

# **International Conference on the Safe and Secure Transport of Nuclear and Radioactive Material**

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## **Book of Abstracts**



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## **Safe Transport of Nuclear and Radioactive Materials: Innovations, Technologies, and Regulatory Compliance**

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## **Practices and Challenges in the International Transport of Radioactive Material: Addressing Post-Storage Shipments, Transitional Arrangements, and Special Approvals**

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The international transport of radioactive material plays a critical role in supporting peaceful applications of nuclear technology in energy, medicine, industry, and research. Ensuring the safe and secure movement of such material, especially after periods of storage or during transitional arrangements, presents specific operational challenges. Despite the existence of comprehensive international frameworks such as the IAEA's Regulations for the Safe Transport of Radioactive Material (SSR-6) and harmonized practices embedded within national regulatory frameworks, persistent gaps and challenges in practice continue to require attention, particularly for cross-border shipments involving multiple stakeholders. The paper explores the operational practices and challenges associated with the transport of radioactive materials under three specific conditions: (1) shipments conducted after periods of storage or transit, (2) transitional arrangements between modes of transport (e.g., road to sea or air), and (3) the use of special arrangements in cases where deviations from standard regulatory conditions are necessary.

Post-storage shipments introduce unique challenges related to package integrity, regulatory compliance, and safety verification. Extended storage durations may lead to deterioration of packaging materials, requiring re-assessment, re-certification, or repackaging before transport. These issues can result in additional time, cost, and coordination burdens for consignors, operators, and regulatory authorities. Furthermore, evolving transport regulations may necessitate new compliance measures even for material that was previously certified. International shipments involving transitional arrangements bring about logistical complexities, particularly regarding the synchronization of regulations between countries and modes of transport. Points of entry and exit, transshipment ports, and customs clearances often face bureaucratic delays, primarily due to differences in national implementation of international regulations. Variability in the application of security measures can further complicate coordination, especially for high-activity sources or nuclear material. In some instances, special arrangements become necessary for shipments that cannot fully comply with established regulatory requirements, often due to unique material properties, specialized package designs, or operational constraints. While these arrangements ensure safety through alternative measures, the approval process tends to be lengthy and resource-intensive. It requires demonstrating an equivalent level of safety, which can be challenging for smaller consignors or those in developing countries.

Through examination of case studies and practical experience from national and international stakeholders, this paper identifies key bottlenecks and proposes actionable strategies for improvement. Among these are recommendations to enhance early coordination between consignors, regulators, and carriers; to promote greater harmonization of approval processes for special arrangements; and to leverage digital solutions for real-time tracking and document management. Ensuring the continuity of safe and secure international shipments of radioactive material will depend on strengthening collaboration among all parties involved, addressing regulatory discrepancies, and embracing technological innovation to streamline administrative processes. These efforts will support not only the operational effectiveness of radioactive material transport but also the broader goal of sustaining global applications of nuclear technology in a safe, secure, and efficient manner.

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## **Strengthening Capacity for Safe and Secure Transport of Radioactive Material: Strategies for Human Resource Development and Inclusion of Young Professionals and Women in Nuclear**

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The safe and secure transport of nuclear and other radioactive material is a critical component of the global nuclear sector, supporting applications in energy, medicine, agriculture, and industry. While robust legal and regulatory frameworks have been established, the sustainability and effectiveness of these frameworks depend largely on the availability of competent human resources. In this regard, capacity building—particularly in developing human resources—is a vital enabler for the successful implementation of transport safety and security measures. The paper explores integrated strategies for capacity building with a focus on human resource development, the involvement of young professionals, and the meaningful inclusion of women in the nuclear sector. It highlights global trends, challenges, and opportunities in developing a skilled and diverse workforce capable of supporting the transport of radioactive materials safely and securely. Through an analysis of case studies from national programs, international initiatives, and IAEA-supported efforts, this paper identifies key success factors in building capacity, such as structured education and training programs, mentorship schemes, regional cooperation, and policy frameworks that foster diversity and inclusion. Special emphasis is placed on addressing gender imbalance and supporting young professionals, who represent the future custodians of transport safety and security. The paper offers practical recommendations for Member States, competent authorities, educational institutions, and industry stakeholders to collaborate in designing sustainable and inclusive capacity building programs. By strengthening human resources and ensuring equal opportunities for all, the global nuclear transport community will be better positioned to address emerging challenges and ensure the continued safe and secure transport of nuclear and radioactive materials.

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## **Harnessing Artificial Intelligence for Enhancing Regulatory Oversight in the Safe and Secure Transport of Nuclear and Radioactive**

## Material

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The safe and secure transport of nuclear and other radioactive material is fundamental to supporting peaceful applications in medicine, industry, and energy. Competent authorities face increasing challenges in maintaining effective regulatory oversight due to the growing complexity of supply chains, evolving security threats, and the introduction of advanced technologies in transport systems. Artificial Intelligence (AI) presents a transformative opportunity to strengthen regulatory processes, enhance risk assessment, and optimize decision-making in the transport of nuclear and radioactive material. It explores the potential applications of AI in regulatory activities for transport safety and security. Specific use cases include automated compliance verification, predictive analytics for identifying high-risk shipments, real-time anomaly detection in transport monitoring systems, and AI-enabled inspection technologies. The paper highlights how AI can assist regulators in streamlining inspections, improving operational efficiency, and enhancing the detection of security threats while maintaining compliance with international safety standards. It examines the key challenges associated with integrating AI into regulatory practices, such as data quality, cybersecurity risks, interpretability of AI-driven decisions, and the need for capacity building among regulatory authorities. Drawing on global best practices and relevant case studies, the paper provides recommendations for fostering international cooperation, developing regulatory guidance, and promoting responsible AI adoption in line with the objectives of the IAEA and its Member States. By addressing both opportunities and challenges, it will contribute to the ongoing dialogue on leveraging emerging technologies to ensure the continued safe, secure, and sustainable transport of nuclear and radioactive material in an increasingly digitalized world.

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## **Bridging the Safety-Security Interface: Strengthening Safety and Security Culture in the Transport of Nuclear and Radioactive Material**

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The transport of nuclear and other radioactive material is an essential component of global efforts to support peaceful applications of nuclear technology in fields such as energy, medicine, and industry. While international frameworks established by the IAEA and other organizations have successfully developed distinct standards for transport safety and security, real-world implementation reveals the critical need for a coherent and integrated approach at the operational level. The paper explores the concept of the safety-security interface in the context of radioactive material transport and highlights the pivotal role of safety and security culture in bridging potential gaps between these two domains. The interface between safety and security is often characterized by overlapping but occasionally conflicting objectives. Safety focuses on minimizing the risk of accidental exposure or release of radioactive material, while security emphasizes preventing unauthorized access, theft, or sabotage. In transport operations, conflicting requirements—such as accessibility for emergency responders (safety) versus limiting information dissemination about shipment details (security)—can create operational challenges. Without careful coordination, fragmented approaches may compromise either safety or security, or both. The paper argues that strong organizational culture is the

critical enabler for harmonizing safety and security practices in transport operations. Safety culture, as described in IAEA publications, emphasizes continuous learning, transparent communication, and shared responsibility for preventing accidents. Security culture, by contrast, highlights threat awareness, vigilance, and the protection of sensitive information. Achieving a balanced interface requires cultivating a shared mindset across organizations, supported by leadership commitment, integrated procedures, and joint training programs.

Through analysis of case examples and current practices, the paper identifies key strategies for strengthening the safety-security interface. These include, Conducting joint safety-security risk assessments at both the design and operational stages of transport, Incorporating safety-security interface modules in regulatory frameworks, industry training programs, and emergency planning, Promoting cooperation between competent authorities, industry operators, and law enforcement agencies to build trust and streamline communication, Embedding cultural attributes such as questioning attitudes, personal accountability, and a commitment to both safety and security into all levels of transport organizations. The paper highlights the challenges that some Member States face in harmonizing national frameworks for safe and secure transport, particularly in contexts with limited regulatory capacity or competing priorities. In addressing these challenges, the role of capacity building—including targeted training for regulators, operators, and front-line personnel—is emphasized. Enhancing the safety-security interface through an integrated cultural approach is not only desirable but necessary to ensure the robust, resilient, and sustainable transport of nuclear and radioactive material worldwide. This paper calls for increased international cooperation, the development of practical guidance for implementing integrated culture programs, and continuous assessment of cultural effectiveness to adapt to evolving risks and operational realities. By focusing on the human and organizational factors that underlie successful safety and security performance, this paper contributes to ongoing global efforts to strengthen transport frameworks, promote sustainable nuclear technology use, and build a common foundation for future challenges in the transport of nuclear and radioactive material.

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## **Establishment, Evolution, and Competency Development of Competent Authorities and Compliance Assurance Mechanisms: The Experience of the Ethiopian Radiation Protection Authority**

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## **Safe and Secure Nuclear Material Transport: Global Perspectives and Best Practices**

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## **”IT enabled door-delivery based, Pan India logistics of Radiopharmaceuticals and other radioactive consignments through outsourced carrier –A paradigm change in Indian Context”**

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Board of Radiation and Isotope Technology (BRIT) - A unit of Department of Atomic Energy, Government of India was constituted in the year 1989 and mandated to serve the nation through Radiation and Isotope Technology. Since then, it has been serving the nuclear medicine and industrial sector in the country with host of radiopharmaceutical products and industrial radiography exposure devices, which are manufactured in its production centre in Mumbai and subsequently distributed across the nation. Until July 2021, clients of BRIT, had the sole option of making their own arrangements for the collection of these radioactive consignments from the nearest airports at their location or by arranging surface transportation between BRIT and their location on their own. BRIT used to make the arrangements for the Air Cargo bookings at Mumbai. Amidst changing business environment, BRIT embarked upon the novel initiative for IT enabled safe, secure and timely Pan India door delivery of radiopharmaceuticals and radiography cameras, by selecting and authorising a competent outsourced carrier for this demanding task. Emerging as a gamechanger, this IT enabled unique logistics service has been well acclaimed by the stakeholders of BRIT and has been providing client centric timely logistics services with full compliance to extant statutory and regulatory provisions in the country for the safe and secure transportation of the radioactive consignments in public domain. Until April 2025, BRIT has provided nationwide door delivery of over several thousand consignments of radiopharmaceuticals and radiography cameras with no single deviation from the normal conditions of operation from safety and security standpoint with scrupulous Person-Sv budgeting. Capitalising on the myriad capabilities of IT enabled features of the logistics services, entire supply chain has now been ensuring real time tracking of the radioactive consignments from the instance of order placement until ultimate delivery thus enabling optimum resource utilisation and prudent business planning. The selection of a suitable logistics service provider using Quality and Cost based selection had myriad challenges considering safety and security of radioactive consignments while Pan India transportation in public domain. Scrupulously laid penal provisions have been incorporated for any safety and security centric deviations by the carrier. Quantitative evolution of the performance of the carrier periodically has been devised for the entire contract period stipulating minimum quantitative performance criteria. Special emphasis has been accorded to periodic safety training requirements. As of now the extant regulation in the country recognises only the Consignor and the Consignee of the radioactive consignments. The operational experience of BRIT gained through this paradigm change is expected to pave the way for formal recognition of the outsourced carrier for transportation of radioactive consignments in the country. Recognition of the carrier as an independent agency under the regulatory framework shall bolster the eco system for safe and secure Transportaion of radioactive consignments as carrier would be directly accountable to the regulatory authority. In future BRIT would also endeavour to bring the footprints of Emerging Technologies into this web-based services for overall improvement. In future efforts would also

be made to reflect upon the carbon foots prints of the logistics service modalities (Surface/Air) into the final cost of the radioactive consignments keeping the safety and security paramount. This paper attempts to provide a wholistic insight into this paradigm change entailing the challenges faced right from the selection of an authorised logistics service provider for this safety and security centric time sensitive task, its pros and cons, operational experience gained and its overall impact on performance of BRIT.

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## **SAFETY AND SECURITY INTERFACE CHALLENGES IN THE TRANSPORT OF CATEGORY I Co-60 SOURCE IN ALBANIA.**

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The Republic of Albania, a non-nuclear state situated in the Balkan region, utilizes radiation sources across various sectors, including medicine, industry, agriculture, research, and education. The Institute of Applied Nuclear Physics (IANP) is the country's primary user of radioactive sources. It operates under license issued by the Radiation Protection Commission. This license covers activities such as the use, transport, storage, import-export, and treatment of DSRS and radioactive waste.

High-activity sources are also used at the Radiotherapy Department of the University Hospital "Mother Teresa," where Category I Co-60 sources have been in operation. In July 2023, the teletherapy device head containing a Category I Co-60 source was dismantled with the support of two International Atomic Energy Agency (IAEA) experts from South Africa. Following the dismantling, the device head was safely and securely transported from the Radiotherapy Department to the IANP's Radioactive Waste Treatment and Storage Facility.

To obtain the necessary transport permit from the Albanian Radiation Protection Commission, both an Emergency Response Plan and a Physical Security Plan were developed. These plans were designed to ensure the protection of radioactive materials against theft, sabotage, or other malicious acts during transport, aiming to prevent any potential radiological consequences.

The Physical Security Plan specifically addressed the secure transportation of the dismantled Co-60 source. The operation was conducted in coordination with law enforcement authorities. Measures were taken in accordance with Decision No. 877, dated 30.10.2015, concerning the physical security of radioactive materials in Albania.

Radiation dose measurements of the teletherapy device head were conducted at the surface and at one meter distance to confirm safety levels. Results indicated radiation levels well within the permissible limits for transportation. The transfer was successfully completed during the night to minimize traffic disruption, with the device head safely and securely delivered to the designated treatment and storage facility.

The overarching goal of the Physical Security Plan for Transport was to support international efforts to enhance the security of radioactive materials, fulfill Albania's national and international commitments, mitigate associated risks, and ensure an effective response to potential threats. This initiative contributes to preventing the misuse of radioactive materials in acts of terrorism, crime, or sabotage, while also ensuring regulatory compliance.

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## **Innovative technologies that impact the Safe and Secure Transport of Nuclear and Radioactive Material**

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The safe and secure transport of nuclear and radioactive materials is a critical aspect of national security, public health, and environmental protection. Emerging technologies—such as the Internet of Things (IoT) and automation—are increasingly shaping the way these materials are handled during transport. These innovations enable real-time monitoring, enhance traceability, reduce human error, and increase protection against both physical and cyber threats. This paper explores the applications of these technologies in minimizing risks associated with the transport of radioactive materials. It also discusses the operational, ethical, and regulatory challenges they present while offering practical recommendations for policymakers, engineers, and industry stakeholders aiming to build secure, efficient, and future-ready transportation systems.

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## **Strengthening the Safety and Security Architecture for the Transport of Radioactive Material in Kenya: Policy Gaps, Operational Challenges, and Strategic Recommendations**

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The safe and secure transport of radioactive material is a critical component of nuclear safety and security infrastructure, particularly in countries experiencing increased medical, industrial, and research applications of radioactive sources. This study investigates the current policy and regulatory framework governing the transport of nuclear and radioactive material in Kenya, evaluates operational practices, and identifies gaps that undermine compliance with international safety and security standards.

The research adopts a qualitative case study approach, incorporating document analysis, expert interviews, and field observations across major transport corridors and institutions mandated with regulatory oversight, law enforcement, emergency response, and material consignments. The study is anchored in the framework of the IAEA Regulations for the Safe Transport of Radioactive Material (SSR-6 Rev.1) and the Convention on the Physical Protection of Nuclear Material and its Amendment. Preliminary findings reveal fragmented institutional coordination, limited awareness and training among frontline responders, logistical inadequacies in secure transport means, and the absence of a national strategy for emergency response during transport incidents. Moreover, while Kenya has made strides in ratifying relevant international instruments, the domestication and enforcement of these instruments remain inconsistent.

The paper proposes a strategic model for strengthening national transport security and safety, including: integrated inter-agency coordination mechanisms; capacity building for transport operators and response agencies; development of a national transport security plan; and enhanced regulatory oversight through digital tracking and risk-based inspections.

The research aims to contribute to the global discourse on best practices in radioactive material transport, offer context-specific insights from the Global South, and provide actionable policy and operational recommendations to enhance Kenya's alignment with international obligations and safeguard public and environmental health.

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## **Enhancing Operational and Administrative Controls for Safe and Secure Multimodal Transport of Radioactive Material: Integrating Emergency Planning and Security Measures**

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The safe and secure transport of nuclear and other radioactive material is a critical element in sustaining the peaceful uses of nuclear technology in medicine, industry, agriculture, and energy. As global reliance on radioactive material grows, ensuring the robustness of operational controls and administrative frameworks for transport becomes increasingly important. These controls must address safety, security, and emergency preparedness across all modes of transport—road, rail, air, sea, and inland waterways.

This paper explores best practices and challenges in implementing operational and administrative controls for the transport of radioactive material, emphasizing the integration of emergency planning and security measures. The operational controls discussed include pre-shipment inspections, secure packaging verification, in-transit communication systems, and tracking mechanisms to ensure continuous oversight. Administrative controls focus on licensing, documentation, chain of custody arrangements, and the involvement of competent authorities to maintain regulatory compliance.

A critical focus of this paper is the alignment of emergency response plans with transport operations, including the coordination between consignors, carriers, consignees, regulatory bodies, and national emergency services. It highlights the importance of preparedness exercises, communication protocols, and the integration of emergency response with national and local frameworks. Additionally, the paper examines the development and implementation of transport security plans, based on threat and risk assessments, to mitigate risks from potential malicious acts during shipment.

Drawing on international guidance such as IAEA SSR-6 and relevant Nuclear Security Series publications, the paper identifies key areas where international cooperation, capacity building, and stakeholder engagement can strengthen transport safety and security. It also explores technological innovations, such as digital tracking and automated alert systems, as enablers for improving operational efficiency and security assurance.

By presenting real-world practices, challenges, and potential solutions, this paper aims to contribute to ongoing efforts to harmonize global approaches to the safe and secure transport of radioactive material. It underscores the necessity of fostering a robust interface between safety and security in transport operations, especially in the face of evolving technological and logistical environments.

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## **Strengthening National, Regional and International Cooperation for Safe and Secure Transport of Radioactive Material in Rwanda**

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### **I. Background**

Rwanda has developed a robust legal and regulatory framework to ensure the safe and secure transport of nuclear and radioactive materials, including Regulation No005/R/RS-NRP/RURA/2021 on transport and Law No. 59/2017 on radiation protection. Although the number of shipments remains low, they are expected to rise significantly with Rwanda's forthcoming nuclear power program. Early planning and cooperation are critical to ensure future readiness.

### **II. National Capacity and Coordination**

RURA is empowered to inspect and license all transport activities involving radioactive materials within Rwanda and at its borders. National coordination mechanisms are operational and involve Rwanda National Police, Customs, and Border Control Agencies. Rwanda also maintains an Emergency Preparedness and Response (EPR) framework (Regulation No006/R/RS-NRP/RURA/2021) to ensure timely and effective response to incidents. However, the number of qualified transport companies remains limited.

### **III. Regional and International Cooperation**

Rwanda works with neighboring countries and regional forums (e.g., AFRA) to harmonize safety and emergency procedures. It actively contributes to international nuclear security by submitting reports to the IAEA's Incident and Trafficking Database (ITDB) and collaborating with IAEA peer networks. No unauthorized transport has been recorded to date, showing the effectiveness of Rwanda's regulatory oversight and border vigilance.

### **IV. International Legal Instruments Ratified**

Rwanda has demonstrated strong commitment by ratifying key instruments relevant to nuclear transport:

1. Convention on the Physical Protection of Nuclear Material (CPPNM) –1 October 2001 Amendment to the CPPNM –16 July 2021
2. Treaty on the Non-Proliferation of Nuclear Weapons (NPT) –7 May 2010  
IAEA Statute –15 December 2011

These instruments guide Rwanda's licensing, physical protection, transit control, and emergency response frameworks.

### **V. Conclusion and Outlook**

Rwanda's experience illustrates the importance of comprehensive national regulations, institutional coordination, and international cooperation. Anticipating growth in radioactive material transport, Rwanda recommends strengthened regional training programs, wider licensing of transport operators, and continued use of international reporting platforms like ITDB to enhance transparency and security in nuclear material transport.

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## **Sudan's Integrated Approach to Radioactive Source Transport: Authorization, Coordination, and Sustainability**

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#### Abstract

The transport of radioactive sources poses significant safety and security risks that require a comprehensive, well-coordinated, and sustainable national framework. Sudan has made measurable progress in strengthening its capabilities in this area, guided by its Nuclear and Radiological Regulatory Act (2017) and aligned with international standards, particularly those of the International Atomic Energy Agency (IAEA).

The Sudanese Nuclear and Radiological Regulatory Authority (SNRRA) plays a central role in overseeing the safe and secure transport of radioactive materials. The authorization process involves a detailed safety and security assessment, including risk-informed categorization of sources, route planning, physical protection measures, emergency preparedness, and real-time tracking. All transport activities require prior approval and coordination with multiple agencies.

A core feature of Sudan's approach is robust interagency coordination, involving key national stakeholders such as the General Intelligence Service, Military Intelligence, Customs Authority, Civil Defense, National Police, and the Nuclear Security Support Centre (NSSC). This collaboration ensures real-time communication, incident response readiness, and efficient operational support during each transport operation.

To ensure the sustainability of this framework, Sudan has institutionalized several mechanisms: periodic review of laws and regulations, continuous capacity building for personnel, establishment of secure communication and tracking systems, and strategic investment in technology and emergency response infrastructure. Furthermore, national exercises, stakeholder engagement, and routine performance evaluations help to improve coordination and resilience over time.

Despite challenges such as limited resources and regional security conditions, Sudan's experience demonstrates a clear commitment to

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## Information and monitoring system to ensure physical protection of nuclear, other radioactive materials and radiation sources in transport and at facilities

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Nuclear and radioactive materials in Ukraine remain most "vulnerable" to unauthorized access during transportation. In this regard, it is proposed to consider strengthening physical protection for the transportation stage, as an integral part of measures to improve physical protection and ensure control over the functioning of the physical protection system at facilities.

In Ukraine, the safety of handling and security of RM is regulated by two main laws "On the Use of Nuclear Energy and Radiation Safety" and "On the Physical Protection of Nuclear Installations, Nuclear Materials, Radioactive Waste, and Other Sources of Ionizing Radiation", which define the requirements for the transportation of RM.

The safety of RM in transport must be ensured by the quality of packaging, the reliability of transport and lifting equipment, special transportation conditions and the relevant level of physical protection at all stages, both under normal and emergency transportation conditions.

The need to significantly improve safety and physical protection of RM in transport is related to the following factors:

☒ strengthened requirements of physical protection, adoption at the state level of DBT and implementation of the requirements of the CMU Decree "On the order of functioning of the State Physical Protection System";

- ☒ modern challenges (including direct russian aggression, threats of sabotage, theft, illegal trafficking, disturbance of public peace);
- ☒ public expectations regarding the improvement of RM in transport safety, emergency preparedness and protection;
- ☒ the need to carry out RM transportation in the shortest possible time, both for safety purposes and when transporting RS to medical institutions.

Composition of the complex of engineering and technical means (CETM) of physical protection systems

CETM is built on the basis of:

- automated information and control complex of technical means consisting of:
  - technical means of communication, surveillance and transportation;
  - central alarm station (CAS);
  - software;
- engineering means, consisting of:
  - engineering equipment;
  - means of access restriction and “violation interruption”.

In view at the stated above, during RM in transport, as an object of physical protection, it is necessary to create conditions that allow:

- maximally reduce the risks of abnormal situations (delay at customs, communication with traffic police, traffic jams, accidents, natural and man-made emergencies, social unrest);
- ensure reliable protection from unauthorized access and theft;
- effectively react in case of abnormal situations or attempts to commit illegal actions against the object;
- ensure reliable and secure communication with law enforcement agencies, local authorities, other departmental agencies;
- ensure online information communication on condition, location and each movement of the RM in transport.

Structure of the information and monitoring system of the PPS of RM in transport

The system consists of:

- automated information and control complex located in the SNRIU to monitor the PPS of RM at enterprises, organizations and transport;
- technical means of transport, communication and software;
- engineering - technical means: access restriction equipment at enterprises and organizations;
- secure communication equipment.

The system is completed with special trucks equipped with complexes of means: physical protection and data transmission to the monitoring center, information on location, radiation and fire safety, and, if necessary, escort vehicles equipped with mobile means of special secure communication.

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## **NUCLEAR SECURITY MEASURES FOR TRANSPORTATION OF INTERMEDIATE LEVEL WASTE –CASE STUDY OF GHANA RESEARCH REACTOR 1**

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Ghana research reactor-1 (GHARR-1) has been operational since early 1995. It was mainly used for research and educational purposes. It was fueled with approximately 90.2% enriched HEU. There was the need to convert the fuel from HEU to LEU which aligned with global non-proliferation initiatives and involved the removal and transportation of the HEU core to China in 2017. The safe and secure transport of nuclear material is a critical aspect of nuclear safety and national security. This

paper describes the security measures employed during the transportation of the HEU from Ghana to China. The transportation of the HEU focuses on adherence to IAEA recommendations for the Secure Transport of Nuclear Material and the requirements for the Convention on the Physical Protection of Nuclear Material (CPPNM). Nationally, the shipper complies with Ghana's Nuclear Regulatory Authority transport security requirements and licensing conditions for the transportation of the HEU. Transporting nuclear material involves significant risks, including theft and sabotage. To mitigate these, a comprehensive set of security measures was implemented. Key security measures which were adhered to include route planning and risk assessment, physical protection, personnel security (armed escort), real-time tracking and Communication, emergency preparedness and response, and personnel vetting. This paper also discusses the challenges faced in resource allocation, inter-agency coordination, and public awareness. The paper concludes by highlighting the importance of continuous training, international cooperation, and technological upgrades to enhance the robustness of nuclear material transport security in Ghana.

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## **”Safety and Security in the Transport of Radioactive Materials and NORM”**

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The safe and secure transport of radioactive materials, including Naturally Occurring Radioactive Materials (NORM), is a critical component of nuclear and radiation safety. These operations involve complex logistics spanning initial shipment, post-storage movement, transitional handling, and special arrangements. Robust safety and security practices are essential to protect human health, property, and the environment. Best practices follow international standards, particularly those set by the IAEA, and include certified packaging, proper labeling, accurate documentation, and qualified personnel. Operational controls such as vehicle inspections, routing, driver training, and shipment tracking are reinforced by administrative oversight through permits, inspections, and detailed record-keeping. Key challenges arise from differences in regulatory frameworks across borders, which can result in delays, compliance issues, and logistical complications. Additional risks occur during the transport of materials after prolonged storage, where packaging degradation or changes in material integrity must be addressed. Special arrangements such as those for high-activity or oversized materials require enhanced security, route planning, and multi-agency coordination. Transport of NORM, often generated from mining, oil and gas, or water treatment industries, presents unique issues. Though typically lower in radioactivity, the large volumes and lower regulatory scrutiny increase the potential for misclassification and long-term exposure risks. Effective categorization, labeling, and hazard communication are essential to mitigate these concerns. Security planning is especially vital, involving measures such as GPS tracking, escorts, restricted access, and contingency protocols for theft or sabotage. Emergency preparedness including scenario-based training and coordination with first responders is equally important across all modes of transport: road, rail, air, and sea. Public perception also plays a critical role. Even with minimal risk, the presence of radioactive materials can provoke public concern. Transparent communication and public education are necessary to foster understanding and build confidence in safety procedures. In conclusion, the transport of radioactive materials and NORM requires coordinated regulatory compliance, technical expertise, and proactive risk management. Continued harmonization of international standards, investment in personnel training, and adoption of advanced tracking and security technologies are essential for maintaining safe and secure transport operations.

**Country or International Organization:**

**Instructions:**

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## **SAFE AND SECURE TRANSPORT OF NUCLEAR AND OTHER RADIOACTIVE MATERIAL IN UGANDA**

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The Atomic Energy Council is a body corporate established by the Atomic Energy Act Cap. 154, with a mandate to regulate peaceful applications of ionizing radiation in Uganda.

In Uganda, radioactive material are used in medical applications for diagnosis and treatment of cancer, in industry for level gauging particularly in the bottling companies, for nuclear gauging operations during road construction of compaction of the mixture of tarmac, for non-destructive testing of welded joints in fabrications and, during oil well logging prospecting, in agriculture for pest and disease control as well as breeding high yielding crops, and in education institutions for research purposes.

In order to realize the benefits of the above applications, safety and security measures need to be undertaken during transport of radioactive material for all modes of transport. Currently, Part XII of the Atomic Energy Regulations, 2012 provides national framework for the transportation of radioactive material.

Uganda through Atomic Energy Council developed standalone regulations on safe and secure transport of nuclear and other radioactive material that are at the stage of legislative drafting by the First Parliamentary Counsel under the Ministry of Justice and Constitutional Affairs. To further strengthen the legal and regulatory framework, the Atomic Energy Act, Cap. 154 is undergoing amendment to make it more comprehensive and inclusive of all aspects of transportation of nuclear and other radioactive material.

These transport regulations have to undergo all the required stages before they are gazetted, and then popularized by operators. These regulations are in line with SSR-6 and NSS-9, hence bridging the compliance gaps with the operators due to inadequate safety measures and lack of security measures.

Whereas developing national framework for the legal and regulatory framework for transport, a number of challenges have been encountered such as; gaps in the law, inadequate sensitization of operators, inadequate expertise in the area of transport among others.

**Country or International Organization:**

**Instructions:**

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## **CHALLENGES AND BEST PRACTICES IN THE SAFE AND SECURE TRANSPORT OF NUCLEAR AND RADIOACTIVE MATERIALS: A TANZANIAN PERSPECTIVE FROM OCEAN ROAD CANCER INSTITUTE**

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### Background

The safe and secure transport of nuclear and radioactive materials is crucial in the practice of Nuclear Medicine, particularly in developing countries such as Tanzania. At the Ocean Road Cancer Institute (ORCI) in Dar es Salaam, we rely heavily on radioactive isotopes like Technetium-99m (Tc-99m) for diagnostic imaging and iodine-131 (I-131) for the treatment of thyroid diseases, including Graves' disease and thyroid carcinoma. Additionally, we are transitioning into using Gallium-68 (Ga-68) sourced from Germanium-68 (Ge-68) generators for Positron Emission Tomography (PET) scans. With the completion of a new cyclotron for radiotracer production, we aim to reduce our dependency on imported materials. However, the importation and secure transport of these materials present significant challenges due to infrastructure limitations, regulatory issues, and security concerns.

The transportation of radioactive materials is governed by international regulations, notably the International Atomic Energy Agency (IAEA) guidelines, but applying these regulations within the Tanzanian context is often challenging. The complexities of navigating local legislation, weak enforcement mechanisms, and logistical hurdles create a challenging environment for ensuring safe and secure transport.

### Challenges in Transporting Radioactive Materials to Tanzania

#### Regulatory and Compliance Issues

The first challenge we face in transporting radioactive materials is regulatory compliance. International standards, such as the IAEA's safety regulations, provide clear guidelines on the safe transportation of radioactive substances, but local implementation remains inconsistent. The Tanzanian regulatory framework, though governed by the Tanzania Atomic Energy Commission (TAEC), lacks sufficient capacity for enforcement and oversight. This results in confusion among suppliers, especially when importing complex materials like Mo-99 generators and I-131 capsules. Furthermore, customs officers and logistics personnel often lack specialized training in handling and processing radioactive materials, leading to delays and inefficiencies in the transport process.

#### Logistics and Infrastructure

Transport infrastructure is another key challenge. Tanzania's roads and ports, especially in Dar es Salaam, are ill-equipped to handle sensitive shipments of radioactive materials. While most radioactive materials arrive through Julius Nyerere International Airport and Dar es Salaam Port, the absence of specialized storage facilities and secure transport systems heightens the risk of theft, contamination, and delays. The lack of dedicated routes for the transport of radioactive materials further complicates the situation, as shipments are often subjected to the same security measures and logistical inefficiencies as conventional goods.

#### Environmental Risks

Many of the materials we import, such as Mo-99 generators, the environmental safety is a critical concern. The risk of radiological contamination, especially during accidents or mishandling, could pose serious threats to public safety and environmental integrity.

#### Security Concerns

The risk of diversion, theft, or sabotage is a particular concern, especially given the long distances these materials must travel across borders and through areas where enforcement of security measures may be weak. This risk is compounded by the lack of a dedicated, regionally coordinated security framework for the safe transport of radioactive materials in East Africa.

### Conclusion

The safe and secure transport of radioactive materials is a significant challenge for facilities in Tanzania, including ORCI. Addressing the regulatory, logistical, environmental, and security issues associated with the importation of these materials requires substantial improvements in infrastructure, training, and regional cooperation. At ORCI, we have made strides in mitigating these challenges through collaboration with international suppliers, enhanced staff training, and the establishment of secure storage facilities. As we expand our capabilities with the cyclotron and PET/CT scan technologies, continued focus on safe and secure transport will be essential to ensure the sustainability and growth of nuclear medicine services in Tanzania.

**Country or International Organization:**

**Instructions:**

## **Comprehensive Insights on Safe and Secure Transport of Radioactive Materials Across Legal, Operational, Design, and Cyber Domains**

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Every year, over 20 million shipments of radioactive materials are transported worldwide for medicine, energy, industry, and research. Ensuring the safety and security of these shipments is critical.

This submission presents insight across four key areas:

- 1. Legislative and Regulatory Framework:**  
Strong national laws and international agreements are needed to control the movement of radioactive materials. Countries must align their regulations, train responsible authorities, and update legal frameworks to address modern risks.
- 2. Safety and Security by Design:**  
Transport systems must be designed from the start with built-in safety and security features. This includes robust packaging, tamper-resistant containers, and secure loading procedures. Early design thinking prevents vulnerabilities later.
- 3. Safety and Security During Transport Operations:**  
Successful transport depends on coordinated action between transporters, regulators, and emergency services. Real-time tracking, proper labeling, emergency planning, and risk-based decision-making help reduce incidents. With rising global threats, criminal and terrorist risks must also be addressed using strong protocols, personnel screening, and surveillance.
- 4. Computer Security and Emerging Technologies:**  
As digital systems are used for routing, tracking, and communication, cybersecurity has become essential. Systems must be protected from hacking and data breaches. Tools like artificial intelligence and blockchain offer new ways to detect threats, track movements, and enhance security across the supply chain.

By focusing on these four areas, countries can ensure that the peaceful use of radioactive materials continues safely and securely. This approach helps protect people, the environment, and global cooperation

**Country or International Organization:**

**Instructions:**

## **SAFE TRANSPORT OF RADIOACTIVE MATERIALS IN MADAGASCAR**

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Radioactive sources are used in different fields and several sectors, in Madagascar: health, industry, mining, and research. Currently, Madagascar exports large quantities of Normally Occurring Radioactive Material (NORM), and uses a significant number of radioactive sources in industry and medicine, that increase widely the movement of radioactive material in transport at national level. In Madagascar, all transport action of radioactive materials is subject to safety control, followed by authorization. Such process aims to ensure that each transport operations complies with the safety and security requirements stipulated by the Legislation and Regulations and other relevant IAEA's requirements dealing with the safe transport of radioactive materials.

Control of radioactive packages consists of an exhaustive verification of the transport documents, all the requirements according to the type of package and the security aspects especially the categories of radioactive sources. Dose rate measurements around the package are part of the control.

Keywords: transport, authorization, control

**Country or International Organization:**

**Instructions:**

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## **REGIONAL COOPERATION AS A STRATEGIC NECESSITY FOR STRENGTHENING SAFETY AND SECURITY IN THE CROSS-BORDER TRANSPORT OF RADIOACTIVE MATERIALS IN SUB-SAHARAN AFRICA**

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### **Abstract**

The safe and secure transport of radioactive materials is a critical element of nuclear security and radiation protection. As the use of radioactive materials grows across Sub-Saharan Africa, especially in medical, industrial, and research applications, effective regulation and oversight of their cross-border movement becomes increasingly vital.

However, the region faces significant challenges. These include disparities in national regulatory capacities, the absence of harmonized regional frameworks, gaps in the implementation of international standards, and inadequate infrastructure at borders. These weaknesses lead to shipment delays, inconsistent safety practices, and increased risk of radiological incidents and malicious acts.

Many countries in the region have adopted national regulations aligned with the IAEA Transport Regulations (SSR-6), yet practical coordination across borders remains limited. Fragmented customs clearance processes, uncoordinated inspections, and poorly integrated emergency response systems weaken the security and efficiency of international shipments. The inconsistent application of safety standards undermines trust and hinders regional collaboration.

The case of Malawi, a landlocked country dependent on neighbouring states for importing and exporting radioactive materials, highlights these issues. A lack of harmonized licensing and notification procedures, limited communication between regulatory bodies, and untrained border personnel contribute to delays and vulnerabilities during transit.

Regional cooperation offers a strategic solution. Institutions such as the Forum of Nuclear Regulatory Bodies in Africa (FNRBA), the African Regional Cooperative Agreement (AFRA), and regional economic blocs like SADC and COMESA can play a pivotal role in improving coordination. These platforms can support capacity-building, facilitate mutual recognition of authorizations, and enhance emergency preparedness and response.

### **Key Focus Areas**

#### *Current Practices and Challenges:*

- Inconsistent regulatory enforcement across borders
- Customs and transit delays
- Uneven application of international safety standards
- Security risks during post-storage or transitional shipment

#### *Transport of Naturally Occurring Radioactive Material (NORM):*

- Limited regulation and classification of NORM
- Inadequate packaging standards and awareness
- Lack of enforcement mechanisms

#### *Operational and Administrative Controls:*

- Absence of standardized emergency protocols
- Incomplete security planning across transport modes
- Limited training for customs and border officials
- Proposed Strategic Interventions

### **Proposed solutions**

#### *Bilateral and Multilateral Agreements:*

- Establish shared procedures for shipment notification, authorization, and inspection to streamline regulatory processes.

#### *Regional Digital Notification and Tracking System:*

- Create an interoperable platform for real-time monitoring of radioactive shipments, integrated with national systems.

#### *Joint Training and Exercises:*

- Conduct regular cross-border training sessions, simulation drills, and joint inspections involving regulators, customs, and security personnel.

#### *Regional Working Groups:*

- Set up dedicated working groups under AFRA or FNRBA to guide harmonization efforts and facilitate ongoing improvement in transport safety and security.

### **Conclusion**

Regional cooperation is essential for strengthening the safety and security of radioactive material transport in Sub-Saharan Africa. Without coordinated frameworks and shared systems, national efforts remain fragmented and insufficient. Implementing the proposed interventions will support the development of a resilient, secure, and efficient transport system. Continued support from the IAEA and international partners through technical assistance, policy dialogue, and institutional capacity-building will be vital to help African countries meet their obligations under international frameworks and protect public health, the environment, and regional stability.

### **Country or International Organization:**

### **Instructions:**

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## **Regulatory Oversight in Ensuring the Safe and Secure Transport of Nuclear and Radioactive Materials in Ghana: Challenges and Recommendations**

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The safe and secure transportation of nuclear and radioactive materials is a vital aspect of the peaceful application of nuclear technology. In Ghana, the Nuclear Regulatory Authority (NRA), which was established by the Nuclear Regulatory Authority Act, 2015 (Act 895), has the responsibility to ensure that the transportation of these materials adheres to strict safety and security standards consistent with international obligations. As part of its legal and regulatory framework, the NRA has developed draft regulations based on the International Atomic Energy Agency (IAEA) Regulations for the Safe and Secure Transport of Radioactive Materials. The oversight of NRA includes the licensing of transport operators, conducting thorough inspections, and enforcing transport activities that involve radioactive materials. Safety measures include the use of Type A and Type B packaging, following pre-approved transport routes to reduce risks, and maintaining detailed documentation with hazard labelling. Security measures are also strict, featuring armed escorts for high-risk shipments, GPS tracking, and cooperation with the Ghana Armed Forces, Ghana Police Service, and Customs Service to deter theft, sabotage, or unlawful trafficking. Despite these initiatives, challenges persist, such as insufficient funding for cutting-edge monitoring technologies, a lack of public understanding regarding transport hazards, and the necessity for improved cross-border cooperation to meet regional standards. To address these issues, key recommendations include funding advanced detection technologies, enhancing public education, and reinforcing regional partnerships to maintain safety and security in the transportation of nuclear and radioactive materials in Ghana. This abstract highlights Ghana's commitment to conforming with international best practices, as demonstrated through its adherence to IAEA conventions, including the Convention on the Physical Protection of Nuclear Material (CPPNM). By sharing its experiences and strategies at this international conference, Ghana seeks to contribute to global discussions on strengthening regulatory oversight for the safe and secure transport of nuclear and radioactive materials, fostering collaboration to mitigate risks in an interconnected world.

**Country or International Organization:**

**Instructions:**

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## IAEA EVT2501005 - Paper Synopsis\_SE USIE IZOTOP, Ukraine

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Paper title: Sharing Best Practices and Challenges for the Safe and Secure Transportation of Radioactive Material in Ukraine

### SYNOPSIS

SE "USIE IZOTOP" is a state enterprise that was established in 1962 and specializing in the comprehensive management of radioactive material (RM) and sources of ionizing radiation (SIR) throughout their entire life cycle (that includes the transportation and storage activities), as well as the supply of radioisotope products and equipment utilizing RM and SIR.

Among other key areas of activity, SE "USIE IZOTOP" deals with transport of Class 7 dangerous and hazardous goods (incl. high-level sources of ionizing radiation of several thousand Curie –medical Cobalt-60) for medical (radiotherapy), industrial, scientific and research applications.

SE "USIE IZOTOP" possesses all required licenses and permits from the regulatory authorities of Ukraine to have a right to transport radioactive materials and radiation sources on the territories of Ukraine, as well as internationally through the EU countries (e.g. Poland, Czech Republic).

SE "USIE IZOTOP" has its own transport fleet that includes the specialized vehicles equipped to meet the standards of the Rules for the Safe Transportation of Radioactive Materials (PBPRM-2020) and the requirements for transporting hazardous Class 7 goods. The vehicles have the sanitary passports and are equipped with the engineering and technical means of security and physical protection, including tracking and monitoring system operated by the Central Dispatcher Center.

For the transport operations, SE "USIE IZOTOP" uses specially designed transportation and packaging sets meeting the international IAEA safe transport standards.

Almost 20 years, SE "USIE IZOTOP" is an active partner (both as a contractor and a recipient) of the

international technical assistance projects supported by the Government of the USA through the Department of Energy. This international cooperation includes implementation of the source removal, transportation and storage projects and assistance in capacity building of the transport infrastructure and capabilities of SE "USIE IZOTOP".

Personnel of SE "USIE IZOTOP" on a regular basis is involved into national and international training courses, advanced training, practical exercises and technical exchanges on the RM and IRS transportation aspects.

The cooperation with the International Atomic Energy Agency includes participation in the subject matter conferences, meetings, training courses, as well as receiving the humanitarian assistance from the IAEA donor countries (within the RANET network) in the form of radiation protection and physical protection equipment and transport vehicles to enhance the transportation capabilities of SE "USIE IZOTOP".

Despite the ongoing war in Ukraine, SE "USIE IZOTOP" continues on a regular basis to implement activities on the RM and IRS transportation in a safe and secure manner, including near the crisis frontline regions and high-risk areas, and remains committed to the national legislation, regulatory compliance and international standards in the field of RM and SIR transportation safety and security. Several case studies will be presented in the paper to demonstrate the successful practical implementation of the projects that included transportation of the radioactive sources to show the challenges and peculiarities of the safe and secure work under the current military and security conditions and challenges in Ukraine.

The paper will include the relevant pictures/photos of the transport infrastructure, vehicles, packaging sets, work execution areas, tracking and monitoring systems, etc. (excluding security sensitive and confidential information).

**Country or International Organization:**

**Instructions:**

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## **Safety and Security Considerations in the Transport of EK-10 Spent Nuclear Fuel from a Research Reactor**

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Synopsis

Spent fuel is highly radioactive and must be shielded and contained to be transported safely. Safe shipment requires a large, robust spent fuel container called a cask. The Nuclear Waste Policy Act sets a policy for safe, permanent disposal of spent fuel and other high-level radioactive wastes. The Nuclear Regulatory Commission (NRC) regulates nuclear research and power reactors, nuclear fuel cycle facilities, and industrial uses of nuclear materials, the transport packaging, storage, and disposal of nuclear materials, and licenses the export and import of radioactive materials. The IAEA regulations for materials packaging and transport serve as a model for the United States and other nations [1].

Proper handling of spent nuclear fuel (SNF) ensures the protection of the public, environment and plant workers. The NRC rigorously reviews spent fuel cask designs to meet the regulatory standards. The NRC regulatory safety standards for SNF cask designs must pass four key tests: impact, puncture, fire, and submersion in water to ensure the following:

- SNF must remain subcritical under all conditions, i.e., prevent criticality;
- The radiation dose rates should remain within acceptable limits

The ŠKODA VPVR/M transport packaging system (TPS) owned and operated by ÚJV Řež, as., Czech Republic. The ŠKODA VPVR/M cask is licensed and certified for the transport and storage of SNF from Russian research reactors, namely, EK-10, S-36, VVR-M, VVR-M2, VVR-M5, VVR-M7, VVR-(S)M, IRT-2M, IRT-3M, IRT-4M, TVR-S, as shown in Figure 1 [2].

