2.2.5 Transport, Domain Insight

2.2.5 Transport radioactive wastes between facilities in accordance with regulatory requirements (Transport)

Theme 2: Pre-disposal

Sub-theme 2.2: Implementing predisposal management of radioactive waste to support key risk and hazard reduction, and to help reduce costs and save space at interim storage and disposal facilities

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OVERVIEW

Radioactive material transport by land, water or air is a standard procedure worldwide for decades. The practice has well established guidelines to comply with regulations and stakeholder expectations. Distinctions are typically made between domestic and international transport, as well as internal site transport and that which is via public roads. The objective of this overview document is to provide guidance focused on public and international transport issues in the pre-disposal stage of waste management.

About 20 million transport consignments of radioactive material take place annually, though it is estimated that just 5% of radioactive material shipped globally each year relates to nuclear power production. The other 95% is related to transport of radioisotopes for medical and industrial use. In the USA, the US Department of Transportation estimates that the average distance per shipment of radioactive material is about 55 km, which is significantly below the average transport distance of 185 km for all other types of hazardous material. [WNE 2021]

When radioactive materials are transported with respect to nuclear power product and waste management, there are often multiple steps of the transport activities through the fuel cycle process. Transport must consider initial source uranium all the way through waste transport to fuel cycle service and material processing

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facilities, interim storage facilities and finally towards disposal. Shipment is done by specialised authorised companies, sometimes using purpose-built transport vehicles/ships and containers. Dual-purpose containers (casks) may be used which are designed for both storage and transport. Certain radioactive materials like used fuel and high-level radioactive waste can require additional shielding during internal transfers to reduce potential radiation exposure. The level of radioactivity will control the level of safety assessment and regulatory oversight demands, for instance based on the higher hazard level.

The international guidelines and regulations for safe transport of radioactive materials continue to be updated to account for best practices and towards harmonisation where possible. Some variations exist between practices of Member States that hopefully can be overcome in the future to reduce costs and risks while maintaining safety of transport.

KEYWORDS

cask, inspection, package, predisposal, radiation protection, safety, security, transport

KEY ACRONYMS

GBS – goals breakdown structure
DGR – deep geological repository
IAEA – International Atomic Energy Agency
MS – Member State
NPP – Nuclear Power Plant
RW – radioactive waste
RWM – radioactive waste management

1 TYPICAL OVERALL GOALS AND ACTIVITIES IN THE DOMAIN OF TRANSPORT

This section provides the overall goal for this domain, extracted from the EURAD Roadmap goals breakdown structure (GBS). This is supplemented by typical activities, according to phases of implementation, needed to achieve the domain goal. Activities are generic and are common to most regional and geological disposal programmes.

Domain Goal	
2.2.5 Transport radioactive wastes between facilities in accordance with regulatory requirements (Transport)	
Domain Activities	
Phase 1: Planning and Programme Initiation	Establish locations of anticipated and existing wastes, packages, processing and treatment facilities, interim storage facilities, final repository locations. Evaluate transport means and routes, - demonstrate transport regulatory compliance, fulfil stakeholder requirements.
Phase 2: Program Implementation	Land (road, rail), waterway or air transport of waste between facilities, including potential cross-national borders. Including loading and unloading of packages from transport vehicles.
Phases 3–4: Program Operation/Optimisation and Closure	Manage iterative reviews and updates of transport plans and methods, responding to latest RD&D, technology development, international requirements, licenses.

2 INTERNATIONAL LEGISLATION

International regulations on radioactive waste transport aim at protecting people and the environment, both in routine activities and in case of accidents. The transport of radioactive substances also needs to adhere to the international regulations and treaties on the transport of hazardous goods, such as those within the UN Recommendations on the Transport of Dangerous Goods – Model Regulations [United 2019b]. The international regulations addressing radioactive material transport have been established for 50 years, with the most recent version of the IAEA SSR-6 regulations updated in 2018 [IAEA 2018]. The IAEA document is also integrated to national policies and international organisations such as the International Civil Aviation Organization (ICAO), the International Maritime Organization (IMO) and regional transport organisations. These specific regulations apply to roads (ADR) [United 2021], railway (RID) [OTIF 2021], waterways (AND) [United 2019a] and air (ICAO-TI) [United 2018].

It is important to plan the types of certified packages that will be needed for the transport. Each package type has its own requirements for compliance and labelling.

- A-type: designed for normal conditions of transport, including moderate degrees of heat, cold, reduced air pressure, vibration, impact, water spay, drop, penetration and stacking tests (typically low-level and intermediate-level waste, relevant package type for radwaste)
- B-type: designed for accidental conditions of transport, containing shielding against radiation (including higher-level radioactive waste, such as spent fuel casks)

- C-type designed for severe impact (velocity of 90 m/s, similar to a fall from 450 metres), having an overpack (potentially for air transports, special arrangements and UF6).

