metallic
Stainless steel	Only stainless steel	170407	Metallic
Electrical material (cables only)	Copper cables, non-tarred cables, not impregnated with oil or hazardous substances	170411	Other materials
Earth (with organic content)	Earth	170504	Other materials

WITS MATERIAL	DESCRIPTION AND ALLOWED TYPES	CER	CLEARANCE MATERIAL
Asbestos in matrix / Insulating materials containing asbestos	Construction materials, insulating materials, insulating putty, etc. containing asbestos	170601*	Other materials
Rock wool / Glass wool	Insulating materials containing hazardous substances, rock wool	170603*	Other materials
Technologically inert material	Non-hazardous insulating materials, plasterboard panels, water pipe insulation	170604	Other materials
Gypsum	Gypsum	170802	Cementitious
STONE	Waste stone from demolition activity (windowsills, thresholds, copings, etc., not rocky)	170203	Cementitious
Demolition materials / Mixed inert materials	Mixed inert demolition waste from non-hazardous substances	170903*	Cementitious
Demolition materials / Mixed inert materials	Mixed material from demolition, non-hazardous (glass, brick, brickwork, plaster, tiles, cement, etc.)	170904	Cementitious
Paper and cardboard	Packaging paper and cardboard	200101	Other materials
Wood	Wood (furniture, desktops, workbenches, laboratory furniture)	200138	Other materials
Mixed technological materials	Bulky items (plastic, glass, iron, non-secondary waste)	200307	Other materials