It was first deployed at the Dalat Research Reactor in Vietnam and has since been used in the Global

Threat Reduction Initiative (GTRI) to transport over 3,400 fuel assemblies from countries including the Czech Republic, Bulgaria, Hungary, Poland, Ukraine, Belarus, Serbia, and Vietnam, using a total of 100 casks.

In this paper the ŠKODA, VPVR/M cask will be used for the transport of SNF of type EK-10 fuel from a typical research reactor of Russian design [3]. The source term characterization of EK-10 SNF will be calculated against different cooling times using MCNP and ORIGEN codes including:

- Gamma emission spectrum,
- Neutron emission spectrum, radioactivity, decay heat, radionuclide inventory,
- Toxicity, dose rates around the cask; and sub-criticality of the cask.

Moreover, we will present the NRC regulations for the spent fuel transport security through the protection in transit against sabotage, malicious acts or theft, which includes:

- Coordination with law enforcement agencies;
- Advance notification to States, and the NRC;
- Using a communications center and other means to monitor and tracking the shipments while in route;
- Using armed escorts, and; using devices that allow drivers and escorts to immobilize the vehicle.

Figure 1 Schematic diagram of the ŠKODAVPVR/M cask [2]

References:

[1] United States Nuclear Regulatory Commission (USNRC), Safety of Spent Fuel Transportation, NUREG/BR-0292, Rev. 2 February 2017

[2] ŠKODA VPVR/M Transport Packaging System and its Use for Transport of Spent Fuel from Research Reactors, the 17th International Symposium on the Packaging and Transportation of Radioactive Materials PATRAM 2013, Aug. 18-23, 2013, San Francisco, CA, USA

[3] Research Reactors Database, INIS- IAEA, 2020

**Country or International Organization:**

**Instructions:**

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## **The Role of Regulatory body in capacity building train the trainers of Front Line Officers (FLO); Sudan as case study 2018-2022.**

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Introduction

Sudanese Nuclear and Radiological Regulatory Authority (SNRRA) has been fully independent after the promulgation of the Nuclear Law Act 2017. Nuclear Security Support Center (NSSC) is one of technical arms of the Nuclear Security Directorate- SNRRA. NSSC was established and equipped with the main equipment and material to deliver the training in efficient way and the establishment was done through generous support from the IAEA.

INSSP was signed between Sudan and the IAEA which has been developed in consultations with the identified stakeholders and under guidance of the IAEA experts. The roles and responsibilities of the national stakeholders is of paramount important in effective and efficient implementation of the INSSP. The national stakeholders were identified based on the IAEA guidelines and the mandate of each stakeholders. In order to strengthen the collaboration between SNRRA and the stakeholders; MoUs were signed and contact points were assigned.

SNRRA as the sole body in the country for regulating the Nuclear and Radioactive activities.

SNRRA is the focal point authorized by the state regarding implementation of International and

regional conventions, treaties and protocols having connection with Safety, Security and the safeguards agreement .

General Objective:

To reflect the role of NSSC-SNRRA in building capacities of stakeholders in the area of nuclear security.

Specific Objectives:

To raise the awareness of the policy makers and decisions takers in the following areas of nuclear security: Security of Radioactive Material, Physical Protection and Transport of Nuclear Material

Methodology:

The capacity building programme was developed to meet the expectations of each stakeholders and taking into consideration the diversity in academic backgrounds and the mandate of the different stakeholders as well as the expected role to be played in case on any security accident/incident.

The programme can be classified into three categories: awareness workshops for policy makers and decision takers, national training courses and on-the-job training.

The training activities were organized by the NSSC of SNRRA between 2018 and 2022.

Results:

The identified stakeholders are:

11 stakeholders affiliated to 7 ministries were identified as shown in table (1), MoUs were signed to strengthen the collaboration with them.

The training programmes.

National workshops implemented by national expertise

11 workshops were conducted by national experts at the sites of the stakeholders. The details of these 9 workshops as follows: 4 training workshops on the basic of nuclear security (40 participants), 3 medium level training workshops on Detection, threat and response (15 participants) and 4 advance training workshops on application of NSSC-MIST(10 participants; both theoretical and practical) as shown figure 1.

Workshops supported by IAEA experts

Three IAEA experts missions were conducted to raise the awareness of policy makers and decisions takers; the identified stakeholders were participated in the three missions. The details of the missions are shown in table 3).

Table (3) the details of the IAEA experts missions

Ativity Dates

Workshop on threat detection and response

Workshop on development of INSSP

The International Nuclear Security Advisory Service (INSServ)

Capacity building IAEA events

Participants from different stakeholders used to participate in the training workshops organized by the IAEA; for each event at least two participants participate in the training programme; one from the SNRRA and the other from one of the stakeholders. The most benefited stakeholders are General Directorate of Customs, General Intelligence Services, Sea Ports Corporation and General Directorate of Forensics Evidence

Discussion and conclusion

The implemented training programme led to create trainers from the different stakeholders to train others in their institutions, training materials and equipment were provided through IAEA support.

References

National Nuclear Law Act of Sudan 2017

INSSP

Technical reports

Evaluation and assessment report of the implemented activities

**Country or International Organization:**

**Instructions:**

## Strengthening Transport Security for Radioactive Materials in Ghana: Challenges and Innovations

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The secure transport of radioactive materials is essential for nuclear safety and security. This paper outlines Ghana's strategic approach to transport security, detailing regulatory frameworks, operational procedures, and technological measures. The paper outlines various regulatory requirements such as written procedures, shipper and carrier credentials, route selection, transport schedules notification and coordination among stakeholders, conveyance verification, detection measures used during transportation, and communication and response measures as stated in Nuclear Security Regulation Part IV on transport security.

It also emphasizes the applications of nuclear materials in medicine, industry, food preservation, and education while addressing the associated transport challenges and key legal instruments, including international conventions such as the Convention on the Physical Protection of Nuclear Material and its amendments as well as licensing and authorization processes.

The paper analyzes Ghana's new technical innovation of using a tracking system simulation tool to optimize routes, assess vulnerabilities, and develop escort protocols. Also, strengthening cooperation between government entities and private transport companies is an innovative approach to improving security. By leveraging private sector expertise, resources, and technology, Ghana can improve both security and efficiency in transporting radioactive materials.

The paper identifies operational challenges, including resource constraints, interagency coordination, infrastructure deficiencies, and emergency response readiness. These challenges are examined, alongside strategies for enhancing cybersecurity in transport systems. Additionally, shortages of key personnel, such as specialized security forces, emergency response teams, and trained drivers are a major transportation security challenge.

By sharing Ghana's experiences and proposed innovations, this paper informs the global discourse on improving the secure transport of radioactive materials.

The findings are particularly pertinent for policymakers, regulators, and practitioners aiming to fortify transport security systems amid evolving threats and resource limitations.

In conclusion, strengthening the transport security of radioactive materials in Ghana requires a multifaceted approach that combines infrastructure development, innovative technologies, enhanced regulations, and human resource capacity building. Overcoming these challenges through innovation will help ensure that Ghana can safely and securely manage radioactive materials, supporting both the peaceful use of nuclear technology and the public's confidence in its benefits.

**Country or International Organization:**

**Instructions:**

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## Emergency Response Measures for the Transportation and Packaging of Material Contaminated with Cs-137

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In early 2024, the Department of Atomic Energy (Atom Malaysia) was informed by the Royal Malaysian Customs Department (RMCD) regarding the detention of five containers carrying zinc oxide intended for export. The Radiation Portal Monitoring (RPM) system installed at Pulau Pinang Port, located in northern Peninsular Malaysia, had been activated, indicating the possible presence of radioactive contamination in the zinc oxide contained within the shipment.

The First Responder Team (FRT) from the Northern Zone Office of Atom Malaysia was deployed to the port to evaluate the incident. Upon inspection, the team confirmed that all five containers were contaminated with Caesium-137 (Cs-137), with recorded dose rates ranging from 0.50 to 6.55  $\mu\text{Sv}/\text{hour}$ . The container owner was instructed to return the containers to their premises under the supervision of the FRT. A subsequent inspection revealed that the containers held approximately 1,000 jumbo bags of zinc oxide suspected to be contaminated with Cs-137.

Due to a limited number of available FRT responders, the Secondary Responder Team (SRT) from Atom Malaysia's Headquarters located approximately 400 kilometres away was deployed to support the FRT in conducting further verification of the 1,000 jumbo bags of zinc oxide. Both teams carried out additional monitoring and verification of the jumbo bags, as well as assessments of the zinc oxide processing stages within the company's milling plant. The monitoring results confirmed that only 312 out of the 1,000 jumbo bags were fully contaminated with Cs-137. However, radiation measurements conducted at each stage of the processing equipment indicated levels below the permissible limits as stipulated under the Atomic Energy Licensing Act 1984 (Act 304), thus permitting the area to be classified as a 'Clean Area'.

All 312 jumbo bags of zinc oxide contaminated with Cs-137 were consolidated within designated warehouse, and a "Control Area" was demarcated to restrict public access and ensure their safety. In addition, staff from the Northern Zone Office will visit the warehouse every two weeks to monitor radiation levels and verify the presence of the contaminated zinc oxide.

To identify the source of the Cs-137 contamination, the company was asked to provide a list of suppliers for the processing raw material known as steel dust. Five supplier companies were identified, and one of them confirmed that its premises were contaminated with Cs-137. The contamination detected by Survey and Monitoring Team (SMT) starting from the consolidated scrap metal cart and extending to the ground near the furnace facility. It is suspected that the Cs-137 source was burned along with scrap metal in the furnace. The supplier company then was instructed to excavate the contaminated ground, discard the scrap metal cart and then dispose all of them at national radioactive waste management facility in Nuclear Malaysia Agency (Nuclear Malaysia). The steel dust supplier was also asked to provide a list of its scrap metal suppliers to enable Atom Malaysia together with Royal Malaysia Police (RMP) to investigate any further possibility remaining of Cs-137 sources.

As for the 312 jumbo bags of zinc oxide contaminated by Cs-137, they were transferred into several containers and drums by the company under the consultation and supervision of the Nuclear Malaysia and also Atom Malaysia, before being consolidated in the warehouse for long-term of storage until an appropriate radioactive waste disposal is built in future.

**Country or International Organization:**

**Instructions:**

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## **Strengthening Transport Safety of Radioactive Material through Standardization and Conformity Assessment: Indonesia Challenges and Opportunities**

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### Abstract

The safe transport of radioactive material requires robust regulatory systems, standardization, and accredited conformity assessment bodies (CABs). Indonesia has adopted several regulations [6] [18] and national standards [11–15], yet faces critical challenges in aligning with updated international standards such as IAEA SSR-6 Rev.1 [1] and the quality management system standard SNI ISO 19443 [16][18]. Currently, only three CABs operate (one Certification Body and two Testing Laboratories), and there is no Management System CB under the scope of SNI ISO 19443 [Table1]. Furthermore, standards ISO 2919, ISO 12807, ISO 9978, ISO 7195, and ISO 1496-1 [2][3][8-10] have yet to be adopted into national standard and conformity assessment scopes. This creates a significant gap in implementing quality assurance and regulatory compliance [1].

Standardization contributes between 0.3% and 1% annually to a country's GDP [19][20]. Indonesia has initiated national roadmaps and inter-agency coordination strategies [4][5] to address these gaps. A comparative analysis of ASEAN and selected countries [Fig.3][Table 2] reveals varying maturity in integrating technical regulations, standards, and conformity infrastructure. Standardization and Conformity Assessment (SCA) and CABs are vital for safety, quality, competitiveness, and regulatory recognition [17]. Of 96 identified potential CABs (18 CBs, 10 TLs, and 86 MS CBs) [Fig.2] [Table 1], their development is essential to meet national SCA needs. International benchmarking, harmonization, capacity building are key strategies to support Indonesia's safe, standards-based transport system for radioactive materials.

**Keywords:** radioactive material transport, standardization, conformity assessment, Indonesia, SSR-6, ISO, CABs

### Standardization and Conformity Assessment (SCA) and CABs Mapping.

Indonesia currently has three CABs, one Certification Body (CB) and two Testing Laboratories (TL), but no Management System CBs (MS CBs) under the SNI ISO 19443 scope to support Standardization and Conformity Assessment (SCA). This limited availability creates gaps in regulatory [1] and quality assurance standard implementation. Furthermore, ISO 2919, ISO 12807, ISO 9978, ISO 7195, and ISO 1496-1 have yet to be adopted, with no CABs operating under these scopes. To address this, 96 potential CABs, comprising 18 (19%) CBs, 10 (10%) TLs, and 86 (71%) MS CBs could be developed. Strengthening CAB capacity is essential to support Indonesia's strategic plan [4][5].

### Country Readiness Assessment and Comparative Study

Most countries assessed have adopted ISO standards (2919, 12807, 9978, 7195, 1496-1) through national equivalents, with SSR-6 fully integrated[A] and partial alignment remains[B]. Regulatory frameworks vary in maturity. Indonesia has Regulation No. 7/2020 and adopting SSR-6 (2012). Common challenges include limited CAB capacity[B], fragmented inter-agency coordination[\*], technical complexity[#], and workforce aging[@] also face logistics and enforcement constraints[Y]. Key improvement strategies involve digital licensing, CAB capacity building and international training. Conformity assessment systems led by national bodies vary in strength and shows the need for SCA strategic expansion is important to ensure standard, regulatory compliance and international recognition

### Conclusion

National strategic are need to be align with national laws, regulations and standards, expand CAB accreditation scope in radioactive transport, digitalize tracking and supervision systems, enhance human resources through internationally-based training, promote international and regional collaboration for benchmarking and harmonization[Figure 3].

Most countries assessed [Table 2] have adopted ISO standards, SSR-6 Rev1 and have common challenges in limited CAB capacity, fragmented inter-agency coordination, technical complexity, workforce aging, face logistics and enforcement constraints. Conformity assessment systems led by national bodies vary in strength. Indonesia's limited CAB capacity—three active bodies and no MS CBs under SNI ISO 19443 [Table1, figure 2] —creates critical gaps in implementing standards and regulations [1]. Key international standards (ISO 2919, 12807, 9978, 7195, 1496-1) remain unadopted, with no accredited CABs in these scopes. Developing 96 identified potential CABs is essential to strengthen national SCA and support strategic regulatory goals [4][5].

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**ADVANCING TRANSPORT SAFETY OF NUCLEAR AND RADIOACTIVE MATERIALS THROUGH EMERGING TECHNOLOGICAL INNOVATIONS****Author:** Noel Ninio<sup>1</sup>**Co-authors:** Ini Godwin<sup>1</sup>; Oladokun Ojewole<sup>1</sup><sup>1</sup> *Nigeria Atomic Energy Commission***Corresponding Authors:** nnyabai@gmail.com, olanlaoluwa2256@gmail.com, ini.godwin@nigatom.gov.ng

1. **INTRODUCTION** Nuclear and radioactive material transportation is a common yet dangerous operation that calls for strict safety and security protocols. From spent nuclear fuel to sealed sources used in radiography, materials are transported. According to the International Atomic Energy Agency (IAEA), over 20 million shipments of radioactive material are transported annually worldwide [1]. Emerging technologies are now enhancing transportation safety with an additional layer of automation and intelligence, whereas conventional systems have concentrated on emergency response plans, escorting procedures, and sturdy packaging. This paper looks at a few of the major new technologies that are changing the safety scene.
2. **OVERVIEW OF SAFETY CHALLENGES IN TRANSPORT** Several issues still exist even with standardized Type A, B, and C packages:
  3. Exposure risk in the event of accidents
  4. Theft or sabotage during transit
  5. Lack of real time information on the location and status of materials
  6. Delays in communication during emergencies.
7. **EMERGING TECHNOLOGIES ENHANCING TRANSPORT SAFETY**
  - 3.1 Smart Packaging with Embedded Sensors Smart packaging refers to transport containers equipped with sensors that monitor conditions such as radiation levels, temperature, humidity, impact, and unauthorized access. For example, a sensor-integrated container that provides real-time alerts when conditions deviate from safety thresholds. These smart containers can transmit data via satellite or GSM to command centers, allowing early intervention in the event of anomalies [2].
  - 3.2 Blockchain for Secure Chain-of-Custody Tracking Blockchain technology creates an immutable digital ledger of all events that occur throughout transportation, from origin to destination. It can safely document emergency response procedures, inspection logs, and custody transfers. The use of blockchain technology in the nuclear industry guarantees auditability, transparency, and the avoidance of transport record tampering all of which are critical in the event of legal disputes or regulatory audits [3].
  - 3.3 Artificial Intelligence for Predictive Risk Analysis AI-based platforms can analyze historical data, weather forecasts, traffic patterns, and security alerts to predict possible transport risks and suggest optimal routes. Machine learning models can predict likelihoods of delay, theft-prone zones, or even mechanical failures based on previous transport missions, allowing proactive adjustments [4].
  - 3.4 Satellite and Drone Surveillance Satellites can provide macro-level monitoring of radioactive material shipments, while drones offer close-up views and quick inspections during transport stops. Real-time drone surveillance of transport convoys helps detect suspicious activity, assess road conditions, and even assist with emergency containment if necessary [5].
8. **INTEGRATION WITH REGULATORY FRAMEWORKS** While these technologies offer great promise, they must align with existing regulations such as:
9. IAEA SSR-6 on Safe Transport of Radioactive Material

10. National nuclear safety laws and emergency response protocols Close collaboration between technology developers, regulators, and operators is essential to ensure that new solutions are harmonized with safety standards.
11. CONCLUSION Emerging technologies are revolutionizing the safe transport of nuclear and radioactive materials. Smart packaging, AI, blockchain, drones, and digital twins are not just theoretical ideas, they are already being piloted or deployed in various nuclear programs.

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## **Transport Challenges of Radiopharmaceuticals and Other Radioactive Materials in Developing Countries: A Case Study of Kenya**

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**Background:**

The safe and secure transport of radioactive materials is an essential element of a country's nuclear infrastructure. In Kenya, radiopharmaceuticals such as Fluorine-18 (<sup>18</sup>F), Technetium-99m (<sup>99m</sup>Tc), Iodine-131 (<sup>131</sup>I), Lutetium-177 (<sup>177</sup>Lu), and Gallium-68 (<sup>68</sup>Ga) play a central role in nuclear medicine for diagnosis and therapy. Their short half-lives, specialized storage needs, and strict regulatory requirements present significant challenges in transport. In parallel, Kenya also handles other radioactive materials such as Cobalt-60 (<sup>60</sup>Co), Iridium-192 (<sup>192</sup>Ir), and Americium-241 (<sup>241</sup>Am) used in medical, research and industrial applications. These present additional transport safety and security challenges due to higher activity levels, security risk categorization, and infrastructure demands.

**Purpose:**

This paper aims to identify and analyze key barriers affecting the transport of both radiopharmaceuticals and other radioactive materials in Kenya. It seeks to offer practical recommendations for building a sustainable, safe, and secure transport system in a developing country context.

**Methodology:**

The study adopts a qualitative, descriptive approach, including:

- A review of international guidance, IAEA Transport Regulations, published nuclear safety and security requirements and guidelines for radioactive materials and our national laws (Kenya Nuclear Regulatory Act (2019));
- Case analyses involving import and domestic distribution of <sup>18</sup>F, <sup>131</sup>I, <sup>177</sup>Lu, <sup>99m</sup>Tc, <sup>60</sup>Co, and <sup>192</sup>Ir;
- Key informant interviews with radiopharmacists, regulators, logistics companies, and radiation safety professionals;
- Examination of transport chains to public and private nuclear medicine facilities and industrial users.

**Results:**

Preliminary findings highlight several critical issues:

- Time-sensitive delays for short-lived radiopharmaceuticals due to customs clearance and inter-agency disconnect
- Inadequate cold chain systems and shortage of Type A/B containers
- Fragmented and lengthy licensing and authorization processes
- Security vulnerabilities, especially in the inter-city and cross-border movement of Category 1 and 2 sources
- Lack of real-time tracking systems and insufficient training of transport personnel and customs officers

**Conclusion:**

Addressing these challenges requires the alignment and strengthening of Kenya's legal and regulatory framework for radioactive material transport. Sustainable solutions will involve investment

in infrastructure, development of digital tracking systems, harmonized inter-agency coordination, and specialized capacity building. A robust, integrated system will not only enhance the safety and security of radioactive materials in transit, but also improve access to essential health services and support compliance with international obligations.

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## Consideration of damage after mechanical impacts in accident conditions of shipment in criticality, radiation and thermal safety calculations for a spent fuel cask

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The technical design of the Increased Capacity Cask (ICC) for storage and shipment of 30 VVER-1000/1200/1300 spent fuel assemblies (SFA), including the possible modification for storage, shipment and disposal (in the future, in an intermediate-depth repository) of canisters with ~5,4 m<sup>3</sup> of vitrified Cs-Sr fraction of High-Level Waste (HLW) resulted after spent fuel reprocessing was prepared in 2024. ICC was designed in the framework of the project "Development and Referencing Spent Fuel and High-Level Waste (HLW) Long-Term Storage Systems for Foreign Nuclear Power Plants (NPP)", part of the Sustainable Nuclear Fuel Cycle (NFC) solution of Rosatom State Corporation for Atomic Energy, which proposes spent fuel reprocessing with HLW fractioning in order to optimize spent fuel management systems' economical parameters.

A series of innovative approaches was used during ICC design calculations, which may lead to improvements of dual-purpose casks safety assessment practices:

- Storage of SFA in ICC in normal operation and during abnormal operating conditions;
- Strength calculations in accident conditions [1] takes into account accumulative damage during the worst sequence of impacts bringing maximum damage to the integrity of the ICC and radioactive contents: free drops from 0.3 m and 9 m heights on an unyielding target and free drop from 1 m to a bar according with SSR-6 (Rev.1) requirements;
- A 3D model of the SFA was developed that takes into account SFA material parameters after 60 years of storage in the ICC. The SFA 3D model was used for calculating two additional scenarios bringing worst damage to the radioactive content, also taking into account accumulative damage;
- The damage of each cask component that impacts the thermal release from SFA to the outside environment, criticality, shielding and leaks was determined and taken into account in the corresponding calculations [2], [3], [4];
- The minimal burnup of SFA with maximal U-235 enrichment was determined and taken into account in the criticality calculations [3] provided that instrumental confirmation of SFA burnup during ICC loading is foreseen in the operational flowchart of cask storage facilities (CSF).

In result the performed calculations confirmed the following:

- Safety of ICC in all analyzed operation conditions, including abnormal operation conditions and fulfillment of all regulatory limits and criteria on criticality and radiation safety is assured;
- Absence of fuel cladding breaches and of fuel material release from the fuel cladding into ICC cavity in accident conditions, compliance with fuel cladding temperature limits at all times;
- ICC design complies with the technical and economical parameters imposed by the technical specification and provides for realizing all planned operation regimes, cost optimization during long-term storage of SFA and also assures the possibility to handle vitrified radioactive waste.

Elements of the ICC design are taken into consideration for small modular reactor (SMR) spent fuel handling.

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## **Organization of Multimodal Transport Corridors for the Transportation of Nuclear Materials Between Europe and Asia Via the Territory of the Russian Federation**

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The geographical location of the Russian Federation (hereinafter referred to as Russia), the existing developed railway network (in terms of the length of railways, Russia is in the top 3 after China and India with an indicator of 44.3 thousand km) together with the developed sea ports infrastructure, good-quality highways, specialized places for processing and storage of nuclear materials allow the Russian side to offer foreign customers and successfully carry out multimodal transportation of nuclear materials between Europe and the countries of the Asian region via the territory of Russia.

Current experience and experience of previous years indicate that all transportations nuclear materials via the territory of Russia meets the requirements for ensuring the safety and protection of people, property, and the environment from the harmful effects of ionizing radiation during transportation. Protection is ensured by measures to retain radioactive contents, control over external dose rate, measures to prevent criticality, and measures to prevent damage caused by heat.

The fulfilment of the above requirements, in addition to the differentiated approach to the limits of the contents of packages and conveyances, as well as to the regulatory characteristics of the design of packages depending on the hazard posed by the radioactive contents, and with regard to the design and operation of packages, as well as the servicing of packaging assemblies, including taking into account the nature of the radioactive contents, is achieved, inter alia, through the mandatory application of administrative control measures, including, where necessary, approval procedures by competent authorities - this is an important aspect.

During transportation of nuclear materials, measures of control, route selection, physical protection, which are established for reasons not related to radiation safety. The said control measures must take into account radiation and non-radiation hazards without deviating from the safety standards prescribed by the IAEA Rules for the Safe Transport of Radioactive Materials.

The Russian side ensures reliable measures to ensure the safety of nuclear materials during transportation in order to prevent theft and damage, and also takes into account additional risks during transportation together with other dangerous goods.

The Conference participants will be presented with a general transport and technological scheme for organizing multimodal transport corridors for the transportation of nuclear materials between Europe and Asia via the territory of Russia.

Currently, Russia consistently continues its course towards establishing mutually beneficial cooperation with countries interested in services for the movement of nuclear materials via the territory of Russia. The use of multimodal corridors via the territory of Russia is the shortest route in terms of distance and optimal in terms of cost and duration of transportation for nuclear materials between Europe and Asia. De facto, Russia, being a transport bridge between the two largest world regions, can ensure seamless transportation of nuclear materials, taking into account the experience of Russian organizations and foreign customers.

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## **Packaging for HALEU: Current Market Supply Opportunities**

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The current stage of nuclear energy development is characterized by growing interest in advanced reactors, including small modular reactors (SMR), fast reactors and nuclear power plants for space projects. These technologies require the use of high-grade low-enriched uranium fuel (HALEU) with enrichment from 5 to 20% U-235. The increasing global demand for HALEU poses the challenge of providing reliable, safe and cost-effective transport solutions for the supply of this fuel. This report presents Russian experience in developing transport packages for HALEU, as well as proposals for international cooperation in this area.

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## **CUBAN EXPERIENCE IN THE APPLICATION OF SAFETY IN THE TRANSPORT OF RADIOACTIVE MATERIALS**

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The transport of radioactive materials includes the transportation of radioisotopes for industrial, medical, and research uses, and shipments of nuclear fuel cycle materials. In Cuba, CITMA Resolution 121/2000, "Regulations for the Safe Transport of Radioactive Materials," defines the requirements for establishing, implementing, evaluating, and constantly improving a management system that integrates technological and physical security in all operations and conditions associated with the transport of radioactive materials, including the design, manufacture, maintenance, and repair of packaging, as well as the preparation, shipment, loading, transportation (including storage in transit), unloading, and receipt at final destination of radioactive materials and packages.

The Office of Environmental Regulation and Safety (ORSA), Cuba's nuclear regulatory authority, has paid special attention to verifying compliance with safety requirements during the transportation of radioactive materials and has established a consistent policy based, among other aspects, on the direct implementation of audits, inspections, and surveillance measures, in conjunction with police forces, in the transportation of the most active sources (categories I and II).

This paper presents the results of the technical criteria considered in establishing the aforementioned policy, describes the current situation, evaluates the results obtained in relation to the objectives pursued, and outlines the key aspects to be taken into account for the subsequent development of the adopted policy.

In addition, it describes the training and qualification activities for personnel related to transport, the responsibilities related to the interfaces between shippers, transporters, and stakeholders for compliance with regulatory requirements for the transport modes to be used, and mentions the current opportunities and challenges in the safe and secure transport of radioactive materials.

Reference is also made to the activities carried out by the Regulatory Authority that promote the development of a solid safety culture that enables the implementation and maintenance of an effective

and efficient management system in radioactive materials transportation activities, as well as to the self-assessment of the processes this Authority applies to transportation-related activities.

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## **Fuelling the Future: A Global Centre for Capacity Building in Nuclear Transport and Radiation Protection**

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As nuclear energy, medical isotopes, and radiological applications grow worldwide, so too does the volume and complexity of nuclear and radioactive material transport. Ensuring its safety and security depends not only on robust regulation and infrastructure, but on a well-trained, diverse, and future-ready workforce. This includes not just technical specialists, but also project managers, regulators, logistics coordinators, and other professionals who must understand the science, policy and regulation and the practical skills underpinning nuclear and radioactive material transport.

Yet today, capacity gaps persist- particularly in areas such as radiation protection, nuclear safety and security, and regulatory implementation. The challenge is especially acute for young professionals, women, and individuals entering the field from adjacent disciplines. Current training pathways are fragmented, and international mobility of skills is often hindered by a lack of formal, recognised qualifications.

To address this, the World Nuclear Transport Institute (WNTI), in partnership with the International Commission on Radiological Protection (ICRP) and the University of Liverpool, is launching the Centre for Nuclear Transport and Radiation Protection - a dedicated global hub for education, skills development, and applied research in these fields.

Uniquely, the Centre will offer academically underwritten qualifications –including short CPD modules, Summer Schools, and postgraduate research pathways - ensuring that credentials are formally recognised across borders. While certifications from international bodies often carry authority, academic qualifications from accredited universities provide the legal and professional portability needed for cross-border employment. This makes them especially valuable for professionals working in multinational supply chains, or in jurisdictions requiring national academic recognition.

The Centre's initial base in the UK is only the beginning. It is designed to evolve into a network of regional hubs, partnering with local universities and institutions to deliver consistent, high-quality training adapted to regional needs. This ensures global accessibility while maintaining alignment with international safety and security standards.

The presentation will outline how this initiative responded directly to the ICRP's Vancouver Call for Action on workforce development and capacity building. Drawing from lessons learned in large Gigawatt Nuclear New Build projects in the UK, we will demonstrate how targeted collaboration between academia, industry, and international policy bodies can bridge the nuclear and radioactive materials transport skills gap and prepare the next generation of professionals.

In an era of expanding nuclear deployment, diverse transport modalities, and growing public and regulatory scrutiny, the Centre offers a timely and practical solution - building competence, advancing careers, and supporting the safe and secure transport of radioactive material worldwide.

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**Artificial Intelligence Approach to Enhancing Detection and Verification of Illicit Trafficking and CFSI within Nuclear Supply Chain****Author:** Md. Dulal Hossain<sup>1</sup><sup>1</sup> *Bangladesh Atomic Energy Commission***Corresponding Author:** edhossain@gmail.com

The nuclear supply chain (NSC) extends the vulnerabilities through disruption by illicit trafficking and counterfeit, fraudulent, and suspect items (CFSI) of nuclear and radioactive materials (NRM). These pervasive issues of illicit trafficking and CFSI can diminish the integrity of systems, structures, components or devices that poses a significant nuclear cyber and physical security threat and public safety. Therefore, it is essential to ensure the cyber physical security and safety in the NSC by enhancing the existing detecting, preventing, and deterring illicit trafficking and CFSI instruments. Therefore, an integrated approach is required for building a sustainable NSC to facilitate the border controls of illicit trafficking and CFSI of NRM. Despite the potential of vulnerabilities, threats, and risks with illicit trafficking and CFSI of NRM within the NSC, states lack in addressing these issues properly when they should not be. In this aspect, member states require to reformulate the existing framework through incorporating artificial intelligence (AI) approach to govern these nuclear safety and security risks. These are the prime motivation of this research. Drawing upon these limitations, this research introduces AI approach through integrating of Blockchain Technology (BT), Machine Learning (ML), and Data Analytics (DA) to enhancing detection and verification of illicit trafficking and CFSI within its NSC. First, to address these issues, this study aims to design a robust blockchain architecture based on cloud infrastructure to enhance detection with ensuring the technical sustainability for NSC. The complex structure of the NSC involves tremendous processes and data derived from diverse actors are sources for big data analytics which can be enhanced by ML. Therefore, this study introduces this important issue of integrating machine learning into data analytics on cloud infrastructure to enhancing detection and verification of illicit trafficking and CFSI within NSC. Illicit trafficking and CFSI of NRM within the global supply chain are growing security concern that poses a significant threat to public safety because of its frequent occurrences, growing complexity, inherent uncertainty of the extent of infiltration, and dynamic nature of the problem. The developed cloud based BT that aims to create a tamper-proof and transparent ledger of all transactions within the NSC. Hence, this would provide an immutable record of all activities, making it easier to track and verify the movement of NRM. The developed ML algorithms that aim to analyze large amounts of data from sensors and other monitoring devices to identify patterns and anomalies that may indicate potential threats or issues in the supply chain. Hence, ML enables early detection and prevention of potential security breaches or accidents. Integration of data analytics that aims to process and analyze big data from various sources including border controls systems, regulatory agencies, suppliers, and customers. Hence, it is possible to identify trends, patterns, and other insights that can improve the efficiency and effectiveness of the supply chain. To combine, the use AI approach through integrating BT, ML, and DA technologies provide a powerful tool for detecting potential vulnerabilities, threats and improve the overall efficiency and effectiveness of the NSC. The findings shed light on trust building between the various stakeholders in the NSC through providing a professional, planned response as rapidly and appropriate manner and stimulating organizational security culture through inter-stakeholder's communication, cooperation and collaboration. Finally, the combined outcome of developed AI approach through integrating BT, ML, and DA provide an enhanced, leveraged effectiveness of the detection and verification system at border control within NSC through mitigating the risk of illicit trafficking and CFSI which can be used to reformulating member states existing framework to building a robust nuclear security regime.

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## Kingdom of Saudi Arabia Experience in the National and International Arrangements for the International Transport of Nuclear and Radioactive Materials and Its Contribution to the International Nuclear Security Regime

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The Kingdom of Saudi Arabia (KSA) affirms its commitment to strengthening the national and international nuclear security regime. The KSA is party in the Convention of Physical Protection of Nuclear Material and its Amendment (A/CPPNM) since 2009 and 2011, respectively, and party in the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management since 2011. In addition, the KSA has submitted its political commitment to the Code of Conduct on the Safety and Security of Radioactive Sources (CoC) and its Supplementary Guidance in 2019, acknowledging the threats associated with national and international transportation of Nuclear and Other Radioactive Material.

Accordingly, the KSA has established the national legal framework, shown in Fig.1, that is based on National Policies and National Laws including the law of Nuclear and Radiological Control (law). The law mandates the Nuclear and Radiological Regulatory Commission (NRRC) to develop technical regulations related to Nuclear Security. Moreover, the KSA has adopted in its national legal framework the mechanisms that fulfil the obligations within the international instruments by developing Joint Government Organizations Protocols (JGoPs), a legally binding mechanism for ensuring roles and responsibilities, and coordination between the NRRC and other relevant government authorities, enacted by the Cabinet of Ministers. JGoPs between the NRRC and other national authorities responsible for Civil Aviation and Sea Ports describe the roles and responsibilities of each government authority to assure achieving highest degree of Nuclear Security commitments with international legal instruments. NRRC has developed State Variation that illustrates the national requirements for the import, export and transit of Nuclear and Other Radioactive Material to, or from, or through the Kingdom's airspace or waterways.

Nevertheless, the KSA has developed a comprehensive national procedure to digitally process requests for the authorization of the international transport of Nuclear and other Radioactive Materials, before their departure from the state of origin. Such a procedure complies with the international obligations specified in A/CPPNM, including arrangements for notification to states involved in the transportation. Accordingly, this has resulted in a reduction of possible denial or delay of shipment in the transiting and/or importing states since the arrangement of the shipment has been processed. In addition, this demonstrates the alignment of KSA's objectives with the International Atomic Energy Agency's (IAEA) objectives by reducing the chance of any occurrence of denial or delay of shipment. The IAEA has defined the denial of shipment (DoS) as an explicit or implicit refusal to carry or accept a shipment of radioactive material though it conforms to all the applicable Regulations.

Through this national procedure, 31% of requests were not authorized to pass through or into Kingdom's airspace/waterways as shown in Fig.2, due to various reasons including, but not limited to, incomplete shipping documents, mismatch of information among the shipping documents, and failure to provide assurance to apply physical protection measures in accordance with the A/CPPNM by states involved in the transportation and are not party to the convention nor its amendment.

This paper illustrates the national nuclear legal framework and the national procedure for the international transport of nuclear and radioactive material in compliance with the A/CPPNM and CoC while concerning the facilitation of safe and secure transport of nuclear and other radioactive materials, and presents the effectiveness of such procedure and associated results.

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## **Strengthening the Safe and Secure Transport of Radioactive Material in Nepal: Current Status, Issues & Challenges.**

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The safe and secure transport of radioactive material is increasingly important in Nepal, a landlocked and non-nuclear country where the use of radiation is growing in the medical field, mainly for imaging and cancer treatment. While Nepal does not produce or possess nuclear materials, but it imports both sealed and unsealed radioactive sources for medical applications.

A notable incident in 2014, involving the disappearance of a disused Iridium-192 source en route to Belgium for disposal raised serious concerns about the safety and security of radioactive material transport in Nepal. This paper presents the current status, regulatory framework, institutional responsibilities, and capacity-building efforts related to the transport of radioactive materials in the country.

At present, several agencies are involved in regulating this area, including the Department of Drug Administration (Ministry of Health and Population), the Nuclear Materials Management Division (Ministry of Education, Science and Technology), the Ministry of Home Affairs, and the Customs Department (Ministry of Finance). Nepal follows IAEA safety guidelines and has gained significant support through international cooperation, notably from the IAEA and the U.S. Office of Radiological Security in developing safety and security standards for transport of Radioactive Materials.

This abstract highlights progress made in strengthening national legislation, licensing procedures, emergency preparedness, and inter-agency coordination. Persistent challenges include limited regulatory infrastructure, shortage of qualified personnel, lack of dedicated transport carriers, insufficient training of customs and border officials. Despite existing constraints, Nepal remains committed to enhancing its regulatory framework through legal and robust regulatory infrastructure, regional cooperation, and capacity-building efforts. These initiatives are especially relevant for landlocked developing countries striving to align with international best practices in the safe and secure transport of radioactive materials.

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## **INTERFACES BETWEEN SECURITY AND SAFETY IN TRANSPORTATION**

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**Introduction**

Materials are transported both domestically and abroad via land, sea, air, train, and road for uses in sophisticated scientific research, agriculture, nuclear power generation, and medicine and health. The annual shipment of radioactive materials is estimated by the International Atomic Energy Agency (IAEA) to be 20 million. Equally important is the need for transportation security.

During transportation, radioactive and nuclear materials may be subject to security risks. The IAEA

helps governments establish and uphold a national nuclear security framework for the transportation of these kinds of goods.

The IAEA's role includes helping its member states secure nuclear and other radioactive active materials while they are being transported.

#### Objective

The goal of transport security is to prevent nuclear and other radioactive materials from getting into the wrong hands by using technology and procedures such as locks and seals. Transport safety seeks to safeguard the public from radioactive contents of packages.

#### Methodology

Transport regulations will encompass the design, composition, categorization, documentation, labeling, and marking of containers. These regulations will focus on specific transport activities such as actual shipments, special arrangements, and the transport index number assigned to each package to manage radioactive exposure. They will also address transportation methods, whether by road, rail, water, or air, to, through, and across the country's borders. Safety and security considerations regarding the transport of radioactive materials will be aligned to ensure compliance with transport regulations and adhere to IAEA safety standards and nuclear security guidelines.

#### Results

Guidelines for establishing regional modal transport security will need to be created with the assistance of the European agreement on the international transport of hazardous materials by road, inland waterways, and the convention regarding international transport by rail.

#### Conclusion

Nuclear material is a small subset of the radioactive material family, because of the increased attractiveness of nuclear materials, the security requirement and recommendations for them will be specified separately from those for other radioactive materials.

Basics for security during the transport of nuclear material and transport of other radioactive materials will be in place.

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**Country or International Organization:**

**Instructions:**

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## **Strengthening the Security of High-activity sealed radioactive sources Transport in France: A new authorisation regime**

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This paper focuses on the French approach to nuclear security in the transport of High-activity sealed radioactive sources (HASS). It describes the legal framework and the new authorisation process to ensure that security measures are applied correctly.

**Country or International Organization:**

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**Instructions:**

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## Sudan regulatory infrastructures during transport of radioactive material

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Sudan uses radioactive sources in an increasing number of applications in medicine, agriculture, industry, and research and education and hundreds of radioactive sources are transported around the country and/or pass through Khartoum International Airport every year. Sudan is also considering the introduction of nuclear power in its energy mix. In this regard Sudan has in place a legal and regulatory framework that includes an independent regulatory body since 2017. Since 2017, the IAEA has supported Sudan in establishing its legal and regulatory framework, including in drafting requirements for the safe and secure transport of nuclear material and assistance in capacity building in this area, including by providing training for inspectors. Sudanese Nuclear and Radiological Regulatory Authority (SNRRA) is working for Being able to protect people from consequences of any transport nuclear incident. . currently the final draft of the transport regulations is ready to be approved by the board of SNRRA.

**Country or International Organization:**

**Instructions:**

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## Kenya's Leadership in Advancing Transport Security of Radioactive Material in East Africa: Strengthening Capacity Building, Instructor Development, and Regional Cooperation

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### Purpose

The secure transport of radioactive material (RAM) is critical to ensuring public safety, preventing malicious acts, and sustaining the peaceful use of nuclear technology in health, industry, agriculture, and research. Transport is often the most vulnerable phase in the lifecycle of RAM, taking place in the public domain and exposed to risks such as theft, diversion, or sabotage. Kenya has emerged as a leader in East Africa by implementing an integrated strategy that strengthens national regulatory frameworks, builds inspector competence, and fosters regional cooperation. This abstract outlines Kenya's sustained initiatives, with Transport Security Inspections Workshop and East Africa Regional Transportation Security Symposium serving as examples within a broader programme that also incorporates instructor development to ensure sustainability.

### Methodology

Kenya's approach aligns with IAEA Nuclear Security Series guidance, particularly NSS No. 14, NSS-9G (Rev.1), and the Code of Conduct on the Safety and Security of Radioactive Sources, as well as legally binding instruments such as the Convention on the Physical Protection of Nuclear Material (CPPNM) and its Amendment. The Kenya Nuclear Regulatory Authority (KNRA), in collaboration with the IAEA, the U.S. Department of Energy's Office of Radiological Security (ORS), and other partners, has implemented a dual-track methodology:

**Technical Capacity Building for Inspectors:**

Delivery of modular courses covering the full inspection lifecycle: legal framework, inspector behaviours, planning, conducting inspections, reporting, and continuous improvement.

Practical application through scenario-based exercises and mock transport inspections, incorporating the graded approach and risk-informed decision-making.

**Instructor Development:**

Integration of Course Transition (CT) Series and Systematic Approach to Training (SAT) methodologies to prepare Kenyan subject matter experts as certified trainers.

Building national capacity to design, deliver, and evaluate transport security courses tailored to regional needs.

**Regional Engagement:**

Hosting multi-State courses, inviting participation from East African regulators, law enforcement agencies, and border authorities.

Establishing platforms for operational experience exchange, harmonization of inspection procedures, and joint exercises for transboundary shipments.

**Results**

This sustained programme has achieved the following outcomes:

**Enhanced Inspector Competence:** Participants demonstrate improved ability to plan, conduct, and report on RAM transport security inspections in line with national and international standards.

**Sustainable Training Capacity:** Development of a cadre of Kenyan instructors capable of independently delivering high-quality transport security training, reducing reliance on external facilitation.

**Strengthened Regional Cooperation:** Improved interoperability and trust among East African States through joint training and shared best practices, supporting harmonized approaches to inspections and enforcement.

**Institutionalized Continuous Improvement:** KNRA has embedded post-inspection feedback mechanisms, lessons-learned dissemination, and adaptation to emerging IAEA guidance and technologies, such as tracking systems and secure communication tools.

**Conclusion**

Kenya's leadership in transport security of radioactive material demonstrates the effectiveness of combining national capacity building with proactive regional engagement. By developing both technical inspection skills and instructional capability, Kenya is ensuring long-term sustainability of nuclear security competencies, in line with the objectives of the International Conference on the Safe and Secure Transport of Nuclear and Radioactive Material. These initiatives contribute to a robust, durable, and responsive transport security regime—one that safeguards radioactive materials in transit, maintains public trust, and facilitates their uninterrupted use for peaceful purposes.

**Country or International Organization:**

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**Instructions:**

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## **Strengthening Transport Safety for Radioactive Material in Namibia: Challenges, Experiences, and Opportunities for International Collaboration**

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The safe and secure transport of radioactive material is essential to protect public health, the environment, and critical infrastructure. Namibia, as a significant uranium-producing nation, occupies a strategic role in the global nuclear supply chain and faces challenges in ensuring transport safety for materials used in mining, healthcare, and research. This submission examines Namibia's current transport safety framework, documents operational experiences and gaps, and identifies practical opportunities for regional and international collaboration to strengthen capacity.

This study uses a mixed approach: a review of national regulations and industry guidance, analysis of operational practices in mining supply chains and port operations, and interviews with stakeholders including the Namibian Radiation Protection Authority, mining logistics managers, customs officers, and emergency responders. The assessment focuses on packaging and labeling compliance, transport tracking and monitoring, training and competency of personnel, and emergency preparedness for incidents during long-distance land and maritime transport.

Key findings indicate that Namibia has adopted many international technical standards for packaging and labeling, and some industry operators follow robust internal procedures. However, systemic gaps remain: limited availability of specialized transport containers, inconsistent real-time monitoring and tracking tools, and a shortage of specialized training for first responders and customs personnel. Cross-border shipments present further complexity due to variable regional capacities and long transit routes which increase response times in the event of an incident. The analysis also identifies uneven resourcing for radiation monitoring equipment at intermediate transfer points and port facilities.