The European Union Directive “Supervision and Control of Shipment of Radioactive Waste and Spent Fuel” [European 2006] and EU standard document for the supervision and control of shipments of radioactive waste and spent fuel [European 2008] summarise the key points of transport issues, that:

- require operators to notify national authorities about shipments of radioactive materials which depart from, go through, or end up in the EU
- allow EU countries to ship spent fuel to each other for reprocessing and organise the return of the resulting radioactive materials
- allow EU countries to send shipments of radioactive materials that do not comply with the directive back to their country of origin
- prohibit the export of radioactive waste to African, Caribbean or Pacific countries, to Antarctica, or to any country which does not have the resources to safely manage it.

Member states must comply with EC Council Regulation No 428/2009 for the exportation of dual use goods [European 2021].

In addition, it is recognised that each Member State has their own national level regulations which comply with IAEA and international regulations and individual Member States may also have their own protocols for evaluating safe transport and handling of radioactive materials. Transport oversight is the responsibility of the national radiation safety regulator.

3 GENERIC SAFETY ISSUES FOR TRANSPORT

This section describes the safety precautions associated with radioactive material transport issues during each of the three phases noted in the table of Section 1. They are described with respect to a waste management program, addressing pre-disposal activities (prior to final geological disposal). It shall be noted that the transport safety and regulations issues do not change during the three phases yet are reviewed iteratively through each phase and with progressively greater detail.

3.1 Planning and Program Initiation

In the early phases of pre-disposal program initiation, it is essential to assess the waste inventory locations and facilities that are anticipated (e.g. processing, treatment, storage, repository) as the waste is conveyed within and/or between public sites that may have great distances. In this way the transport route alternatives and vehicle alternatives as means of transport are assessed to evaluate the safety, costs and stakeholder requirements. The service provider transport companies are assessed to evaluate their certification and experience. Special applications may be needed if transport takes place in multimodal means including transfer and temporary storage of waste packages. Cross-border transports, for instance to waste processing facilities, require special attention to any potential national-level deviations and requires an export and import control license from governmental and regulatory bodies.

The route alternatives assessment contains, e.g. statistics of traffic and impact accident densities, estimates of stopping times during transportation, and possible incident and accident scenarios to be analysed.

During the planning phase, transport issues closely link to the other EURAD Roadmap Domains of Inventory (2.1.1) and Waste Acceptance Criteria (2.1.2).

3.2 Program Implementation

Getting closer towards actual operation of facilities and handling of radioactive waste streams, it is critical to prepare all materials and packages for transport. This applies to transport plans for both internal site and external (public road) transport. The fissile material and sources must be registered to a national database, indicating the activity below or exceeding the exemption limits. Prior to actual movement of radioactive materials by land (road or rail), waterways or air, it is necessary to make a detailed transport plan and ensure all aspects meet the regulatory requirements. These shipping requirements address route selection, vehicle condition and placarding, driver training and licensing, package marking, labelling, and other shipping documentation. Any pauses or interruptions of transport need to be detailed and potentially certified, including sites where packages will be within short-term interim storage.

Plans need to be in-place for loading and unloading of packages from vehicles and to interim storage facilities. Also in preparation for transport, the materials must be properly packaged and documented regarding activity, chemical and physical state. Waste packages typically have a certificate of compliance (CoC) or certificate of approval (CoA) from which it can be evaluated if further testing or maintenance is required. It may be necessary to visually inspect, check or change package seals and other components or perform leak testing to ensure the package is safe for transport. It is required to make radiation (e.g., dose-rate) measurements at specific locations on and around the package and transport vehicle to make sure that the levels are below the required limits. This can include for instance proof that there are no pure alpha or beta emitting radionuclides existing on the surfaces, and in the case of high active waste transport involving actinides also the neutron doses are measured prior to transport.

After all final checks are approved, the transport documentation is certified, including labels to the packages and UN numbering. The labelling of the package depends on the dose rate at the surface and at 1 metre distance from the package. Some limits of dose rate are defined at the surface of the vehicle. There are also limits to the residual contamination at the surface of the package and in the vehicle after transport. An analysis of possible safety risks and scenarios should be documented, including consequence assessments for hypothetical accident cases.

General actions that need to be taken prior to transport include:

- informing regulatory of transport (applying for license and getting approval),
- using regulatory approved routes for the first option and back-up plan,
- arranging local support from law enforcement for armed escort in heavily populated areas,
- arranging reliable communication system,
- making sure that spent fuel is protected against radiological sabotage,
- having procedures and training for addressing emergencies,

- ensuring safeguards of transport info, to guard against acts that could threaten the shipment.