Despite these constraints, there are strong foundations for improvement. The establishment of a national Radiation Protection Authority and prior participation in IAEA training initiatives provide a platform for scaling capacity building. Industry-regulator partnerships have demonstrated the feasibility of implementing site-level monitoring and emergency drills. There is clear potential to adopt low-cost tracking and tamper-detection technologies, expand targeted training programs for transport operators and first responders, and integrate transport safety into regional corridor plans.

This submission proposes a set of pragmatic recommendations: (1) strengthen regulatory guidance and harmonize cross-border procedures with neighbouring states; (2) prioritize modular training and certification for customs and emergency personnel; (3) invest in basic monitoring and tracking infrastructure at key nodes (mining sites, transfer hubs and port facilities); and (4) pursue targeted technical cooperation with IAEA and regional partners to pilot tracking and response systems adapted to long-distance land and coastal routes.

Support for participation at this conference would enable exchange of best practices, access to technical guidance, and the formation of partnerships necessary to implement the recommendations. Sharing Namibia's experiences will also inform broader discussions on transport safety in resource-exporting developing countries and contribute to strengthening the global transport safety framework.

**Country or International Organization:**

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**Instructions:**

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## **Monte Carlo Simulation for Safety and Security Assessment of Radioactive Material Transport Packages**

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Ensuring the safe and secure transport of radioactive material requires robust evaluation methods that address both regulatory requirements and practical operational challenges. This work explores the application of Monte Carlo simulation codes, specifically MCNP and PHITS, to support safety and security assessments of transport packages across different modes of transport. The study investigates shielding design, dose evaluation for workers and the public, and potential exposure scenarios under both normal and accident conditions. Special attention is given to the optimization of package design, including innovative materials and geometrical configurations, to ensure compliance with international standards and reduce effective dose. By comparing simulation results with regulatory dose limits and safety guidelines, the study demonstrates how computational modeling provides a reliable decision-support tool for regulatory bodies, package manufacturers, and operators. This contribution also highlights the role of simulation in facilitating harmonized practices among Member States by improving transparency, knowledge sharing, and confidence in safety margins. Overall, the integration of Monte Carlo methods into transport safety assessments strengthens international cooperation and supports the continuous improvement of radiological protection measures in the transport of nuclear and radioactive material.

**Keywords:** Radiological protection, transport safety, Monte Carlo simulation, MCNP, PHITS, shielding optimization, regulatory compliance.

**Country or International Organization:**

**Instructions:**

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## «Approaches to Safe Transport of Radioactive Waste in Ukraine: From Generation to Disposal»

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The safe and secure transport of radioactive waste (RW) in Ukraine involves a multi-stage process encompassing preparation, packaging, loading, shipment, unloading and receipt at interim storage facilities, followed by transfer to long-term storage or disposal sites. Each stage is governed by national regulations harmonised with IAEA standards. The paper highlights Ukraine's regulatory approaches, technical solutions, and practical experience in RW transport, with a particular focus on licensing procedures, safety assessments, and certification of package designs. Recent regulatory updates in Ukraine, including revised requirements for safety analysis reports, refined licensing procedures, and enhanced management system requirements, will be presented alongside performance indicators such as incident-free transport rates, occupational and public doses, and inspection results. A unique challenge addressed in the paper is the regulation of radioactive source transport from facilities exposed to military actions –an area with limited international regulatory precedent. Case studies illustrate the integration of radiation protection measures, emergency preparedness, and real-time monitoring during transport.

The Ukrainian experience demonstrates a comprehensive, adaptive framework for ensuring transport safety and offers lessons of value to the international community. The analysis covers the entire technological chain –from documentation and classification to loading, in-transit monitoring, unloading, and receipt at storage or disposal facilities.

**Country or International Organization:**

**Instructions:**

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## Enhancing Knowledge Management in Transport Security

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Transport security is essential for the protection of an estimated 15–20 million shipments of nuclear and other radioactive materials annually across various sectors, including medicinal, nuclear, and agricultural sectors. This paper examines the critical role of effective knowledge management practices in overcoming systematic and cultural barriers that hinder operational efficiency and innovation within transport security, specifically through the lens of two countries with operating Nuclear Power Plants including the Czech Republic and South Africa. Key barriers include inadequate mentorship programs, regulatory challenges, limited communication channels, and a lack of collaborative culture, which all impede the development of a skilled and knowledgeable workforce crucial for addressing complex security challenges.

Implementing robust knowledge management strategies offers numerous benefits, such as enhanced decision-making, innovative problem-solving, and diverse perspectives necessary for tackling intricate security dilemmas. Organizations that thrive in managing knowledge can tap into a broader talent pool, which leads to improved creativity, operational success, and better business outcomes. By fostering a culture of knowledge sharing, the transport security sector can become more adaptable and resilient to respond more effectively to evolving threats.

To promote effective knowledge management, the authors recommend developing structured mentorship programs, developing related regulatory requirements, creating inclusive communication platforms, and implementing targeted training initiatives that focus on best practices in knowledge sharing. Regular assessments of knowledge management practices are also crucial in identifying gaps and facilitating continuous improvement. By adopting these measures, organizations with a nexus to transport security can enhance their operational capabilities and strengthen the sector as a whole.

**Country or International Organization:**

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**Instructions:**

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## Ghana's International Cooperation efforts in improving the Regulatory framework for Nuclear Transport safety and security.

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Ghana upholds and recognizes international cooperation as a critical pillar in strengthening its regulatory framework for nuclear transport safety and security. Given the transboundary nature of nuclear and radioactive material transport, effective oversight requires alignment with international standards and best practices. Ghana is actively progressing in her quest to add nuclear power to her energy mix, Small Modular reactors (SMRs) are been considered as a possible NPP technology for this purpose. Since, most SMRs are factory built and transported to the site, an adequate and robust regulatory framework is required. The Nuclear Regulatory Authority of Ghana (NRA-Ghana) actively collaborates with the International Atomic Energy Agency (IAEA), European Union, Instrument for Nuclear Safety Commission (EU-INSC), regional regulatory networks like the Forum for Nuclear Regulatory Bodies in Africa (FNRBA), and bilateral partners like the USNRC to enhance its technical and institutional capacity. Through participation in international training programs, peer review missions, and joint exercises, Ghana has integrated international transport safety and security best practices into our regulatory framework while building a culture of compliance and accountability among stakeholders. These collaborations have also facilitated knowledge transfer, harmonization of procedures, and the adoption of risk-informed approaches to nuclear transport safety and security. Through international cooperation, Ghana continues to strengthen its regulatory infrastructure, ensuring safe, secure, and sustainable transport of nuclear and radioactive materials.

**Country or International Organization:**

**Instructions:**

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## **Namibia's nuclear and radioactive material transport practices: the challenges and experiences at the national level.**

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### **Problem**

In Namibia, the safety and security of transporting nuclear and radioactive material are governed by the Atomic Energy and Radiation Protection Act, No. 5 of 2005, along with other applicable laws concerning different modes of transport and international legal instruments. This Act, together with relevant regulations and guidelines, aims to reduce radiation exposure to individuals and the environment and to ensure control over these materials during transportation. Nonetheless, the National Radiation Protection Authority (NRPA), the regulatory authority responsible for overseeing safety and security during the transportation of nuclear and radioactive materials, encounters various challenges in the transportation process, such as international shipments, storage post and prior to shipment or during transit, and transitional arrangements. The research seeks to analyze these challenges.

### **Purpose**

The research aims to assess the Namibian laws governing the registration of business entities, various modes of transport, the transportation of nuclear and radioactive material, and to identify challenges affecting shipments, post-storage or transit shipments, and transitional arrangements concerning the transportation of nuclear and radioactive material in Namibia. The findings and recommendations will be provided.

### **Method**

The analysis of the challenges impacting the safe and secure transport of nuclear and radioactive materials in Namibia.

### **Conclusion**

Challenges that affect the shipment and storage or transit of nuclear and radioactive material in Namibia are highlighted. It also examines transitional arrangements and identifies gaps in the transportation process. Finally, it provides recommendations to ensure the safe and secure transportation of these materials in Namibia.

**Country or International Organization:**

**Instructions:**

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**USABILITY EXTENSION OF THE ŠKODA VPVR/M CASK FOR TRANSPORTING IRRADIATED FUEL ASSEMBLIES****Authors:** Igor Bolshinsky<sup>1</sup>; Josef Podlaha<sup>2</sup>; Pavel Ruzicka<sup>3</sup>; Sandor Tozser<sup>None</sup>; Wendell Hintze<sup>1</sup><sup>1</sup> INL<sup>2</sup> ÚJV Řež, a.s.<sup>3</sup> ŠKODA JS a.s.**Corresponding Authors:** smtozser@yahoo.com, igor.bolshinsky@inl.gov

In the ever-changing environment of nuclear fuel management, including issues related to nuclear non-proliferation efforts, the safe transportation of various spent or irradiated fuel elements, especially those containing highly enriched uranium (HEU) fuel, continues to pose critical technical and regulatory challenges. The technical challenges, primarily driven by security and pragmatic considerations, are focused mainly on transport technologies, which would prefer in many cases the use of the transport technology based on the ŠKODA VPVR/M cask which has good references and is well-established in terms of service and can also be used for those fuel elements for which the transport technology (i.e. the transport cask) is not yet licensed. This paper introduces the ŠKODA VPVR/M cask and then highlights its flexibility by describing the internal basket adaptations that have been implemented, which have proven versatile for these needs.

As is known, the Russian Research Reactor Fuel Return (RRFR) programme, since its inception, has continuously utilized the ŠKODA VPVR/M cask fleet, designed for the repatriation of spent nuclear fuel. As the programme progressed from a shutdown and a quasi-abandoned reactor, and as it began to include fuels of different countries of origin, new challenges emerged for the transport cask. These new challenges presented fuel types that had not yet been licensed for the ŠKODA VPVR/M cask. Although these requirements did not arise during the design of the ŠKODA VPVR/M cask, a retrospective analysis has revealed the adaptability of its internal basket construction to accommodate additional fuel types. In response to user demand, various internal basket constructions have been designed and manufactured over the years, and then successfully used as new internal baskets tailored to accommodate specific fuel elements in the ŠKODA VPVR/M cask.

Section 1 of the paper briefly introduces the ŠKODA VPVR/M cask, which holds a B(U) type license issued by the licensing nuclear authority of the country of the cask's origin (the Czech Republic). The licensed Russian origin research reactor fuel types are also specified, as are the licensed types for transportation.

Section 2 describes, almost in a list-like manner, the previously developed internal basket types with which various fuel elements, let's call them exotic HEU irradiated fuel types, were successfully returned to the country of fuel origin. These internal baskets are:

☒ TVR-S type internal basket for the removal of the irradiated HEU fuel assemblies from the RA research reactor (Vinča Institute of Nuclear Sciences, Belgrade, Serbia) — Section 2.1;

☒ Internal basket for liquid irradiated HEU fuel transport from the IIN-3M "Foton" Research Reactor (Tashkent, Uzbekistan) — Section 2.2;

☒ Internal basket for irradiated HEU MNSR core and fresh fuel pins transport — Section 2.3.

In Section 3, the most recently developed new internal basket type is presented in detail, which is designed to accommodate MTR-type or TRIGA-type irradiated fuel assemblies. This includes a detailed presentation of the design basis and the new MTR-TRIGA internal basket, as well as the licensing matters of the package under the name ŠKODA MTR-TRIGA cask, and the conformity test (dry- and wet-run) operations made to verify compliance with the internal basket.

Then, in Section 4, a summary of the usage record for the ŠKODA VPVR/M cask fleet is presented. Finally, the paper concludes (Section 5) with a consolidated overview of the experiences gained during the utilization of the cask fleet, emphasizing the high degree of cask flexibility ensured by the internal basket's construction. Based on the successful adaptations of the internal basket redesigned for new fuel element types so far, the paper concludes that the ŠKODA VPVR/M cask boasts a high degree of inherent adaptability due to its embedded construction architecture.

**Country or International Organization:**

**Instructions:**

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**Establishment of National Regime for Safe Transport of Radioactive Material****Author:** Asad Ejaz<sup>None</sup>**Corresponding Author:** asadilu@yahoo.com

Pakistan Nuclear Regulatory Authority (PNRA) is the national authority in Pakistan to regulate the transport of radioactive material (RM) in the country. The PNRA regulations for the Safe Transport of Radioactive Material PAK/916 (Rev.1) is based upon IAEA SSR-6(2018). PNRA ensures the compliance of these regulatory requirements by their licensees as well as consignor and/or consignee of radioactive material.

Other national departments such as Ministry of Communications, Ministry of Railways, Ministry of Maritime Affairs, Pakistan Civil Aviation Authority, Ministry of Commerce, Federal Board of Revenue, Ministry of Foreign Affairs etc. are also involve to ensure safe transportation of all dangerous goods including class-7 (RM) in Pakistan by implementing their regulations in-line with international regulations/Codes such as RID, IMDG, ICAO etc.

Based upon different cases and queries related to transit and transport of RM from carriers/consignors within and outside Pakistan, as well as from other national authorities/ministries, some challenges/gaps were identified at national level. These challenges/gaps were the lack of coordination among the relevant national stakeholders, lack of clear understanding of the responsibilities for activities related to transport of RM within their jurisdiction, matter of regulating the carriers involve in transport of RM, lack of common understanding of regulatory frameworks of all national stakeholders etc. All these outline the need for strengthening the national regime for safe transport of RM in the country. In order to meet the underlying challenges, PNRA took a number of initiatives, such as coordinated with relevant national stakeholders; conducted a number of meetings and organized seminars & training courses for them on safe transport of RM; nominations of points of contact for smooth coordination among the relevant stakeholders ; involved all relevant stakeholders in revision of PNRA transport regulations PAK/916 and vice versa etc. to set common understanding related to safe transport of radioactive material in Pakistan.

This paper will present a detail of efforts made by PNRA for establishment of a national regime for safe transport of radioactive material, challenges faced and future recommendations.

**Country or International Organization:****Instructions:**

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**Beyond Radiological Containment: Establishing Transport Security Framework for the Integrated SMR as a Mobile High-Value Asset****Author:** AMAL TOUARSI<sup>1</sup>**Co-author:** AMINA Kharchaf<sup>2</sup>

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The global deployment of Small Modular Reactors (SMRs) presents unprecedented transport security challenges that existing regulatory frameworks are inadequately equipped to address. Unlike conventional radioactive material shipments, SMR modules constitute high-value strategic nuclear assets requiring extended multi-modal transport through vulnerable maritime, rail, and road networks, creating significant security exposure periods that can span weeks or months.

This study identifies critical security vulnerabilities unique to SMR transport operations. Physical security threats include targeted hijacking, sabotage, and theft by state and non-state actors seeking to acquire advanced nuclear technology or disrupt critical energy infrastructure. Cyber-physical attack vectors target transport monitoring systems, GPS tracking, and communication networks, potentially enabling real-time location compromise or route manipulation. Insider threats within the extended transport chain pose risks through personnel with privileged access to transport schedules, routes, and security protocols across multiple jurisdictions and organizations.

Current international transport security regulations—including IAEA transport safety standards, IMO maritime security codes, and national road transport security requirements—fail to adequately address SMR-specific risks. Key regulatory gaps include: absence of standardized security classifications for reactor modules versus traditional radioactive cargo; inadequate security escort and monitoring protocols for oversized nuclear components; insufficient coordination mechanisms between transport modes and national security authorities; and lack of harmonized information security standards for protecting sensitive transport logistics data.

Critical operational vulnerabilities emerge at modal transfer points, during extended port storage periods, and through predictable transport corridors that enable adversary surveillance and targeting. The multi-jurisdictional nature of SMR transport creates accountability gaps where security responsibility transfers between manufacturers, transport operators, port authorities, and national security agencies remain unclear or inadequately coordinated.

Physical Protection System (PPS) challenges for SMR transport include the adaptation of detection, delay, and response capabilities to mobile, multi-modal environments. Critical security implementation gaps include: inadequate real-time monitoring and tracking systems for oversized cargo; insufficient tamper-evident packaging and sealing technologies for reactor modules; limited deployment of mobile security escorts with appropriate detection and response capabilities; and absence of standardized secure communication protocols between transport operators and security authorities.

Recommended security measures encompass layered protection strategies that extend beyond current IAEA Nuclear Security Series guidance, including: enhanced pre-transport security assessments and route planning with threat-based analysis following IAEA NSS No. 46-T principles; implementation of GPS-based tracking systems with encrypted communications and backup redundancy exceeding SSR-6 monitoring requirements; deployment of mobile physical protection teams trained specifically for nuclear transport operations; establishment of secure staging areas with appropriate physical barriers and surveillance systems; development of rapid response protocols coordinated between law enforcement, military, and nuclear security agencies across transit jurisdictions; and integration of cyber-physical security measures addressing both IAEA safety-security interfaces and emerging digital threats to transport infrastructure.

This analysis demonstrates that effective SMR transport security requires integrating traditional PPS concepts with innovative mobile protection technologies and coordinated multi-jurisdictional response capabilities. The development of comprehensive SMR transport security standards, including specific PPS requirements and implementation guidelines, is essential to prevent the compromise of these critical energy infrastructure components and ensure the secure global deployment of advanced nuclear technology.

Keywords: SMR transport security, nuclear material protection, multi-modal transport threats, regulatory harmonization, critical infrastructure protection

**Country or International Organization:**

**Instructions:**

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## **Enhancing Cross-Border Coordination for the Secure Transport of Radioactive Materials in East Africa: A Port-Based Perspective from Kenya**

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The secure transport of radioactive materials in East Africa is increasingly challenged by rising cargo volumes, diverse regulatory frameworks, and shifting geopolitical dynamics. As a frontline operator at Kenya's primary seaport—a vital gateway to East and Central Africa—I regularly encounter issues in screening cargo for illicit or misdeclared radioactive materials. These include concealment within mineral shipments, mislabeling of medical or industrial isotopes, and undeclared special nuclear materials from high-risk origins.

The region's expanding industrial and medical sectors have heightened reliance on radioactive materials, amplifying transport risks. Kenya's ports, especially Mombasa, serve landlocked nations such as Uganda, Rwanda, and South Sudan. Despite regional efforts under frameworks like AFRA and EAC protocols, enforcement remains uneven, and coordination limited, creating exploitable gaps in safety and security.

This paper shares operational insights into cargo screening, detection technologies, and risk profiling strategies used to intercept unauthorized radioactive materials. It highlights vulnerabilities stemming from inconsistent enforcement, limited data sharing, and inadequate emergency preparedness. Common concealment tactics include embedding sealed sources in mineral ores or mislabeling isotopes as benign cargo. Detection is further hindered by outdated equipment and insufficient staff training, increasing the likelihood of undetected threats, especially during peak cargo seasons.

A notable case involved a shipment labeled as medical equipment that contained a high-activity cobalt-60 source without documentation. The cargo had transited through two neighboring countries before arriving in Kenya, exposing weaknesses in upstream inspection and communication. This incident underscores the urgent need for harmonized protocols and real-time data exchange.

Drawing on case studies and anonymized incident data, the paper proposes a regional framework to strengthen coordination among East African states. Recommendations include harmonizing transport regulations and inspection protocols, establishing joint task forces and intelligence-sharing platforms, investing in detection infrastructure and personnel training, and integrating seaport screening data into national nuclear security strategies. The framework envisions multi-agency teams—customs, radiation safety officers, and law enforcement—working collaboratively across borders, supported by a centralized digital platform for alerts, cargo tracking, and regulatory updates.

The paper also explores emerging technologies such as passive radiation sensors, AI-driven cargo profiling, and blockchain-enabled tracking, offering scalable solutions suited to regional infrastructure and resource constraints. While grounded in Kenya's port operations, the insights and recommendations are applicable to other regions facing similar challenges. By fostering regional cooperation and leveraging technology, East Africa can become a model for secure transport practices globally.

**Conference Theme Alignment:** This paper aligns with the theme “safety and security during transport operation of Radioactive Materials,” focusing on regional collaboration, operational best practices, and technology integration.

**Country or International Organization:**

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## **Pakistan's Experience Regarding Revalidation Experience of Type B(U) Package**

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This paper will outline the issues faced and solutions regarding country experience for Revalidation of Type B(U) Package with Depleted Uranium

**Country or International Organization:**

**Instructions:**

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## **Establishing and Strengthening National Regulatory Oversight to Achieve the Safety and Security of Radioactive Material during Transport in Pakistan**

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In Pakistan, radioactive sources, from low to high activity, are used in medicine, industry, agriculture, research, and education. A number of radioactive sources are imported for such applications that, after their useful life, are returned back to the manufacturer/supplier or are disposed of within the country at designated storage sites. These sources during transport, operation, and storage could fall out of regulatory control due to unauthorized use, theft, loss, etc., which could lead to malicious acts of improvising a Radiological Dispersal Device or Radiation Exposure Device that may lead to severe radiological as well as psychological, political, financial, and health consequences.

The safe and secure transportation of radioactive material is a vital element of a national regulatory framework. Pakistan has undertaken substantial measures to establish and strengthen its regulatory framework governing the safe and secure transportation of radioactive materials. The Pakistan Nuclear Security Regime, issued by the Ministry of Foreign Affairs, specifies the roles of the organizations for safe and secure transport of radioactive material which include the Pakistan Nuclear Regulatory Authority (PNRA), Pakistan Atomic Energy Commission, and Pakistan Customs. PNRA, the national nuclear regulator, is empowered to control, regulate, and supervise all matters related to nuclear safety and radiation protection, including the safe and secure transport of radioactive material in Pakistan.

PNRA has established an effective regulatory framework that includes policies, regulations, and regulatory guides. The framework for the safety and security of radioactive materials throughout their life cycle, including transport, includes regulations and regulatory guides. PNRA "Regulations for the Safe Transport of Radioactive Material", which is generally based on IAEA SSR-6, specifies requirements for the transport of radioactive material by all modes (land, water, and air), including transport that is incidental to the use of the radioactive material. PNRA "Regulations on the Security of Radioactive Sources" has established the regulatory requirements for the security of radioactive sources during manufacture, use, storage, and transport. It specifies requirements for approval of transport security arrangements, provision of prior transport information to PNRA; escort by trained security personnel, real-time tracking; and establishing credible liaison with the law enforcement agencies. IAEA Code of Conduct on the Safety and Security of Radioactive Sources is also being used for the safety and security of radioactive sources, including transport.

To cover the security aspects and emergency situations during the transportation of radioactive material, PNRA is following various regulatory guides: "Format and Content of Physical Protection Plan for Radiation Facilities having Radioactive Sources"; "Management of Nuclear Security Events Involving Radioactive Sources"; "Advisory Material for the IAEA Regulations for the Safe Transport of Radioactive Material"; "Preparedness and Response for a Nuclear or Radiological Emergency Involving the Transport of Radioactive Material". In case of loss and theft of radioactive sources, the

licensee is required to immediately notify the event to National Radiation Emergency Coordination Center (NRECC) of PNRA and inform other response organizations for recovery and mitigation actions.

Pakistan has implemented a comprehensive framework, National Nuclear Detection Architecture (NNDA), to prevent the illicit trafficking of radioactive materials, coordination mechanism and identification of responsibilities of designated organizations for NNDA management. To deter and detect unauthorized movement of radioactive materials, Pakistan has deployed radiation detection equipment at entry/exit points of the country. This deployment is aimed at regulating authorized imports/exports of radioactive material, its transport within the country, and combating illicit trafficking.

This paper will highlight Pakistan's experience in establishing and strengthening the regulatory framework for safety and security of radioactive material during transport, integrated elements for response to incidents during transport of radioactive materials, role of PNRA in NNDA framework, associated challenges and future recommendations.

**Country or International Organization:**

**Instructions:**

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## **Harmonization in International Framework for Transport Safety & Security of Radioactive Material and National experience in Safety-Security Interface**

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The international framework for the safe and secure transport of nuclear and other radioactive material by all modes of transportation (land, water, air) comprises of IAEA Regulations for the Safe Transport of Radioactive Material (SSR-6) (Rev.1), Convention on Physical Protection of Nuclear Material and its amendment (CPPNM/A), IAEA NSS No. 13, IAEA NSS No. 14, UN Orange Book on the Transport of Dangerous Goods and Modal Transport Regulations. The Modal Transport Regulations for dangerous goods include IMDG Code for sea, ICAO Technical instructions for air, European agreement ADR for road, RID for rail transportation and ADN for Inland waterways.

The IAEA standards play a vital role in encouraging Member States to implement a harmonized approach in safe and secure transport of nuclear and other radioactive material. However, based on experience during implementation of these standards, the following areas still need to be harmonized:

- i. In order to define the basic and enhanced security level/measures for transport packages, the IAEA NSS-14 refers to the older version of IAEA SSR-6 i.e. TSR-1 2009 edition. However, the safety standard has been revised multiple times after 2009 i.e. in 2012 and 2018. Besides other changes, some of the major changes in SSR-6 2018 edition are the introduction of new classification of radioactive material SCO-III-Surface Contaminated Objects (large objects which cannot be transported in a type of package because of their size) and requirements for shipment of packages (dual purpose casks) after long term storage. Therefore, for a harmonized approach, the IAEA NSS-14 should consider the new areas defined in SSR-6, 2018 edition.
- ii. The IAEA safety standard refers transport comprised of design, manufacture, maintenance/repair of packaging, preparation, consigning, loading, carriage including in-transit storage, shipment after storage, unloading and receipt at the final destination of loads of radioactive material and packages. However, the security standards refer transport comprised of carriage of radioactive material beginning with the departure from a facility of a shipper to arrival at facility of receiver. Furthermore, the categorization concept in safety and security standards is applied in different context. Therefore, the IAEA safety and security standards should be revisited for harmonization of these concepts.

iii. Recognizing the fact that both safety and security have a common aim to protect persons, property and environment from harmful effects of radiation, the IAEA SSR-6 section III (General Provisions) should also consider inclusion of requirements related to “Safety-Security interface during transport”. In addition, in Annex I of SSR-6, all relevant security standards are referred, however, IAEA recommendation level standard NSS-14 is missing, which is equally relevant in the context of secure transport of radioactive material. During the next revision of SSR-6, NSS-14 may also be included in the list of referred standards in Annex I.

One of the tools for harmonization is to enhance safety-security interface among the areas during development of safety and security framework for transport of radioactive material. During implementation of transport safety and security framework in the country, difficulties were faced in complying the requirements in safety-security interface areas related to Marking, Labelling and Placarding of transport packages and conveyances. During implementation of such requirements as per Section V of SSR-6, it creates an additional security threat/concern for the States due to visible information for adversaries to perform any malicious act. Therefore, IAEA safety & security standards should consider the said areas for effective implementation of the requirements at national level.

This paper will highlight the key areas for harmonization of IAEA safety and security framework. It will also share national experience related to safety-security interface during transport of radioactive material and challenges & difficulties faced during implementation of safety-security framework.

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## **Pakistan’s Approach to Radiological Emergency Management in Transport Scenarios**

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The Pakistan Nuclear Regulatory Authority (PNRA) has issued regulations for the Safe Transport of Radioactive Material - PAK/916 (Rev.1), in line with IAEA SSR 6, that requires the licensee to ensure safety during transport activities by the use of the right packaging and placarding for radiation and criticality control in all modes of transport and having emergency plans in place. Furthermore, the PNRA Regulations on Management of a Nuclear or Radiological Emergency (PAK/914)(Rev.1), in line with IAEA GSR Part-7, requires the licensees to have arrangements for managing incidents and accidents during transport of radioactive material. Adopting a graded approach, these arrangements may include provision of radiation monitoring and handling equipment as well as trained radiation protection official(s) depending upon the hazard of the consignment. The concept of operations starting from the use of Operational Criteria to detection and evaluate the emergency, to mitigation and termination of emergency is planned and reflected by the licensee in its emergency plans.

Pursuant to PNRA Regulations on Security of Radioactive Sources (PAK/926), the licensee is required to inform PNRA before commencement of any transport activity and to seek route clearance from law enforcement agencies. PNRA has established the National Radiation Emergency Coordination Centre (NRECC), which serves as the focal point for the Early Notification and Assistance Conventions for communication with the IAEA. It remains active 24/7 to closely monitor any emergency for technical and situational awareness and interface with the public and law enforcement / rescue agencies. Toll-free helplines and designated technical resources, address queries and provides assistance and guidance. Field teams situated at various locations throughout the country can be mobilized to technically assist in the emergency response if required. About 2500 notifications of source movements are received by NRECC in a calendar year, majority of them being related to medical applications or industrial radiography. During transport, regulatory checks and unannounced inspections are performed by PNRA to verify compliance with regulatory requirements.

The Government of Pakistan has established National Radiation Emergency Plan (NREP), that is supported by a dedicated Nuclear Emergency Support Centre (NuRESC), to cope up with transport

emergencies where the licensee is incapacitated or public can be affected at large, The NREP stipulates the roles and responsibilities of various response organisations along with their interface and communication channels for several hazards including emergencies at unforeseen locations. The first responder to any emergency, the Emergency Services Department have been equipped with radiation detection equipment and trained to look out for observables, indicators and radiation alarms to detect and identify a radiological emergency. Adequate response measures are then taken to mitigate consequences and are reported to the NRECC for technical reachback. Likewise, the relevant authorities that play a role in managing transport operations i.e. the National Highways and Motorway Police (NH&MP) and Civil Aviation Authority (CAA) have been involved in trainings, workshops and scenario specific drills, to understand the radiation risks and manage public during any emergency occurring during transport of radioactive material.

Lastly, for detection of any undeclared transport of radioactive material the Government of Pakistan has established a National Nuclear Detection Architecture under the Customs Authority that monitors the transport of passengers and cargo through land, air and seaports. Any detected material is assessed in accordance with PNRA regulations and communicated to the NRECC; noncompliance results in the shipment being placed in abeyance and its transport being denied. This regime comprising of different agencies with specified domains play a collective role in responding to any emergency during transport of radioactive material throughout the country and covers the intent of the applicable regulations and guidance as provided by IAEA SSG-65.

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## **Licensing as an Independent Carrier of Radioactive Material: First-ever Regulatory Experience in Pakistan**

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This paper elaborates the step wise regulatory approach opted by PNRA to establish the process, process details and details of activities performed by PNRA while issuing license as carrier of radioactive material. Some experience feedback to improve regulatory framework of the member states will also be explained in the paper

**Country or International Organization:**

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**Instructions:**

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## **PNRA regulatory approach for prohibiting the use of 660 Series Gamma Radiographic Projectors in Pakistan**

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This paper will describe the challenges faced, issues highlighted, and regulatory approach adopted by PNRA to abolish the use of 660 series gamma projectors in Pakistan. Furthermore, experience of implementation of regulatory order “Regulatory Order on Prohibition of 660 Series Gamma Radiographic Projectors’ Use in Pakistan - (01/2018) will also be discussed.

**Country or International Organization:**

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## **Development of a System to Get Data for the Periodic Assessment of the Radiation Doses due to the Transport of Radioactive Material in Türkiye**

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The study focuses on the periodic assessment of radiation exposures to workers and members of the public arising from the transport of radioactive materials within, to, and from Türkiye, acknowledging that the safe transport of such materials is an essential element of radiation protection and nuclear safety since they are routinely transported for medical and industrial purposes. The actual level of exposure depends on a combination of factors, including the type and intensity of radiation, the design and shielding characteristics of packages, the amount of time workers spend in proximity to them, and the specific working arrangements of transport and handling personnel. While doses are usually expected to remain within very low ranges, it is important to conduct systematic, evidence-based, and periodically repeated assessments to confirm compliance with international safety standards and to identify where additional protective measures or optimization efforts may be beneficial. In line with the International Atomic Energy Agency (IAEA) Regulations for the Safe Transport of Radioactive Material (2018 edition), competent national authorities are required to ensure periodic evaluation of the radiological impact of routine transport. This obligation was further underlined by the 2022 IAEA Integrated Regulatory Review Service (IRRS) mission to Türkiye, which recommended that the Nuclear Regulatory Authority of Türkiye (NDK) should arrange for the periodic assessment of the radiation doses due to the transport of radioactive material, to ensure that the system of protection and safety complies with GSR Part 3. Against this background, the present study introduces a framework for development of such a system in Türkiye, relying on structured data collection and standardized dose estimation methodologies. Data are being collected through voluntary surveys sent to NDK-licensed transport companies, covering types and quantities of radioactive material, package categories and shipment frequencies, modes and routes of transport, and detailed information on the working conditions of drivers and loading staff.

The survey also includes questions on time spent near packages, and measurements of radiation dose rates around vehicles, all of which provide a realistic foundation for estimating occupational exposures and, where relevant, public exposures along transport routes or during handling operations. Transportation of high activity radioactive sources within the country is also examined in this study. The collected data is analyzed using internationally recognized dose assessment approaches to estimate annual doses for transport workers and to identify possible scenarios in which the public might also receive measurable doses. These estimates are then compared with IAEA reference levels and national regulatory requirements, thereby providing both regulators and industry with a clear picture of current exposure levels. Outcomes provided an enhanced regulatory oversight through the establishment of a consistent national system for periodic assessment and the provision of evidence-based feedback to transport operators that can help them evaluate radiation protection performance and identify practical ways to further optimize safety practices. In this way, the project represents an important step toward creating a sustainable, transparent, and systematic approach to monitoring and managing radiation doses from the transport of radioactive materials in Türkiye, ensuring that transport activities continue to be conducted in full compliance with safety principles while protecting both workers and the public.

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## **The Legislative and Regulatory Framework for The Transport of Radioactive Material and the Experience Gained During the Transport of Fresh Nuclear Fuel**

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This study provides an in-depth analysis of the legislative and regulatory framework governing the safe and secure transport of radioactive materials in the Republic of Türkiye (Türkiye), where thousands of such consignments are undertaken annually for medical, industrial, and energy-related purposes. Particular emphasis is placed on the operational experience gained from the recent transport of fresh nuclear fuel to the Akkuyu Nuclear Power Plant, scheduled to be commissioned in the near future.

The Nuclear Regulatory Authority (NDK) is the competent authority having a regulatory control on activities related to nuclear energy and ionizing radiation carried in Türkiye and responsible for authorization, inspection, and enforcement of all activities related with the transport of radioactive materials. Its legislative framework reflects alignment with International Atomic Energy Agency (IAEA) standards, particularly the Regulations for the Safe Transport of Radioactive Material, and is firmly embedded in Turkish national legislation. For transport security, Regulation on Physical Protection in the Transportation of Nuclear Material, which is in line with the Convention on the Physical Protection of Nuclear Material (CPPNM) and its Amendment; and the recommendation in IAEA's Nuclear Security Series No. 13 (INFCIRC/225/Revision 5) is implemented. Authorization procedures are structured to integrate safety and security considerations into every stage, starting from packaging to emergency preparedness. For radioactive sources, a dual authorization system (licensing and permitting) applies, while for nuclear materials, specific transport permits are required.

Institutional responsibilities in Türkiye are distributed among several actors, ensuring regulatory clarity and operational effectiveness. The NDK has the authority to regulate activities related to nuclear energy and ionizing radiation. The Ministry of Energy and Natural Resources provides strategic direction and policy coordination for the nuclear sector. The Ministry of Transport and Infrastructure regulates transport of dangerous goods (except for issues related to safety and security in the transport of radioactive materials which remains under the jurisdiction of the NDK) according to conventions to which Türkiye is a party (ADR, COTIF, SOLAS, ICAO) and national regulations. The Ministry of Interior (the police, gendarmerie, coast guard) provides escort services and physical protection during shipments. The Ministry of Customs is involved when transports cross borders, ensuring compliance with international obligations. In parallel, the Disaster and Emergency Management Authority (AFAD) ensures preparedness and response capacity in case of radiological emergencies. This multi-agency approach demonstrates the interconnectedness of safety, security, and emergency response capabilities.

International cooperation has been instrumental in strengthening Türkiye's capacity in this field. The IAEA has provided expert support through its International Physical Protection Advisory Service (IPPAS) and the Integrated Regulatory Review Service (IRRS), both of which benchmark national practices against international norms. Additionally, capacity development has been advanced through IAEA Technical Cooperation (TUR) projects and the European Commission's Instrument for Nuclear Safety Cooperation (INSC). These initiatives have enhanced regulatory expertise, improved institutional performance, and ensured the sustainability of a competent technical workforce.

In conclusion, Türkiye's system for the transport of radioactive materials is comprehensive, integrating national legislation, international obligations, and operational experience. The Akkuyu fresh fuel transport exemplifies how regulatory authorities, security forces, transport institutions, and emergency responders can coordinate effectively under a milestone-based strategy. This achievement demonstrates that Türkiye's nuclear infrastructure is being built on solid foundations and adheres to international best practices. As the country enters the nuclear power era, the continued integration of safety, security, and international cooperation will remain essential for sustaining public trust and ensuring the highest standards in radioactive material transport.

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## Safe and Secure Transport of Nuclear and Radioactive Material: Definition, Importance, Egyptian Legislation, and Recommendation

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Regarding their multi-pleentiful applications in different fields, the safe (avoiding accidents) and secure (protecting from theft, attack, and sabotage) transport of radioactive materials is becoming a critical environmental and political issue to prevent accidents and avoid radiological releases. Furthermore, the decommissioning activities of the existing nuclear power plant will increase the transportation of radioactive waste to the interim waste storage facilities and/or the final disposal.

In Egypt, the nuclear program includes various activities with peaceful applications such as research reactors, radiological facilities (accelerators, gamma irradiation units, Radioisotope production facility), facilities using radioactive isotopes and sealed radioactive sources (hospitals and medical laboratories, research laboratories, industrial sector), and radioactive waste management facilities. In this regard, the Egyptian Nuclear and Radiological Regulatory Authority (ENRRA) was established as the independent regulatory body for the management of all activities relating to the transport of radioactive materials inside the country, through the ports and territorial waters. Therefore, the Egyptian legislation in accordance with ENRRA board decree No.2 of 2022 for the safe transport of radioactive materials has been developed based on all the regulations of the IAEA (as SSR-6, 2018), aligned with international laws. According to the Egyptian law no. 7 of 2010, the Egyptian Atomic Energy Authority, EAEA (Hot Laboratories Center-Radioactive Waste Management Unit, RWMU), is responsible for the safe and secure transportation, storage, and management of radioactive waste in Egypt.

Practically, the transportation of nuclear and radioactive materials in Egypt, which are carried by air, road, rail, and sea, is performed under the control of ENRRA as follows: a) International transportation: All the documents of radioactive material consignments shall be submitted to the ENRRA for compliance assurance prior to their arrival by at least 2 weeks to regulate safe entrance in the country or the safe passage of such consignments through the different ports. On the arrival of these consignments, the experts of the Egyptian radiation detection team from EAEA examine all incoming shipments to ensure they are free of any artificial radioactive contaminants. Radiation inspection committees from the EAEA are deployed across all Egyptian sea, air, land, and river ports. In the case of shipments rejected for radioactivity, the ENRRA will be informed to take the final decision. b) Internal transportation of radioactive materials/waste (Radioisotopes, SRS, DSRS, NORM, etc.): Also, the documents of these consignments are submitted to the ENRRA by the Radiation Protection Expert at least 7 days before the transportation to coordinate with police, and civil defense to emphasize the safe and secure delivery and to mitigate the transportation threats and their consequences. Finally, I would suggest some recommendations to guarantee the safe and secure transportation of radioactive materials: a) Full details about the consignments (nature, number, and weight, etc.), licenses (facility, persons) and the transportation mode should be provided; b) Training of the personnel involved in the transportation to handle the radioactive material safely; c) Revision and updating

of the guidance on physical security during transport of radioactive materials; d) Lessons learned and sharing information between the competent authorities and stakeholders (designers, manufacturers, consignors, carriers, consignees) regarding the safe transport; and e) Initialize the computer security role in the radioactive material transportation.

The present paper will introduce more comprehensive details regarding the best practices and regulations for managing a sustainable, synergistic, and integrated approach between safety and security in the transportation of nuclear/radioactive materials/waste.

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## **Strengthening Safety and Security Competence through Inclusive Stakeholder Engagement in the Transport of Radioactive Material in Indonesia**

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Indonesia is preparing to operate its first nuclear power plant by 2032, marking a critical milestone in its national energy transition and long-term net-zero target. One of the most sensitive stages in this development is the transport of nuclear and radioactive material, which requires addressing dual challenges: ensuring safety against accidents, radiation exposure, and environmental contamination, while simultaneously safeguarding security against theft, sabotage, or other malicious acts. This research introduces a Grand Design Competency Framework that strengthens national readiness for transport operations by integrating safety and security into a single structured approach. The framework supports the establishment of competent authorities, reliable compliance assurance mechanisms, and capacity building for transport personnel. Key strategies include competency mapping across safety and security domains, development of inspection and monitoring systems, adaptive training modules, and multi-stakeholder validation with regulators, operators, and security forces. The outcomes provide clear role definitions, measurable benchmarks for personnel competence, improved institutional coordination, and enhanced preparedness for safety and security scenarios. The novelty lies in embedding both safety and security competencies together well before nuclear power operations commence, offering Indonesia and other Member States, a replicable model for resilient, transparent, and trusted radioactive material transport systems.

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## **Advancing Radiation Safety and Nuclear Security through Virtual Inspection (VI) for Radioactive Material Transport in Special Conditions: A Case Study of Balochistan, Pakistan**

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Radioactive materials are vital globally in industry, medicine, research, and academia, necessitating safe and secure transportation for radiation safety and nuclear security. However, physical inspections are not always feasible in special conditions such as pandemics, natural disasters, or regions with difficult geography and security risks, exemplified by Balochistan (46% of Pakistan's area). This paper explores the application of virtual inspection (VI) for radioactive material transport in such challenging environments. Field observations (e.g., verification of safety perimeters, radiation dose monitoring), stakeholder interviews, and technology assessments demonstrate that VI enhances regulatory oversight and operational efficiency, significantly reducing time and resources compared to physical inspections in these conditions. Challenges like connectivity limitations, cyber security risks, equipment and financial constraints, and the need for regulatory staff capacity building are also discussed. The findings highlight regulatory leadership's critical role in adopting emerging technologies to optimize resources and uphold safety standards in exceptional circumstances.

The global use of radioactive materials across diverse sectors underscores the critical importance of their safe and secure transportation to maintain robust radiation safety and nuclear security protocols. The international community boasts an enviable safety record, largely due to continuous development and application of transport safety standards by organizations like the International Atomic Energy Agency (IAEA). Ongoing reviews and revisions emphasize a proactive commitment to anticipating evolving challenges and integrating technological opportunities. This includes addressing the Global Context of Radioactive Material Transport and Inherent Challenges, especially in unique regions like Balochistan, Pakistan, which present unique challenges for regulatory oversight.

This study aims to analyze existing international and national regulatory frameworks governing radioactive material transport, identifying gaps during special conditions. It assesses VI's effectiveness, considering challenges, cost-effectiveness, and the feasibility of a graded approach. Finally, it proposes policy and operational strategies for wider VI adoption. This section explores the legal and regulatory provisions supporting or needing adaptation for virtual inspections.

The merits of VI in special conditions include cost efficiency (time saving), increased frequency, reduced risk exposure, remote access to experts, and streamlined digital documentation. However, demerits, or challenges, include connectivity limitations, high initial costs, policy gaps, equipment constraints, cyber security risks, and regulatory hesitation. Challenges of physical inspections in special conditions further underscore the need for VI, including legal, security, and movement barriers, complicated inspections, geographical barriers, and resource intensity. The methodology employed is a qualitative case study, incorporating direct field observations and comprehensive technology assessments. This section establishes the foundational legal and regulatory justifications at both national and international levels for virtual inspection techniques. Virtual inspections are designed to verify critical regulatory requirements, including documentation compliance, safety and security adherence, availability of relevant personnel and safety gadgets, and observation of radiation doses. The study's key findings indicate enhanced security, operational efficiency, energy saving, real-time monitoring, and improved regulatory compliance. Despite its benefits, VI implementation faces several hurdles including connectivity gaps, initial costs, policy gaps, equipment constraints, cyber security risks, and regulatory hesitation. Recommendations include framework development and cyber security enhancements.

The transportation of radioactive materials in special conditions and remote areas demands innovative solutions. Virtual inspections offer a transformative opportunity to enhance safety, security, and efficiency while reducing operational burdens. Despite challenges like connectivity and cyber security risks, strategic investment and proactive regulatory leadership can establish virtual inspections as a global best practice. This study advocates for a future where technology-driven inspections ensure safer and more sustainable radioactive material transport in special conditions.

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## **Development and Implementation of Effective Transport Security Regime for Nuclear and Other Radioactive Material - Nigeria Experience**

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Abstract:

Nigeria utilizes nuclear and other radioactive materials extensively across various sectors of the economy to support national development. Consequently, ensuring the safe and secure transport of these materials is a vital aspect of the country's national security strategy. This paper outlines Nigeria's comprehensive approach to developing and implementing an effective transport security regime, aligned with international standards and regulatory guidance. It examines the application of risk-based methodologies, threat assessments, and graded security measures to ensure security of nuclear and radioactive material across multiple modes of transport. The paper also highlights the significance of a strong legal and regulatory framework, effective inter-agency collaboration, capacity building, and the deployment of advanced technologies, including real-time tracking and tamper-indication systems. Furthermore, it discusses lessons learned from past events and addresses current challenges such as evolving security threats, insider risks, and the need for enhanced international cooperation. The paper concludes with practical recommendations for strengthening national transport security frameworks to mitigate risks thereby supporting the peaceful and secure utilization of nuclear and other radioactive material.

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## Lessons Learned in the Transportation of Radioactive Material

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Technical Cooperation

Report Title: Transportation of Disused Sealed Radioactive Sources: Lessons Learned in Venezuela (2022–2025)

Report Issue Date: August 25, 2025

Author: Belkys Araque

Institución: National Center for Development and Research in Telecommunications Foundation CEN-DIT

Introduction

The transportation of disused sealed radioactive sources is a critical operation within the life cycle of radioactive materials, due to the risks they pose to human health and the environment if not properly managed. This practice requires a robust regulatory framework, both national and international, highly trained personnel, and strict adherence to safety protocols that guarantee the protection of people and the environment during their transfer and final disposal.

In Venezuela, the experiences accumulated since 2022 have allowed us to identify strengths and areas for improvement in nuclear security. This document presents the main lessons learned, with the aim of strengthening national practices, improving radiation protection, and complying with international standards.

Disused sources come from medical (radiotherapy), industrial (scintigraphy, density measurement), and academic applications. This experience has been with medical sources, whose transfer to tempo-

rary storage facilities requires rigorous physical security measures to prevent theft, loss, or malicious use.

#### Lessons Learned

1. **Interinstitutional Coordination** Effective planning has been key to synchronizing the work of multiple institutions: logistics operators (CENDIT, IVIC, FIIIDT), regulatory bodies (Ministry of Defense and Ministry of Internal Affairs, Justice and Peace), and source holders (hospitals). The early definition of roles, safe routes, checkpoints, and emergency protocols significantly reduces operational risks.
2. **Threat and Vulnerability Assessment**  
Before each operation, a systematic threat assessment was conducted, considering geographic, social, and political factors. This allowed for the adjustment of physical protection measures, incorporating satellite tracking and armed escorts, with the active participation of security forces, first responders, and emergency response teams, perimeter protection, and immediate response to contingencies when transporting Category 1 and 2 sources.
3. **Staff Training**  
Technical training has been essential to ensure compliance with procedures, proper packaging handling, and contingency response. Ongoing training has strengthened operational efficiency and awareness of nuclear safety, hazardous cargo lifting, and radiation protection.
4. **Regulatory Compliance**  
Strict implementation of the IAEA Regulations for the Safe Transport of Radioactive Materials (SSR-6 Rev. 1), harmonized with the national legal framework for environmental, safety, and transport matters. Classification, labeling, documentation, and the use of packaging designed with in-house resources have been essential to facilitate audits, inspections, and traceability, under the supervision of the regulatory body.
5. **Physical Security and Endogenous Development**  
During transportation, we have armed escorts and national geolocation technologies, remote speed control, and safety sensors, allowing us to generate:
  6. Safe route map
  7. Flowchart of the transportation process
  8. Chart of reported incidents Recommendations
  9. Consolidate national safe transportation protocols
  10. Strengthen international technical cooperation
  11. Conduct periodic drills
  12. Promote national technological development
  13. Ensure continuous and transparent financing
  14. Assert communication with the public Conclusion

The Venezuelan experience in transporting disused radioactive sources has generated valuable lessons that should be systematized and shared. The results include:

- List of transported sources (2022–2025)
- Secure transport protocol
- Threat assessment
- Training record
- Funding projects

Nuclear physical security is an essential part of national critical infrastructure and requires institutional commitment, adequate resources, and a deep-rooted security culture.

#### **Country or International Organization:**

#### **Instructions:**

## Advancing Safety and Security by Design through the Development of RadSecure Mover for the Transport of Radioactive Material in Indonesia

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Indonesia's nuclear programme is entering a decisive stage with the planned commissioning of its first nuclear power plant (NPP) by 2032. This milestone will significantly increase the demand for the safe and secure transport of radioactive materials, spanning medical isotopes, research reactor fuel, radioactive sources, and ultimately nuclear fuel cycle materials. Transport is widely recognized as one of the most sensitive links in the nuclear infrastructure chain, where both safety risks—such as accidents, radiation exposure, and environmental contamination—and security threats—such as theft, sabotage, or malicious acts—must be managed in an integrated manner. To address Indonesia's lack of purpose-built transport vehicles, this research introduces the RadSecure Mover, the country's first dedicated design for radioactive material transport, formally registered as industrial design intellectual property. Unlike modified commercial trucks, the RadSecure Mover integrates safety-by-design and security-by-design principles into a single platform. Key features include multilayer shielding for gamma and neutron emitters, reinforced aerodynamic cabin functioning as a command-and-control centre, controlled access doors for inspection and secure loading, an integrated hydraulic crane, and internationally compliant hazard communication elements. Beyond static design, the project advances into simulation-based validation to ensure regulatory compliance and operational credibility. Shielding effectiveness will be quantified using PHITS, while accident and sabotage release scenarios will be modelled with ALOHA. Outputs will be combined with QGIS geospatial mapping to overlay dispersion pathways with real transport routes, population density, and emergency response nodes. Finally, discrete-event simulations using SimPy will test response performance, measuring time-to-safe-state and cumulative dose under different operational scenarios. The RadSecure Mover thus bridges a critical infrastructure gap ahead of NPP deployment, establishing a replicable model for newcomer states. By embedding safety and security functions from the outset, it strengthens resilience, compliance, and public confidence in radioactive material transport, supporting IAEA goals of innovation and preparedness in nuclear infrastructure.

**Country or International Organization:**

**Instructions:**

## Shielding Design and Dose Assessment for the Transport Vehicle of Radioisotopes Produced at the Jordan Research and Training Reactor

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Demand for Jordan Research and Training Reactor (JRTR) radioisotope products is rising, requiring round-the-clock transport scheduling to ensure timely delivery, especially for short-lived isotopes. JRTR now transports its products using its own vehicles. Radiological Protection (RP) measures are

taken during the transport of Radioactive Material (RAM) to protect both personnel and the public nearby. One such measure is the installation of shielding within the transport vehicle, including shielded boxes and driver back shields. This paper presents the shielding design and dose assessment for the new JRTR RAM transport vehicle. A conservative methodology was employed, utilizing three independent computational tools—the Monte Carlo code (MCNP), the hybrid Monte Carlo and deterministic approach code (MAVRIC), and the point-kernel code (MicroShield)—to simulate radiation transport and determine the required shielding configuration. Furthermore, a systematic assessment of the annual effective dose to the transport team from the transport activity was conducted, based on the expected source terms of JRTR-produced radioisotopes. Simulations identified optimal shielding thickness and placement based on peak dose rates among the used calculation tools. The final design ensures robust compliance with regulatory dose limits, effectively mitigating uncertainties inherent in the simulation methodologies and nuclear data. Considering the results of the conducted simulations, regulatory requirements of annual doses, operational conditions, and JRTR applied ALARA principle, a 0.2 cm lead for the wooden boxes, and a 0.4 cm lead behind the driver cabinet are installed in the transport vehicle.

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## Utilization of the “Dose to Transport Index Approach” in Individual Annual Dose Assessment for the Radioisotopes Transport Team at the Jordan Research and Training Reactor

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Ensuring no individual is committed to an unacceptable risk due to radiation exposure during the transport of radioactive materials (RAM) is essential. A radiation monitoring program for the radioisotopes transport team is applied at the Jordan Research and Training Reactor (JRTR). Thus, a limit of 50 mSv/y, not exceeding 100 mSv/5y, is set at the JRTR. Additionally, a transport dose constraint of 6 mSv/y is established in order to achieve the optimization of radiation protection. In principle, the annual doses of the radioisotopes transport team are monitored by applying different independent techniques, including the passive personal dosimeters, direct measurements, and in-advance calculations prior to any shipment. Technically, passive personal dosimeters provide accumulated readings over long durations covering many shipments but not per each shipment. The transport of radioactive materials usually includes shipments of different numbers and types of packages and activities, hence, the direct measurement of radiation dose rates is the most reliable way to assess the anticipated doses during each transport process. The computational calculation of doses is also applicable, however, it is time-consuming modeling the entire contents of the shipment. To expedite obtaining these annual doses, the “Dose to Transport Index Approach” is adopted as a quick initial assessment tool. Furthermore, this approach is also applicable, and mandated for licensing purposes by conducting assessments of yearly doses based on the annual produced activities of each radioisotope. In this work, this approach is adopted in performing a systematic annual effective dose assessment for the radioisotopes transport team, based on the anticipated annual radioisotopes production at the JRTR. The hybrid Monte Carlo and Deterministic code, named MAVRIC, is exploited to simulate such radiation exposure scenarios during the RAM transport. The results showed high compliance with the JRTR dose constraint of 6 mSv/y.

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## Sûreté des transports et de la logistique : 9 priorités à connaître pour une solution

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Que pour 100 accidents de circulation corporels au sein desquels on dénombrerait un taux moyen de 6,6% de tués, ce taux s'élevait à 17,4% lorsqu'un poids lourd transporte les marchandises.

Voici neuf éléments clés pour relever les défis actuels de la sûreté dans le secteur des transports et de la logistique.

1. Les avancées technologiques transforment le paysage de la sûreté

Le secteur des transports et de la logistique évolue rapidement, porté par le rythme des innovations technologiques.

2. La sous-traitance dans le secteur des transports : un défi majeur pour la traçabilité et la sûreté

L'un des défis majeurs en matière de sûreté dans le secteur des transports et de la logistique concerne la gestion des sous-traitants et des tiers.

3. Le vol n'est pas la seule menace, la contamination aussi

Le vol reste une préoccupation majeure en logistique, cependant il ne faut pas négliger le risque de contamination ou de sabotage, notamment dans les secteurs de l'alimentaire, du pharmaceutique ou du fret aérien

4. La gestion des accès à distance, un indispensable pour les actifs en mouvement

Pendant le transport, il arrive que les cargaisons doivent être ouvertes, souvent par les douanes ou les services de police.

5. Une utilisation intensive use les clés et les serrures sauf si elles sont numériques

Dans la logistique, certaines serrures sont ouvertes des dizaines de fois par jour. Cette utilisation intensive finit par user aussi bien les clés que les mécanismes.

6. La traçabilité permet d'éviter la fraude avant qu'elle ne survienne

La visibilité est un levier clé en logistique pour prévenir les vols et la fraude, en particulier lorsque les marchandises transitent par plusieurs intermédiaires.

7. Il suffit d'une seule faille pour compromettre l'ensemble de votre sûreté

Peu importe la performance de votre système de verrouillage : si les composants environnants ne sont pas solides, votre sûreté est compromise.

8. Matériel, logiciel, services : sans une approche centralisée, votre sûreté reste vulnérable

Un matériel robuste est essentiel, mais un bon processus de sûreté est ce qui fait la différence au quotidien. Si les droits d'accès ne sont pas bien gérés, si les identifiants ne sont pas révoqués à temps ou si les procédures ne sont pas respectées, même le meilleur équipement devient inefficace.

9. Qui accède à quelle zone, quand et pourquoi ? Une sécurité centralisée pour une traçabilité sans faille

Les systèmes numériques actuels permettent d'assigner des droits d'accès précis : à une personne, pour une serrure donnée, pendant une durée déterminée, avec révocation instantanée si besoin.

L'objectif est de faciliter l'échange d'informations entre les leaders d'opinion, les décideurs mondiaux sur l'approche de sécurité et de sûreté pour les transports nationaux et internationaux en tenant compte de tous les modes de transport.

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## Development of an Automated Reporting of Disused Sealed Source Movement System (RAM-FSD for its acronym in Spanish)

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RAM-FSD is a initiative of the Cendit Foundation to contribute to the improvement of national strategies for moving disused sealed radioactive sources. This project seeks reinforce the generation and management of reports on the transportation of disused radioactive material in the country, but also represents a step in digital transformation by promoting platforms developed using free software and open standards, aligning with the modernization and efficiency tech of the venezuelan State.

Currently the manual method for generating reports on moving is obsolete radioactive material, It is slow and prone to significant human error, compromising data integrity, traceability, and regulatory compliance. The absence of a centralized system increases these difficulties. The RAM-FSD system addresses these challenges through a web-based application that automates and standardizes report generation, improving efficiency and data quality.

The system's development was based on an iterative and incremental methodology, enabling the delivery of features in short cycles, early feedback, and easy adaptation to changes. Initial planning was based on "use case diagrams" to define the functional requirements.

Methodology and Development:

The system was developed using an iterative and incremental methodology, using use case diagrams for functional planning. Its architecture was base on the Model-View-Controller (MVC) pattern with the PHP CodeIgniter 4 framework, which allowed for modular and organized development.

Templates: These manage interaction with the database. A notable feature is that the data from a completed report is copied to the `_finalized` tables to preserve its integrity against future modifications.

Views: 24 responsive views were created using Bootstrap 5.3.3 and DataTables.js for user-friendly and efficient data management. The use of modals improves the user experience when managing forms.

Controllers: Seven main controllers handle client requests, ranging from authentication (Login.php) to transfer management (Transfer.php) and a recycle bin (Trash.php).

Innovative features.

- **User Management:** The system assigns specific permissions to control access to different views and features.
- **CRUD Modules:** Comprehensive functionality has been implemented to Create, Read, Update, and Delete (CRUD) key entities such as institutions, personnel, vehicles, and others.
- **Recycle Bin Function:** Records are not permanently deleted, but rather marked as inactive, with the option to restore or permanently delete them from a specific controller.
- **PDF Report Generation:** Before generating a PDF report, the system validates that all required fields are complete and marks the transfer as "complete" to prevent alterations.
- **Configurable Numeric Control:** Allows you to customize the format of the report control number, defining the date order, numbering, and an acronym.

The RAM-FSD project successfully culminated in a robust web application that automates the generation of reports for the transportation of radioactive material. The implementation of validated forms and a relational database has significantly increased the reliability and accuracy of the information. Beyond optimizing document management, this system is a clear example of digital transformation applied to a strategic and highly sensitive sector in Venezuela. It represents a tangible advance

toward the modernization of public administration, contributing to more efficient and secure management of critical processes and strengthening the country's technological sovereignty.

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## **The Cuban Experience in Managing the Interface between Nuclear Safety, Radiation Protection, and Nuclear Physical Security in the Transportation of Radioactive Materials**

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Presentation title:

The Cuban Experience in Managing the Interface between Nuclear Safety, Radiation Protection, and Nuclear Physical Security in the Transportation of Radioactive Materials

Objective of the presentation:

To present the national practice, challenges, achievements and lessons learned in Cuba regarding the coordination between the disciplines of nuclear safety , radiological protection ( radiation protection ) and nuclear security during the transportation of radioactive materials , in compliance with international IAEA standards.

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## **Advancing Vulnerability Assessment for Nuclear Material Transport Security**

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The protection of nuclear material in transport against acts of sabotage is a fundamental element of a State's nuclear security regime. Ensuring that such transports are adequately protected against credible threats is essential to prevent unacceptable radiological consequences resulting from sabotage.

International guidance, as set out in the IAEA Nuclear Security Series, emphasises the importance of taking a graded approach to transport security based on the potential consequences of sabotage and informed by the Design Basis Threat. Vulnerability assessments are therefore pivotal in determining whether existing protective measures are sufficient, or whether additional security measures are required.

In Germany, approximately 400 transports of nuclear material are conducted annually. These transports are categorized not only with respect to the risk of unauthorized removal, as set forth in the CPPNM, but also with respect to sabotage. The latter requires a comprehensive vulnerability assessment that considers the potential release of radioactive material and the resulting radiological consequences. Such assessments rely on analytical and numerical models, supported by an evolving experimental basis. Recent research undertaken by the Gesellschaft für Anlagen- und Reaktorsicherheit (GRS) gGmbH and funded by the Federal Ministry for the Environment, Climate Action, Nature Conservation and Nuclear Safety (BMUKN) aims to strengthen this capability by providing new experimental data and simulation tools.

The research addresses the internal processes that occur within a transport package during an attack with advanced weapon systems, particularly shaped charges. Key phenomena in such scenarios include the generation of overpressure inside the transport package, material fragmentation leading to particle production, and the ejection of particle-laden gas jets through penetration caused by impact. Although the fundamental physics of gas dynamics and particle dispersion are well documented, their direct application to the highly transient and complex processes relevant in this context is limited. The specific conditions arising from shaped charge impacts and subsequent release mechanisms are too dynamic and complex to be captured by established models alone. This complexity highlights the need for experimental research to establish a reliable empirical basis for application-oriented modelling. Within its research programme, GRS has therefore conducted dedicated experiments on pressure evolution in transport packages subjected to shaped charge impacts, complemented by studies of the transient two-phase free jets resulting from overpressure-driven release. These experiments, together with associated numerical simulations, provide essential insights into the dynamics of such events and contribute to the development of validated models that can be applied in vulnerability assessments of nuclear transports.

The findings support the ongoing enhancement of vulnerability assessments for nuclear transport. They provide a robust experimental basis and flexible simulation capabilities for evaluating sabotage scenarios, in line with IAEA recommendations in NSS No. 13 and NSS No. 26-G. The results show that such an approach significantly improves the accuracy and reliability of vulnerability assessments, supporting informed decision-making on security measures.

This research directly advances the objective of strengthening nuclear security in transport by reinforcing the methodological and technical basis for vulnerability assessments. It helps to ensure that nuclear material is protected in a way that reflects the potential consequences of sabotage, thus improving the resilience of national nuclear security regimes.

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## **SOME REGULATORY AND PRACTICAL ASPECTS OF SAFETY AND SECURITY INTERFACES AT RADIOACTIVE MATERIAL TRANSPORT**

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The report notes that despite the record of safety and security in transport of radioactive materials (RM) in Russia and other countries, ones of the most pressing issues of improving the regulatory system and implementing the regulatory requirements in practice of transport of RM are issues of interfacing of safety and security.

Effective interfacing requires consideration of some general aspects and specific safety and security requirements, their justifications and comparisons, an assessment of the possibility of eliminating or at least mitigating inconsistencies in approaches and specific requirements. The report examines some such issues, the resolution of which would mitigate difficulties of simultaneously meeting safety and security requirements, namely: - inconsistency of boundaries of activity thresholds for safety and security

(A1/A2 thresholds and other safety thresholds include an upper limit, while thresholds of radioactive source (RS) categories in IAEA D system do not include upper limits); - issue of possible rounding of D values in order to establish the same threshold values for some radionuclides of RS category 2 (10D) and A1 values when these values are close (in particular, for Co-60, Co-57, Se-75, Ir-192, Cs-137, I-131, Cf-252, etc.), and on the other hand, consideration of justification for significant differences in such values for other radionuclides; - justification for extending D-system for RS to the radioactive contents of

transport packages containing the same radionuclides in a different form (various concentration, for example, in the form of LSA) in the modal rules, and, on the other hand, justification for activity threshold 3000A2 in the modal rules (i.e. thousands of times higher) for radionuclides not included in the D-system for RS; - absence in justifications for security requirements of taking into account

practical limitation of activity release from packages in the event of accidents, including, obviously, accidents associated with violation of security (sabotage) at transport, where even in the event of package destruction in practice releases from packages are not all, but only about 10<sup>-2</sup>-10<sup>-3</sup> part of radioactive contents of packages; - significant difference in the volume of IAEA requirements for the security

of non-nuclear RMs compared to requirements of the modal rules, virtual absence of a connection between IAEA approaches to the security of RM and of international documents for other dangerous goods;

- absence in IAEA fundamental security principles of optimization principle (ALARA) and of probabilistic approach to assessing security violations and their consequences, and on the other hand, the presence in UN Recommendations of a reference to the mass socio-economic disruption at a terrorist event, especially for class 7 goods; - provisions of IAEA documents on practical absence of dangerous contamination of public water sources in the event of a security violation, including RS categories 1 and 2 with a high degree of solubility of radioactive substances, and on the other hand, strict restrictions on activity of LSA and SCO transported by inland water transport in accordance with safety regulations; - in contrast to IAEA safety regulations, international security system does

not have uniform requirements for permits from competent authorities confirming compliance with security requirements.

The authors believe it would be appropriate, within the framework of IAEA activity, to form a joint working group of safety and security specialists to examine the above and other inconsistencies with the aim of interfacing safety and security at transport of RM.

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## Ten Years of Excellence in the Logistical Management of Safe and Secure Transport of Radioactive Materials in Brazil: The Experience of Medical ALD.

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Over the past decade, Medical ALD (Medical Storage, Logistics and Distribution Ltda.) has consolidated an innovative logistical management model in Brazil, becoming a reference in the distribution of radiopharmaceuticals, sealed sources, and calibration standards. This paper presents the company's 10-year experience, highlighting strategies in operations, infrastructure, compliance, and innovation, aligned with IAEA regulations (SSR-6) for the safe transport of radioactive materials and related guides.

Since 2015, Medical ALD has been building a robust operation, supported by a multidisciplinary team of approximately 90 professionals, including physicists, pharmacists, logistics specialists and drivers. The company holds ISO 9001:2015 certification, adopts ESG practices, and follows TRAM best practices recognized by CNEN (Brazilian Nuclear Competent Authority), ensuring excellence and regulatory compliance across all processes. Its fleet consists of 50 certified vehicles, covering more than 220,000 km per month to serve 39% of the Brazilian nuclear medicine market, which includes approximately 500 clinics. Over the course of a decade, the company has performed more than 210,000 transport operations dedicated to clinics, ensuring the timely delivery of radiopharmaceuticals and contributing to the continuity of clinical services throughout the country, and was awarded an honorable mention in the 2024 "Highlight Award" of the Brazilian National Land Transport Agency (ANTT). Due to Brazil's vast continental size, the air transport of radiopharmaceuticals is a necessity. With this in mind, Medical has adopted an innovative and unprecedented strategy in the country. One of Medical ALD's key strategic differentiators is its exclusive franchise with a national airline, ensuring virtually zero denials or delays in the acceptance of radioactive shipments. This innovative mechanism guarantees reliable distribution of short half-life radiopharmaceuticals such as technetium-99m generators and fluorodeoxyglucose (FDG), securing uninterrupted access to essential therapies and diagnostics. The company also holds licensing and authorization for international logistics, covering MERCOSUL countries, which provides strategic alternatives for supply continuity during crises or restrictions in domestic radiopharmaceutical availability. All of these transports are carried out in compliance with the regulations of the competent air transport authority, whose national regulations reflect the ICAO and IATA publications. In terms of radiation protection, more than 64 trained drivers operate under strict protocols, with an annual average effective dose of 2.8 mSv/year, reflecting the company's commitment to occupational health and compliance with international radiation safety standards. Medical ALD also promotes continuous training, capacity building, and professional development, cultivating a strong and sustainable safety culture. The involvement of young professionals and gender diversity further align the company with the IAEA's objectives on workforce development and inclusion. The transport operations integrate the interface between safety and security, with complete traceability, secure communication channels, and contingency planning for emergencies, thereby minimizing both accidental and malicious risks. This integrated approach strengthens confidence among competent authorities, healthcare institutions, and end-users. Currently, the company faces strategic challenges related to the international logistics of theranostic radiopharmaceuticals, the management of the radioisotope supply chain, and the provision of standards sources for nuclear medicine, which drive continuous innovation and operational planning to maintain excellence in an increasingly complex global regulatory environment. The outcomes of this consolidated experience demonstrate that a structured, long-term logistics management model for the transport of radioactive materials can reduce systemic vulnerabilities, ensure timely access to nuclear medicine services, strengthen national capabilities, and serve as a replicable model for other Member States. The combination of regulatory compliance, infrastructure investment, strategic airline franchise, workforce training, and the integration of safety and security constitutes an efficient model, balancing protection, reliability, and innovation. In conclusion, Medical ALD's ten years of operation demonstrate that a private operator can make a significant contribution to safety, security, and efficiency in the transport of radioactive materials.

**Country or International Organization:**

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## **A Numerical Framework for Calculating Fuel Damage Ratio in Horizontal Drop Accidents of SNF Transport Packages**

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To assess the risks associated with spent nuclear fuel (SNF) transportation, it is essential to calculate the fuel damage ratio (FDR) of SNF rods loaded in transport casks. Owing to the geometric and material complexity of SNF, modeling the detailed behavior of every fuel rod and assembly within a single cask is impractical. This study therefore proposes a systematic methodology for calculating the FDR using simplified representations of nuclear fuel rods and assemblies optimized for failure analysis.

Three primary failure modes of SNF rods have been reported in the literature: (i) transverse tearing under bending (mode I), (ii) transverse tearing induced by bending and defects (mode II), and (iii) longitudinal tearing due to pinch loads and defects (mode III). The present work develops a numerical methodology that addresses all three modes, incorporating reported or suggested failure criteria for each. Particular emphasis is placed on evaluating mode III failure under pinch loading.

First, a simplified fuel rod model was developed to reproduce failure behavior using through-thickness membrane plus bending stresses of the cladding as the failure criterion. The rod was modeled as a hollow beam of identical diameter to the actual fuel rod, with material properties and cross-sectional characteristics calibrated to reproduce the moment–deflection response of a detailed rod model. A stress correction factor was introduced to account for stress concentrations arising from pellet–clad interaction (PCI).

Second, a detailed model of a CE 16×16 fuel assembly was constructed using the simplified fuel rod model. This assembly was subsequently reduced to cuboid representations with identical external dimensions. The equivalent material properties of these cuboids, corresponding to fuel rod and spacer grid sections, were derived from compression, shear, and torsion analyses of the detailed model. The validity of the simplified assembly was confirmed by comparing key structural responses, such as impact accelerations, against those of the detailed model under drop conditions.

A post-processing script was then developed to extract maximum contact forces on individual fuel rods during impact events, thereby determining pinch loads. These loads were compared with a provisional pinch load failure criterion for FDR evaluation. Since the criterion for fuel rod failure under pinch loads remains under investigation, a new numerical approach is presented that derives this criterion from image-based finite element modeling with continuum damage mechanics. This approach enables explicit assessment of the influence of hydrides within SNF cladding on fracture resistance, and in particular, facilitates the evaluation of uncertainties arising from hydride morphology.

Fuel rod failure due to bending loads was evaluated based on calculated stress values from beam elements, which were compared against the membrane plus bending stress failure criterion to determine the FDR.

This methodology provides an efficient and reliable approach for assessing SNF rod failure in transportation scenarios, reducing computational complexity while maintaining accuracy in structural response predictions.

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## Harmonization of Transport Regulations for Class 7 Dangerous Goods in Thailand

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Thailand has undertaken efforts to harmonize its national regulations governing the transport of radioactive materials (Class 7 Dangerous Goods) with international standards, particularly those of the International Atomic Energy Agency (IAEA) and the European Agreement concerning the International Carriage of Dangerous Goods by Road (ADR). These efforts are led by the Office of Atoms for Peace (OAP) and the Department of Land Transport (DLT), following the enactment of the Nuclear Energy for Peace Act in 2016.

This paper outlines the recent development and implementation of transport safety and security regulations, including the application of security recommendations from the IAEA Nuclear Security Series: Security of Radioactive Material in Transport, as well as the integration of ADR under ASEAN Protocol 9. It also highlights the role of stakeholder engagement, regional cooperation, and capacity-building activities supported by international partners.

Current challenges in the regulatory framework, such as outdated regulations and limited inter-agency coordination, are addressed.

Finally, the paper discusses strategies including the deployment of the DG-TSA system and the regulatory activities to enhance emergency preparedness and shipment tracking. These initiatives aim to strengthen Thailand's transport safety and security infrastructure for radioactive materials in alignment with global best practices.

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## Human Factors in the Secure Transport of Emerging Nuclear Technologies

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The global nuclear sector is experiencing a wave of innovation driven by the development of emerging technologies such as advanced small modular reactors (SMRs), microreactors, floating nuclear power plants (FNPPs), many of them using novel fuels such as high-assay low-enriched uranium (HALEU) or TRI-structural ISO-tropic fuel (TRISO), and autonomous and AI-driven systems for transport and logistics. These advancements offer potential for more flexible and distributed nuclear power deployment, but they also present new challenges for the secure transport of nuclear and other radioactive material.

As novel fuels and transportable reactor units are designed for greater mobility and wider geographic reach, security requirements must adapt to account for previously unconsidered operational, technological, and human vulnerabilities. These include, e.g., increased transport of sensitive material across international boundaries and waters, new modes of conveyance with embedded digital control systems, and more frequent interaction between public-private operators in diverse security environments.

The increased complexity of multi-modal and international transport operations, often involving temporary personnel and subcontractors, heightens the risk of insider compromise. Furthermore,

emerging technologies themselves (e.g., AI-enabled tracking, mobile reactor controls, integrated sensors) create new digital dependencies that could be exploited by adversaries, including insiders with privileged access.

While much attention is given to the technical security measures necessary for these innovations, this paper argues that secure transport planning must also integrate human-factor considerations, such as personnel trustworthiness, human reliability, and nuclear security culture. Specifically, regulations should require assessments and improvements of nuclear security culture, procedures to ensure personnel and contractor trustworthiness and to detect behavioral anomalies, and training programs tailored to the unique operational realities of emerging nuclear technologies. Design Basis Threat (DBT) development must also be updated to reflect insider risks associated with digitally augmented transport systems.

The paper will propose practical steps for regulators and other competent authorities to include the incorporation of insider threat scenarios into licensing and certification of transporting novel reactors and fuels; cultural maturity assessments for operators involved in emerging technology transport chains; and international cooperation to harmonize expectations, particularly in regions where digital infrastructure or personnel reliability frameworks are underdeveloped.

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## Challenges with Transport Security Regulation Development in Ghana

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The secure transport of nuclear and other radioactive material is a critical component of a State's nuclear security regime. Preventing theft, sabotage, or unauthorized removal during road, air, and maritime shipments requires a systematic and coordinated approach involving multiple stakeholders, including regulatory authorities, operators, law enforcement, and customs agencies. Ghana's Nuclear Regulatory Authority (NRA) is in the process of developing comprehensive transport security regulations for nuclear and other radioactive material, drawing on International Atomic Energy Agency (IAEA) Nuclear Security Series (NSS) guidance —particularly NSS No. 9, NSS No. 14, and NSS No. 26-G—as well as relevant international best practices. This paper outlines Ghana's regulatory development process, highlighting the technical, legal, and resource-related challenges encountered, and presents lessons learned from stakeholder engagement and international cooperation. The adoption of a graded approach and defence-in-depth principles in developing transport security regulation is emphasized, alongside the integration of law enforcement response and route security measures.

**Country or International Organization:**

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## Effective Collaboration and Challenges among Key Stakeholders in the Safe and Secure Transportation of Radioactive Materials in Ghana

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The successful transportation of radioactive materials from the port of entry to the end users and vice versa is a highly regulated and technical process which involves key stakeholders to ensure safety and security. This paper is aimed at highlighting how the presence of effective collaboration among key stakeholders has aided the transportation of radioactive materials, the challenges encountered and the way forward. The key stakeholders include the Nuclear Regulatory Authority, Licensed Carriers, Consignees, the Radioactive Waste Management Centre (RWMC), the Police Service, Fire Service and other emergency service providers. These stakeholders have worked collaboratively in ensuring the safe and secured transportation of all radioactive materials in Ghana. Two transport and logistics companies with varying carrying capacities have been licensed by the Regulator for inland transport of radioactive materials. The end user applies to the Regulator for the relevant authorization and permit to import, export and use radioactive material and upon meeting the stringent regulatory requirements based on the category of the radioactive material involved the permit is then issued. The end user then contacts a licensed carrier and the RWMC depending on where the material will be stored. The RWMC plays an important role in the provision of radiation safety assessment, decommissioning, uninstallation of mounted radioactive devices, storage and permanent management of decommissioned radioactive materials or devices. A graded approach is used in the provision of security during and after the transport process. For category 1 and 2 radioactive materials, a police escort with all the necessary emergency protocols are deployed. A briefing session is normally held before commencement of operations and prior to the movement of the packaged material in the special purpose transport vehicle with relevant radiation protection protocols fully in place. The effective collaboration among key stakeholders has been demonstrated on a number of occasions as shown in the Figures below during the transport of category 1 and 2 sources.

Fig. 1: Operational briefing session for all stakeholders during the retrieval and transportation of category 2 disused source from a Gamma Scanning Facility at Tema Harbour, Ghana

Fig. 2: Emergency Fire service on standby during the retrieval and transportation of category 2 disused source from a Gamma Scanning Facility at Tema Harbour, Ghana

Fig. 3: Fork lifting of Co-60 device into transport packaging (a); transporting source in Type B(U) transport package (b)

Fig. 4: Police escort transport of Category 2 disused Co-60 device from Tema Harbour to GAEC, Kwabena

Fig. 5: Receipt and removal of disused Cat. 2 Co-60 teletherapy source package from the transport vehicle to the Radioactive Waste Management Facility at GAEC, Kwabena for temporary storage

Although stakeholder collaboration in the transport of radioactive materials has been very effective in Ghana, a major challenge entails delays in contracting a flight carrier for the transport of disused radioactive materials for refilling for NDT applications. Secondly, the high fees and charges by the carriers, licensed transport and logistics companies to transport these class 7 hazardous materials imposes significant financial responsibility on the end user leading to delayed operations. The provision of a special purpose transport vehicle for radioactive material to RWMC via donor support will help reduce the cost of transportation drastically. Finally, the timeframe for obtaining the requisite authorization and permits from the competent authority can be frustrating especially if it affects

the arrangement with the carriers particularly by flight. However, these challenges are been addressed to guarantee the provision of safe, secure and sustainable transport of radioactive materials in Ghana.

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## **Renforcer la sûreté, la sécurité et la résilience dans le transport des matières nucléaires et radioactives : perspectives réglementaires, industrielles et technologiques**

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Le transport des matières nucléaires et radioactives constitue un maillon stratégique du cycle nucléaire et représente un enjeu majeur en matière de sûreté, de sécurité et de confiance publique. Alors que les flux mondiaux de matières sensibles s'intensifient pour des usages médicaux, industriels et énergétiques, la communauté internationale doit relever le défi d'assurer un cadre cohérent, résilient et adapté aux risques émergents. Ce synopsis propose une réflexion intégrée sur l'évolution des approches réglementaires, industrielles et technologiques visant à renforcer la sécurité du transport de ces matières, en s'appuyant sur des expériences pratiques, des normes existantes et les perspectives d'innovation.

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## **Development of a geolocation web service during the transport of DSRs to the long-term storage**

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<sup>3</sup> *Development of an Automated Reporting of Disused Sealed Source Movement System (RAM-FSD for its acronym in Spanish)*

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Nowadays, in the age of the digital transformation, the control and monitoring of assets has transcended, becoming a strategic dominant. Asset geolocation web services emerge as a cutting-edge solution that unifies satellite tracking technology with a robust and scalable software architecture.

This work details the structure and key components of a platform designed and developed for software engineers from Fundacion Cedit to suit the requirements control during transport of DSRS to the long-term storage.

1. Software Architecture.

The core of this implementation lies in its software architecture, designed to guarantee performance, security and adaptability. The platform is based on a web server with a public IP address, acting as the central brain that processes and distributes information.

Interaction with the user is through a dynamic and responsive user interface. The HTML language provides the base structure of the pages, while Cascading Style Sheets (CSS) elevate the aesthetics and visual experience. Interactivity and user-side logic powered by JavaScript, a language that gives the application dynamism and responsiveness in real time. To streamline the design process and ensure an impeccable presentation on any device, a tool like Canva is integrated, guaranteeing a clean and adapted user interface.

2. Satellite Tracking and Geographic Visualization.

The web service has the ability to display the position of DSRS and the vehicles that transport them on an interactive map. To do this, a leading open source library such as Leaflet is used, optimized for real-time satellite tracking. The map module not only shows the location of assets, but also offers advanced filtering and search capabilities, allowing users to identify devices by their connection status (online, offline) or by their name.

The system receives and processes data from satellites in orbit, decoding the positioning information to obtain the precise location of each vehicle. This data is visually represented on the map through interactive markers, which update in real time as the vehicle moves using encryption protocols.

(a) Control and Management Modules.

Beyond simple tracking, the platform offers a set of management modules that transform data.

3. Reports Section: Allows data analysis, customization of reports and event summaries. It is an indispensable tool for optimizing routes, monitoring route efficiency and making strategic decisions based on historical performance. In this section, you can view reports customized with information by routes, trips, each monitored device, events (separated by date and time) with graphs and statistics.

- Settings Section: Offers control over system preferences. Users can configure crucial parameters such as time zones, language, and date format. In this section, you can configure notifications, user permissions, default zones or maps, tracking devices, drivers, calendars, maintenance and more.
- Account Section: Gives users the ability to manage profile of the users, change passwords, manage permissions for each profile of users and more.

This geolocation web service is not only a monitoring tool, but a comprehensive ecosystem that enables informed decision-making, operational optimization and proactive security of DSRS during their collection and transport to the long-term storage, driving efficiency in an increasingly dynamic environment which has already been field tested in the last two years and certified by the national regulatory authority.

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## **Transportation and Long-Term Storage Management of DSRS in the Bolivarian Republic of Venezuela**

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Starting in the second half of 2022, the Ministry of Science and Technology began receiving national powers regarding the peaceful and safe use of atomic energy policies, formally authorized by presidential decree, effective March 9, 2023.

Among the responsibilities received was addressing the DSRS reported by the IAEA in 2012 during

In the last quarter of 2022, the inspection, collection, transportation, and safe long-term storage

- Advisor from IAEA through expert missions.
- Drafting of a bill proposal to create a single regulatory authority for atomic energy and ionizing radiation.
- Development of the National Policy for the Management of DSRS, identifying the stakeholders.
- Inspection schedule for the sites identified in the 2012 IAEA report.
- Purchase of equipment, vehicles, and supplies through funds from the Ministry of Science and Technology.

The sources identified in the last three years of management are detailed below:

- Collection, transport, and safe storage of 170 Radium 226 sources related to the 2012 IAEA report.
- Collection, transport, and safe storage of 20 Cobalt 60 cobalt therapy equipment heads related to the 2012 IAEA report.
- Inspection, collection, transport, and safe storage of new sources of Cesium 137 found in public places.
- Inspection, collection, transport, and safe storage of additional sources (new findings) in public places.
- Inspection, collection, transportation and safe storage of sources (new findings) in public places.

Additionally, work is underway to build a new temporary warehouse for DSRS long-term storage, with funding of approximately USD 800,000 from the Ministry of Science and Technology.

In terms of training, the following has been achieved in the last three years:

- More than 400 people were trained in the country by the IAEA in radiation safety through Expert Missions.
- More than 1.227 people were trained in the country by national radiation safety specialists.

To manage the safe transport and storage of DSRS, it was necessary to develop national solutions:

- Construction of over-containers for Cobalt-60 head containers.
- Construction of racks to support the tons of weight of the Cobalt-60 heads.
- Placement of ID seals to identify DSRS containers.
- Development of software to inventory DSRSs during transport.
- Development of software for satellite tracking of DSRS containers and transport.

Above actions summarize the management of transportation and long-term storage in the Bolivarian Republic of Venezuela.

**Country or International Organization:**

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## Enhancing the Security and Traceability of Radioactive Material Transport for Well Logging Applications through QR Code and Geo-Tagging Integration

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Indonesia's Nuclear Energy Regulatory Agency (BAPETEN) currently utilizes the Bapeten Licensing and Inspection System Online (Balis Online), a web-based platform integrated with the Indonesia's Online Single Submission - Risk Based Approach (OSS-RBA), to manage the licensing of nuclear activities. This system includes the transport of radioactive materials, a frequent activity in various industries. The well logging sector was specifically selected as the focus for this project due to several key factors: a historically high level of compliance with licensing and reporting requirements, a more established radiation safety and security infrastructure, and the significant involvement of multinational corporations that adhere to stringent international standards. This sector is characterized by the high mobility of radioactive sources, which presents unique regulatory challenges. The current protocol requires operators to secure transport approval and submit periodic reports via Balis Online. While this system documents the initial and final locations, it lacks the capability for real-time tracking of radioactive sources during transit. This reliance on periodic reporting presents a significant gap in ensuring continuous traceability and security oversight.

To address this challenge, this paper proposes the integration of an end-to-end tracking system into the Balis Online platform, leveraging the synergistic capabilities of QR Code and Geo-tagging technologies. These technologies are proven to be robust, user-friendly, and cost-effective, with widespread successful implementation in the logistics sector. In the proposed framework, the QR Code serves as a unique digital identifier for each radioactive package, encoding critical information such as the radionuclide type, serial number, and activity. Simultaneously, Geo-tagging provides real-time location tracking by capturing precise GPS coordinates and timestamps at each scanning point.

The operational workflow begins when a transport permit is issued, at which point Balis Online generates a unique QR code that the licensee prints and affixes to the package. Authorized personnel then scan the QR code at the point of departure and at every subsequent key transit point (e.g., warehouses, ports, airports). Each scan transmits the location and time data to a centralized Monitoring Dashboard. Upon arrival at the final destination, a concluding scan updates the transport status to "completed." This automated process creates a verifiable and transparent digital ledger of the material's entire journey, offering a more valid and reliable oversight mechanism than traditional periodic reporting.

Fig. 1 Integrasi QR Code and Geo Tagging

The successful implementation of this system depends on four critical components: (1) an intuitive and integrated monitoring dashboard within Balis Online for efficiency; (2) a scalable and secure server infrastructure for data management; (3) comprehensive training for personnel on the new scanning protocols; and (4) robust data security, achieved through an authenticator application that restricts scanning privileges to authorized users with unique credentials. By adopting this technological solution, regulatory oversight becomes significantly more effective and efficient, substantially strengthening the safety and security framework for the transportation of radioactive materials.

**Country or International Organization:**

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The secure transport of radioactive sources requires a capable workforce that understands not only their own job role and responsibilities, but also the interfaces with other parties involved in a transport. The World Institute for Nuclear Security (WINS), in partnership with Thailand's Office of Atoms for Peace (OAP) and with the generous support of Global Affairs Canada's Weapons Threat Reduction Program, developed a two-part train-the-trainer curriculum to teach the technical skills required to support security in the transport of radioactive source and the instructional skills needed to facilitate other professionals to develop those technical skills.

Both courses were designed to be appropriate for all of the various professionals involved with the transportation of radioactive sources, from licensees and carriers to regulators and law enforcement. The representatives of different organisations were brought together in interactive, practical exercises designed to mutually build each other's understanding of the different roles and their perspectives throughout the transport process. The activities were also designed to guide the participants to understand the importance of security measures, the implications of the safety-security interface, and some of the dimensions of a transport security plan through the constructivist approach.

Supporting the instructional skills of regional professionals in tandem with the technical skills provides a sustainable model that multiplies the impact of the original training. The training materials were designed with a focus on the principles of andragogy and a participatory framework. This approach also provided the opportunity to exchange insights on customising training materials and exercises for further/future capacity building in line with the specific needs of each organisation. Participants completed increasingly complex exercises designed to scaffold the development of their instructional skills, presenting increasingly complex and tailored material.

Six months after the train-the-trainer event, WINS and OAP held an ASEAN regional technical training with the support of participants from the original course. The technical course also focused on active learning with small groups of participants from different backgrounds (both national and professional) working together on projects to apply the skills taught in the course. These exercises were also designed to help them develop appropriate attitudes toward the secure transport of radioactive sources through real-world case studies demonstrating that the threat is real and the real impact that security planning and preparation can have in preventing, detecting and responding to incidents.

The training also incorporated regional guidelines and practices, contributing to a deeper understanding of regional transport security challenges, promoting harmonisation of standards and practices within Southeast Asia and highlighting the importance of a robust security culture. Facilitating this exchange provided an excellent opportunity for sharing the country status of the transport security framework and practical experience within the region.

Both the train-the-trainer and technical courses saw strong results on the intended learning outcomes based on the gains immediately before and after the training. WINS and OAP are following up six months after the initial trainings to measure how well the participants have retained and are implementing the intended outcomes. Their self-assessments will be enhanced with qualitative responses from colleagues positioned to observe the knowledge, skills and attitudes of the participants in their workplaces. To measure the continuing impact of the training, participants are asked how they are sharing the content of the training courses more widely. Additional analysis by gender offers insight into the impact of training on women in the nuclear/radioactive source security field.

This approach to innovative capacity building and regional collaboration in the ASEAN region can provide a model for promoting a sustainable approach to competence and capacity in order to meet the challenges of evolving threats and risks both within this region and beyond.

**Country or International Organization:**

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## Strengthening Ghana's Regulatory Framework for Safe and Secure Radioactive Material Transport: Challenges and Prospects

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The safe and secure transport of radioactive materials is a crucial requirement for protecting human health, the environment, and national security. It is also vital for sustaining public trust in the peaceful applications of nuclear science and technology. In Ghana, where radioactive sources are widely used in medicine, industry, research, and agriculture, the development and enforcement of a robust legislative and regulatory framework for transport has become increasingly important.

Ghana's framework is grounded in international conventions and standards, particularly the International Atomic Energy Agency's (IAEA) Regulations for the Safe Transport of Radioactive Material (SSR-6, Rev. 1). These requirements are harmonized with those of other global bodies such as the International Maritime Organization (IMO) and the International Civil Aviation Organization (ICAO). At the national level, the Nuclear Regulatory Authority Act, 2015 (Act 895) provides the legal basis for regulating the transport of radioactive materials. Complementary instruments and guidelines empower the Nuclear Regulatory Authority (NRA) to authorize, inspect, and enforce compliance among institutions and individuals involved in transport activities.