During the implementation phase, transport issues closely link to the other EURAD Roadmap Domain of Storage (2.2.4) which includes further issues on packaging, and the Domain of Safety and Security.

3.3 Program Operation and Closure

During operation of (pre-disposal) waste management facilities there is a continuous process of reviewing transport routes, vehicles and regulations. There are opportunities to take into practice new technologies and practices with regard to handling packages and documentation management. Optimisation of routes for cost and safety can be enhanced.

Regulatory oversight will continue to evaluate transport of radioactive materials, including issues like:

- compliance with transport routes and safety precautions towards public and environment,
- documentation of the physical properties of the radioactive material and transport casks,
- safety and ruggedness of the transport container,
- accurate operating procedures applicable to both the transportation package and the vehicle transporting the package,
- accurate markings and labelling imposed on packages and vehicles during transport,
- verifying the packages are safe for transport:
  - transportation package users have taken the appropriate package measurements to ensure radiation levels are not exceeded,
  - casks have been properly inspected for certain specific criteria, such as leak-tightness,
  - bolts and other equipment are intact.

An example generic transport safety case link can be found from the UK's report [RWM 2016].

During the operation phase, transport issues closely link to the other EURAD Roadmap Domain of Quality & Management Systems (2.3.1) and Optimisation (2.3.2).

4 CRITICAL ISSUES, INFORMATION, DATA OR KNOWLEDGE IN THE DOMAIN OF TRANSPORT

The key radiological critical issues for transport are summarised by transport regulation objectives:

- containment to prevent spread of radioactive material,
- shielding to prevent harmful radiation levels,
- criticality safety for fissile materials,
- heat management to safety dissipate decay heat.

There are also addition issues relevant to dangerous goods. The critical information that is needed for safe transport are starting and ending locations, the material's activity and the package or transport cask integrity. Issues of the transport route, vehicles, loading equipment and certifications must be documented. Local regulations regarding transport must be known and followed.

There are numerous companies that are available for commercial services offering transport of radioactive materials. These are typically sought based on geographical location familiarity with regulations and availability of required vehicles.

The primary responsibility for safe transport is placed on the material owner (consignor or company shipping away the material), since that entity best knows the material being packaged and shipped. The actual transporter or carrier actions are limited to operational controls, such as safe loading and unloading, limiting accumulation of packages, and keeping containers safely separated from persons or other cargo. For example, spent fuel needs to be transported in exclusive use vessels. Persons responsible for organising and then executing the transport must have proper licenses and training, also for handling potential emergency scenarios and be notified to the regulator prior to transport activity.

5 MATURITY OF KNOWLEDGE AND TECHNOLOGY

This section provides an indication of the relative maturity of information, data and knowledge for the domain of transport. It includes the latest developments for the most promising advances, including innovations at lower levels of technology maturity where ongoing RD&D and industrialisation activities continue to improve.

Advances in waste transport issues

New technologies related to transport that are being implemented or could be applicable to the radioactive waste domain include for instance:

- the use of robotics and autonomous vehicles, which can significantly reduce human exposure
- new types of dual-use casks, which are continuously being developed that can be used for both transport and storage,
- new package/basket innovations, for instance having multiple positions,
- new types of materials that provided added safety, such as shock absorbers, dampers, and cask components with greater impact protection,
- integration of sensors to packages and transport vehicles for quality control of waste condition, package integrity and safety assessment evaluation,
- tracking of thermal load monitoring during transport,
- utilisation of digital technologies for transport route planning aid efficiency and reduce hazards based on real-time conditions, including traffic and weather.

Optimisation challenge and innovations

Challenges exist with regarding to efficient (time and cost) transport of radioactive material, especially regarding cross-borders between Member States or countries further afield. Varying legislation between countries and stakeholder concerns may lead to contradictory policies on the transport allowances, for instance based on

national level Waste Acceptance Criteria (WAC) for cask types, transport vehicles or routes. When shipping routes are denied, more complicated and longer routes may be needed, resulting in increased costs and possible compromises to safety and security. The delay of shipments of radioactive material is also very critical for the medical isotope sector, where delays cause concern among patients and their doctors.

Most reports of transport shipment denials relate to non-fissile materials, for instance cobalt-60 or tantalum-niobium concentrates. For uranium concentrates, a main concern is there are very few transport hubs or ports which handle them, as well as relatively few marine carriers which accept them. For all radioactive materials, consignors must provide training/certification to personnel handling the packages which may create a significant cost and extra inconvenience to shippers.

Future developments to enhance transport safety are related to:

- Further harmonising criteria and regulatory issues across Member State on transport practices and transport safety protocols.
- Establishing stronger safeguards of transport security (and related information security) regarding location of radioactive materials, to minimise threats of harmful acquisition of radioactive material.
- Providing sufficient training regarding inspection and licensing for transport security, for regulatory staff and companies responsible for shipping and carrying the radioactive packages.