The regulatory framework requires authorization prior to transport, strict adherence to packaging and labelling standards, and contingency planning for potential accidents. Package integrity and classification remain central to safety, ensuring containment, shielding, and heat dissipation under both normal and accident conditions. For higher-risk consignments, the framework mandates additional security provisions, including route planning, physical protection, real-time tracking, and coordination with security agencies to prevent theft, diversion, or sabotage.

Institutionally, the Ghana Atomic Energy Commission (GAEC) supports implementation through technical expertise, training, and collaboration with law enforcement, customs, and border control agencies. This integrated approach strengthens national capacity to oversee the safe and secure movement of radioactive materials while also aligning with international nuclear security initiatives.

However, challenges remain in the practical application of the framework. Limitations in specialized infrastructure, gaps in technical capacity, and the need for greater inter-agency coordination can hinder effective implementation. Public awareness of radioactive material transport is also limited, raising the risk of misinformation or resistance during emergency scenarios. Regionally, disparities in regulatory development among neighbouring countries complicate cross-border transport and emergency preparedness.

Despite these challenges, significant opportunities exist to enhance Ghana's framework. These include increased investment in modern transport infrastructure, expansion of training programs for regulators and operators, and the adoption of digital technologies for monitoring and tracking consignments. Regional cooperation under the auspices of the African Regional Cooperative Agreement for Research, Development and Training related to Nuclear Science and Technology (AFRA) and other IAEA-led initiatives could further harmonize standards and strengthen emergency response mechanisms.

In conclusion, Ghana has established a strong legislative and regulatory foundation for the safe and secure transport of radioactive materials, reflecting both international best practice and national priorities. Yet, as the country expands its nuclear applications and prepares for a potential nuclear power program, sustained efforts to address existing challenges will be critical. By investing in capacity building, infrastructure, and international collaboration, Ghana can further strengthen its transport regulatory framework, ensuring that safety and security remain at the core of its nuclear technology agenda.

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## Next Generation Pathways for Safe and Secure Transport of Nuclear and Radioactive Material Integrating Digitalization, Resilience and Supply Chain Innovation

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The safe and secure transportation of nuclear and other radioactive material is a component of international nuclear safety and security, essential to protecting people, society, and the environment while enabling the numerous benefits of nuclear science and technology. Ranging from applications like medical isotopes and industrial sources, power generation, and research, international transport of radioactive material is a cornerstone of modern society. At the same time, the global transport outlook is becoming increasingly complex, powered by increasing demand, multimodal logistics, diverse and interconnected supply chains, and evolving safety and security requirements. These dynamics, coupled with emerging technology, regulatory, and environmental concerns, make the case for next-generation approaches that go beyond mere compliance, focusing instead on resilience, adaptability, and international collaboration.

This article discusses new possibilities for developing national and international transport systems by introducing high technologies, improved safety and security levels, and effective regulatory systems. Digitalization offers unprecedented opportunities to enhance transparency, monitoring, and risk assessment in all modes of transport. Real-time monitoring, blockchain-based paperwork, digital twins, and artificial intelligence-based predictive analytics are the technologies that can provide operators, regulators, and global stakeholders with enhanced situational awareness, improved decision-making, and rapid response options in case of deviation or accident. In addition to such technological reactions, sound package design, rigorous testing, and proactive maintenance programs remain at the foundation of the physical integrity of highly radioactive material during transportation.

Equally important is the harmonization of regulatory and legal frameworks, both nationally and internationally. Mutual recognition of regulatory approvals, harmonized emergency preparedness procedures, and coordinated response arrangements are necessary for sustaining trust among States and continuity of operations under normal and exceptional conditions. Strengthening such frameworks not only improves operational safety and security but also facilitates freer cross-border transport, in support of the efficient supply of nuclear materials for peaceful purposes.

The paper further emphasizes the central importance of capacity building, stakeholder coordination, and knowledge sharing. The development of technical capacity for regulators, operators, carriers, and law enforcement officials, along with engaging local communities and international organizations, is fundamental to fostering a culture of safety, security, and shared responsibility. Exercises, training sessions, and workshops enhance preparedness and resilience while developing a common appreciation of risks and protection practices.

In addition to safety and security considerations, it is increasingly important to introduce principles of sustainability into transport activities. This includes reducing environmental impacts through routing optimization, energy-efficient logistics, and green transport technologies. Advances in recyclable or reusable packaging, improved fuel efficiency, and careful planning of multimodal operations have the potential to reduce the carbon footprint of radioactive material transport to a much lower level without compromising the highest standards of safety and security. Securing that these practices are compatible with global sustainable development goals ensures that nuclear transport operations satisfy not just current needs but also more extended-term societal expectations.

By encouraging a culture of trust, openness, and collaboration, this paper gives a comprehensive framework for keeping the transport of nuclear and radioactive material safe, secure, sustainable, and internationally coordinated. The next-generation strategies outlined here involve the integration of technology, resilience, regulatory harmonization, capacity building, and sustainability to address existing as well as new challenges. Last but not least, this document reaffirms the shared commitment of the international community in protecting human health, preserving the environment, and strengthening confidence in the peaceful and responsible use of nuclear technology for current and future generations.

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## **Current State and Prospects for the Improvement of the Russian Regulations on the Safe Transport of Radioactive Materials**

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The Russian regulatory framework establishing requirements for the safe transport of radioactive material is constantly being improved. One of the most important directions for improving the national regulatory documents is their harmonization with the IAEA Safety Standards reflecting the current state of international experience in ensuring of the safe transport of radioactive materials. The Russian regulatory body (Rostekhnadzor) with the involvement of its technical and scientific support organization (SEC NRS) also develops and approves requirements based on the gained national experience of regulating and ensuring the safety of activities which are not covered by existing IAEA documents. In particular Federal rules and regulations have been developed to establish safety requirements for the on-site transport of radioactive materials. In addition, recommendations for the structure and content of lifetime management program for containers used for storage and transportation of radioactive material have been developed to facilitate compliance with existing requirements for ageing management of containers.

The report provides an overview of the current state and plans for improvement of the Russian regulatory documents on the safe transport of radioactive materials.

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## **Methodological Support of Tests of Transport Containers**

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In the Russian Federation, both operational and under construction nuclear power plants are implementing fuel assemblies with an increased mass of nuclear fuel and a design burnout depth, as well as nuclear fuel containing regenerated nuclear materials. In addition, new types of reactor installations are being built, which are also planned to use new types of nuclear fuel.

Deep-burnt highly enriched spent nuclear fuel and prospective fuel have increased radiation characteristics and residual heat generation, which give rise to certain difficulties when transporting it to centralized handling facilities for further storage or processing.

To ensure the safety of handling the above-mentioned spent nuclear fuel, some work on the development and implementation of containers used for the transportation and storage of spent nuclear fuel is currently underway. The compatibility of transport containers sets with the requirements of Federal norms and regulations in the field of atomic energy use is confirmed by carrying out estimates and tests of transport packaging sets for various mechanical and thermal effects that may occur during storage and transportation of spent nuclear fuel.

SEC NRS, as the scientific and technical support organization of the regulatory body (Rostekhnadzor), provides methodological support for conducting these tests from the preparation stage to the stage of confirming the compliance of transport containers with the requirements of Federal norms and regulations in the field of atomic energy use.

The report presents the experience of SEC NRS providing scientific and technical support to Rostekhnadzor in terms of methodological support for testing transport containers.

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## **Africa's Nuclear Regulatory Approaches for Handling and Transporting Radioactive Materials NORM/TENORM**

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The International Atomic Energy Agency (IAEA) estimates that approximately 20 million shipments of radioactive materials are transported annually worldwide for peaceful purposes across diverse sectors. This extensive utilization of nuclear technologies enables countries to advance their economies, strengthen societal resilience, and contribute to climate change mitigation. Ensuring the safe and secure transportation of radioactive materials is therefore fundamental to achieving global sustainable development objectives. The transportation of these materials including naturally occurring radioactive materials (NORM/TENORM) and medical isotopes raises significant safety and security concerns, particularly within the African continent, where recurrent conflicts, fragile peace, and uneven regulatory capacity compound existing risks. The main objective of this study is to critically assess the status and effectiveness of radioactive material transportation systems across selected African countries, with particular emphasis on the alignment of national policies with IAEA safety standards. It seeks to identify regulatory gaps, evaluate cross-border coordination mechanisms, and provide evidence-based recommendations for enhancing safety and security frameworks. This is not limited to a single case study; instead, it draws on comparative analyses across multiple African states, thereby offering a broader regional perspective. A comprehensive mixed-methods approach was adopted. First, regulatory frameworks were systematically analyzed to examine the degree of harmonization with international standards. Second, structured interview was conducted with international shipping company and regulatory officials to capture operational challenges and best practices. Third, stakeholder surveys targeting transport operators, regulators, and end-users were used to document local experiences and perceptions. Preliminary findings indicate wide disparities in implementation levels: while some countries have established robust systems, others lack essential legal instruments, trained personnel, and emergency preparedness capabilities. Moreover, cross-border coordination remains weak, highlighting the urgent need for harmonized policies, joint response strategies, and sustained inter-agency collaboration. This study is currently underway, with preliminary findings presented here to underscore key areas of concern. The results to date

strongly suggest that advancing nuclear transport safety in Africa requires integrated policy frameworks, capacity-building initiatives, and investment in infrastructure for monitoring and detection. Establishing tailored, enforceable legislation coupled with strengthened awareness and training will be vital for ensuring the safe, secure, and sustainable transportation of radioactive materials across the continent.

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## **A Canadian Experience in Updating Legacy Radioactive Material Transportation Spent Nuclear Fuel Type B Packaging with Current Regulations**

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Canada's nuclear sector has a long-standing history of transporting radioactive material. As the regulations have evolved, so has the design of the packaging used to perform the transportation. The Canadian Nuclear Safety Commission (CNSC) current requirements for the transportation of radioactive material are detailed in the Packaging and Transportation of Nuclear Substances Regulations 2015 which follows the IAEA Regulations for the Safe Transport of Radioactive Material, as amended from time to time.

Canadian Nuclear Laboratories (CNL) is Canada's premier nuclear science and technology organization. Our scientific expertise helps solve some of the world's biggest problems. This includes a large selection of packaging for the transportation of nuclear substances. This large selection of packaging has evolved as the regulations have evolved to meet our needs.

This paper presents a detailed case study of the Canadian experience in updating legacy Type B(U) packaging for radioactive materials including spent nuclear fuel, highlighting both the technical and regulatory pathways employed. The effort, led collaboratively by the Canadian Nuclear Laboratories, with technical service providers, and willing regulatory bodies open to discussion encompassed key activities such as leak testing, structural and thermal performance reassessment, material aging analysis, application of updated shielding and containment methodologies, and enhanced security considerations.

The paper outlines the challenges encountered in bridging the design and testing expectations of historical packages with modern regulatory criteria, and describes solutions developed to extend the service life of these packages while maintaining compliance with IAEA SSR-6 Rev. 1 requirements. Special attention is given to the use of engineering justifications, graded approaches to safety demonstration, and regulatory engagement strategies that facilitated efficient certification and continued safe operation.

CDN 2048 B(U)F AECL F-257 1973 Slowpoke

In 2018, CNL prepared an addendum intended to be used in conjunction with the original evaluation of the AECL-CP Shipping Package F-257 from 1986. The safety analysis report only had approval for Highly Enriched Uranium SLOWPOKE-2 cores. The new addendum demonstrates the use of the F-257 radioactive material transportation packaging for shipment of SLOWPOKE-2 LEU spent fuel core and supplements the existing safety analysis for the spent HEU fuel core.

The original safety analysis report demonstrated that the packaging met the requirements of the IAEA "Regulations for Safe Transport of Radioactive Materials," Safety Series 6, 1973 Revised Edition (as amended).

This addendum provided updates to meet the PTNSR, 2015 and IAEA 2012 Edition SSR-6. Package approved contents now include the spent HEU and LEU cores from the SLOWPOKE-2 reactors.

During the preparation of the addendum, CNL performed a detailed physical review of the packaging and performed repairs to the outer heat shielded and returned it to within the specifications.

CDN 2061 B(U)F-85 AECL IMT

AECL began the process to update of the IMT packaging in 2012 to meet the latest regulations. The

original safety analysis report demonstrated that the packaging met the requirements of the IAEA Safety Series No. 006 1985 (as amended 1990). In 2019, CNL performed an internal review and prepared an addendum intended for continued operations which included several physical updates. The most significant update included physical changes to allow the packaging to meet the ANSI N14.5 2014, the American National Standard for Radioactive Materials –Leakage Tests on Packages for Shipments.

Currently, the latest safety analysis report update for the IMT is with the CNSC for review demonstrating compliance with the IAEA SSR-6 R1, 2018 also requesting an expanded approved content.

Other Packaging

Additional discussion will be provided regarding the CDN 2060 B(U)-85 Tritide packaging and the CDN 2052 B(U)-96 Used Fuel Transportation Packaging (UFTP).

**Country or International Organization:**

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## Practice of Shielding Design of Container for Industrial Irradiation Radioactive Sources transport

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<sup>60</sup>Co radioactive source is a kind commonly used radioactive source in industrial irradiation processing, usually with an activity of about 10 kCi per source and a total activity of about 200 kCi per individual package. Radiation shielding is an important factor considered in the design of industrial irradiation source transportation containers, and an increase in shielding thickness can lead to an increase in the volume and weight of the package, which will make operation inconvenient. The increase in shielding materials will also increase the cost of container manufacturing and transportation. A multi-layer shielding structure container combining steel-tungsten-steel-lead-steel was designed for the convenient transportation of industrial irradiation sources, taking into account factors such as volume limitations, shielding effectiveness, and manufacturing costs. The external dimensions of the shielding container responsible for shielding function in the container are  $\varnothing 909\text{mm} \times 1241\text{mm}$ , with a shielding material tungsten alloy thickness of 62mm, a lead layer thickness of 147.5mm, and a steel total thickness of 31mm. Shielding performance testing results show that the maximum radiation level at a distance of 5cm from the outer surface of the package is 603.7 uSv/h, and at a distance of 1m from the outer surface of the package is 84.3 uSv/h, when the maximum design source quantity of the container is  $6.66 \times 10^{15}\text{Bq}$  (180000 Ci). The shielding design meets the requirements of SSR-6 for B (U) type packages.

**Country or International Organization:**

**Instructions:**

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## Le renforcement du cadre juridique pour la sûreté du transport des matières radioactives : défis contemporains et perspectives d'avenir.

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#### 1- Introduction

Le transport de matières radioactives, avec plus de 20 millions d'expéditions annuelles, est une opération logistique de grande ampleur, vitale pour la médecine, l'agriculture, la recherche scientifique et la production d'énergie. La sûreté et la sécurité de ces opérations reposent sur un ensemble de règles internationales, dont les normes de l'AIEA sont les piliers. Toutefois, le paysage mondial évolue rapidement en raison des avancées technologiques dans les secteurs du nucléaire et des transports. Il est donc impératif d'évaluer si les cadres législatifs et réglementaires actuels sont suffisants pour relever les défis émergents. Cet article propose d'analyser ces défis et de suggérer des pistes pour renforcer les normes mondiales.

#### 2- Harmonisation législative et conformité

L'un des principaux défis est de s'assurer que les systèmes juridiques et réglementaires nationaux sont en pleine conformité avec les instruments internationaux, tels que les normes de sûreté de l'AIEA et les règlements types de l'ONU. Les pays peuvent rencontrer des difficultés pour traduire ces exigences internationales en législations nationales efficaces, en particulier concernant les aspects de la sûreté et de la sécurité dès la conception et pendant les opérations de transport. Les lacunes dans l'harmonisation peuvent créer des incohérences qui compromettent la sûreté et la sécurité de l'ensemble de la chaîne de transport. Il est crucial de mettre en commun les données d'expérience pour améliorer les capacités de sécurité et de sûreté, notamment les cadres juridiques et stratégiques

#### 3- Les enjeux des nouvelles technologies et de la cybersécurité

Les avancées technologiques introduisent de nouvelles dynamiques dans le transport de matières radioactives. L'émergence des petits réacteurs modulaires (PRM), des centrales nucléaires flottantes et des microréacteurs, qui nécessitent le transport de nouveaux types de combustibles et de déchets, pose des questions inédites en matière de réglementation et de sécurité. Parallèlement, la digitalisation croissante des chaînes de transport rend la cybersécurité plus critique que jamais. Les systèmes de suivi, de communication et de gestion des risques sont potentiellement exposés à des cyberattaques qui pourraient compromettre la sûreté des expéditions. Le cadre réglementaire doit s'adapter pour intégrer ces nouvelles menaces et garantir une protection efficace.

#### 4. Renforcement de la sécurité et de la sûreté opérationnelle

Au-delà du cadre juridique, le renforcement de la sûreté et de la sécurité opérationnelle est une priorité absolue. Les matières nucléaires et radioactives peuvent être exposées à divers risques et menaces selon le mode de transport (route, rail, mer, air). La conférence de Vienne se concentrera sur le partage d'expériences sur le renforcement des capacités en matière de sécurité et de sûreté, en mettant l'accent sur la protection tout au long du transport. Cela inclut l'amélioration des pratiques de conception des emballages, la formation du personnel et la mise en place de plans d'intervention d'urgence.

#### 5. Conclusion et perspectives

Le transport de matières radioactives nécessite un cadre de gouvernance mondial robuste et agile. La Conférence de Vienne en mars 2026 offre une plateforme essentielle pour stimuler l'innovation et renforcer les normes mondiales. La collaboration entre les décideurs politiques, les organismes de réglementation, l'industrie et les universités est cruciale pour relever les défis posés par l'évolution rapide des technologies et des menaces. En partageant les expériences et en renforçant les cadres juridiques et réglementaires, la communauté internationale peut continuer à garantir la sûreté et la sécurité des expéditions de matières radioactives pour les décennies à venir.

**Country or International Organization:**

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**Instructions:**

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Dear Ladies and Gentlemen,

My name is Andrii BACHURIN, the Deputy Head of Integrated Radioactive Material Management Department of the SSE Chornobyl NPP in Ukraine.

I would like to present the requirements and the description of activities at the SSE Chornobyl Nuclear Power Plant associated with transport of radioactive materials of different types by the SSE Chornobyl NPP within Exclusion Zone at the Conference.

**Country or International Organization:**

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## **STRENGTHENING NATIONAL CAPACITY FOR THE SAFE AND SECURE TRANSPORT OF NUCLEAR AND RADIOACTIVE MATERIAL: EXPERIENCE FROM MALAWI**

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The transportation of nuclear and radioactive materials remains to be an essential component of nuclear applications due to its broad use across such fields as medicine, industry, research, and agriculture. Considering its possible risks and global mobility, it is important to take into account the safety and security of such materials when they are being transported. For developing countries like Malawi, where regulatory capacity is expanding but faces obstacles such as scarcity of resources, infrastructure constraints, and gaps in stakeholder awareness, safety and security of nuclear and radioactive materials is also important. The paper reviews Malawi's regulatory framework on transportation of nuclear and radioactive material and how they comply with international instruments such as the IAEA Regulations for the Safe Transport of Radioactive Material (SSR-6) and nuclear security guidance.

The paper also highlights both progress and gaps in implementing transportation of nuclear and radioactive materials in Malawi. Finally, the paper also explores ways of improving the safe and secure transport of nuclear and radioactive materials in Malawi.

**Country or International Organization:**

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## **Reassessing Transport Safety Regulations in the Era of Emerging Propulsion Technologies**

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For over six decades, the IAEA Transport Regulations (SSR-6) have provided the international framework for safe transport of radioactive materials, classified as Class 7 Dangerous Goods under the UN Orange Book. These regulations establish tiered safety requirements for different package types based on historical accident data and conventional transport conditions. The thermal testing protocols for Type B packages designed to withstand severe accidents were developed specifically to simulate hydrocarbon fuel fires, reflecting the dominant vehicle propulsion technology of the 20th century.

Type B package testing involves subjecting pre-damaged specimens to extreme thermal conditions. The current standards require specimens to first reach thermal equilibrium at 38°C to account for solar heating and internal heat generation, followed by exposure to a fully engulfing hydrocarbon fire for 30 minutes. This test fire must maintain an average temperature of 800°C with specific emissivity and absorptivity coefficients. These parameters were carefully established to represent worst-case scenarios involving traditional fuel-powered vehicles.

However, the rapid global adoption of electric vehicles (EVs) powered by lithium-ion batteries has introduced fundamentally different fire hazards that challenge these long-standing safety benchmarks. Battery fires exhibit several unique and concerning characteristics compared to conventional fuel fires. They can reach significantly higher peak temperatures, often exceeding 1,000°C, and are prone to thermal runaway - a self-sustaining exothermic reaction that can cause reignition even after initial suppression. Additionally, these fires release toxic gases like hydrogen fluoride and require substantially more time and resources to extinguish, sometimes burning for hours rather than minutes.

The growing prevalence of EVs on roadways creates two distinct safety challenges for radioactive material transport. First, as logistics operators pursue decarbonization, EVs may increasingly be used to transport radioactive materials directly, particularly for medical isotopes and industrial sources. Second, and perhaps more immediately concerning, is the risk posed by mixed traffic scenarios where conventional radioactive material transport vehicles share roads with numerous EVs. In such cases, an EV fire adjacent to a radioactive materials shipment could subject the containment system to more extreme conditions than those tested under current standards.

These emerging risks highlight several potential gaps in the existing regulatory framework. The 30-minute fire duration requirement may be insufficient given the prolonged burn times characteristic of battery fires. The temperature profiles and heat transfer mechanisms differ significantly between hydrocarbon and battery fires, potentially affecting material performance.

Addressing these challenges will require a comprehensive reassessment of transport safety regulations. Potential updates could include extending fire duration requirements, incorporating battery-specific thermal parameters, and adding criteria for resistance to toxic gas exposure. Container designs may need to evolve as well, potentially incorporating advanced insulation materials or active cooling systems. Operational measures such as establishing EV-exclusion zones for high-activity shipments or implementing real-time thermal monitoring could provide additional layers of protection.

The transition to alternative propulsion technologies represents a significant evolution in transport safety considerations. As battery-powered vehicles become increasingly prevalent, international regulatory bodies must proactively adapt safety standards to ensure continued robust protection against emerging hazards. This will require close collaboration between regulators, battery manufacturers, fire safety experts, and transport engineers to develop science-based updates to the SSR-6 regulations that reflect 21st century transportation realities.

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## **Towards Strengthened Regional Cooperation on Transboundary Movement of Radioactive Material: The ASEAN Information Exchange Arrangement**

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The dynamic economic growth of ASEAN Member States has led to an increasing use of radioactive materials across multiple sectors, including industry, healthcare, services, oil and gas, and construction. Various regulations on the safety and security of radioactive materials utilization have been enacted and are strictly enforced. Nevertheless, incidents of loss or theft of movable radioactive sources remain a potential risk, particularly during cross-border transport. This challenge poses significant implications for regional nuclear safety and security, thereby necessitating a collaborative approach among ASEAN Member States under the ASEANTOM network. This paper aims to propose a framework for cross-border information sharing on the movement of radioactive materials, based on a review of national regulations, relevant international standards (IAEA), and an analysis of the concept note “ASEAN Regional Arrangement for Information Sharing on the Transboundary Movement of Radioactive Material” submitted by Singapore to the ASEANTOM forum. The analysis identifies the need for arrangements that include: (i) an information-sharing mechanism through designated Points of Contact (PoC) among competent authorities, (ii) the specification of Category 1 and Category 2 radioactive sources as the scope of application, and (iii) provisions covering two principal scenarios, namely, the authorized transboundary movement of radioactive sources for export–import, and the interdiction of unauthorized shipments of radioactive material between ASEAN Member States. For the first scenario, information exchange is conducted via email between the competent authority of the exporting State and that of the importing State. For the second scenario, information is exchanged via email between the competent authority of the State of destination and that of the State of origin. The establishment of an ASEANTOM information-sharing platform will enhance oversight of radioactive material movements, strengthen the safety and security of cross-border transport, and reinforce regional preparedness in addressing radiological threats.

Keywords: ASEAN, information sharing, transboundary movement, radioactive material, ASEANTOM

**Country or International Organization:**

**Instructions:**

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## Enhancing Safety and Security of NORM Transportation across Africa’s Extractive Industries: An Integrated Framework for Regulatory Harmonization and Risk Management

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The management and transport of Naturally Occurring Radioactive Material (NORM) within Africa's rapidly expanding extractive sector presents critical challenges in radiological safety and nuclear security governance. Despite the establishment of comprehensive international frameworks including IAEA Safety Standards Series SSR-6 (Rev. 1) and Nuclear Security Series NSS 46-T, the implementation and enforcement across African jurisdictions remains fragmented and inconsistent. This comprehensive analysis synthesizes findings from systematic literature review (2010-2024), comparative regulatory assessment across 15 African nations, and empirical data from major extractive operations in Niger, Namibia, South Africa, Nigeria, and Ghana. Through a multi-methodological approach incorporating quantitative exposure assessments, qualitative stakeholder interview with a regulatory official, and benchmarking analysis against IAEA general safety requirements (3-7 parts). This study reveals significant disparities in regulatory transposition, methodological inconsistencies in NORM characterization protocols, inadequate incident reporting mechanisms, and limited integration between safety and security frameworks. The research identifies exposure rates in certain operations exceeding ICRP and UNSCEAR public dose limits, with measured activities reaching 186 Bq/kg for  $^{232}\text{Th}$  in artisanal mining sites and transport practices frequently diverging from established international protocols. Building upon these empirical findings, the paper proposes an integrated regulatory framework featuring harmonized classification matrices, standardized transport protocols, enhanced monitoring systems, and strengthened regional cooperation mechanisms through Forum of Nuclear Regulatory Bodies in Africa (FNRBA) and African Network for Education in Nuclear Science and Technology (AFRA-NEST) platforms. The proposed framework addresses critical gaps in current practices while providing actionable pathways for improving NORM transport safety and security across Africa's extractive value chains.

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## **NucleoGuard prioritizes safety through stringent protection, regulatory compliance, and real-time oversight during the transport of radioactive materials.”**

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Transportation of radioactive materials is one of the most sophisticated and sensitive means of transport, where even a minor mistake can cause disastrous consequences—ranging from small or large radiological accidents to money loss, delivery delays, and threats to patient care. In order to overcome these obstacles, we created the “Nucleo Guard Application”, An overall digital platform based on 21 years of experience in nuclear logistics and radiation protection field. The application, offers an end-to-end control system intended to benefit not just expert companies with radioactive shipment, but also shipping companies and carriers, petroleum companies, and even first-timers in the industry. The Nucleo Guard application simplifies the preparation of document required by shipping regulations, issues alerts in case of deviations from regulatory requirements, and performs all decay and activity calculation necessary to ensure consignments reach the delivery destination with the intended activity at the specified time. Additionally, the platform enables real-time tracking of the shipments by recording and transmitting radiation dose-rates on container surfaces. This feature allows transparent monitoring for both clients and regulatory agencies. Among the most unique features of Nucleo Guard is its inbuilt reservation for flights, which displays exclusively authorized airlines approved to transport radioactive materials, thereby reducing administrative workload and

ensuring operational safety. Furthermore, a technical team of licensed radiation protection specialists is available 24/7 to undertake technical consultancies, international regulatory advice (IAEA, IATA, ICAO), and emergency response support. By integrating regulatory compliance, operational performance, and advanced monitoring, Nucleo Guard enhances safety, reliability, and transparency for the international transport of radioactive materials.

Key Words: Nucleo-Guard, radioactive materials, Transport, Environment

**Country or International Organization:**

**Instructions:**

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## **Challenge in the Safe and Secure Transport of Nuclear and Radioactive Material: Facing the Threat of Sabotage**

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Abstract

Indonesia's growing use of radioactive materials in medicine and industry has increased transport frequency across its vast archipelagic territory. This poses safety and security challenges, including risks of unregistered shipments, smuggling, sabotage through contaminated scrap metal, and human factor vulnerabilities. Limited regional presence of the regulatory authority further complicates emergency response. A case of illicit radiography source handling highlights the importance of cooperation with law enforcement. Strengthened regulation, mandatory training, improved coordination, and IAEA-supported capacity building are critical to ensuring the safe and secure transport of radioactive materials and protecting national health, environment, and security.

**Country or International Organization:**

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## **Operational Controls and Additional Administrative Controls for Safe and Secure Transport of Radioactive Material in Pakistan**

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Several shipments of radioactive material take place both domestically and internationally. The effective controls required both safety and security measures being well placed when radioactive material

is moved. The responsibilities of the consignor, consignee, carrier, regulatory bodies, modal authorities, border and law enforcement agencies play an important role in defining and implementing the operational control measures. IAEA SSR-6 defines 'Transport' as set of all operations and conditions associated with and involved in the movement of radioactive material; these include design, manufacture, maintenance and repair of the packaging and the preparation, consigning, loading, carriage, including in transit storage, transit, shipment after storage, unloading and receipt at the final destination.

This paper will cover the operational part of transport of radioactive material. Since the safety and security concerns are elevated for radioactive material on move as compared to those in storage. All entities involved are required to play an effective role in establishing and implementing a harmonized regime for both safe and secure transport.

PNRA as a regulatory body has established comprehensive requirements for both safety and security for operational control measures during shipment. These include measures for radiation protection, emergency management, contamination controls and segregation, consideration for other dangerous goods transport, handling of shipment including loading and unloading, security protocols, storage in transit and transit, mode specific measures, emergency planning and response, notification of shipments and communication with respect to transport of radioactive material. This paper will outline how a balanced approach is adopted to ensure implement of safety specific operational control measures from preparation of consignment till its delivery at final destination in the light of revised PNRA regulations for "Safe Transport of Radioactive Material"- PAK/916 (Rev.1) and security measures in the light of PNRA "Regulations on Security of Radioactive Sources - (PAK/926)" and "Regulations on Physical Protection of Nuclear Material and Nuclear Installations —(PAK/925)". The paper will highlight additional administrative control measures which PNRA regulatory framework covers in addition/alteration to international framework depending on operational experience feedback and national practices. These include measure related to transit authorization and in-transit storage control measures, consignments notification and communication, placarding and additional emergency arrangements like change of route in case of elevated threats. Implementation of these additional requirements pose some challenges which would also be discussed in this paper.

**Country or International Organization:**

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## **DEVELOPMENT OF AN OVERPACK-TYPE CONTAINER FOR THE SECURE STORAGE AND TRANSPORT OF DISUSED SEALED RADIOACTIVE SOURCE HEADS.**

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<sup>1</sup> DEVELOPMENT OF AN OVERPACK-TYPE CONTAINER FOR THE SECURE STORAGE AND TRANSPORT OF DISUSED SEALED RADIOACTIVE SOURCE HEADS.

<sup>2</sup> FUNDACION CENTRO NACIONAL DE DESARROLLO E INVESTIGACION EN TELECOMUNICACIONES (CENDIT)

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The management of disused sealed radioactive source heads requires packaging systems that ensure both radiological safety and structural integrity during transport. Guidelines established by the International Atomic Energy Agency (IAEA), along with national regulations, mandate rigorous testing under impact, pressure, and extreme environmental conditions. In response to these requirements, the overpack concept has emerged as a reinforced solution that supplements the primary container with additional layers of mechanical protection and shielding, addressing critical gaps in the design and experimental validation of containment systems tailored to deactivated source heads.

The use of radioactive sources in medical and industrial applications generates residual materials which, upon losing operational effectiveness, remain exposed and pose significant safety risks. To

mitigate these risks, an overpack-type container has been developed in accordance with IAEA recommendations, featuring a geometric configuration adaptable to various head models. The selected materials provide the necessary mechanical strength, deter unauthorized access, secure the load to the transport vehicle, and facilitate handling with pallet jacks and jib cranes until the source is relocated to a secure facility.

International experience with overpack containers lacks detailed technical data, yet demonstrates effective design solutions. Based on a Czech model validated in Uruguay, the containers incorporate an adjustment plate, a sealed body, a lid with locking mechanisms, reinforced trusses, and stacking ports.

Another Argentine proposal employs a simple structural design using steel sheets.

This design is based on solid principles of mechanical engineering load and stress analysis, deflection and stiffness, failure due to static loading, bolts, fasteners and the design of non-permanent joints, welding, adhesion, and the design of permanent joints.

In this context, two overpack containers were successfully modeled and constructed: one for the Theratron 80 head and another for the Picker Advance Tele Cobalt (ATC) C/9. Both feature a truss-type structural configuration with cross-mounted uprights to optimize stress distribution.

At the top, four (4) lifting lugs facilitate secure handling and hoisting operations. The main support area includes threaded holes designed to accommodate optional hooks for enhanced anchoring. Finally, the lid is opened and closed using non-permanent bolted elements. For their construction, polished steel and IPN (double-T) beams were used, selected for their durability and mechanical strength.

The bolted joints have been designed to incorporate security seals that guarantee physical traceability and provide evidence of any unauthorized tampering throughout the entire journey.

Through the construction of these overpack containers, internal capabilities in CAD modeling and structural simulations have been strengthened, while handling procedures and inspection protocols have been optimized—resulting in reduced loading times and enhanced physical security. By employing an overpack secured with bolts, strapped with tension belts, and equipped with tamper-proof security seals, a delay function is ensured, providing the necessary response time for security forces in the event of theft, sabotage, or accident.

This development has been conceived to meet the technical requirements established for transport under the Special Arrangement regime, in accordance with UN 2919 classification. This modality allows for the shipment of radioactive sources that do not fully comply with conventional packaging standards, provided that radiological and structural safety conditions are demonstrated through technical evaluation and competent authority approval. The proposed overpack container represents a robust and validated solution that supports such authorization, offering a safe and adaptable alternative for the containment and transport of deactivated source heads. Venezuela has successfully collected more than twenty (20) disused sealed radioactive source heads (DSS), utilizing overpack containers constructed by Venezuelan labor.

**Country or International Organization:**

**Instructions:**

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## **Practice of the shielding design of low-level radioactive waste transport containers**

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With the rapid development of the global nuclear energy industry, the number of nuclear power plants is constantly increasing, and the application of nuclear technology in medicine, industry and scientific research is also becoming more and more widespread. Along with this, the generation of low-level radioactive waste is also increasing. Low-level radioactive waste refers to radioactive waste with a relatively low radioactivity and a short half-life. Although its radioactivity is relatively low, it still poses a potential threat to human health and the environment. Therefore, the safe and efficient transportation and disposal of low-level radioactive waste are of vital importance. During the transportation of low-level radioactive waste, to prevent the leakage of radioactive substances and protect transportation personnel and the public from radiation hazards, specialized transportation containers are required. The shielding performance of the transportation container directly affects the safety of the transportation process. Poor shielding effect may lead to radiation leakage, causing radiation accidents and having a significant impact on human health and the environment.

This study aims to optimize the design of transportation containers for low-level radioactive waste in compliance with SSR-6 requirements. Specifically, these requirements stipulate that the surface radiation level must be less than 2 mSv/h, and the radiation level at a distance of 2 meters from the transportation vehicle should not exceed 0.1 mSv/h, alongside meeting specified transportation capacity criteria. The container is designed to hold 400 liters of cement-bound low-level radioactive waste contained within steel drums (weighing 0.8 tons). The radioactivity is primarily measured through gamma radiation, with cobalt-60 contributing approximately 85.6% and exhibiting a surface dose rate ranging from 2 to 10 mSv/h.

The shielding performance of the container was assessed using TopMC software via Monte Carlo simulation techniques. A geometric model was developed that simplified the structure while assuming a worst-case scenario for dose effects during transport. The type and thickness of shielding material were optimized to achieve an effective balance between mass, volume, and adherence to SSR-6 dose limits. Results indicated that a carbon steel layer with a thickness of 45 mm emerged as the optimal choice, yielding a surface dose rate of only 1.17 mSv/h; this option proved superior to lead alternatives concerning weight, cost-effectiveness, and manufacture. Furthermore, an experimental investigation into the shielding performance of the container was conducted wherein measurements were taken on the radiation dose rate at its surface to validate the accuracy of numerical simulation results. In conclusion, strategic design considerations for containers can effectively meet regulatory standards while enhancing operational efficiency and minimizing worker exposure risks. A carbon steel shielding layer measuring 45 mm provides a practical solution for ensuring safe transportation practices regarding low-level radioactive waste.

**Country or International Organization:**

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## **”The Cuban Experience in Managing the Interface between Nuclear Safety, Radiation Protection, and Nuclear Security in the Transportation of Radioactive Materials”**

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The purpose of this paper is to present the results of Cuba’s experience in establishing the principles that were taken into consideration in order to evaluate the effectiveness of the process of establishing an effective synergy between safety and security during the transportation of radioactive material. One of the riskiest activities during the use of radioactive materials is related to the transport of these materials, mainly because they are carried out in the public domain, and control systems must be more comprehensive and rigorous to prevent malicious acts.

Synergy between safety and security in the transport of radioactive materials is not optional, is a fundamental requirement. As our regulatory framework and case studies demonstrate, only through an integrated approach that considers both radiological risks and nuclear security threats can truly safe transport be guaranteed.

This synergy has an important role in the case of Cuba because, despite being a small country, there are two competent authorities: the Ministry of Science Technology and Environment in matters of radiation safety and the Ministry of the Interior in matters related to the security of nuclear materials and radioactive sources. Therefore, effective coordination is needed in the fulfillment of the functions of each of them without detriment to either one over the other.

This synergy has been achieved in the first instance through the creation of a security committee and the constant exchange of information, based above all on a well-defined organizational structure, where the obligations and responsibilities of each of the authorities are established in national regulations and joint audits and inspections are carried out, as well as coordination in responding to possible incidents related to sources.

Other aspects that are taken into consideration are the technologies used by both authorities, the handling and evaluation of the response of these systems, as well as the joint interpretation of the signals received. In addition, there is close cooperation between both authorities on staff training issues through the development of training programs and the creation and sustainability of a Nuclear Security Support Center. These aspects are discussed periodically in security committee.

#### Conclusion

As a result of this coordination, new national regulations are being reviewed and published, with both authorities participating in their creation, and we believe that the management of the risk of incidents related to the commission of malicious acts during the transportation of radioactive materials has been significantly improved.

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## International shipment of category 1 sources under special arrangement

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The proposed paper will present the uruguayan experience in the approval and execution of an international shipment under special arrangement. The shipment involved a multipurpose self-shielded modular irradiator with category 1 cobalt-60 sources. The paper will describe the stages of the shipment process for the reloading of the modular irradiator. It will also outline the provisions approved by the competent authorities involved and the bilateral coordination and cooperation between regulatory bodies.

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## Safety Test Verification and Performance Analysis of Medical Radioactive Source Transport Container

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The transport of radioactive materials is an indispensable component in the application of nuclear technology, and the safety of transport containers—as critical equipment during transit—has always been a major concern. This study focuses on the GT-CIRP-01 medical radioactive source transport container, aiming to comprehensively verify and evaluate its safety performance under extreme accident conditions through a series of standardized safety tests. The package is designed for the transport of special-form medical sources such as  $^{60}\text{Co}$ ,  $^{192}\text{Ir}$ , and  $^{137}\text{Cs}$ . When fully loaded, it is classified as a Type B(U) package, Category III-YELLOW, with a transport index (TI)  $\leq 3.0$ , making it suitable for road, rail, air, and water transport. The verification tests were conducted in accordance with the “Regulations for the Safe Transport of Radioactive Material” (IAEA SSR-6) and relevant national standards, covering both normal and accident transport conditions. The tests were performed at the Radioactive Material Transport Container Test Center of the China Institute for Radiation Protection, which features a comprehensive 150-ton test platform with 22 test items, fully meeting the requirements for various container tests specified in SSR-6. The accident condition tests included:

- 1) Free Drop Test I: A 9-meter drop in the most severe orientation to verify structural integrity and containment performance when the container impacts a rigid target at its maximum weight and most vulnerable attitude;
- 2) Free Drop Test II: A 1-meter puncture test to evaluate its resistance to sharp object impact;
- 3) Thermal Test: A 30-minute fire test at  $800^{\circ}\text{C}$  to assess thermal insulation performance and shielding effectiveness under high temperatures.

The test results demonstrated that after undergoing these rigorous tests, the container’s overall structure remained intact, the inner cavity was preserved, radiation shielding performance did not significantly degrade, and surface temperatures were strictly within regulatory limits. This study successfully verifies the reliability and safety of the GT-CIRP-01 medical radioactive source transport container design, providing solid data support and compliance justification for its broad application in engineering practice. It also offers valuable insights for the design and testing of similar containers.

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## **Planning for Robust, Safe and Secure Transportation of Low Level Waste from Waste Generating Sites to Future Disposal Facilities in Pakistan**

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Pakistan has a comprehensive nuclear power program, covering all facets of nuclear technology. Currently, six nuclear power plants, two research reactors, 20 cancer hospitals and four nuclear agriculture centers are in operation under the umbrella of Pakistan Atomic Energy Commission. From operation of these facilities, radioactive waste including Disused Sealed Radioactive Sources (DSRS) are being generated. Safe and secure management of radioactive waste plays a pivotal role in sustainable operation of these facilities and for protection of people, society and environment from harmful effect of ionizing radiation. In this regard, dedicated and licensed waste processing facilities are in operation and the conditioned waste packages are stored onsite. For final disposal of Low Level Waste (LLW), two Near Surface Disposal Facilities (NSDFs) are being developed in the country. Subsequently, waste packages will be transported from storage facilities to the disposal facilities. The transportation of radioactive waste is a critical aspect of nuclear safety, environmental protection and public health. Keeping in view the hazards associated with transportation of radioactive waste, Pakistan Atomic Energy Commission (PAEC) has initiated concrete steps to safely and securely transport the radioactive waste to disposal facilities. Pakistan Nuclear Regulatory Authority (PNRA), an independent organization in the country is responsible to regulate all matters pertaining to ionizing radiations. PNRA International Atomic Energy Agency has issued “Regulations for the Safe Transport of Radioactive Material - (PAK/916) (Rev.1)” in January 2022. Moreover, to assist

Member States, International Atomic Energy Agency (IAEA has also issued “Regulations for the Safe Transport of Radioactive Material SSR-6”2018 Edition. It is planned that the transportation of the LLW packages in the country will be carried out in accordance to the above mentioned regulations. To meet the regulatory requirements, the LLW packages have been categorized as Industrial Package Type 3 (Type IP-3). To gain confidence before gaining authorization from PNRA, tests for normal conditions of transport have been carried out on the dummy package, commensurate with the original waste package. Moreover, standard operating procedure for transportation of LLW packages have also been developed. The procedure defines roles and responsibilities to safely and securely transport the LLW packages. Moreover, different parameters like dose, surface contamination, waste package identification, transport index, etc., type of vehicle and adoption of appropriate security measures during transportation are elaborated in the procedure to ensure that the waste packages are transported safely and securely.

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## **Experience of the regulatory authority in controlling the transport of different types of radioactive sources over long distances**

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The use of radioactive sources in low-income countries entails a number of challenges, including the supply and transport of sealed and unsealed sources to and from their locations.

Though there is enough experience and regulatory support, both internationally and domestic, for this activity, practical implementation and compliance monitoring appear to be the main considerations regarding radioactive material transport. Recent publication by the IAEA of Specific Safety Guide No. SSG-26 (Rev. 1) “Explanatory Material for the Application of the IAEA Regulations for the Safe Transport of Radioactive Materials (2018 Edition)” is conclusive evidence of this.

This work, a practical continuation of the presented at previous transport Conference CN 280 paper, “Regulatory activity experiences and aspects to be strengthened in safe and secure of radioactive materials transport,” updates how interactions between consignors, carriers and consignees are established, controlled, and evaluated in our country, as well as between these and the competent authorities involved in transport. This work is based on the available information from inspection and licensing actions for entities related to this activity since last Conference.

The paper provides a brief update on regulatory support for radioactive packages transport and analyzes transport processes carried out, both for industrial practices and for radioactive materials for medical services. These transportations, in industrial practice, are related to new radioactive sources installation in stationary nuclear gauges, and for services using mobile nuclear gauges.

The radioactive package transport control for medical practice is also presented, both for high-activity radioactive sources for teletherapy equipment with <sup>60</sup>Co, and for medium-activity brachytherapy sources. Likewise, radioactive packages frequently movement for medical use (with <sup>131</sup>I and <sup>99m</sup>Tc generators) to nuclear medicine services in the territory is analyzed. Spent and disused radioactive sources and radioactive waste transport in the eastern part of the country are not excluded from this analysis.

In conclusion, it can be stated that, although established more than 20 years ago, the national regulatory support for control of radioactive material transport is tempered by current international

regulations. This, coupled with regulatory authority's action, based on graded approach to this activity, has allowed for strict control of the transportation of radioactive sources in this territory of the country. This has resulted in none of these transportations being carried out outside of regulatory control, no significant doses being received by personnel involved in the transportation or by the public, and no conventional or radiological accidents having occurred during radioactive packages transport.

Notwithstanding the achievements, the need is recognized, based primarily on the participation of newly recruited personnel in transport execution and control, and the need to prioritize this personnel training in a differentiated manner.

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## **Consignor-carrier-consignee integration, essential cooperation factor for safety and security in $^{131}\text{I}$ and $^{99\text{m}}\text{Mo-Tc}$ generators national transport**

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One of main challenges facing nuclear medicine in terms of quality and efficiency of this increasingly in-demand medical service is reliable radiopharmaceuticals supply to medical units. This aspect is even more relevant for hospitals located far from production sites in low-income countries.

This paper presents the experience of national cooperation between consignor, carrier and consignee in radioactive iodine and  $^{99\text{m}}\text{Mo-Tc}$  generators transport for nuclear medicine services, in compliance with their responsibilities, assigned in "National guide for implementation of regulations for safe transport of radioactive materials," by road for the consignor and consignee, and by plane, between them. This operation has been carried out twice a month over last seven years.

The paper presents too, established requirements in the regulatory framework for this activity by country competent authorities on this matter and analyzes other requirements for this cooperation stated in issued regulatory authority authorizations.

Evidence of compliance with prescribed in authorizations requirements, and of monitoring these activities has been taken from Hospital radioactive packages transportation records.

As result, it can be concluded that strict collaboration, based on compliance with assigned responsibilities in force applicable regulations, reflected primarily in existing regulatory framework and in authorizations granted by regulatory authority for transport, has guaranteed the safe and secure supply of radioactive material required for this service to the Hospital.

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## IoT Based Real-Time Tracking Framework for Safe and Secure Transport of Radioactive Materials

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The transport of radioactive materials poses significant safety and security challenges that require innovative solutions. Thousands of radioactive materials are transported during applications in nuclear medicine or in different industrial activities such as NDT and nuclear imaging. However, Core, the materials must be transported with extreme care due to their hazard. To protect these shipments, several traditional tracing and monitoring mechanisms have been developed and used. However, these methods are lack in adjusting to emerging threats due to the challenge of real-time capability, and robustness. Apart from this, lack of constant monitoring makes in-bound materials susceptible to an array of dangers such as, theft, unauthorized diversion, and environmental hazards due to accidents or other natural phenomena.

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## Advancing Nuclear Security in Transport in West Africa: Bridging Safety and Security in Radioactive Material Movements.

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The transport of radioactive material presents dual challenges: ensuring safety to protect people and the environment from accidental exposure, and ensuring security to prevent malicious acts such as theft, sabotage, or illicit trafficking. Traditionally, transport safety has long focused on the prevention of accidents, radiation exposure minimisation, and ensuring the integrity of packaging systems. Currently, the evolving global threat environment has necessitated a broader perspective that incorporates transport security. Security measures aim to prevent, detect, and respond to intentional acts such as theft, sabotage, and illicit trafficking during transport.

This paper explores the conceptual and practical shift from transport safety to transport security, examining how the two domains intersect and diverge. It draws upon international frameworks, including the IAEA Safety Standards (SSR-6) and the Nuclear Security Series (NSS 9-G), to illustrate the interface between safety requirements and security obligations.

A Case study from the West Africa region is highlighted to demonstrate region-specific challenges, such as under-declaration of radioactive consignments, limited detection capabilities at points of entry, and the need for inter-agency coordination. The analysis underscores that achieving resilient nuclear security in transport requires policy harmonization, investment in secure tracking and detection technologies, and sustained capacity building for frontline officers.

The paper concludes with recommendations for enhancing the integration of safety and security practices in transport systems, contributing to the prevention of materials becoming out of regulatory control and strengthening the global nuclear security regime.

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SAFE AND SECURE TRANSPORT OF SMALL MODULAR REACTORS FOR DEPLOYMENT IN NIGERIA

Nigeria is seriously considering the feasibility of deploying small modular reactors (SMRs) across its geopolitical zones in order to achieve the goal of energy sufficiency for the country. The rationale behind this decision is due to; the country's low-capacity grid, cost considerations for the deployment of SMRs compare to the conventional nuclear power plants (NPPs) and other non-electrical power applications that Nigeria could benefit from the deployment of SMRs such as utilization of waste heat from nuclear reactors for industrial or district heating as well as water production.

Nigeria Atomic Energy Commission (NAEC) as the Nuclear Energy Programme Implementing Organization (NEPIO) saddled with the responsibility of coordinating Nigeria's Nuclear Power Programme (NNPP) is currently developing Strategic Plan document for the development and deployment of SMRs in Nigeria.

Thus, the objective of the presentation is to address the safety and security requirements, robust regulatory framework and major challenges for safe and secure transport of SMRs development and deployment in Nigeria within the country's national nuclear power roadmap framework.

It is expedient to note that the transportation of SMRs in a safe and secure manner in Nigeria will require careful planning, execution and compliance with international and national regulations as well as adherence to industry standards and guidelines for SMR security. Some of the key areas of focus to achieve safe and secure transport of SMRs for deployment in Nigeria are:

**Safety Requirements**

**Perimeter Security:** This can be achieved through the implementation of robust physical barriers and surveillance systems to prevent unauthorized access.

**Insider Threats:** To reduce insider threats, undertake extensive background checks and develop staff reliability programs.

**Remote Monitoring:** Enhancing security through the use of emerging technologies such as drones, AI-driven surveillance, and real-time monitoring systems.

**Security Requirements**

**Transportation Security:** Securing the transport of fuel, components, and reactor modules through advanced tracking and monitoring systems.

**Cybersecurity:** Strong firewalls, encryption, and intrusion detection systems are used to protect digital systems from cyber-attacks.

**Safeguards by Design:** This can be achieved by working with the reactor vendor by incorporating non-proliferation measures into reactor design, such as material accountancy and containment systems.

**Major Challenges**

**Infrastructure:** Ensuring the upgrade and expansion of the existing infrastructure to support the transportation and deployment of SMRs.

**Regulatory Readiness:** Developing a robust regulatory framework that can oversee the safe and secure deployment of SMRs.

**Electric Grid Capacity:** Nigeria's electric grid capacity is of low-capacity, hence the integration of SMRs into the existing grid infrastructure would be of immense benefit.

**Financing and Funding:** Securing funding for SMR projects is a significant challenge, and Nigeria may need to explore alternative financing options, such as public-private partnerships.

Coordination and Planning: SMR deployment needs coordinated planning at regional and national levels, which might be a little difficult due to Nigeria's decentralized system of government.  
Public Acceptance: Addressing public concerns and educating communities about the benefits and risks of SMRs.

Figure 1: Strategy for Safe and Secure Transport of Small Modular Reactors in Nigeria  
NAEC as the NEPIO can ensure safe and secure transport of SMRs deployment by addressing the major challenges and implementing robust safety and security measures in order for the country to harness the enormous potential of SMRs to meet its energy needs while ensuring the safety and security of its citizens.

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## **Strengthening Nuclear Security in Chad: An IAEA-Supported Assessment for the Security of Radioactive Material in Transport**

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Chad, a Central African country with a population of approximately 12 million, uses radiation sources in medicine and industry, particularly in petroleum exploration. Radioactive sources are also used in sectors such as breweries, road construction, and other sectors of socio-economic significance. While these applications offer important benefits, the risks of diversion, theft, and sabotage remain a concern. Among these, the security of transport represents one of the most complex challenges due to its multi-institutional nature.

The transport of radioactive material in Chad is a reality that requires security measures commensurate with national challenges. Although a legislative and regulatory framework exists, its implementation by stakeholders remains limited.

To address this, the Chadian Agency for Radiation Protection and Nuclear Security (ATRSN) requested technical assistance from the International Atomic Energy Agency (IAEA). In June 2025, a national workshop was held in N'Djamena with the assistance of three IAEA experts. The workshop evaluated the current regulatory infrastructure and security measures supporting the transport security of radioactive materials throughout Chad, engaging all relevant stakeholders, including operators and security agencies, with the aim of identifying gaps and formulating recommendations.

This paper presents the results of the assessment and the approach used to evaluate Chad's transport security culture and practices.

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## Testing and Certification of Packaging for the Safe Transport of Monazite According to IAEA SSR-6 from Brazil to Canada.

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**Introduction:** Due to the presence of radionuclides, monazite is classified as NORM. For transport purposes, however, the classification of monazite as radioactive material depends not only on the mass fraction of uranium and thorium, but also on the activity concentration (Bq/g). According to the IAEA's SSR-6, NORM and ores containing radionuclides are exempt from regulatory control provided that their activity concentration does not exceed ten times the exemption values established in paragraph 401(b). In Canada, when the U or Th content exceed 3% by mass, it can no longer be classified as Low Specific Activity-I (LSA-I), but as LSA-II. In such cases, the SSR-6 requires the use of Industrial Package Type 2 (IP-2). Canadian national regulations also require LSA material to be transported in Type IP-3 packages unless they can be (1) transported in conveyances that are not carrying passengers; (2) are transported in conveyances or freight containers from one consignor only; and (3) are only loaded at the consignor's location and unloaded at the consignee's location. For ocean transport, where the containers are loaded into a freight container, this is possible and then the IP-2 package can be used for monazite transport. For an air shipment, this is not possible due to the multiple loading and unloading operations and therefore the Type IP-3 package is needed. Section VI of SSR-6 establishes requirements for the testing of packaging intended for the transport and storage of NORM. The prescribed tests include free drop, penetration, water spray, stacking, and, additionally, the internal pressure test of 95 kPa for air transport.

**Objectives:** This study aims to evaluate the certification and transport of industrial packages containing NORM, highlighting the differences between Canadian and Brazilian regulatory frameworks. Despite existing regulations, many operators remain unaware of specific national requirements, which can lead to improper handling and transportation of radioactive materials. In Brazil, there are currently no local suppliers of packages fully compliant with SSR-6 specifications. Consequently, TAM International, the company responsible for NORM logistics between Brazil and Canada, submitted domestically manufactured packages to qualification testing to ensure transport safety. These tests were conducted by the Nuclear Technology Development Center (CDTN/CNEN), a Brazilian reference institution in applied research and specialized services in nuclear safety.

**Methodology / Tests:** Performance tests for the certification of Industrial Package Types IP-2 and IP-3 were conducted in accordance with IAEA SSR-6 requirements, evaluating two package types based on their intended transport modes: flexible intermediate bulk containers (FIBCs) for ocean and ground transport, and metal drums for air transport.

The 80 × 80 × 65 cm FIBC was fully filled with a non-radioactive surrogate simulating monazite sand (density 5,000 kg/m<sup>3</sup>; total mass ~2,000 kg) and subjected to stacking and penetration tests to verify compliance under simulated operational conditions for IP-2.

The 50-liter cylindrical steel drum (384 mm diameter, 595 mm height; net weight 6.3 kg; maximum gross mass 180 kg) with a removable lid and lever-type locking ring was filled with a surrogate simulating monazite (density 2,300 kg/m<sup>3</sup>; mass ~115 kg) and underwent drop, penetration, and stacking tests to ensure IP-3 compliance, complementing previous water spray and internal pressure assessments. These procedures allowed verification of both package types under realistic transport scenarios.

**Results:** The successful performance of the Type IP-3 drum and Type IP-2 FIBCs tests demonstrates that the package meets IAEA SSR-6 requirements for transport of monazite.

**Conclusion:** A preliminary and critical step in radioactive material transportation is the comprehensive evaluation of the material type, the packaging design, and the regulatory frameworks of all transit and destination countries. This study underscores the importance of understanding and complying with both national and international regulations.

**Country or International Organization:**

**Instructions:**

## Accident-Induced Battery and Hydrogen Fires: Challenges for the Safe Transport of Packages with Radioactive Material

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The transport of radioactive material is governed by stringent safety requirements defined in the IAEA regulations SSR-6. These requirements, especially the thermal and mechanical accident conditions, originate largely from concepts established in the 1960s and have remained essentially unchanged with respect to key thermal boundary conditions. At the same time, the rapid introduction of battery-electric and hydrogen-fueled vehicles into heavy-duty freight and dangerous goods transport is altering the boundary conditions of transport accidents. This raises a critical question: do today's regulatory test requirements, such as the regulatory 800°C/30 minute thermal test, remain sufficiently conservative for accidents involving vehicles with alternative propulsion technologies? Battery fires present specific challenges due to the properties of lithium-ion cells widely used in electric vehicles. In addition, other battery chemistries, such as NMC (Nickel-Manganese-Cobalt oxide), LFP (Lithium iron phosphate), and NCA/LTO (Nickel-Cobalt-Aluminium oxide / Lithium-titanate oxide) must be considered, as they are increasingly deployed across diverse transport applications. Electrolytes are highly flammable; thermal runaway can trigger cascading reactions; toxic and corrosive gases may be released. Unlike conventional fuel fires, such events can last well beyond 30 minutes and may reignite after seeming extinction, creating complex risks for emergency response and for the integrity of packages containing radioactive material. These characteristics call into question whether current thermal test specifications sufficiently represent real accident conditions involving battery-powered vehicles.

Hydrogen-fueled vehicles introduce additional hazards. Accidental releases can form explosive mixtures; ignitions may lead to intense jet fires or explosions with high radiative heat fluxes. In proximity to packages, such events could generate thermal loads and transient pressure effects that are not explicitly captured by the current regulatory test envelope. Beyond peak temperature and exposure time, parameters emphasized in the IAEA Advisory Material SSG-26 such as emissivity, absorptivity, heat flux and energy density of the involved fuels are decisive for the net heat input into a package and should therefore be assessed against realistic accident scenarios.

To close this gap, it is necessary to initiate a research program that investigates vehicle fire scenarios with the safety assessment of packaging for radioactive material under transport accident conditions. This necessary work must take into account the development of conservative accident scenarios reflecting different battery chemistries and capacities, as well as large-scale experimental investigations using calorimetric reference containers and instrumented test setups to quantify heat fluxes, temperatures, radiation intensities, and propagation/reignition phenomena.

In conclusion, the ongoing transformation of transport systems through electrification and hydrogen use necessitates proactive evaluation of their implications for the safe transport of radioactive material. Notably, there are currently no experimental investigations of accidents involving transport vehicles with alternative propulsion in which the dangerous goods - the package and its loading - have been the central focus rather than the vehicle itself. A necessary research project must aim to assess the relevance of the IAEA's existing transport testing requirements with regard to these new risks and, if necessary, propose changes or supplementary measures. Furthermore, such a program must be deliberately designed so that its methods, data sets, and benchmarks can also be applied to the assessment of other classes of dangerous goods outside radioactive materials by transferring heat inputs and exposure histories to other packaging types for other dangerous goods. By predicting the potential effects of battery and hydrogen fires, the Community can ensure that regulatory requirements continue to provide comprehensive protection, thereby maintaining the high level of safety in the transport of dangerous goods in a rapidly changing technological landscape.

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## Impact analysis and optimization of tie-down device for radioactive material transport container

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In order to ensure the safe transportation of radioactive materials, it is necessary to design a safe and reliable tie-down device that meets the requirements of transportation organizations. Considering the load and space constraints of transport vehicles, the size and weight and freight volume of transport containers, the tie-down device should be designed as lightweight and miniaturized as possible. In addition, the good matching between the front and rear transport links should be taken into account to facilitate the transfer, fixation, loading and unloading operations.

In this paper, the design of tie-down device for square radioactive material transport container is carried out: The tie-down device is mainly composed of base, rotary lock and linkage operation board. Four locating pins matched with the bottom of the container are designed at the four corners of the base. it plays the role of guiding and locating, and it restrains and limits the horizontal direction of the transport container; Two rotary locks are designed in the middle of two sides of the base. the two rotary locks are rotated by 90 degrees to clamp the bottom beam of the transport container, so as to restrict and limit the vertical direction of the transport container. The two rotary locks are operated by a linkage control panel, which can realize synchronous locking and unlocking operation simply and quickly; Anti-loosening grooves and limit pins are designed on the linkage control board, which can ensure that the rotation lock will not be loosened due to the loosening of the linkage control board during transportation.

In order to further optimize the operation, combined with the mechanical simulation calculation and analysis, the maximum acceleration factor generated in the transportation process is used as the verification safety factor for modeling and calculation. Through the comparison of stress, strain and other parameters, the iterative optimization design is carried out: Four corners of each base are provided with a shaft seat, wherein every two are coaxial; The two rotary lock shafts can penetrate through the shaft seats of all the bases along the arrangement direction, so as to realize rotatable connection; The rotary lock shaft is provided with pressing plates, and the position of pressing plates is changed by rotating the rotary lock shaft, so that the pressing plates is attached to or separated from the bottom beams of the transport container, thereby restraining and limiting the vertical direction of the transport container, and two rotary lock shafts can realize the linkage fastening of a row of transport containers. Handles are arranged at both ends of the rotary lock shaft, and quick pins are arranged on the handles which are used for matching with the bases to prevent the accidental rotation of the rotary lock shaft from causing the tethering device to fail. this scheme reducing the difficulty and time of fastening operation.

The tie-down device is installed in a 20 ft container by anchor bolts, welding or other alternative ways. The 20 ft is a open-top fully enclosed container, the transport containers to be hoisted in and out of the box from the top. The two ends are provided with door opening design, the operator avoids entering the container to carry out multiple fixing operations in a narrow space, but can complete the fastening operation outside the box body. The container meets the needs of multimodal transport by sea, highway and railway.

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## AI-Enhanced Documentation Analysis in Regulatory Safety Assessment of Transport Packages

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The transportation of radioactive material requires, dependent on type and quantity of the radioactive material, a regulatory approval based on the package type. Safety assessments shall be conducted in compliance with the International Atomic Energy Agency (IAEA) regulations and documented in a comprehensive package design safety report to obtain approval from authority. This comprehensive safety report evaluates a broad range of requirements from the regulations, including mechanical, thermal, shielding, criticality and transport requirements and controls, and testing assessments. Additionally, it encompasses supporting documents such as specifications, inspections, certifications, drawings, and guidelines in a variety of complex documents.

Safety and manufacturing reports contain multiple interconnected sub-reports covering various topics. Changes, such as component modifications, material property updates, or regulatory revisions, often impact multiple sections of the safety analysis reports, making even minor adjustments complex and time-consuming. Each transport package has unique requirements to be fulfilled, making every safety report distinct, despite following the same regulatory framework.

Most documentation exists in standard digital formats but is often not machine interpretable, preventing automated analysis of the critical dependencies between them. This paper argues that moving beyond simple digitization towards structured knowledge representation is essential for addressing these challenges. We propose a multi-stage approach, beginning with foundational AI technologies such as Large Language Models (LLMs) and Retrieval-Augmented Generation (RAG), and progressing toward the construction of Knowledge Graphs (KGs). KGs convert unstructured and semi-structured information into a connected, queryable network, enabling precise tracing and visualization of complex interdependencies within the documentation landscape.

By linking interpretable content directly to datasheets, tables, simulations, experimental results, standards, and regulations, such a system would automatically identify changes and interdependencies. Related conditions could be validated using AI-based tools, reducing the need for manual intervention, improving both efficiency and safety.

Human error plays a significant role in drafting, reviewing, and revising safety reports, often requiring iterative review cycles and multiple reviewers before approval. A digital quality infrastructure could reduce iterations and further improve efficiency. Integrating AI into this process could optimize safety assessments and enhance their robustness by leveraging interpretability to enhance safety.

This preliminary study explores the readiness and requirements for using intelligent documentation analysis system in the context of regulatory compliance for package safety for the transport of radioactive material. By analysing current documentation workflows, we identify how LLM-based tools can interpret complex safety reports and highlight critical interdependencies and then demonstrate why a KG-based architecture is necessary to robustly manage and query critical interdependencies. This lays the groundwork for future agentic AI systems capable of proactively supporting the safety assessment lifecycle, while stressing the importance of robust data governance and AI reliability in this highly regulated context.

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## **Synopsis: Reimagining Nuclear Logistics: Sustainable Hybrid Airships for SMR Deployment**

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The attached synopsis is submitted for consideration of being selected for inclusion in the 2026 Conference on the Safe and Secure Transport of Nuclear and Radioactive Material.

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## Development of an Advanced Cryogenic Transport Container for Radiopharmaceuticals

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Safe and reliable transport of radiopharmaceuticals is a critical requirement for patient treatment and public health systems worldwide. Many therapeutic radiopharmaceuticals are highly sensitive to temperature changes and must be kept under strict cryogenic conditions to preserve their stability, quality, and therapeutic effectiveness. However, existing transport containers face significant limitations in maintaining ultra-low temperatures over long periods, providing adequate radiation shielding, and meeting increasingly strict international transport regulations. These constraints have created challenges for long-distance and cross-border shipments, increasing the risk of supply chain disruption and reduced product quality during transit.

To address these challenges, we have developed an advanced cryogenic transport container designed to maintain both the thermal and mechanical safety of radiopharmaceuticals throughout extended transport operations. From the initial design phase, the container was engineered to meet international requirements, including IAEA transport regulations, ensuring suitability for both air and ground shipment under diverse environmental and logistical conditions.

The newly developed container incorporates a multi-layer vacuum insulation system together with a high-efficiency coolant storage unit. This combination enables the container to maintain internal temperatures below  $-60\text{ }^{\circ}\text{C}$  for more than 144 hours without interruption. During the engineering stage, extensive mechanical shock analyses and radiation shielding simulations were conducted to optimize structural integrity. These studies confirmed that the container can withstand vibration, mechanical impact, and potential contamination risks, while keeping radiation exposure levels strictly within IAEA regulatory limits to protect workers, the public, and the environment.

Comprehensive performance evaluations were carried out through both laboratory-based simulation testing and real-world transport trials. Thermal stability tests demonstrated that the container maintained internal temperatures below  $-60\text{ }^{\circ}\text{C}$  continuously for six full days, even under simulated transport conditions involving frequent handling and environmental fluctuations. Mechanical stress testing further showed that the internal vials containing radiopharmaceuticals were neither overturned nor damaged under severe vibration and impact scenarios. Radiation shielding performance was also confirmed to remain well within internationally accepted safety thresholds across all testing stages, verifying the container's reliability for practical applications.

The main engineering components of the container are illustrated in Figure 1, while Figure 2 provides a detailed view of the interior of the manufactured container, highlighting the reinforced structural design specifically developed to resist physical shocks during transportation. Together, these results clearly demonstrate that the container ensures both thermal stability and mechanical safety throughout the entire delivery process, addressing two of the most critical requirements for radiopharmaceutical transport.

Overall, the advanced cryogenic transport container presented in this study offers a standardized, safe, and efficient solution for the international shipment of radiopharmaceuticals. By integrating engineering design, regulatory compliance, and empirical testing, the work establishes a foundation for improving transport safety, operational efficiency, and global supply chain security. Beyond technical achievements, this development also provides a model for how engineering innovations can align with public health objectives to ensure uninterrupted access to essential medical isotopes worldwide.

Future efforts will involve collaboration with regulatory agencies, medical institutions, and logistics providers to support international adoption, technology transfer, and eventual commercialization. The long-term goal is to establish this advanced transport container as a reference standard for the secure, efficient, and regulation-compliant delivery of radiopharmaceuticals across borders, contributing to improved patient care and treatment continuity on a global scale.

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## **Development and Performance Evaluation of a Data Logger for Radiopharmaceutical Transport Safety.**

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Ensuring real-time safety monitoring during the transport of radiopharmaceuticals has become increasingly important as global supply chains expand and shipment distances grow. Effective management of environmental conditions and radiation exposure throughout the logistics process is now recognized as a critical component of maintaining product integrity and patient safety. However, long-distance and cross-border shipments face multiple risks, including temperature fluctuations, radiation shielding failures, mechanical shocks, and unforeseen delays. These factors can directly compromise product quality and therapeutic effectiveness. At present, most transport systems lack advanced tools for continuous, real-time monitoring of critical safety parameters and for issuing timely alerts when abnormal conditions occur.

To address these challenges, we developed a data logger capable of continuously measuring and recording both temperature and radiation dose throughout the entire transport process. The device integrates high-precision temperature sensors and radiation detection modules within a compact, lightweight design that allows easy installation inside or outside transport containers without interfering with routine logistics operations. Importantly, the data logger operates reliably under extreme cryogenic conditions below  $-70$  °C and offers a battery life exceeding 10 days, ensuring stable, long-term functionality even during extended transport durations or unexpected delays. This capability significantly improves resilience for both domestic and international shipment scenarios.

Extensive laboratory evaluations were conducted to verify measurement accuracy, data integrity, and system reliability under controlled environmental conditions. The device successfully collected precise temperature and radiation data over extended periods while maintaining uninterrupted operation. The integrated alert system functioned effectively, issuing real-time notifications whenever pre-set thresholds were breached, thereby enabling transport operators to respond rapidly to potential safety concerns before they escalated into critical incidents.

To assess real-world performance, domestic and international transport trials were performed across multiple routes and environmental conditions. Despite exposure to vibration, mechanical impact,

and variable temperatures typically encountered during long-distance shipments, the data logger consistently maintained accurate data recording and reliable alert functionality. Figure 1 illustrates representative transport test result, showing continuous records of temperature and radiation dose measurements over time, thereby demonstrating the device's capability to ensure both environmental monitoring and operational safety throughout the entire shipment process. These results confirmed that the system can serve as more than a passive data recorder, offering proactive risk detection and operational decision support for enhancing transport safety management frameworks.

#### Image

Figure 1. Continuous records of temperature and radiation dose measurements obtained during domestic transport test using the developed data logger.

Building on these successful outcomes, our team is now actively developing next-generation IoT-based data loggers that will incorporate additional sensing capabilities, including shock detection, illumination measurement, and real-time geolocation tracking. By integrating these devices with an IoT-enabled data management platform, we aim to provide simultaneous, real-time monitoring capabilities for consignors, carriers, consignees, regulators, and medical institutions. We expect this integrated system to significantly enhance transparency, ensure regulatory compliance, and optimize supply chain coordination across national and international transport networks.

In conclusion, the data logger presented in this study provides a practical, innovative, and regulation-ready solution for monitoring radiopharmaceutical transport safety. By combining continuous environmental monitoring, early warning capabilities, and compatibility with international transport standards, it establishes a solid foundation for modernizing safety management practices. Future collaboration with competent authorities, industry partners, and international organizations will focus on large-scale deployment, international standardization, and integration into global regulatory frameworks, ultimately contributing to safer, more efficient, and more resilient radiopharmaceutical transport systems worldwide.

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## Transport cask nuclide inventory calculations for spent pebble-bed reactor fuel

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The Arbeitsgemeinschaft Versuchsreaktor (AVR) Jülich, a prototype pebble-bed high-temperature gas-cooled reactor (HTGR) operated from 1967 to 1988, was designed with the intent to demonstrate the feasibility of graphite-moderated, helium-cooled reactors with spherical fuel elements and for commercial power generation. AVR used three primary types of pebbles: fuel, moderator, and absorber spheres. Fuel pebbles contained coated fuel particles (initially BISO, later TRISO designs) embedded in graphite matrix. Uranium fuel with <sup>235</sup>U enrichment up to 17%, or high-enriched uranium up to 93% mixed with thorium to enable higher burnups, was used. Moderator pebbles, composed primarily of graphite, served to reduce spatial power density gradients within the reactor core, while absorber pebbles incorporated so-called “neutron poisons” to aid with the reactivity control. The distinct pebble geometry and material composition, together with the dynamic recirculation scheme, created reactor core conditions fundamentally different from those of light water reactors (LWRs).

Between 1993 and 2009, fuel elements, moderator and absorber spheres were loaded into 152 CASTOR® THTR/AVR dual-purpose casks for interim storage and transport. The design approval of this cask was last revised in November 2024 by the Federal office for the Safety of Nuclear Waste Management (BASE). The associated safety assessment is based on a covering inventory description, which was derived by the license holder, i.e. the Gesellschaft für Nuklear-Service (GNS), by performing depletion calculations using the SCALE code system. These results were subsequently validated by BASE, utilising both SCALE models, homogenised on the level of pebbles, and heterogeneous Serpent calculations with explicitly modelled TRISO particles. Additionally, for an individual pebble, gamma-spectrometry measurements of selected radionuclides were compared against model predictions, contributing to additional validation of the computational methods.

Compared with LWR fuel, AVR fuel pebbles typically have a higher initial enrichment and have a much smaller scale of heterogenisation. Operating conditions are also very different: a lower power density, a more thermalised neutron spectrum, larger temperature changes and gradients, continuous variation in boundary conditions from pebble circulation, higher achievable burnup, and substantially longer irradiation times. The sensitivity analysis showed that temperature variations of a few 100 K can lead to changes of up to 10% in higher actinide concentrations. Power density fluctuations strongly affect short- and medium-lived fission products, but only have a minor influence on production of important actinides.  $^{244}\text{Cm}$  production in particular is sensitive to fuel density (at a constant total fuel mass). The radii of TRISO/BISO kernels influence  $^{239}\text{Pu}$  and  $^{241}\text{Pu}/^{241}\text{Am}$  production, though less so for  $^{244}\text{Cm}$ . Graphite matrix density was identified as an important parameter, with sensitivity for  $^{239}\text{Pu}$  production exceeding unity depending on fuel burnup and initial composition. Calculations using ENDF/B-VII.1 and ENDF/B-VIII.0 nuclear data libraries lead to consistent results, with differences in important nuclide concentrations of up to about 1%.

In August 2025 BASE issued the transport approval for the transport of all 152 casks from Jülich to interim storage facility in Ahaus, for which the validity of design approval of the CASTOR® THTR/AVR cask is a prerequisite. The findings presented above confirm on one hand the robustness of modern reactor physics tools for pebble-bed fuel analysis, and on the other hand show that the sensitivity to operational conditions and consequently also the overall uncertainties in important parameters of the spent fuel are significantly higher compared to SNF from conventional LWR systems. For the safety assessment of the CASTOR® THTR/AVR cask, these factors have been considered, leading to a reliable inventory description.

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## Transport of nuclear and radioactive materials for microreactor deployment in Canada

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In Canada and around the world, there has been increasing interest in the possible use of small modular reactors (SMRs) as a low-carbon footprint energy solution to achieve climate change targets. Three potential applications for SMRs in Canada are: on-grid; heavy industry; and remote communities, each characterized by different energy demands [1]. A subset of SMRs (microreactors) with power outputs of up to 20 MWe are expected to be suitable to offset diesel use in remote communities and mining sites.

Canada is home to over 275 remote communities which are not currently connected to the North American electrical grid nor to the piped natural gas network [2]. These communities are dispersed over a vast geographical area, many lacking year-round road access or only connected by air. In

these remote communities, there will be unique challenges for deployment of microreactors which may be transported fueled or have the fuel shipped separately to the remote sites. Additionally, they will require transportation of the spent fuel to a disposal site. It will be essential to maintain the safe and secure transportation of nuclear and radioactive material to/from the microreactor deployment site.

While on-grid applications of SMRs are well-supported in Canada, off-grid SMRs and microreactors do not yet have the financial support of strong proponents or a well-defined deployment path. In order to expedite microreactor deployment, a framework for microreactor deployment has been established in Canada to align stakeholders on important actions and strategies within priority areas. This framework will meet Milestone 1 of IAEA Milestones for infrastructure development to support a nuclear power programme [3]. Transportation of radioactive materials is governed by national laws and the IAEA regulation [4] and is an important consideration in developing this microreactor framework.

Transportation of the fuel to the location of a Deep Geological Repository will be necessary. Moreover, northern SMRs may not have the same capacity for spent fuel storage as existing power reactor sites, and may require transport of spent high assay enriched uranium (HALEU) or novel chemical forms to an interim storage location. The different input fuel compositions result in different amounts of radioactive nuclides present in spent fuel. Previous work has noted that assessment of radioactive activation products in the complex geometry of a microreactor configuration as well as design of new shipping packages are issues that a licensee or vendor would have to consider.

Another aspect that should be considered is the method of transport. Remote siting may involve transporting nuclear substances on roads with lower weight limits than higher trafficked locations, or seasonal differences in transport route availability. Additionally, understanding the categorisation of transport routes may be less obvious, such as winter roads across a frozen lake.

Canadian Nuclear Laboratories, and Canada more broadly, is undertaking several projects that begin to address some of these issues. These include technical assessment capability enhancements in the areas of nuclear criticality safety and shielding. As well, a systemic review is planned of potential vulnerabilities during transport and pathways that result in radiological releases. This will result in a roadmap to address gaps in national standards and regulation that can guide future policy and research needs. A status update on this work will be discussed at the meeting.

[1] Canadian Small Modular Reactor Roadmap Steering Committee, "A Call to Action: A Canadian Roadmap for Small Modular Reactors," 2018. <https://smrroadmap.ca/>.

[2] Remote Communities Energy Database, Natural Resources Canada. <https://atlas.gc.ca/rced-bdece/en/index.html>.

[3] Technology Roadmap for Small Modular Reactor Deployment, IAEA Nuclear Energy Series No. NR-T-1.18, IAEA, Vienna (2021).

[4] Regulations for the Safe Transport of Radioactive Material, SSR 6 (Rev. 1), 2018 Ed., IAEA, Vienna, Austria.

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## From Compliance to Confidence: Strengthening Regulatory Cooperation for Safe Transport of Nuclear and Radioactive material in the Kingdom of Saudi Arabia

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The safe and secure transport of nuclear and radioactive materials is a critical element of national and international nuclear security frameworks. Given the increasing reliance on radioactive sources in medicine, industry, agriculture, energy production, and research, the transport of these materials

demands a comprehensive, coordinated approach to guarantee safety, security, and regulatory compliance.

The Nuclear and Radiological Regulatory Commission (NRRC) plays a pivotal role in ensuring the safe and secure transport of nuclear and radioactive materials within the Kingdom of Saudi Arabia. A cornerstone of this effort is the collaboration with key stakeholders at the national level. These cooperative arrangements facilitate streamlined procedures for the import, export, and transfer of ownership of radiation sources, fostering a cohesive regulatory framework that enhances safety and compliance.

This cooperation not only expedites regulatory processes but also ensures that all entities involved adhere to international safety standards and best practices. By aligning the NRRC's regulatory requirements with those of relevant key stakeholders, a comprehensive approach to monitoring and managing radiation sources is achieved. This effective cooperation is essential to mitigate risks associated with the transport of nuclear and radioactive materials, prevent unauthorized access, ensure adherence to international obligations, and promote a culture of safety across sectors.

A graded approach among national authorities is essential to ensure that safety and security measures are commensurate with the potential risks associated with the transport of nuclear and radioactive materials. This approach allows for the prioritization of resources, regulatory oversight, and response strategies based on the nature, quantity, and intended use of the materials being transported. By tailoring protective measures to specific threat levels and operational contexts, authorities can optimize efficiency without compromising safety. Effective coordination under a graded framework ensures that each stakeholder—whether regulatory, law enforcement, customs, or emergency response—plays a well-defined role, aligned with the level of risk. This enhances overall national preparedness and supports international obligations under frameworks such as the IAEA's transport safety regulations and nuclear security recommendations.

Moreover, capacity building and the exchange of knowledge among national stakeholders play a vital role in reinforcing the overall safety and security framework. This collaborative help authorities stay aligned with evolving IAEA guidelines, emerging threats, and innovations in secure transportation technologies. This ongoing capacity development reinforces national resilience and supports the implementation of standardized practices across all key stakeholders.

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## **Challenges and Perspectives in Document Management for the Extra-EU Import of Radioactive Material: An Integrated Approach Between Industry and Institutions**

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The import of radioactive material from non-EU countries is a highly regulated activity, requiring strict compliance with national and international legal and documentation frameworks. However, current authorization and customs procedures are characterized by operational complexity due to regulatory fragmentation among States, overlapping institutional responsibilities, and the lack of shared digital tools. This work, developed through collaboration between industrial operators and national authorities, presents an analysis of the key challenges faced by an Italian company in managing the import of radioactive material from third countries, with a focus on permit acquisition, documentation traceability, and authorization timelines.

The case study highlights the need for a structured intervention aimed at streamlining document flows and simplifying authorization procedures through solutions such as interoperable IT systems, harmonization of documentation requirements at the EU level, and the establishment of formal communication channels among competent authorities of different countries. The work also emphasizes the commitment of the Italian Authorities, particularly in ensuring effective engagement with economic operators and promoting an integrated approach that balances safety, regulatory compliance, and the efficiency of logistics operations. The proposed measures aim to offer a concrete contribution to the institutional debate on modernizing authorization processes, with a view toward increased efficiency, transparency, and international cooperation.

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**Supporting Secure Transport through Detector Calibration by Design: Regulatory and Technical Developments in Tunisia****Author:** Leila Ounalli Mejri<sup>1</sup><sup>1</sup> *CNSTN-Tunisia***Corresponding Author:** leila.ounalli@cnstn.rnrt.tn

In response to growing transnational threats such as terrorism and the illicit trafficking of radioactive materials, Tunisia has enhanced its national security measures by deploying radiation detection systems at critical border points. Despite these efforts, challenges remain, including the limited availability of Radiation Portal Monitors (RPMs) and the need for improved training of customs personnel. To address these issues and support national and international nuclear security objectives, the Nuclear Safety and Security Department of the National Center for Nuclear Sciences and Technologies (CNSTN) is aiming to establish a specialized radiation calibration laboratory. This facility supports the accurate calibration and validation of radiation detection equipment used in border security, nuclear forensics, and the prevention of smuggling.

A key innovation emerging from this initiative is a novel mobile calibration device centered around a pilot Cobalt-60 source. The device features a cylindrical design optimized via SolidWorks and Monte Carlo simulations (FLUKA and GEANT4), incorporating advanced dosimetry techniques such as ionization chambers, EPR in alanine, thermoluminescence, and Fricke dosimetry. Now officially registered under patent application, this portable system enhances the reliability of radiation detectors and represents a significant advancement in Tunisia's nuclear security infrastructure. The project received support from the International Atomic Energy Agency (IAEA) through a dedicated research contract CRP-JO2014.

These technical developments are complemented by a robust institutional and legal evolution. Since the establishment of the National Atomic Energy Commission (NAEC) in 1962 and the creation of the CNSTN under Law No. 93-115 in 1993, Tunisia has committed to the peaceful and secure use of nuclear technologies. CNSTN plays a central role in nuclear research, international cooperation, and acts as Tunisia's National Liaison Office with the IAEA. In parallel, the country is finalizing a comprehensive legal framework for nuclear safety and security, including a draft law on the peaceful uses of nuclear energy and the establishment of a National Nuclear Safety Authority. Ongoing collaboration with the U.S. National Nuclear Security Administration (NNSA) also supports the implementation of the Additional Protocol (AP) and further alignment with IAEA safety, security, and safeguards standards. Collectively, these efforts reflect Tunisia's strategic commitment to enhancing nuclear security through integrated technical innovation and regulatory development.

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**Strengthening the Safe and Secure Transport of Nuclear and Radioactive Materials in Costa Rica: Regulatory, Administrative, Technological, and Regional Advances****Author:** Martn ECHEVERRI<sup>1</sup>

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Dear Members of the Scientific Programme Committee,

It is my honor to submit the following synopsis for consideration as a presentation at the International Conference on the Safe and Secure Transport of Nuclear and Radioactive Material, organized by the International Atomic Energy Agency (IAEA). The proposed presentation will focus on Costa Rica's recent efforts to enhance safety and radiological protection in the transport of nuclear and radioactive materials through regulatory, administrative, technological, infrastructural, and regional initiatives.

Synopsis

Costa Rica has been developing a set of regulatory, administrative, technological, and infrastructural actions aimed at strengthening safety and radiological protection in the transport of nuclear and radioactive materials, in accordance with international standards and the recommendations of the International Atomic Energy Agency (IAEA). This presentation seeks to highlight the progress achieved, as well as the remaining challenges, in consolidating a robust framework for the safe transport.

First, significant progress has been made in the regulatory sphere, particularly through the review and updating of the current legal framework. Among the most relevant initiatives is the joint effort with the Ministry of Health, in its role as regulatory authority, to draft the Technical Regulation on the Safe Transport of Nuclear and Radioactive Materials, which represents a step toward harmonizing national regulations with IAEA guidelines. Furthermore, the promulgation of Executive Decree No. 44653-S (2024), which strengthens the Regulation on Safety and Radiological Protection, are noteworthy. These legal reforms seek to eliminate regulatory gaps and ensure that national procedures are fully aligned with international best practices in radiological protection and safe transport. In the administrative sphere, significant improvements have been implemented in the procedures related to the issuance of Weights and Dimensions permits. Through coordinated efforts with the Single Investment Window (VUI), the Ministry of Foreign Trade (COMEX), and PROCOMER, the authorization processes and the issuance of permits for the transport of hazardous materials have been optimized. These enhancements have reduced processing times, while increasing transparency and traceability. This modernization directly contributes to risk minimization and ensures that authorized vehicles comply with the established requirements for the transport of dangerous goods.

Third, the Department of Weights and Dimensions has driven a process of technological transformation aimed at strengthening control and enforcement capacities. Notable innovations include the implementation of a digital appointment system, specialized Weights and Dimensions control software, and the acquisition of mobile devices (tablets and smartphones) that facilitate vehicle diagramming and field monitoring. These tools have improved operational efficiency, enhanced the quality of collected data, and reinforced response capacity in the event of contingencies.

Likewise, investments in public infrastructure have been made to ensure more effective controls at strategic locations across the country. Notable examples include the inauguration of the La Julieta weight station and the Integrated Control Centers at Paso Canoas and Peñas Blancas, which strengthen supervision at key border crossings for regional transit, as well as at weighing stations for domestic transport. These facilities, equipped with specialized resources, represent a model of interinstitutional cooperation and modernization of border control processes.

Finally, Costa Rica is actively working on regional coordination with the Secretariat for Central American Economic Integration (SIECA) with the goal of moving toward the unification of control criteria for international transit vehicles. This initiative not only enhances safety in the transport of materials, but also contributes to trade facilitation by avoiding duplication of requirements and promoting system interoperability at the regional level.

In conclusion, Costa Rica's experience reflects a comprehensive approach that combines regulation, administrative simplification, technological innovation, infrastructure modernization, and regional coordination.

I sincerely thank the Committee for considering this proposal, and I remain at your disposal for any additional information

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## **Sri Lanka's Multi-Agency Approach to the Secure Transport of Radioactive Materials: Lessons for Emerging Nuclear Infrastructures.**

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### Background

The secure transport of radioactive materials is a global security priority due to risks of theft, sabotage, and potential misuse in terrorism. Sri Lanka, a strategic hub in the Indian Ocean with a growing radiological industry, has developed a localized, risk-informed transport security framework. This approach integrates international best practices with domestic capabilities, offering practical insights for countries with emerging nuclear infrastructures.

### Methods

Sri Lanka's security framework evolved from decades of institutional development, beginning with IAEA membership in 1957, the establishment of the Atomic Energy Authority (1969), and the enactment of the Atomic Energy Act No. 40 of 2014, which created the Sri Lanka Atomic Energy Regulatory Council (SLAERC). Recognizing the need for sovereign capacity, a Radiological Security Incident Response Team (RSIRT) was established within the Special Task Force (STF) of the Sri Lanka Police in 2011, supported by training from the U.S. Global Threat Reduction Initiative (GTRI).

A multi-agency approach was institutionalized, involving SLAERC (regulation), STF (escort and tactical response), State Intelligence Services (threat assessment), Customs and Ports (border control), and the National Disaster Management Centre (emergency preparedness). Mission-specific security plans incorporate risk assessments, specialized transport vehicles, armed convoys, drone surveillance, redundant communications, and pre-established safe houses.

### Results

Sri Lanka's framework demonstrates effective integration of safety and security. Measures such as tamper-evident packaging, joint training, and shared communication protocols balance regulatory transparency with operational secrecy. Regular scenario-based drills simulate adversary tactics including ambushes, diversions, and drone surveillance, ensuring system resilience.

Key outcomes include:

- Establishment of sovereign capability for radiological transport security.
- Significant cost savings compared to outsourced international services.
- Enhanced inter-agency coordination and intelligence sharing.
- Increased national resilience against insider and external threats.
- Contribution to global non-proliferation by ensuring lifecycle protection of high-activity sources.

### Conclusion

Sri Lanka's multi-layered, risk-informed approach provides a scalable model for countries with developing nuclear infrastructures. By combining localized innovation, inter-agency collaboration, and international support, the framework strengthens both national security and global non-proliferation efforts. Lessons from Sri Lanka's experience can inform other middle-income nations seeking to build sustainable, cost-effective, and internationally aligned transport security systems for radioactive materials.

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## **Strengthening Radiation Protection for Transport-Related Radiation Emergencies Accidents and Malicious Events: Insights from ICRP Task Group 120**

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The International Commission on Radiological Protection (ICRP) Task Group 120 (TG120) is developing recommendations on protecting people and the environment across a wide spectrum of radiation emergencies and malicious events, complementing ICRP Publication 146 (2020) on large nuclear accidents. The scope includes emergencies during the transport of nuclear and radioactive materials, accidents at facilities, damage to sealed sources, and malicious acts such as radiological dispersal devices, targeted poisoning, and nuclear detonations. The consequences of armed conflict are also considered.

A graded approach has been taken to ensure protection strategies are broadly applicable, balancing radiological risk reduction with wider health, societal, environmental, and sustainability considerations. Case studies of past events have been used to capture both radiological parameters (radionuclides, pathways, doses, protective actions) and non-radiological dimensions (optimisation, psychosocial and economic consequences, stakeholder engagement, and communication effectiveness).

TG120 guidance distinguishes between preparedness, response, and recovery, with recent work focusing on the early response phase and now moving into the late response phase. Topics include urgent protective actions, responder protection, dosimetry, triage, decontamination, environmental monitoring, and psychosocial support. Emphasis is also placed on the interface between emergency planning and response and nuclear security requirements, recognising that coordinated approaches are essential for malicious events and transport threats.

This presentation will highlight TG120's transport-related recommendations and their impacts, illustrating how the work of the Task Group can strengthen radiological protection in practice. The forthcoming report, to be released for public consultation in 2026, will provide updated and expanded recommendations to be considered in the revision of the IAEA safety and security standards.