There are ongoing IAEA activities aimed at easing challenges associated with transport of radioactive materials, as described in [WNE 2021].

6 PAST RD&D PROJECTS ON TRANSPORT

Past IAEA and/or European Commission funded projects that have partially addressed radioactive waste transport have included:

- Safe transport of radioactive materials, IAEA CRP 684 (Coordinated Research Project, CRP), 1979–1988.
- The radiation protection implications of transport accidents involving radioactive materials, IAEA CRP 693, 1986–1990.
- Development of probabilistic safety assessment techniques related to the safe transport of radioactive material, IAEA CRP 718, 1989–1994.
- Studies of Minimising Transport of Spent Fuel, FP2-RADWASTOM 4C, 1991–1993.
- Accident severity at sea during transport of radioactive material, IAEA CRP 1003, 1994–1998.
- Accident severity during air transport of radioactive material, IAEA CRP 909, 1998–2006.

Enhancing security in transport of nuclear and other radioactive material, IAEA CRP, Project J02009, Approved 2016. No recent European Commission/EURATOM projects have been identified that have addressed transport issues. There are also no current work packages of EURAD (2019–2024) or PREDIS (2022–2024) projects that are addressing waste transport issues.

7 UNCERTAINTIES

Domestic and international transport practices are advanced, with minimal uncertainties. Existing implementation guidelines, for instance from the IAEA and Regulatory bodies, provide a good basis for safe transport.

In 60-years, there have been no reported transport accidents with serious radiological consequences, despite the significant growth in volume. [WNN 2021]

8 GUIDANCE, TRAINING AND COMMUNITIES OF PRACTICE

This section provides links to resources, organisations and networks that can help connect people with people, focused on the domain of transport.

Guidance
• IAEA International Atomic Energy Agency (2018), Regulations for the Safe Transport of Radioactive Materials, Specific Safety Requirement, IAEA Safety Standards Series No. SSR-6 (Rev. 1), Vienna. online • IAEA International Atomic Energy Agency (2018), The Management System for the Safe Transport of Radioactive Material, IAEA Safety Standards, Safety Guide No. TS-G-1.4, Vienna. online
Training
• IAEA e-learning course on the Safe Transport of Radioactive Material (2x 12 hours, with certificates) https://elearning.iaea.org/m2/course/index.php?categoryid=83 • Transportation Emergency Preparedness Program: Radioactive Material Shipping Packages, e-learning (12 pages) and quiz. https://training.fema.gov/emiweb/is/is302/ss_mod05_sg.pdf
Active communities of practice and networks
• World Nuclear Transport Institute (WNTI) https://www.wnti.co.uk/ • European Commission Advisory Committee (Working Group of National Experts) on Safe Transport of Radioactive Materials

Key competences that are needed in the area of radioactive waste transport include radiation safety, transport engineering, material science for package integrity, logistics, radiological measurements and monitoring, data handling and preservation, risk management, scenario preparation, communication (stakeholder engagement), programme management.

9 ADDITIONAL REFERENCES AND FUTURE READING

European Union Council Directive 2006/117/Euratom (2006). Supervision and Control of Shipment of Radioactive Waste and Spent Fuel. online

European Union Council Regulation No 428/2009 (2021). Community regime for the control of exports, transfer, brokering and transit of dual-use items. online

European Union Commission Decision 2008/312/Euratom (2008). Standard document for the supervision and control of shipments of radioactive waste and spent fuel. online

International Maritime Organization (2019). IMDG-Code: International Maritime Dangerous Goods Code. online

OTIF – Intergovernmental Organisation for International Carriage by Rail (2021). RID: Regulations concerning the International Carriage of Dangerous Goods by Rail. online

RWM – Radioactive Waste Management (2016). Geological Disposal – Generic Transport Safety Case – Main Report. NDA Report no. DSSC/201/01. online

United Nations (2018). ICAO-TI: Technical Instructions for the Safe Transport of Dangerous Goods by Air (Doc 9284). online

United Nations (2019a). AND: European Agreement concerning the International Carriage of Dangerous Goods by Inland Waterways. online

United Nations (2019b). Recommendations on the Transport of Dangerous Goods – Model Regulations, 21st revised edition. online

United Nations (2021). ADR: European Agreement concerning the International Carriage of Dangerous Goods by Road. online

U.S. Nuclear Regulatory Commission (2020). Materials Transportation. online

U.S. Environmental Protection Agency, Transportation of Radioactive Material. online

World Nuclear Association (2021). Transport of Radioactive Materials. online

WNN – World Nuclear News. (2021). IAEA Aims for Easier Transport of Radioactive Materials, 26.7.2021. online