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## **Seaport Security during Floating Nuclear Power Plant Deployment - the Interface between Maritime and Nuclear Security**

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The deployment of floating nuclear power plants (FNPPs) at seaports raises novel questions about the adequacy and sufficiency of existing nuclear and maritime security guidance because of the long-standing history of seaports as transit locations for nuclear material compared to long-term associated facilities, now considered with FNPP deployment. Many ports will have existing infrastructure that will play a role in the security of an FNPP; however, the adequacy of these measures and how they meet both international maritime security requirements and international nuclear security requirements and recommendations is largely unknown and likely lacking. Possible misalignment between nuclear and maritime security regimes is due to the focus of the nuclear security regime compared to maritime security, namely, the protection of nuclear material compared with protection of vessels, port facilities, and personnel, respectively. Traditionally, ports are concerned with nuclear security because nuclear material is transiting through, whereas with FNPP deployments, the seaport itself is now considered part of the nuclear facility. In both nuclear security and maritime security guidance, there is limited insight about the prolonged deployment of nuclear material at seaports and how the proper level of security is maintained. This paper aims to bridge maritime and nuclear security recommendations, specifically within the International Atomic Energy Agency's Nuclear Security Series No. 13 and the International Maritime Organization's International Ship and Port Facility Code by assessing high-level recommendations and how they translate into physical protection systems for FNPPs operating at seaports. First, this paper assesses relevant International Atomic Energy Agency and International Maritime Organization instruments for nuclear security and maritime security. For maritime security especially, existing requirements do not directly address the security of nuclear material, creating ambiguities about how these apply to nuclear security principles, if at all. Next, the paper describes how nuclear security principles, including threat assessments, may be integrated into maritime security to adequately protect an FNPP based on standard port infrastructure. Finally, the analysis will provide recommendations for generic integrated security measures to be considered for FNPP deployments in seaports.

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## **Safety and Security Measures during transfer of radioactive sources for the Gamma Knife device to the Martyr Ghazi Al-Hariri Hospital in Baghdad**

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An inspection team from the National on Nuclear, Radiation, Chemical and Biological Regulatory Commission inspected the shipment of radioactive sources arriving via Baghdad International Airport - air cargo and supervised the process of transporting these radioactive sources from the airport to the site of the installation at the Martyr Ghazi Al-Hariri Hospital in the Bab Al-Muadham area - Medical City Complex on 5 April 2023. The purpose of escorting a radioactive source during transport is to ensure compliance with radiation safety and security requirements during transport, at the work site, and at the installation site of the Gamma Knife system.

The package of radioactive sources that the Authority supervised the transfer of includes a large cylindrical container with a diameter of (85 cm) and a height of (160 cm) made of steel and lined with a thick layer of lead that acts as a radiation shield. The package contains 192 radioactive sources of type Co-60 with a radioactivity rate of (24 Ci) or (0.9 TBq) per source, and the total radioactivity of the radioactive sources is (4738.9 Ci) or (175.3 TBq) on the date of manufacture on 28 February 2023, as reported in the inspection document for the radioactive source attached to the report affixed to

the package of the radioactive source. The transport mark affixed to the surface of the package was Class II with Transport Index 1.2 and the transport package type B(U) bearing the number UN2916 according to the United Nations classification.

After completing customs procedures for the clearance of the shipment of radioactive sources arriving via the Baghdad International Airport air cargo terminal on March 29, 2023, under shipping document number 501-13893552 (Stockholm - Baghdad), the customs clearance procedures for this shipment were completed by Alkata Instruments on Wednesday, April 5, 2023. The transportation process was carried out with the facilities of the following entities:

1- The Iraqi Authority for the Control of Radioactive Sources, represented by Mr. Qais Abdul Amir, Mr. Hassanein Hekmat Muhammad, Mr. Mustafa Karim, and Mr. Ihab Sabah.

2- Al-Sager Security Protection Company.

3- In addition, Alkata Instruments staff, under the supervision of Mr. Muhammad Ammar Nasser, the company's radiation protection officer, and Mr. Muhammad Bashir Alwan (engineer).

The transportation route included air freight, the airport road, the expressway to the Amiriya area, the expressway to the Al-Adl neighborhood, the intersection of Al-Liqa' Square, Al-Iskan, Ali Al-Saleh Bridge, Al-Atifiya, Al-Sarafiya Bridge, Bab Al-Muadham, the Medical City Complex, and the Martyr Ghazi Al-Hariri Hospital, which was considered the secure way for the transport of the shipment. The radioactive source was transported by a large 5-ton truck.

Radiation measurements were performed on the sides of the radioactive source package and the transport wheel after loading the radioactive sources and were as shown in the table below:

Instrument used Dose rate ( $\mu\text{Sv/h}$ ) Measurement site

MiniTrace 173 The package surface contacts the sides of the metal container.

MiniTrace 9.3 60 cm from the surface of the container at the sides

MiniTrace 4.9 1 meter from the container surface at the sides

MiniTrace 15.5 30 cm from the surface of the container at the sides

MiniTrace 0.49 Driver's side cockpit

MiniTrace 0.42 Cockpit for the driver's side of the passenger's side

MiniTrace 9.87 Right side of the transmission wheel

MiniTrace 8.85 Left side of the transmission wheel

MiniTrace 1.79 Behind the vehicle of transport

It was concluded that the measured dose rates for the workers were well within the recommended dose constraint for this mission.

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## **A Portable Culture: Challenges of Maintaining a Strong Security Culture during Radioactive Material Transport**

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Building a robust security culture is a foundational element for any organization, but culture is especially important for ensuring the safe and secure handling of radioactive materials and in reducing the risk of insider threats. Although the characteristics and attitudes among individuals that constitute culture are widely promoted in the operational environments of fixed facilities—power plants, hospitals, research institutions, and industrial users of radioactive sources—the transportation of radioactive materials presents a distinct set of cultural and operational challenges that warrant closer examination, in both policy and practice. To address these challenges, the paper proposes actionable recommendations to align cultural norms and values within the operational realities of being

isolated in a mobile, decentralized environment, ultimately enhancing organizational culture and strengthening security.

Unlike a fixed location where employees and management engage in regular, in-person interactions that help establish and strengthen that cultural element, transport environments are inherently mobile, decentralized, and variable. Radioactive materials can pass through different hands, companies, jurisdictions, and layers of oversight. These movements may involve drivers, logistics personnel, subcontractors, customs officials, and end-users—each of whom may operate under different organizational norms and levels of training. In many cases, transportation personnel—especially those employed by third-party carriers or contracted for short-term operations—may not receive the same level of cultural integration or security reinforcement as their counterparts in fixed facilities. The result is a fragmented operational environment which can dilute cultural continuity and accountability in security operations.

While technical protection measures—GPS tracking, tamper-evident seals, and armed escorts—are central to transport security, physical measures are not sufficient on their own. The human element of security remains a critical piece, particularly for identifying and mitigating the risk of insider threat. A commitment to radiological security must be deeply internalized among all individuals involved in transportation because if staff are insufficiently trained, unengaged, or culturally detached from the mission, technical systems alone—no matter how strong—will not guarantee safety or mitigate insider threats.

International Atomic Energy Agency (IAEA) guidance documents such as NSS No. 7 (Nuclear Security Culture), NSS No. 9-G (Security of Radioactive Material in Transport), and NSS No. 26-G (Security of Nuclear and Other Radioactive Material in Transport) emphasize the need to maintain a strong security culture throughout the transport life cycle. However, these documents also recognize the complexities of implementing such culture in multi-actor environments and cross-border contexts. Using established psychology literature alongside workplace culture research, this paper offers an analysis of the challenges and opportunities for sustaining nuclear and radiological security culture during the transport of radioactive materials and explores how structural, organizational, and behavioral factors contribute to cultural erosion that results in key vulnerabilities of transport operations. Among the key vulnerabilities examined are a reliance on procedural compliance over internalized values, limited visibility of security leadership in mobile contexts, and differing interpretations of security culture across jurisdictions. Ultimately, if organizational security culture is to be truly effective, it must extend beyond static facilities and travel with the material. A well-protected shipment is the result not just of hardened containers and secure routes but of a shared, visible, and enduring commitment to security across the entire chain of custody.

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## **NORM Transport in Brazil: Regulatory, Logistical, and Social Challenges Toward a Holistic Framework**

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The transport of naturally occurring radioactive material (NORM) in Brazil poses challenges related to the country's continental dimensions, infrastructure limitations, and regulatory restrictions. In mining, metallurgy, and oil sectors, thousands of tonnes are generated annually and must be moved over long distances, often across deficient road networks with limited logistical support and emergency response.

These circumstances increase the complexity of applying the National Nuclear Safety Authority (ANSN) framework and related legislation, while also hindering the development of routes for research, treatment, and revalorization. The challenge is compounded by the use of industrial vol-

umes (big-bags and drums), widely adopted for regulatory predictability but which make large-scale transport economically unfeasible and generate secondary waste. Bulk transport, while reducing packaging waste and supporting circular economy approaches, demands certified equipment and specialized operators —still lacking in Brazil.

International experience reinforces these dilemmas. Japan, Germany, and Finland built regulatory frameworks aligned with IAEA requirements (TS-R-1/SSR-6) and conventions, but continue to face conflicts between safety and security [1–4]. Australia and Canada highlight the importance of public acceptance and effective communication [5,6,11]. In all cases, feasibility depends on interinstitutional coordination, involving regulators, environmental agencies, transport authorities, and public security.

Recent experiences broaden these lessons: Argentina integrated safety and security with satellite tracking, national databases, and armed escorts [7]; Germany showed that complex shipments such as vitrified waste returns were challenged mainly by massive protests and sabotage risks [8]; the Global Acceptance program demonstrated that keeping routes open depends on transparent communication with coastal states and communities [9]; and the European Association of Competent Authorities (EACA) proved that regional cooperation improves confidence and increases carrier availability [10]. In Canada, cases involving large irradiated components (steam generators) confirmed that public perception can hinder operations, even when radiological risks are minimal [11].

Brazil must therefore advance in adopting technological solutions (digital tracking, real-time monitoring, integrated emergency response), as well as regulatory harmonization and carrier qualification.

It is concluded that consolidating a safe, efficient, and sustainable model for NORM transport in large volumes and long distances —enabling new routes for research, treatment, and revalorization—requires a holistic approach, aligned with international best practices and adapted to the country's continental scale.

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The safe transport of radioactive materials is a key component of nuclear and radiological safety worldwide. In Ibero-America, this challenge requires not only robust technical standards but also coordinated regulatory efforts across countries with diverse infrastructures and operational practices. To address this need, the Foro Ibero-Americano de Organismos Reguladores Nucleares y Radiológicos (FORO) developed a comprehensive project focused on the Periodic Maintenance and Verification of Packages for the Transport of Radioactive Materials. This initiative highlights the region's commitment to ensuring high levels of protection for workers, the public, and the environment.

The project identifies the technical and regulatory requirements necessary to guarantee the reliability of transport packages under routine, normal, and emergency conditions. It emphasizes the importance of establishing systematic maintenance procedures and periodic verification protocols that ensure the long-term integrity of the packaging. In doing so, it provides a harmonized framework that strengthens compliance with international safety standards while responding to regional needs and experiences.

A central contribution of the initiative lies in its methodology, which classifies package types, outlines their safety functions, and analyzes operational challenges identified during inspections. The resulting recommendations include detailed guidance on inspection frequency, maintenance records, and documentation workflows. Such guidelines are not only practical for operators but also enhance the ability of regulatory bodies to supervise transport activities effectively, reducing risks associated with non-compliance or technical failures.

The FORO's role is fundamental in fostering this achievement. By bringing together regulatory authorities from Spain, Argentina, Brazil, Chile, Cuba, Mexico, Peru, Uruguay, and other member states, the project reflects a unique spirit of regional cooperation. This collaborative platform has enabled the sharing of technical expertise, harmonization of approaches, and development of common regulatory language, thus reinforcing the consistency and robustness of oversight across borders.

Ultimately, the project demonstrates how regional cooperation, under the leadership of the FORO, can strengthen nuclear and radiological safety beyond the national level. It establishes a model for sustainable collaboration, grounded in technical rigor and regulatory harmonization, that can be replicated in other areas of nuclear safety. In doing so, the initiative consolidates the Ibero-American region as an active contributor to the global nuclear safety regime, aligned with the principles, and cooperation, of the International Atomic Energy Agency (IAEA) and international best practices.

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## An Analysis of Challenges in the Land Transportation of Tin Slag 2

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A by-product of tin processing and smelting industries, tin slag 2, is naturally radioactive as it originates from uranium and thorium decay chains. Currently, tin slag 2 is stored only in temporary facilities, creating opportunities and increasing the potential for transportation from one location to another, whether for further processing, temporary storage, or disposal. This paper aims to identify the challenges of transporting tin slag 2 by land, viewed from the aspects of regulation, infrastructure, radiation safety, and human resources. The methodology employed is a literature study of national regulations and international recommendations. Regulations relevant to the transport of radioactive material include Government Regulation No. 58 of 2015 and BAPETEN Regulation No. 7 of 2020. Tin slag 2 is categorized as a Low Specific Activity-I (LSA-I) radioactive material. The transport of LSA-I can be conducted without special packaging if three conditions are fulfilled: the material does not leave the vehicle during transport, it is transported under exclusive use, and it does not contaminate the vehicle. The key challenge is ensuring an effective monitoring system from upstream to downstream so that these conditions are consistently met. Infrastructure limitations, particularly poor road conditions and difficult terrain, can increase travel time and the risk of accidents. Longer travel times directly correlate with potential external and internal radiation doses received by transport personnel. Compliance with personal protective equipment, radiation monitoring devices, and dosimeters adds another layer of complexity. Moreover, drivers and transport personnel must be adequately trained and supported by clear operational procedures. While the challenges seemed primarily domestic in nature, the issue can also highlight the importance of international cooperation. Regional initiatives such as ASEANTOM, and global platforms like the IAEA, can foster knowledge sharing, joint training, and improved monitoring and information exchange, thereby strengthening the safety and security of radioactive material transport.

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## **Safety and security during the transportation process of the Gamma Knife system using the SAFRAN program**

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The Gamma Knife is a highly sensitive and specialized medical device used in neurosurgery to treat brain tumors with precise radiation. Transporting this equipment, especially when it contains radioactive sources, requires strict adherence to safety and security protocols to prevent physical damage, radiation exposure, or security breaches.

This study evaluates the safe and reliable transport of the Gamma Knife system from Basra International Airport in Basra Governorate to Al-Sadr Teaching Hospital, using SAFRAN software. SAFRAN program is a project management tool widely used in critical industries such as nuclear energy and defense. It enables comprehensive risk assessment, scheduling, emergency planning, and real-time monitoring.

Using SAFRAN software to transport sensitive equipment such as the Gamma Knife system is no longer an option; it's a necessity dictated by safety and operational precision. By providing an integrated digital environment for planning and monitoring, the software increases transport efficiency and ensures the safe arrival of equipment without material or technical losses. With the continuous advancement of technology, the importance of such software solutions is expected to increase in supporting vital transport operations, especially in complex environments such as Iraq.

**Keywords :** Gamma Knife ,Safety, Transportation, SAFRAN, Emergency.

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## **: The European Association of Competent Authorities for a safe and sustainable transport of radioactive material (EACA) –working mode**

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The European Association of Competent Authorities for a safe and sustainable transport of radioactive material (EACA) is a network of European authorities responsible for the safety in transport of radioactive material. Membership in the EACA is open to all European countries, is voluntary and not legally binding. Currently, competent authorities from more than 20 countries are members of the EACA. EACA keeps close connections to the Mediterranean Network (MedNet).

The intention of EACA is to improve the implementation of the regulations for the safe transport of radioactive material based on the IAEA safety standard SSR-6 and to harmonize it within Europe. This is achieved by discussing topics possibly relevant to more than one country, by applying questionnaires for comparing the requirements and practices in different countries and by creating guidance etc.

Currently meetings are organized twice a year: one in person meeting hosted by one of the member authorities, and the other meeting being organized virtually. Some typical agenda items from the last meetings were: experiences with the shipment of SCO-III, handling of consignments not declared as dangerous goods but containing radioactive material, changes due to revised international regulations, ageing management issues, guidance on inspections, reporting on transport events and lessons learnt, tabulating variations in regulations between European countries.

The paper will describe more detailed successful past projects as well as topics from a typical current meeting agenda. It aims to explain the benefits and the limitations of such a network.

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## **Radiation Protection Programme in Transport: A Gap Analysis of Annex XIV of BAPETEN Regulation No. 7/2020 and IAEA SSG-86**

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The transport of radioactive material requires specific regulatory frameworks to address safety and security challenges beyond those of general transport. At the international level, the IAEA establishes requirements through SSR-6 [1] and supporting safety guides [2, 3, 4, 5], including SSG-86 on Radiation Protection Programmes (RPP) for the Transport of Radioactive Material [6]. In Indonesia, the legal basis is provided by Government Regulation No. 58/2015 on Radiation Safety and Security in the Transportation of Radioactive Materials, further detailed in BAPETEN Regulation (BR) No. 7/2020, with Annex XIV outlining the national RPP framework. The five years of implementing BR No. 7/2020 Annex XIV provide a timely opportunity to review and strengthen Indonesia's regulation on radiation protection programmes for the transport of radioactive material.

This study conducts a structured gap analysis between Annex XIV of BR No. 7/2020 and the international guidance in IAEA SSG-86. The analysis focuses on the graded approach, roles and responsibilities, dose assessment, integration with management systems, and practical examples. The findings highlight both areas of alignment and critical gaps. Addressing these gaps will enhance Indonesia's regulatory effectiveness and support future revisions to ensure closer alignment with international standards.

Table 1. Gap Analysis of Annex XIV BR No. 7/2020 and IAEA SSG-86

No Aspect BR No. 7/2020

(Annex XIV) IAEA SSG-86 Identified Gap/ Recommendation

1. Graded approach Dose-based graded approach. Risk-based graded approach covering routine, normal, and accident conditions. Add a risk-based graded approach and explicit coverage of all transport conditions.
2. Roles & Responsibilities Consignor, carrier, and consignee. Includes consignors, carriers, consignees, and port/airport operators. Broaden roles with detailed assignments and coordination.
3. Dose Assessment Package-focused, dose-based. Comprehensive, risk-based; includes workers, public, and optimization. Integrate routine, normal, and accident scenarios; expand worker/public evaluation
4. Management System Not explicitly addressed. Requires integration of RPP into the management system (QA/QC, audits). Embed RPP in the management system.
5. Examples No examples. Provides model RPPs and examples. Add practical examples.

The gaps have clear implications. A dose-based graded approach focuses only on worker thresholds, ignoring public exposure, accident conditions, and optimization. This risks missing high-risk but low-dose scenarios such as contamination events, transit storage, or emergency stops. Limited roles and responsibilities to consignor, carrier, and consignee leave interfaces at ports, airports, warehouses, and subcontractors unregulated. In an accident, responders may not know whose procedures apply. A package-focused dose assessment is not comprehensive, leaving workers and the public insufficiently protected in routine and accident scenarios. This creates risks of over-exposure in foreseeable events such as delayed shipments in public terminals. Without integration into QA/QC, the RPP becomes a static document rather than a system for continuous improvement. The absence of practical examples may also cause uneven RPP implementation across the industry.

Closing these gaps would align Indonesia's framework with IAEA standards while also strengthening regional leadership, driving innovation, promoting continuous improvement, and fostering a stronger safety culture. After five years of implementation, it is timely to revise BR No. 7/2020 by incorporating a risk-based graded approach, expanded roles, comprehensive dose assessment, management system integration, and practical examples to enhance regulation. Beyond regulatory alignment, the findings of this study can guide regulatory revisions, support reviews of current practices under BR No. 7/2020 Annex XIV, and provide a benchmark against IAEA SSG-86.

Keyword: radiation protection programme, gap analysis, transport of radioactive material

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## **CONTAS: Design And Qualification Of A High Integrity Container For Intermediate Level Solid Waste**

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Ansaldo Nucleare S.p.A. has designed, fabricated and partially qualified a high integrity container (CONTAS), for the conditioning, transportation and long term storage of solid ILW with low content of  $\alpha$ -emitter radionuclides. Based on national and international norms and standards (IAEA SSR-6, ADR-RID, UNI 11784, Raccolta V.S.R.) CONTAS complies with stringent requirements to ensure protection of persons and environment.

CONTAS is a cylindrical container 1500mm high by  $\phi_{ext}$  1100mm, having a maximum internal usable height of 1165mm by and  $\phi_{int}$  740mm, offering a general shielding wall thickness of 160mm and an internal usable volume of approximately 0,5m<sup>3</sup>.

The main distinguishing features of CONTAS are described as follows:

- base material in forged carbon steel P355 QH1 & QL1
- nominal mass (full load) 10.000 kg, usable volume 500 liters
- 50 straight years lifetime, extendable to 100 years in case of scheduled inspections and/or maintenance activities
- two secondary openings closed by blind flanges: the first one to drain CONTAS after loading underwater and to detect internal pressure during operation, the second one to vent CONTAS during draining
- primary sealing system (between body and lid) made by two axial gaskets in series, co-planar, tightened through bolting; the gaskets are energized metallic C-rings, CONTAS design ensures the sealing performances in every design condition including accidental events
- secondary sealing systems made each by an energized metallic C-ring in series with an NPT plug; the tightening of the flanges is obtained through bolting
- every sealing systems provided with a control volume each, inspectable during CONTAS operation and preserving the overall leak tightness of the package
- geometrical details aimed to prevent stagnation of contaminated water and/or particulate (e.g. conical floor, bolt head open seats, drain holes for bolts)
- lifting devices allowing both lateral and bottom lifting
- bottom end and top lid profiles easing stacking
- suitability to host customized internal baskets and additional shielding panels

Innovative features of CONTAS have been patented (both in Italy and in main EU countries).

CONTAS design, within the scope of a proper defined Qualification General Plan, has been successfully even if partially qualified through a mix of experimental and analytical tests; the experimental ones have been performed both on material samples or even full-scale prototypes, arranging the test sites according to standards criteria, and involving qualified Suppliers and Laboratories.

Experimental tests include:

- free drop on a target rigid platform according to IAEA SSR-6 and SSG-26
- fire accident
- degradation
- dynamic characterization of base material for FEM model validation
- leak tightness
- pressure
- functional (assembly, handling, lifting, stacking, etc.)

Once the FEM model and methodology have been validated by comparing numerical results with experimental outcomes, multiple dynamic simulations have been launched to assess the consequences of as many free drop scenarios.

From the transportation point of view Ansaldo Nucleare has begun to demonstrate the compliance of CONTAS design with IAEA SSR-6, as Type IP-3 package.

Ansaldo Nucleare has recently awarded a contract for the supply of CONTAS for the conditioning of ILW internals at Garigliano spent nuclear plant. For this specific application, Ansaldo Nucleare is aiming to:

- design internal baskets to host the waste streams
- design an impact limiter for transportation purpose
- provide additional shielding devices where needed
- complete the qualification of CONTAS both as IP-3 and B(U) package according to the reference Standards, in particular IAEA SSR-6, by performing a mix of other experimental and analytical tests

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## DEVELOPMENT OF REGULATORY INFRASTRUCTURE FOR TRANSPORT OF RAM

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Current regulatory infrastructure and the needs for development

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## I-NRC's National Role in Strengthening Regulatory Practices for Secure Transport of Radioactive Sources

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The objective of clarifying the scope of licensing and reviewing the regulatory authority's procedures is to ensure safe, transparent, and efficient licensing for the transport of radioactive materials by:

- ☒ Reinforcing the importance of radioactive material transport licenses compared to other radiation practices.
- ☒ Involving multiple entities (legal, financial, administrative, and audit) within the regulatory authority in issuing licenses to ensure strict oversight consistent with national and international standards.
- ☒ Enhancing the role of digital oversight through systems such as RAIS 3.4 for the transport of radioactive materials.
- ☒ Streamlining procedures by reducing the processing time for license applications through a parallel workflow while maintaining accurate reviews.

Nuclear and radioactive materials are transported worldwide for use in medicine, industry, research, and energy production. Vehicles carrying radioactive material travel through public areas, making them targets for thieves or susceptible to accidents and loss. So this indicates that transport is often the weakest link in the security chain, as adversaries may find it easier to intercept materials in transit than to breach a secure facility. So the transport of nuclear and radioactive materials is a critical process that requires the highest levels of security and safety. So the regulatory

In 2024, the National Commission for Nuclear, Radiological, Chemical, and Biological Control (I-NRC) supervised multiple transport operations of radioactive sources, amounting to more than 53,648 sources across different categories and security levels. All transport operations were conducted in accordance with national regulations and instructions issued by the I-NRC, and in line with the standards of the International Atomic Energy Agency (IAEA).

The supervision process included prior review of transport plans, monitoring compliance with radiation safety and physical security requirements, and verifying the readiness of transport equipment. In addition, personnel involved in the transport operations were trained in emergency procedures and response measures for potential incidents.

No observations or incidents related to security discipline or safety were recorded, whether for the workers or the general public.

The radioactive material transport operations in Iraq have significantly increased in recent years, reflecting the growing use of radioactive sources, particularly in the medical sector and the industrial/oil sector

The I-NRC has upgraded its regulatory and oversight systems in line with the recommendations of the International Atomic Energy Agency (IAEA), including the implementation of the RAIS system and updated transport databases. Procedures for obtaining a transport license have been developed and simplified, while strictly adhering to national and international standards.

As a result of comprehensive safety and security measures, no radiological incidents have been recorded during transport operations over the studied period, underscoring the effectiveness of Iraq's regulatory framework.

frameworks and corrective actions are applied (both national and international), and advanced security technologies are used (Locks, GPS tracking, radiation detection, tamper-evident containers, etc.).

**Country or International Organization:**

**Instructions:**

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## From Supplier to Site: Securing Cobalt-60 During North American Transit

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This paper will present how Nordion and ORNL have teamed to create a framework for collaboration to address the transportation challenges of today and tomorrow. Nordion and ORNL share a successful history of collaboration on transportation security and have a long-standing agreement to enhance the safety and security of Cobalt-60 (Co60). This shared history of partnership is important for many reasons, including its many contributions to harmonizing regulations, as well as its enhancement of planning efforts to address and counter rapidly advancing technologies that could enable adversarial groups.

It's widely accepted that high-consequence radioactive materials are most vulnerable to nefarious activities during transport. The global process of transporting nuclear and radioactive materials inherently involves a significant number of entities, from the supplier, carriers, customs, and regulators, to law enforcement organizations and their associated processes and requirements. Therefore, assuring a safe and secure shipment requires a great deal of planning and coordination. Further, as evidenced by recent world events, national disasters, conflicts, and uses of emerging technologies drives the need for more vigorous cooperation between industry and government to navigate the myriad potential challenges faced day in and day out.

Nordion, headquartered in Ottawa, Canada, is the world's leading supplier and manufacturer of Co60 sealed sources. Annually, Nordion ships significant quantities (and numbers of shipments) of Co60 into and through the United States, as part of its global supply strategy for necessary medical and industrial devices. These materials are essential for the health and well-being of the global population, and disruptions to their distribution pose dire effects. Oak Ridge National Laboratory (ORNL), located in Oak Ridge, Tennessee, USA, is a world leader in transportation and transportation security. ORNL is engaged both domestically and globally to enhance protection of nuclear and radioactive materials, particularly when these materials are in transit.

Together, Nordion and ORNL are working to strengthen the security of shipments across North America that are critical to the support of our health and way of life, while also being mindful of safety and operational impacts.

**Country or International Organization:**

**Instructions:**

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**The role of the I-NRC in the secure transportation of high-activity radiotherapy sources****Author:** Mohammed Kadhim<sup>1</sup>**Co-author:** Ban Matoog<sup>1</sup><sup>1</sup> *The Iraqi Nuclear, Radiological, Chemical, Biological Commission***Corresponding Authors:** banmaster81@yahoo.com, mokadhim@yandex.ru

Hundreds of patients from across all Iraqi governorates seek treatment at the hospital each year. With rising patient numbers, timely access to radiotherapy is critical for preventing disease progression. Modernisation of radiotherapy infrastructure, including the replacement of outdated cobalt units with advanced linear accelerators, has therefore become a priority. The dismantling and packaging were carried out in cooperation with the Ministry of Science and Technology, while the Iraqi National Regulatory body (previously IRSRA - Now I-NRC ) supervised the development and approval of a comprehensive transport safety and security plan. The sources were subsequently transferred to the national radioactive waste management facility at Twaitha –Bunker B. This case highlights the importance of institutional and regulatory coordination in handling high-activity sources and demonstrates Iraq's commitment to applying international standards to strengthen radiation safety, security, and protection of society and the environment.

The transport of high-activity radioactive sources is one of the most sensitive stages in the lifecycle of radioactive materials, requiring strict adherence to radiation safety and security standards. This study presents the experience of the Radiation and Nuclear Medicine (RNM) Hospital in Baghdad in decommissioning and transporting three high-activity Co-60 teletherapy units (ISO-1 and ISO-2, Cirus). The dismantling and transport process took place in two phases, the first in 2012 and the second in 2021. This is an interesting and important experience for lessons learned regarding highly active radiotherapy sources.

This work aims to present a practical case study on the decommissioning and transport of high-activity radioactive sources (Co-60 teletherapy units) from the Radiation and Nuclear Medicine Hospital in Baghdad to the national waste management facility at Twaitha –Bunker B, under the regulatory requirements of the Iraqi National Regulatory Commission (I-NRC). The objective is to highlight the importance of coordination among technical and regulatory bodies in ensuring safe and secure transport, while documenting lessons learned to support national efforts in upgrading radiotherapy services and complying with international standards.

This experience highlights Iraq's progress in regulatory oversight at all stages of handling radioactive sources, particularly the transportation of highly active radioactive sources.

The field plans and procedures implemented were consistent with IAEA requirements, including safe transportation, radiation protection, dose recording, and field surveys before, during, and after transportation.

The experience constitutes an important database to support future policies regarding the dismantling and transportation of radioactive sources and can be adopted as a training and educational model for new cadres in Iraq and the region.

**Country or International Organization:****Instructions:**

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**CERETRAM - Electronic System for Radioactive Material Shipments Notifications**

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CERETRAM constitutes a centralized, electronic notification architecture engineered to rationalize the mandatory regulatory reporting requirements for the transport of radioactive material. The platform's data-driven methodology supports a risk-informed and graded approach to regulatory oversight, prioritizing resources based on assessed hazard. This system yields significant operational dividends, including the enhancement of data veracity, provision of real-time informational access for regulatory authorities and a demonstrable increase in risk assessment and planning capabilities. Crucially, CERETRAM provides an empirical basis for fostering a robust safety culture and elevating the overall quality of regulatory services.

**Country or International Organization:**

**Instructions:**

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## Securing the transport of disused medical source cat 1

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Securing the transport of disused Category 1 sources is particularly challenging when carried out in a medical facility, due to the need to ensure continuity of healthcare services while implementing strict security measures. This paper presents the case of decommissioning two medical sources from the Health Center in Kladovo, where PC NFS acted as the project leader and the only licensed operator in Serbia with the capability to conduct such sensitive and demanding operations.

The project included the establishment and maintenance of a functional security system at the medical facility prior to source removal, the coordination of protective measures during preparation and packaging, and the implementation of strict security protocols throughout transport to an authorized facility-secure storage for high activity sources in PCNFS. Emphasis was placed on compliance with IAEA security guidance and national regulatory requirements, as well as on the integration of technical, organizational, and logistical measures designed to minimize security risks during each stage of the operation.

The case study highlights the importance of a comprehensive security approach in managing high-risk radioactive sources, demonstrating how effective planning, coordination, and implementation of security measures can ensure the safe and secure completion of transport activities.

**Country or International Organization:**

**Instructions:**

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## Importance of internal transport in PC NFS

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The internal transport of radioactive material within a nuclear site is a highly sensitive operation that requires precise planning and strict security measures. In the upcoming years, PC NFS will be responsible for the decommissioning of the H1 and H2 hangars, which currently serve as storage facilities for legacy radioactive waste. This task will represent a highly complex and sensitive undertaking, both from a safety and a security standpoint, requiring meticulous planning, robust technical measures, and strict regulatory compliance. This paper presents the operational procedures implemented by PC NFS that will be used during the decommissioning of the H1 and H2 hangars, focusing on the secure movement of barrels containing radioactive material.

The process involves three main stages: first, the transfer of barrels from hangars H1 and H2 to the radioactive waste processing facility; second, processing and temporary containment within the facility under continuous monitoring; and third, the controlled transport of processed material to either hangar H3 or a dedicated secure storage designed to minimize radiation exposure. Each stage will be supported by tailored security protocols, including access control, real-time tracking, and coordinated handling by trained personnel.

The study highlights the integration of organizational, technical, and procedural measures to ensure a high level of security throughout the operation, demonstrating best practices for internal transport, radiation protection, and risk mitigation during the decommissioning of high-risk storage facilities.

**Country or International Organization:**

**Instructions:**

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## Developing transport container for category 1 source

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The first decommissioning project of a disused Category 1 radioactive source, previously applied for medical purposes at the Medical Center Kladovo, was successfully carried out by PC NFS. According to national and international regulations, the transport of a Category 1 source must strictly comply with requirements regarding radiation protection, security, and overall safety.

One of the essential project requirements was to ensure that the source, during removal and transport, remained within its shielding, which provided compliance with radiation dose criteria. Nevertheless, because of additional safety and security considerations, it was necessary to design and apply a specialized transport container. This container was developed, engineered, and manufactured by PC NFS, representing an innovative technical solution tailored to this demanding task.

The realization of this task included a complex multidisciplinary process requiring precise planning, technical expertise, organizational coordination, and strong project management. This paper describes all phases of the development, including the preparatory phase, design and load simulations for the transport container, manufacturing of the container, disassembly of source and its placement within the protective transport container.

**Country or International Organization:**

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# **Integrating Domestic Production and International Supply Chains: A Holistic Review of Kenya's Safety and Security Framework for Medical Radioisotope Transport.**

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## Abstract.

The safe, secure, and timely transport of medical radioisotopes is fundamental to sustaining nuclear medicine diagnostic and theranostic services. In Kenya, demand for radiopharmaceuticals such as Fluorine-18 Fluorodeoxyglucose (18F-FDG), Fluorine-18 Prostate-Specific Membrane Antigen (18F-PSMA), Gallium-68 tracers (PSMA, FAPI04, DOTA), Technetium-99m (Tc-99m), and therapeutic Lutetium-177 (Lu-177) and Iodine-131/123 continues to rise.

Kenya operates three cyclotrons, with two commercial and one institutional, supporting domestic 18F production. Four hospitals rely on these cyclotrons, complemented by imported Ga-68 generators, Tc-99m and therapeutic isotopes.

The supply chain faces substantial security threats. Political volatility, youth demonstrations, and organized terrorist groups such as Al-Shabaab present major risks. Porous borders with Somalia, Ethiopia, and Sudan further enable movement of armed groups that could infiltrate Nairobi Kenya's main hub for isotope medication and transport. These realities underscore the urgency of a holistic safety and security framework.

## 1.0 Background

Medical radioisotope transport in Kenya sits at the intersection of expanding domestic production and continued international dependence. Local cyclotron production reduces import-related delays but intensifies internal transport risks, especially within Nairobi's volatile environment. Imports remain indispensable for Ga-68, Tc-99m, Lu-177, and I-131, yet are vulnerable to clearance delays, airport bottlenecks, and evolving terrorist threats.

## 2.0 Methods

This study applies a qualitative policy review methodology, analysing IAEA Safety Standards Series (SSG-26, TS-R-1) and Nuclear Security Series No. 9-G (Rev. 1) and No. 46-T, IATA Dangerous Goods Regulations and ICAO standards, the Kenya Nuclear Regulatory Authority (KNRA) Act, regulations, and guides, and National policy documents on nuclear security and emergency preparedness.

The analysis emphasizes regulatory oversight, physical protection, interagency coordination, emergency preparedness, and safety-security integration against the common practise. Comparative insights from international, and regional practices provide context for Kenya's evolving framework.

## 3.0 Results and Discussion

### 3.1 Regulatory Oversight and Security Imperatives

KNRA issues a single, integrated license for radioactive material transport embedding safety, security, and emergency response. Pre-transport risk assessments, approved routes avoiding high-risk zones, real-time GPS tracking, and armed escort requirements for high-activity sources are aligned with the national threat profile.

### 3.2 Strengths and Vulnerabilities in a High-Threat Environment

**Domestic Production:** Cyclotrons reduce international freight risks but concentrate supply in Nairobi a city prone to demonstrations, gridlock, and terrorist targeting. Transport disruptions can immobilize shipments, delay procedures, and heighten exposure risks.

**Clearance Delays and Airport Vulnerabilities:** Imports are frequently hindered by customs clearance and airport handling delays. These choke points increase decay risks for short half-life isotopes and expose consignments to security threats. Enhanced screening, personnel vetting, and interagency coordination remain critical.

### 3.3 Persistent Challenges

**Interagency Coordination:** Seamless collaboration among KNRA, National Police Service, Anti-Terrorism Police Unit (ATPU), intelligence agencies, and emergency responders remains limited.

**Human Capacity:** Specialized training is insufficient. Personnel including drivers and regulators require instruction beyond radiation safety, with emphasis on terrorism awareness and response under duress.

**Adaptive Threat Assessment:** Current plans risk obsolescence. Evolving threats demand continuous, intelligence-led reassessment of protocols rather than static security measures.

## 4.0 Conclusion and Recommendations

Kenya's medical radioisotope supply chain operates within a fragile security environment. While the KNRA framework provides a solid foundation, its resilience depends on adaptive, intelligence-driven measures.

Recommendations includes; Establishment of stronger links with security agencies to enable threat-informed routing and scheduling, avoiding hotspots and volatile periods. Deployment of centralized, real-time tracking systems with duress alarms for transport vehicles. Institutionalize advanced training and realistic drills simulating hijackings, demonstrations, and ambushes to prepare stakeholders for high-stress conditions.

By addressing these areas, Kenya can safeguard uninterrupted access to critical nuclear medicine services while strengthening its national nuclear security regime.

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## **Challenges compromising safety of short-lived medical radionuclides during transport in developing countries**

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The safe transport of short-lived medical radionuclides, such as Fluorine-18 labelled compounds, is critical for the delivery of effective nuclear medicine services. In developing countries such as Kenya, several safety-related challenges compromise the integrity of this process. Inadequate regulatory frameworks, limited technical expertise, and weak enforcement mechanisms hinder the consistent application of international safety standards. Infrastructural shortcomings such as unreliable transport networks and the absence of certified radiation-shielded vehicles increase the risk of delays and unintentional radiation exposure. Additionally, a shortage of trained personnel across both regulatory agencies and transport operators contributes to operational errors and lapses in radiation protection protocols. The time-sensitive nature of these radionuclides further compounds safety concerns, as any delay in transport may lead to ineffective dosing and elevated exposure risks. This paper aims to identify and analyze the key safety challenges affecting the transport of short-lived medical radionuclides in developing countries, with the objective of highlighting critical gaps and proposing strategies to enhance safe handling, transport conditions, and regulatory compliance.

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## **The Regulation of Transport Radiation Emergency Preparedness & Response in Great Britain**

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This presentation will give an overview of the regulation of transport radiation emergency preparedness and response requirements within Great Britain and will be delivered by an inspector of the competent authority for this area, the Office for Nuclear Regulation (ONR). The presentation will relate primarily to the conference theme of Legislative and Regulatory Framework for Safe and Secure Transport, and touch on topics including revision and implementation of regulatory guidance and expectations, competency and capacity development within the Great Britain competent authority, national liaison and cooperation and the safety-security interface within emergency preparedness and response. This presentation will discuss;

- An overview of the legislative requirements concerning radiation emergency preparedness and response for the transport of radioactive material within GB and how GB complies with the requirements of SSR-6 Paragraphs 304-305.
- ONR's role as competent authority and its areas of regulatory responsibility.
- A description of how ONR has instigated a program of work to improve its regulation of transport radiation emergency preparedness and response.
- The revision of regulatory guidance to align with how ONR inspects and assesses these requirements in practice and sharing a draft version of the guidance with the dutyholder community for consultation.
- ONR's revised regulatory guidance to aid dutyholders to comply with the regulatory requirements and the stakeholder engagement undertaken to be transparent with expectations.
- A description of ONR's revised regulatory guidance to aid inspectors in understanding what constitutes relevant good practice in the area of transport radiation emergency preparedness and response and to make consistent regulatory judgements on dutyholder compliance.
- An overview of the regulatory intelligence available to ONR to ensure regulatory activities undertaken in this area are risk informed and targeted with limited inspector resource.
- Examples of good practice identified during inspections and assessments of transport radiation emergency preparedness and response arrangements.
- Common areas of non-compliance and areas for improvement identified during inspections and assessments of transport radiation emergency preparedness and response arrangements.
- Work being undertaken in ONR to develop competency and capacity of inspector resource in the area of transport radiation emergency preparedness and response.
- A look at future potential developments, including revising/improving the legislation concerning transport radiation emergency preparedness and response, better defining national arrangements for responding to such events and developing ONR's internal radiation emergency response arrangements for transport events.

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## **PLANNING FOR SAFETY AND SECURITY DURING TRANSPORT OPERATIONS FOR THE BOLIVIAN NUCLEAR REACTOR (RB-01)**

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This synopsis is a summary of how safety and security during transport is being planned for the transport of radioactive material.

**Country or International Organization:**

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## **IT-Security in High-Risk Radioactive Material Transport –The Journey of Container ”Cerberus\_74”**

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This presentation illustrates the practical application of Germany’s national IT security regulations for high-risk radioactive material transport, using the fictional journey of transport container “Cerberus\_74” as a case study. Starting from a nuclear medicine centre in southern Germany, the scenario highlights the logistical and digital challenges involved in safely transporting highly sensitive radioactive substances.

Three core systems are critical to the operation: a real-time transport control system, container monitoring sensors, and a secure communication network. The narrative describes a simulated cyberattack aimed at manipulating GPS data and compromising container integrity data. Thanks to the protective measures outlined in the IT-Security requirements catalogue issued by BASE (Federal Office for the Safety of Nuclear Waste Management), the attack was successfully thwarted. Key safeguards included two-factor authentication, system hardening, baseline monitoring, and trained personnel.

The presentation also emphasizes the role of independent experts in the approval process. Before any transport begins, the applicant must demonstrate compliance with the IT security catalogue through detailed documentation and technical specifications. The expert acts as an auditor, verifying that theoretical concepts are effectively implemented and identifying any weakness.

The case of “Cerberus\_74” underscores that IT-Security in radioactive material transport is not a static checklist but a dynamic, critical function. The combination of regulatory frameworks and expert oversight provides a robust model for ensuring safety in a digitized world and may serve as a blueprint for international standards.

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## **Transportation of Radioactive Material for Handling Evidence in Cases of Criminal Acts of Unlicensed Nuclear Energy Utilisation in Indonesia: The Role of the Regulatory Body**

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Nuclear energy utilisation in Indonesia is extensive, spanning various sectors, including medical and industry. Indonesia has a regulatory body, Indonesian Nuclear Energy Regulatory Agency (BAPETEN), tasked with overseeing all nuclear energy utilisation with three main aspects: regulations, licensing and inspections, as stipulated in Act No. 10 of 1997 on Nuclear Energy.

In practice, not every nuclear energy users comply with regulations. This is common finding when BAPETEN conducts inspections in medical and industrial sectors. In both sectors, BAPETEN has repeatedly enforced law against users who do not have licence. It should be noted that BAPETEN only enforces law when users completely disregard BAPETEN's guidance efforts. The problem statement in the paper is that in the event of law enforcement, how is evidence handled?

The purpose of the paper is to determine the extent to which the implementation of regulations in the context of radioactive material transportation is linked to the law enforcement of nuclear energy. This is important due to responds to the existing gap, there are regulations on radioactive material transport under normal conditions but are faced with the status of law enforcement which is in the process of being implemented in the court. The method used in the paper is qualitative with the main source of research subject coming from law enforcement officers, especially prosecutors, based on cases handled directly in implementation in the field.

Law enforcement is carried out in coordination with law enforcement officers: the National Police and the prosecutor. One of steps taken in law enforcement is handling of evidence. For example, when radioactive materials are used without licence, National Police confiscate radioactive material during nuclear law enforcement. This confiscation is in accordance with Criminal Procedure Code. Law enforcement, following an investigation by National Police, is then handed over to Prosecutor's Office, who then prosecutes the case in the court.

In nuclear law enforcement activities involving radioactive material, law enforcement officers confiscate the radioactive material. These confiscated sources are typically deposited at the Radioactive Waste Management Installation (IPLR BRIN) or in BAPETEN office as regulatory body, as law enforcement officers does not have radioactive material storage facilities. Coupled with the fact that most law enforcement officers in Indonesia are unfamiliar with nuclear energy, including radioactive materials, the deposited of evidence is a real solution.

In practice, the deposited of radioactive material is carried out by BAPETEN as the regulatory body to ensure the security of the evidence itself. The transportation of radioactive material from crime scene to IPLR BRIN or to BAPETEN office is also carried out by BAPETEN with the transporter being a nuclear safety inspector and equipment including vehicles owned by BAPETEN with reference to the provisions of transportation requirements in the regulations including Government Regulation No. 61 of 2013 on Radioactive Waste Management.

In this context, the transportation of radioactive material is a special activity due to it is not included in the definition of nuclear energy utilisation as regulated in Act No. 10 of 1997 on Nuclear Energy, but rather the handling of evidence in the process of enforcing nuclear energy law. BAPETEN transports radioactive material in accordance with nuclear energy law, ensuring the desired safety and security of radioactive material is achieved to the greatest extent possible.

**Country or International Organization:**

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## **Application of the Regulatory Impact Analysis (RIA) using Multi-Criteria Decision Analysis (MCDA) of the Indonesian Regulation for the Safe Transport of Radioactive Materials**

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In 2015, the Indonesian government issued the Government Regulation on the Safety and Security of Transport of Radioactive Materials (GR 58/2015), which was developed based on the SSR 6/2012. Since then, this IAEA safety standard has been revised into SSR 6 rev.1 in 2018. Some improvements in SSR-6/2018 may impact the implementation and necessitate updates to the regulation in Indonesia. In addition, since the regulation was issued in 2015, the implementation issues need to be analysed due to the development of nuclear applications in Indonesia. This study conducts a regulatory impact analysis of the regulation regarding the safety of transporting radioactive materials in Indonesia and provides recommendations to the authority for future improvements in regulations. The method employed is the Regulatory Impact Assessment (RIA), combined with Multi-Criteria Decision Analysis (MCDA), which provides recommendations for decision-makers considering the rankings of preferences from multiple stakeholders. The study shows that to keep updated with the IAEA's latest standard, several changes to the regulation are required, such as adding the Surface Contaminated Object-III (SCO-III), which could be a solution for the transportation of large-sized materials that are activated or contaminated, such as radioactive waste from the process of upgrading or decommissioning a reactor. Moreover, the provision for transportation under the special arrangements is also an important aspect that should be included in the regulation. Besides being in line with international practice, the special arrangement is a possible option in situations where some administrative requirements are impracticable. The competent authority may approve special arrangements for transport operations for a single consignment or a planned series of multiple consignments. Adding the special arrangement provision also affects the provision for transactional shipment approval for transportation under special arrangements. The lack of a graded approach to apply shipment approval causes difficulties, as some activities, such as well logging and radiopharmaceuticals, require frequent movement. Furthermore, the lack of coordination between authorities is also an important issue that causes difficulties for carriers to gain a license for the transportation of hazardous materials under exclusive use. The MCDA is conducted by setting the fundamental objective of the safety of the transportation of radioactive material and some specific objectives, such as increasing the regulation alignment with the latest IAEA standard, increasing the harmonized regulation, reducing the cost for the authority and consignors, and increasing the implementation of the regulation to the operators. To achieve the objectives, the attributes and the performance measurement are created. To find the best recommendation, several alternatives are created, including the actions to support the alternative objectives. Using the MCDA, the different stakeholders' view is considered. The stakeholders' opinions that are included in the analysis are the regulatory body, operators or consignors, consignee, and the public. Each stakeholder gives the scale of each alternative. After combining all stakeholder views, the results indicate that a minimal change to the GR 58/2015 is the best option and is recommended based on the MCDA calculation. As for the second alternative, the comprehensive change can be another option to consider. It is recommended to have a more comprehensive study by increasing the participation of stakeholders to give their preferred alternative, including the consignors, carriers, and consignees.

**Country or International Organization:**

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## **A Proportional Response to the Transportation Misuse for Radioactive Waste in Indonesia**

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Radioactive waste is regulated by Government Regulation No. 61 of 2013 on Radioactive Waste Management. The Indonesian Government's policy in this matter is to return radioactive waste to its country of origin or transfer the waste to the Radioactive Waste Management Installation (IPLR

BRIN). In practice, not all waste processes are carried out legally by either the sender or recipient, including during transportation.

Radioactive waste transportation in Indonesia is based on a transportation approval issued by BAPETEN to the licensee. The approval contains several terms and conditions that must be used by the licensee when carrying out waste management. One of the terms and conditions in the approval is information regarding the initial and final locations of the radioactive material. This is what licensee must pay attention to in order to carry out transportation in accordance with the approval.

In the event of information about the misuse of radioactive waste during the transportation of radioactive materials, BAPETEN, as the regulatory body, has taken the necessary steps to respond to this unexpected event. The regulatory body's response in this context is crucial due to it determines the fate of many people facing the potential risks of radiation to the human body.

In anticipation of such an incident, BAPETEN has undertaken numerous activities involving numerous stakeholders. In the context of its initial response to the discovery of radioactive waste that should have been disposed of but was actually used before the waste transportation was completed, BAPETEN was able to take immediate action, and due to its long-standing involvement, the Indonesian National Police, specifically the Chemical, Biological, Radioactive, and Nuclear Unit (Sat KBRN), was able to detect the presence and mitigate the potential risks of radioactive materials changing hands.

Coordination between BAPETEN and Sat KBRN typically training, including handling misused radioactive waste. The training is conducted both in-person and in the field through practical sessions. This approach supports the implementation of the safety-security interface principle, according to the International Atomic Energy Agency (IAEA) guidelines, which integrate safety and security aspects into supervision, including preparedness for nuclear and radiological emergencies.

After detecting and mitigating potential risks posed by radioactive materials, BAPETEN's next step is to report the matter to the police. With sufficient evidence from the field indicating suspected misuse of radioactive materials, BAPETEN hopes that the nuclear law enforcement process will receive the attention of the Indonesian National Police.

Nuclear energy law enforcement has been implemented by BAPETEN involving the National Police's Criminal Investigation Agency (Bareskrim Polri). However, several obstacles remain in the mission of building character and educating the nation's youth. BAPETEN previously conducted related activities with the involvement of the police. As a result, not only did the workshop participants appear intently engaged in listening to the speakers, but hundreds of police personnel have now participated in BAPETEN programs.

Nuclear energy law enforcement workshops are crucial, as they provide numerous insights for the police to better understand the issues surrounding the oversight of nuclear energy utilisation in Indonesia. These workshops have been conducted both in Jakarta, involving the Jakarta Metropolitan Police and its subordinates, as well as regional police forces, particularly in provinces with extensive nuclear energy utilization.

With these beneficial activities, it is hoped that the objectives of these workshops can be achieved while adhering to the established deadlines. One challenge faced after the workshops is the rapid turnover of police personnel, so such workshops should be conducted at least once every three months.

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## **Challenges and Lessons Learned in Offshore Transport of Radioactive Tracer Sources**

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#### Abstract

This paper analyzes challenges and lessons learned from transporting radioactive tracer sources to offshore oil platforms, emphasizing safety protocols, regulatory compliance, and operational efficiency. A case study involving Bromine-82 transport with 300 mCi activity demonstrates successful multi-modal transportation from reactor facility to offshore platform, providing insights for future operations.

#### Introduction

Offshore radiotracer applications require complex transportation of radioactive sources to remote marine platforms. This study documents operational experience from a successful Bromine-82 transport mission, highlighting critical coordination, safety, and regulatory considerations for high-activity source movement in offshore environments.

#### Methodology

##### Tracer Preparation

Bromine-82 was selected for water and hydrocarbon tracing based on its 35.3-hour half-life and suitable chemical properties. Two compounds were irradiated using the TRIGA-PUSPATI reactor at Malaysian Nuclear Agency:

- Ammonium Bromide (NH<sub>4</sub>Br)
- 1,4-Dibromobenzene (C<sub>6</sub>H<sub>4</sub>Br<sub>2</sub>)

Precise irradiation timing was critical to achieve activity levels exceeding 300 mCi while accounting for decay during transport.

##### Transportation Process

The multi-modal transport chain included:

1. Post-irradiation cooling: 24-hour mandatory cooling period
2. Ground transport: Reactor facility to Kuala Lumpur International Airport (1 hour)
3. Air transport: KLIA to Miri, Sarawak
4. Marine transport: Bintulu to offshore platform (4 hours)

All procedures adhered to International Air Transport Association (IATA) standards, Department of Atomic Energy Malaysia (ATOM Malaysia) regulations, and International Atomic Energy Agency (IAEA) guidelines. Sources were secured in lead-shielded containers throughout transport.

##### Offshore Operations

Upon platform arrival, strict safety protocols were implemented including mandatory personal protective equipment and continuous monitoring. Timing coordination was critical to account for radioactive decay while maintaining operational efficiency.

##### Key Challenges

###### 1. Tracer Preparation

- Achieving optimal irradiation timing to meet activity requirements
- Balancing production scheduling with transport logistics
- Implementing quality control for irradiated materials

###### 2. Transportation Logistics

- Managing regulatory compliance across multiple transport modes
- Coordinating timing between air and marine transport segments
- Handling radioactive decay calculations throughout the transport chain

###### 3. Offshore Execution

- Implementing safety protocols in remote environments
- Coordinating personnel and equipment for timely execution
- Maintaining comprehensive documentation and monitoring

##### Lessons Learned

###### Preparation Phase

Establish clear protocols for tracer preparation timing with robust quality assurance procedures. Develop contingency plans for production delays to ensure operational flexibility.

###### Transportation Management

Enhanced coordination between transport modes is essential. Improved decay calculation procedures and strengthened relationships with regulatory authorities and transport providers signifi-

cantly improve operational success.

#### Operational Execution

Refined safety protocols for offshore environments, improved timing coordination, and enhanced data recording procedures are critical for successful operations.

#### Results and Discussion

The operation was successfully completed with all regulatory requirements met. Key success factors included comprehensive pre-planning, strict regulatory compliance, effective multi-agency coordination, and robust safety management throughout all operational phases. The experience demonstrated that complex radioactive material transport to remote offshore locations is feasible when proper procedures, coordination, and safety measures are implemented. The multi-modal transport approach proved effective, though timing coordination remains critical due to the 35.3-hour half-life of Bromine-82.

#### Conclusion

This successful offshore radiotracer transport operation provides valuable insights for future similar applications. The experience emphasizes the importance of meticulous planning, regulatory compliance, and safety management in radioactive material transport to offshore facilities. Effective coordination between preparation, transportation, and execution phases is essential for operational success. The findings contribute to improved safety and efficiency protocols for offshore radiotracer applications, demonstrating that with proper procedures and coordination, complex radioactive source transport to remote marine platforms can be executed safely and effectively.

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## ROLE OF RADIATION PROTECTION OFFICER IN TRANSPORTATION OF RADIOACTIVE SOURCES IN MALAYSIAN NUCLEAR AGENCY

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Malaysian Nuclear Agency (Nuclear Malaysia) is executing activities involving radioactive sources namely in medical, waste managements, industries and agriculture. The Radiation Protection Officer (RPO) plays a critical role in ensuring the safe transportation of radioactive sources within the Nuclear Malaysia, serving as the primary guardian of radiological safety throughout the entire transport process. An involvement of RPO was examine in several stages; pre-transport planning and assessment, documentation for regulatory compliance, safety implementation, personnel training, emergency preparedness and response and finally the monitoring and quality assurance. Based on the assessment and monitoring of an internal transportation of radioactive sources form shows that Americium -Beryllium -241, Barium-133, Cobalt-57, Cobalt-60, Cesium-137. Iridium-192 and Strontium -90 were the most radioactive sources transported from the agency for different purposes. In addition, as International Atomic Energy Agency (IAEA) was initiate the Global Radium-226 Management Initiative, the RPO in the agency should plan to coordinate multiple stakeholders in ensuring the safe transport of the Radium-226 which will be recycle to other application. This paper demonstrates the organisational structure on radiation protection program in the agency and the practices on the safe transportation of radioactive sources in order to comply with regulatory requirements. Trending of the radioactive sources that were transported from 2022-2024 also will be show.

**Keywords:** Radiation Protection Officer, Role, Transportation of Radioactive Sources

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**The Role of Atomic Energy Council in ensuring Safe Transport of Nuclear and Radioactive Materials in Uganda****Author:** Noah Deogratias Luwalira<sup>1</sup><sup>1</sup> *Atomic Energy Council***Corresponding Author:** noahdeo@yahoo.com

The transport of nuclear and radioactive materials presents one of the most sensitive areas of atomic energy regulation due to the potential risks it poses to the public, the environment and national security. The International Atomic Energy Agency (IAEA) established comprehensive safety standards and requirements for the safe transport of such materials, recognizing that they are essential for peaceful applications in medicine, industry, agriculture, research and energy development. In Uganda, where the use of radioactive sources has expanded significantly in medical applications, industrial applications, oil and gas exploration and academic and research laboratories, the Atomic Energy Council (AEC) serves as the national regulatory authority responsible for ensuring that the transport of these materials is conducted in a safe and secure manner and in accordance with international best practice.

The role of AEC in this domain is anchored in the Atomic Energy Act Cap.154 which empowers it to regulate the possession, use, transport, import and export of radioactive materials. Specifically, the Council issues permits for transport of radioactive materials, reviews transport security and safety plans, inspects consignments of radioactive materials and enforces compliance with the Atomic Energy Act Cap 154 and all security and safety regulations thereunder as well as IAEA transport safety requirements. AEC ensures that packaging, labelling and documentation of radioactive materials adhere to established safety standards to prevent exposure, contamination or accidental release during transit.

One of the AEC's significant contributions has been the development regulations and regulatory guidelines that domesticate IAEA Safety Standards Series No. SSR -6 (Rev. 1) which provide technical requirements for packaging, labelling, segregation and emergency arrangements. The Council also coordinates national inter agency frameworks involving security organs like the Uganda Police Force, Uganda Revenue Authority- Customs department, Civil Aviation authority, Ministry of Works and Transport among others to ensure a holistic approach to safe transport. Through this multi stakeholder collaboration, Uganda is able to respond promptly to transport related incidents, deter illicit trafficking and ensure neighboring states of its compliance with international commitments and obligations.

In addition to regulatory control, AEC prioritized capacity building and training for transport operators, radiation safety officers and customs officials. Training programs emphasize radiation protection principles, emergency procedures and the importance of nuclear security during transport of nuclear and radioactive materials. These initiatives have reduced the risks of human error, strengthened preparedness and promoted a safety culture across institutions that routinely handle radioactive materials. The Council also conducts public awareness and stakeholder engagements campaigns to address misconceptions.

Despite these achievements, several challenges persist. Limited numbers of specialized transport containers and certified carriers present logistical constraints. Resource limitations affects Council's ability to conduct the requisite inspections. Coordination gaps occasionally arise between different agencies involved during transport of nuclear and radioactive materials. Additionally, Uganda's increasing use radioactive materials and potential future nuclear power development means that

the scale and complexity of transport operations will expand requiring more advanced infrastructure and regulatory oversight.

To address these gaps, there will be need to strengthen AEC's institutional capacity through increased funding, acquisition of modern monitoring equipment, training of specialized inspectors, enhance collaboration with regional and international partners to share best practices and build resilience against cross border risks, investment in emergency preparedness, and real time communications systems thus improving response capability. Establishing a dedicated cadre of certified transport operators and fostering continuous training will further reinforce safety and security measures.

Accordingly, AEC plays an indispensable role in ensuring that transport of nuclear and radioactive materials in Uganda is conducted safely, securely and in alignment with global standards.

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## **Building National Capacity for Nuclear Material Transport Emergencies in Nigeria: A Multi-Stakeholder Scenario-Based Approach**

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This paper presents Nigeria's comprehensive emergency preparedness initiative for nuclear material transport, led by the Centre for Energy Research and Training (CERT) in collaboration with the International Atomic Energy Agency (IAEA). In anticipation of a high-security transport operation involving nuclear fuel, CERT coordinated a multi-stakeholder training program that included the Nigerian Nuclear Regulatory Authority (NNRA), the Nigeria Atomic Energy Commission (NAEC), the Office of the National Security Adviser (ONSA), and other critical agencies. The centrepiece of this initiative was a technical workshop tailored specifically to Nigeria's transport context. Conducted with IAEA support, the workshop focused on regulatory frameworks, operational logistics, and inter-agency coordination. A tabletop exercise embedded within the workshop simulated a transport-related security incident, testing Nigeria's emergency response framework in real time. The scenario revealed gaps in communication and resource deployment, leading to targeted improvements in national protocols. CERT also extended training to airport personnel, including customs officers, cargo handlers, and aviation security staff, ensuring preparedness across all transport modalities. Evaluation metrics showed marked improvements in response time, situational awareness, and coordination. This paper demonstrates how targeted, scenario-based training and inclusive stakeholder engagement can build national capacity for managing nuclear material transport emergencies. Nigeria's experience offers a scalable model for other Member States.

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## Securing Nuclear Material in Transit: Nigeria's Transport of HEU and LEU in Compliance with National and International Requirements

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In support of global nuclear non-proliferation and reactor safety, Nigeria successfully executed the transport of high enriched uranium (HEU) and low enriched uranium (LEU) fuels following the conversion of its research reactor. This paper presents a comprehensive account of the planning, coordination, and execution of both export and import shipments, conducted in compliance with the Nigerian Nuclear Regulatory Authority (NNRA) requirements and International Atomic Energy Agency (IAEA) safety and security standards. The HEU removal operation involved packaging the spent fuel in certified Type B(U) transport casks, securing the route with armed escorts, and coordinating with international partners for safe handover. The LEU importation required pre-shipment inspections, customs clearance, and secure delivery to Nigeria's Research Reactor-1 (NIRR-1), operated by the Centre for Energy Research and Training (CERT). Both operations were supported by real-time monitoring, emergency response protocols, and multi-agency collaboration. Recognizing the unique risks posed by insider threats during nuclear material transport, CERT implemented a comprehensive security strategy encompassing a Physical Protection System (PPS), a Trustworthiness Program, and a robust Security Culture framework. Personnel involved in packaging, logistics, and escort duties were vetted, trained, and monitored to ensure reliability and accountability throughout the transport process. This paper highlights the regulatory frameworks, logistical strategies, and security measures employed throughout the import and export transport process. It also discusses operational challenges such as infrastructure limitations and documentation bottlenecks. The experience demonstrated Nigeria's growing capacity to manage complex nuclear logistics and reinforced the importance of early stakeholder engagement, contingency planning, and international technical support. Lessons learned include the need for harmonized documentation systems, flexible operational protocols, and sustained investment in transport infrastructure. Nigeria's shipment both HEU and LEU operation offers a replicable model for other nations pursuing reactor conversion and nuclear fuel transport, contributing to global efforts in nuclear safety and non-proliferation.

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## Regulatory Synergy: Ensuring Safe and Secure Transport of Radioactive Material within Australia's Multi-Jurisdictional Framework

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The safe and secure transport of radioactive material in Australia requires coordination among multiple authorities across various jurisdictions. Governed by Commonwealth, State, and Territory legislations, the regulatory framework implements the IAEA Regulations for Safe Transport of Radioactive Material (SSR-6) through the ARPANSA Code for the Safe Transport of Radioactive Material by road, rail, and inland waterways. For air transport, the Civil Aviation Safety Authority enforces ICAO Technical Instructions, while sea transport follows the IMDG Code under the Australian Maritime Safety Authority.

Eleven Competent Authorities oversee the transport of radioactive material in Australia. Among them, ARPANSA regulates Commonwealth entities for road, rail, and inland waterways not covered by marine legislation. As a National Competent Authority ARPANSA sets national codes, standards

and guidelines for the transport of radioactive material.

The security of radioactive sources is regulated by the ARPANSA Code of Practice for the Security of Radioactive Sources, whereas the Australian Safeguards and Non-Proliferation Office oversees the security of nuclear material through the Nuclear Non-Proliferation (Safeguards) Act.

To maintain national uniformity in the regulation of radioactive material, the National Directory for Radiation Protection plays an important role aiming to create a seamless regulatory framework across Australia, fostering cooperation between Commonwealth, State, and Territory authorities to ensure the safe generation and use of radiation. For the transboundary movement of radioactive material, international harmonisation is achieved through the application of the IAEA Transport Regulations, which are integrated into key global frameworks such as the IMDG Code for maritime transport, the ICAO Technical Instructions for air transport, and the UN Model Regulations.

This paper examines the critical need for regulatory synergy between state and Commonwealth authorities to ensure the safe and secure transport of radioactive materials across Australia. By analysing existing frameworks, policies, and the roles of different authorities, it highlights the necessity of harmonizing safety and security standards to mitigate risks. The paper addresses challenges and opportunities in achieving regulatory coherence and underscores the importance of inter-agency collaboration. Through case studies and comprehensive analysis, the paper provides insights into best practices and recommends measures to enhance regulatory collaboration for the protection of the health and safety of people and the environment, and for improving security. Despite the robustness of Australia's regulatory framework, the paper suggests areas for improvement to further enhance regulatory synergy.

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## Managing the Safety–Security Interface in the Transport of Radioactive Material: The Australian Context

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The regulatory framework governing the transport of radioactive material in Australia is established through a combination of Commonwealth, State, and Territory legislation. There are eleven competent authorities responsible for the safe transport of radioactive material: three at the Commonwealth level, six at the State level, and two at the Territory level.

Australia applies the International Atomic Energy Agency (IAEA) Regulations for the Safe Transport of Radioactive Material (SSR-6, Rev. 1, 2018 edition) through the Australian Radiation Protection and Nuclear Safety Agency (ARPANSA) Code for the Safe Transport of Radioactive Material 2019 (the Transport Code). This Code governs transport by road, rail, and inland waterways not covered by maritime legislation. All States and Territories implement the Transport Code through their respective regulatory systems.

The security of radioactive material is governed by two Commonwealth Agencies namely, ARPANSA and ASNO (Australian Safeguards and Non-proliferation Office). ARPANSA regulates the security of radioactive sources through ARPANSA Code of Practice for the Security of Radioactive Sources 2019 (Security Code), which is adopted across all jurisdictions as part of their regulatory frameworks. ASNO regulates security of nuclear material including uranium, thorium and plutonium through the Nuclear Non-Proliferation (Safeguards) Act 1987, and the object of which is to give effect to certain obligations of Australia as party to the Non-Proliferation Treaty (NPT), Australia's safeguards agreement with the IAEA, and other bilateral safeguards agreements; and certain obligations that Australia has as a party to the Convention for the Physical Protection of Nuclear Materials (CPPNM). The security of dangerous goods in air transport, including Class 7 radioactive materials, is governed by the Aviation Transport Security Act 2004, which aims to prevent unauthorised access to aircraft and airport facilities.

In Australia, the transport of radioactive material necessitates a well-defined interface between safety and security, both of which share the overarching objective of protecting people and the environment from the harmful effects of radiation. Recognising this shared purpose, ARPANSA underscores the importance of regulatory complementarity where safety and security requirements intersect. While such overlap can enhance protective outcomes, it may also result in conflicting measures. ARPANSA therefore promotes coordinated regulatory approaches that ensure alignment and minimise potential inconsistencies.

This paper outlines key elements for managing safety-security interface in the transport of radioactive material by applying a risk-informed and evidence-based approach. It addresses the assessment of transport safety and security plans, safety and security culture, compliance monitoring, emergency preparedness and response, delineation of roles and responsibilities, information management, and training and competency requirements. A case study demonstrating the effectiveness of the safety and security interface is also included.

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## **Assessment of the Regulatory Framework, Authorization Processes, and Procedures for the Safe and Secure Transport of Radioactive Material in Ghana**

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The use of radioactive materials and radiation-emitting devices has become increasingly vital in Ghana's development, particularly in the fields of healthcare, industry, and scientific research. These materials support essential activities such as cancer treatment, medical diagnostics, industrial radiography, and agricultural innovation. A key enabling factor for these applications is the transportation of radioactive materials, which ensures timely and safe delivery to facilities across the country.

Given the potential risks associated with the movement of radioactive substances, transportation is recognized as a critical aspect of nuclear safety and security. It demands rigorous oversight to prevent radiological hazards that could affect people, property, and the environment. Ghana, as a committed member of the International Atomic Energy Agency (IAEA), adheres to international standards for the safe and secure transport of radioactive materials.

To institutionalize this commitment, the Nuclear Regulatory Authority (NRA) was established under Act 895 of 2015. The NRA is mandated to regulate all radiological and nuclear activities in Ghana, including the transport of radioactive materials. Section 51 of the Act stipulates that such transportation must be authorized by the Authority. Additionally, Section 91(k) requires the NRA to issue regulations and technical requirements for transport activities, in alignment with the IAEA Transport Regulations (SSR-6 Rev.1, 2018 Edition).

This regulatory framework provides the legal and institutional foundation for managing transport operations in compliance with international safety and security guidelines. Within this framework, authorization processes including licensing of operators, approval of transport packages, and certification of carriers ensure that only qualified entities are permitted to handle radioactive materials. Moreover, procedural controls such as safety assessments, security planning, emergency preparedness, and compliance verification serve as operational safeguards to minimize risks during transit.

This paper aims to assess the effectiveness and comprehensiveness of Ghana's regulatory framework, authorization mechanisms, and procedural safeguards for the transport of radioactive materials. It explores how these elements interact to uphold safety and security, identifies existing gaps, and proposes recommendations to strengthen regulatory practices in line with global standards.

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## **Considerations for Transportation of Radioactive Waste During the Decommissioning of RADON Type Storage Facility in Lithuania**

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Maisiagala Radioactive Waste Storage Facility (RWSF) is located about 30 km northwest of the Lithuanian capital Vilnius. Facility was built in 1961-1963 according to a typical design for a RADON type facility for low and intermediate level radioactive waste storage from research, medicine, military units and industry. Similar storage facilities have been built in several countries of the former Soviet Union and Eastern Europe. The key structure of Maisiagala RWSF is a 200 m<sup>3</sup> capacity monolithic reinforced concrete vault constructed at a depth of 3 metres under the ground surface. Maisiagala RWSF had been receiving institutional waste since 1963 until its closure in 1989. During this operational period, about 114 m<sup>3</sup> of unsorted long-lived and short-lived radioactive waste of various activities were loaded into the storage vault. When the facility was closed, the remaining vault cavity was filled with concrete and sand. In 2016, the implementation of the project "Decommissioning of the Maisiagala RWSF" was started. The main objective of the project was to retrieve radioactive waste from the storage vault, dismantle and demolish the storage structures, place all stored institutional and decommissioning waste into appropriate transportation packages and transport it to the Ignalina Nuclear Power Plant (which is located approximately 180 km from the Maisiagala RWSF) for further management. At the beginning of 2024, all the technical, design and licence documents necessary for the decommissioning of the Maisiagala RWSF were obtained, including transportation of radioactive waste to the Ignalina Nuclear Power Plant.

This paper discusses in detail waste transportation aspect of the project in the perspective of selecting an appropriate package for transportation based on the properties of institutional and decommissioning radioactive waste. Firstly, the radioactive waste streams that need to be transported, such as institutional radioactive waste mixed with disused sealed radioactive source (DSRS) that cannot be separated, separated DSRS, contaminated concrete structures, contaminated soil, etc., were identified. Then based on historical records, the radionuclide compositions and activities of each waste stream were analysed and transportation packages (IP-1, IP-2, Type A or Type B) that meets the requirements of International Atomic Energy Agency (IAEA) SSR-6 "Regulations for the Safe Transport of Radioactive Material" and "International Carriage of Dangerous Goods by Road (ADR)" were selected for each radioactive waste stream. The 200-liter drums or flexible intermediate bulk containers (FIBC), either standard or IP-1/IP-2 type, were proposed for the transportation of radioactive waste that can be classified as Low Specific Activity material (LSA) and Surface Contaminated Objects (SCO). Assessment has shown that Type A, and in some cases Type B, transportation packages were required for the transportation of institutional waste mixed with unseparated DSRS and separated DSRS (especially for high-activity sources like cesium-137 or neutron sources). Moreover, when choosing a package, it was also necessary to consider the geometrical dimensions and condition of the retrieved waste and the packages that are available on the market. Therefore, various packaging options for radioactive waste transportation were analysed, checking their compliance with safety requirements, as well as evaluating economic aspects of purchasing different types of transportation packages.

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## Assessment of Transport and Radiation Dose from Radiopharmaceuticals in Norway

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In accordance with SSR-6, paragraph 308, competent authorities are required to periodically assess radiation doses to individuals resulting from the transport of radioactive material, ensuring compliance with the system of protection and safety outlined in GSR Part 3. This synopsis will present the main findings from a recent Norwegian study conducted to meet this requirement.

### Phase 1: Transport Characteristics

The study was implemented in two phases. The first phase, carried out in 2024, focused on mapping the characteristics of packages and consignments transported in Norway during 2023. A mandatory questionnaire was distributed to more than 370 companies, nearly reaching an 80% response rate. The results showed that approximately 25,000 packages were consigned by Norwegian companies in 2023, of which near 13,500 were exported. Additionally, around 5,500 packages containing radiopharmaceuticals were imported. Nearly 96% of all packages were transported by road at some point in the transport chain. Type A packages were the most common, accounting for 87% of all packages, followed by excepted packages (7%), industrial packages (5%), and Type B packages (2%). Most packages had low Transport Index (TI) values, with only 0.3% exceeding TI 5. It is estimated that between 1% and 4% of consignments had a TI above 5.

The analysis also revealed that four industry sectors accounted for 96% of all consignments: the medical sector dominated with 78% of packages, followed by oil and gas (9%), nuclear density gauges (6%), and industrial radiography (2%). The medical sector alone contributed approximately 60% of the overall TI of all consignments. These data will support the Norwegian regulator's risk-based compliance assurance program.

### Phase 2: Dose Assessment Related to the Transport of Radiopharmaceuticals

The second phase of the study, conducted in 2025, assessed doses to workers and the public from the transport of radiopharmaceuticals, which pose the highest exposure risk, as identified in Phase 1 of the study. The Norwegian Radiation and Nuclear Safety Authority (DSA) performed direct dose measurements during three road transport operations and one handling operation at an airport terminal. Public dose estimates were also made. In addition, two drivers were equipped with electronic personal dosimeters (EPDs) worn on the chest for two weeks, and doses were recorded for each transport operation.

Measured doses were compared with theoretical estimates based on TI and the duration of activities, and linear models were developed to describe the relationship between measured and calculated doses for both handling and driving. The models showed a strong linear correlation.

Further analysis revealed that asymmetric exposure during handling and driving significantly affected dose assessment. When EPDs were worn only on the chest, the actual dose was underestimated by 13–39%, particularly when no shielding was present between the cab and cargo or during long-distance driving. The estimated maximum dose to the public was 0.1 mSv. At the airport terminal, workers were monitored with passive dosimeters and finger dosimeters for two months, with no doses registered. Following a visit to the terminal, and based on EPD measurements, a cargo handler at the terminal could receive an annual dose of approximately 0.5 mSv.

This study provides the first comprehensive national assessment of radiation doses from the transport of radioactive material in Norway. The findings confirm that doses to workers and the public remain low, while highlighting factors such as asymmetric exposure that warrant attention in regulatory oversight and operational practices.

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## **Transport of usable nuclear materials as part of the decommissioning of research facilities**

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The paper addresses the multifaceted challenges associated with the transport of nuclear material from decommissioned or closed facilities to other locations for potential reuse. This approach not only supports sustainability in the nuclear sector but also contributes to minimizing the generation of radioactive waste, aligning with broader environmental and operational goals.

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## **SAFETY-SECURITY INTERFACE DURING NUCLEAR MATERIAL TRANSPORT OPERATIONS**

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**Abstract.** Peaceful nuclear programs demand transport capabilities that can provide safe and secure Nuclear Material Transport according to the fuel cycle facilities location. This paper will show that countries embarking in nuclear programs should take into account that Transport Operations are inherent to the fuel cycle and should have requirements previously established related to the conveyance and packages, regarding safety features, and a threat assessment, and physical protection system (PPS) regarding security. The paper will demonstrate that both safety and security during transport have the utmost purpose of protecting the population and the environment against the harmful effects of ionizing radiation. Moreover, they should complement each other. In this respect, it is mandatory to address their interface in a comprehensive approach identifying all possible interactions in order to solve conflicts. The paper will include the different modal conveyances used to transport nuclear material, emphasizing that it must be implemented a PPS similar to a facility supported by the three functions: detection, delay and response. The paper will highlight that transport security occurs in the public domain and involves intermodal transfers. Due to this vulnerability, transport security involves many national and international authorities and safeguards provisions and is therefore one of the most complex aspects of nuclear material control. The paper will address the governance established by the Convention on the Physical Protection of Nuclear Material (CPPNM) and the recommendation security measures specified in INFCIRC/225 (IAEA NSS-13). The study will also address the various stakeholders involved in nuclear material transport and the need to create a coordinating body at the national level to address all security aspects, including response forces; information security; cyber security; personnel security; Intelligence; nuclear forensics; and nuclear security culture. The paper will address the importance of exercises as an invaluable tool

to evaluate with a comprehensive approach all the provisions established for nuclear security. Contingency response exercises are a critical component of an effective physical protection system, providing a unique insight into the state of readiness of the security organizations responsible for the physical protection during transport of nuclear material.

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## GPS Jamming and Spoofing –No Longer an Emerging Threat

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In order to monitor and quickly respond to an issue when transporting radioactive material, we need to know where that material is as it is transported. The safety of the shipment necessitates knowing numerous time and position related details during the entire process: when it stops, how long it was stopped, where along its planned route it is, is it on the planned route, and so on. To do this, we need the information provided by a global navigation satellite system (GNSS) receiver. GNSS receivers are also commonly referred to as Global Positioning System (GPS) receivers due to GPS being the most well-known of the GNSS satellite constellations. Once GNSS jamming was a capability possessed by a few militaries, while GNSS spoofing was only a theoretical threat. Today, jammers can be purchased by anyone over the Internet[1]. Spoofing has transitioned from theory, to an emerging threat, to an emerged threat anyone with some technical savvy, YouTube, and a software-defined radio (SDR) can perform[2]. This paper will present some steps that can be taken today to help mitigate the risk from jamming and spoofing.

For context, jamming is the simplest technique and because of that simplicity the most prevalent threat to GNSS positioning. GNSS jamming is when a stronger signal at the same frequencies as the GNSS satellites' signals is transmitted to interfere with a GNSS receiver's ability to receive the signals from the satellites. Spoofing on the other hand is a technique where signals identical to those transmitted by the satellites are transmitted at slightly stronger power to trick a GNSS receiver into using the spoofed signals instead of the true satellite signals. Spoofing can be used to change the time, location, or both reported by a receiver. Spoofing can be used to cause a GNSS receiver to report that it is traveling as expected when it actual may be stopped or traveling in the wrong direction. Spoofing can allow a vehicle to appear to be safely parked to the remote monitoring center when it is actually underway.

What was once only the potential threats of GNSS jamming and spoofing to deny and compromise PNT information used to monitor cargo and assets is now a daily occurrence in and near conflict zones, is used regularly by criminal elements involved in cargo hijacking[3] and by "normal" people circumventing the monitoring of their company vehicle[4] without realizing the risk to everyone around them. In order to protect our abilities to safeguard and securely transport radioactive and nuclear material steps to detect and/or protect from attacks on GNSS derived time and position information that is so critical to monitoring and responding are needed. Several steps that can contribute to detecting and protecting the GNSS receiver that provides this critical information are presented in this paper.

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## **Implementing Safety and Security Measures for the Transport of Radioactive Materials in Myanmar**

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Myanmar has continuously worked to strength national nuclear safety and security infrastructure while attempting to achieve social and economic goals of sustainable development with the peaceful uses of radioactive materials. These materials are usually transported in, out and within the country. The transport of such materials must be operated/handled in a safe and secure manner/process within an adequate nuclear regulatory framework. Myanmar utilizes both legally binding and non-legally binding instruments to manage radioactive materials and activities. Atomic Energy Law governs the import, export, registration, and security of these materials. Myanmar is in the process of drafting a new nuclear law to further strengthen safety, security, and non-proliferation measures, in place of the current atomic energy law. The country is developing regulations for the import and transport of radioactive materials that involves requirements for prior permission, registration, and licensing. Myanmar also regulates the transport of dangerous goods by vehicle through various laws and directives, focusing on safety, security and risk management. The Department of Atomic Energy (DAE) plays as regulatory body with all nuclear safety and security-related activities and appropriate security measures are implemented to provide adequate physical protection for nuclear and other radioactive materials during transport in cooperation and collaboration with all relevant stakeholders. The DAE manages a system for licensing activities and issuing transport certificate related to radioactive materials and technologies. Since global nuclear transport safety and security measures strongly depends on the cooperation and coordination of national, regional and international organizations, the country is part of regional agreements like the ASEAN Framework Agreement to facilitate cross-border transport of goods, including dangerous goods and agreed to develop an ASEAN regional arrangement for information sharing on transboundary movement of radioactive material, in order to enhance nuclear security in the region. DAE team members are implementing safety and security measures through coordinated research project with support of IAEA at the local and border areas in the transportation of radioactive materials and also carried out safety and security activities in the transportation of NORM within the country. This paper describes Myanmar efforts to sustaining and strengthening effective and comprehensive legislative and regulatory framework and to address the challenges in establishing of safety measures and developing security measures of radioactive material in use, transport and storage and to integrate safety and security measures during transport and implementing security measures for all transport of nuclear and radioactive materials.

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## Risk Assessment and Mitigation Strategies for $^{18}\text{F}$ -FDG Transport from Cyclotron to PET-CT Centers in Bangladesh

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### Introduction

PET-CT has become an indispensable imaging modality in modern medicine particularly for oncology, cardiology and neurology. The most commonly used tracer,  $^{18}\text{F}$ -Fluorodeoxyglucose ( $^{18}\text{F}$ -FDG), is produced in a medical cyclotron and then delivered to PET-CT centers for patient imaging. This synopsis evaluates the risk factors associated with  $^{18}\text{F}$ -FDG transport and proposes mitigation strategies within the Bangladesh context.

### $^{18}\text{F}$ -FDG Transport to PET-CT Centres in Bangladesh

The commissioning of the 18/9 MeV IBA Cyclotron at National Institute of Nuclear Medicine and Allied Sciences under the Bangladesh Atomic Energy Commission in 2021 marked a breakthrough for nuclear medicine in Bangladesh. It enables local production of  $^{18}\text{F}$ -FDG yielding 2000–3000 mCi per batch to supply 11 PET/CT centers across Dhaka covering both public and private PET-CT centres. Safe and timely transport of  $^{18}\text{F}$ -FDG is crucial due to its 110-minute half-life. Any delay rapidly decreases activity, risking inaccurate PET/CT imaging and optimizing clinical outcomes.

### Radiological and Logistical Risks

The two most pressing challenges in transporting  $^{18}\text{F}$ -FDG are radiation safety and time sensitivity. In terms of exposure, even though the material is shipped in shielded Type-A containers, mishandling, vial leakage, or accidents can cause external exposure and contamination. Equally important is the decay of radioactivity during transit.

The decay can be expressed mathematically as:

$$A(t) = A_0 e^{(-\lambda t)} \dots (1)$$

If a batch of 2000 mCi is produced and the transport time is 90 minutes, the remaining activity is:

$$A(90) = 2000 \times e^{(-0.0063 \times 90)} \approx 1135 \text{ mCi}$$

This simple calculation shows nearly a 43% activity loss before reaching the patient, underscoring the importance of rapid and predictable transport.

### Security and Regulatory Challenges

Beyond radiological and decay concerns, the risk of unauthorized access or diversion must also be addressed. While  $^{18}\text{F}$ -FDG is not a high-security isotope like  $^{235}\text{U}$ , its transport is still regulated under IAEA and Bangladesh Atomic Energy Regulatory Authority guidelines. Non-compliance, such as improper labeling, missing documents, or lack of trained couriers poses significant regulatory risks.

### Risk Assessment Approach

A structured framework based on hazard identification, likelihood, and consequence evaluation is applied. Risks such as traffic congestion, vial leakage and documentation errors are considered in terms of probability (P) and severity (S). A simplified risk index can be calculated as

$$R = P \times S \dots (2)$$

If traffic congestion has P=4 (high likelihood) and S=3 (moderate impact), then R=12, requiring urgent mitigation. Conversely, theft may have low probability (P=1) but higher severity (S=4), giving R=4, still demanding security precautions.

### Mitigation Strategies

Several strategies can minimize risks. Radiological safety can be reinforced through shielded containers, regular leak testing and use of personal dosimeters. Logistical delays may be mitigated by route optimization, GPS tracking and motorbike couriers in congested Dhaka.

For regulatory compliance, strict standard operating procedures (SOPs) should govern packaging, labeling and documentation and regular audits. Security can be enhanced with tamper-proof seals, real-time communication and coordination with authorities.

Emergency preparedness is also vital. Every transport vehicle should carry a spill kit, personal protective equipment and a contamination monitor. Drivers and couriers should be trained in basic radiation safety and emergency response ensuring safe management of accidents or natural disruptions.

#### Contextual Relevance for Bangladesh

Bangladesh's dense population and frequent traffic congestion make these challenges more acute. Hence, the risk assessment must be localized rather than adopting international models blindly. Incorporating mathematical decay models into scheduling, investing in redundant transport systems and strengthening regulatory frameworks are crucial steps forward.

#### Conclusion

The transport of  $^{18}\text{F}$ -FDG from cyclotron facilities to PET-CT centers in Bangladesh involves intertwined risks of radiation exposure, activity decay, logistics, security and regulatory compliance. Through mathematical modeling of decay, structured risk assessment and the application of layered mitigation strategies, a more resilient transport system can be developed.

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## Integrating Safety, Security and Safeguards in Nuclear and Radiological Transport

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The safe, secure, and proliferation-resistant transport of nuclear and radiological materials remains one of the most sensitive stages of the nuclear fuel cycle. Transport activities encompass a broad spectrum: sealed radioactive sources for medical and industrial use, fresh and spent fuel assemblies, and, increasingly, prefabricated modules of Small Modular Reactors (SMRs) that may include pre-loaded nuclear fuel. Each modality of transport—road, rail, maritime, and air—presents unique operational environments, vulnerabilities, and regulatory challenges.

The “3S interface”—safety (protection against accidental releases), security (protection against malicious acts), and safeguards (verification of non-diversion of nuclear material)—is particularly complex in the context of modern logistics networks and the internationalization of nuclear supply chains. The objective of this work is twofold: first, to characterize synergies and contradictions among the 3S pillars in different transport modalities; and second, to propose technical and regulatory innovations that could enhance resilience and credibility in the global deployment of nuclear technologies, with emphasis on SMRs.

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## Safety and Logistics for SMRs: Brazil's Contribution to Modeling Fresh and Spent Fuel Transportation Based on PWR Data

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The global energy transition points to Small Modular Reactors (SMRs) as a promising solution for decarbonization and flexible nuclear expansion. However, the success of this technology critically depends on resolving its inherent logistical and safety challenges, especially in the transportation of fresh and spent fuel. This study addresses an emerging regulatory and operational gap, using Brazil's vast and consolidated experience with Pressurized Water Reactors (PWRs), the most likely technological basis for the first generation of SMRs, as a key project and case study.

Reference articles (Nuclear Technology, 2019; Waste Management, 2018) already indicate that the modularity and compact design of SMRs fundamentally alter packaging and transportation strategies, requiring a reassessment of safety standards[1,2]. This work aims to go beyond identifying the problems, providing a practical and adaptive roadmap that ensures the radiological and physical safety of SMR-PWR fuel transportation in Brazil and, by extension, in any nation with a history of PWRs. Our methodology is anchored in the principles of the IAEA Regulation for the Safe Transport of Radioactive Material (SSR-6), the global regulatory standard that currently does not explicitly and fully address all the necessary changes for the transport of specific radioactive materials and volumes associated with Small Modular Reactors (SMRs). The current International Atomic Energy Agency (IAEA) regulations provide the fundamental safety framework for all radioactive material, but the rise of SMRs introduces new challenges that require adaptations and clarifications.[3] Integrating these standards into the Brazilian context is a primary mission of the National Nuclear Safety Authority (ANSN, Law No. 14,222, of October 15, 2021).[4] We focus on two critical areas:

1) Radiological Safety and Cask Engineering: We will analyze the suitability of traditional transport casks for the potential new characteristics of SMR fuel (higher burnup, varied cooling times).[5,6,7] Brazilian experience in source calculation (thermosource), shielding requirements, and radiological monitoring will be adapted to propose package acceptance criteria that accommodate the dimensional diversity and potential increase in the number of shipments that SMRs will generate. The conclusions of this study aim to directly inform future ANSN regulations in this area.

2) Nuclear Security and Logistics: The SMR model, with its potential dispersed deployment in licensed locations, will increase the frequency and length of transportation routes. This intensifies physical security vulnerabilities.[8] The study will detail the route security protocols (tracking, escort, and secure communications) that Brazil should adopt. The goal is to establish a defense-in-depth system that prevents material diversion and ensures prompt response to emergencies, working in close collaboration with the oversight agencies coordinated by ANSN.

This research is not merely a theoretical analysis; it presents a critical and timely contribution to global nuclear infrastructure. By adapting the experience of an established nuclear country to the emerging challenges of SMRs, and by focusing on regulatory solutions that can be implemented by the ANSN, we offer a replicable model for SMR safety and governance, vital for knowledge exchange and the formation of a regulatory consensus that supports the safe and responsible deployment of the next generation of nuclear power.

**Keywords:** Nuclear Reactors, Nuclear Safety, Radioactive Material Transportation, Spent Fuel, PWR.

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#### Abstract

Although the International Convention for the Safety of Life at Sea (SOLAS) Chapter 8 (through Resolution A.491.XII in 1981, which is currently being revised) contains the Code of Safety for nuclear-propulsion ships, the relevant legal instruments governing the nuclear safety-and-security by the International Maritime Organization (IMO) and the International Atomic Energy Agency (IAEA) on maritime-nuclear systems were written primarily for transport of nuclear and radioactive materials.

These IMO instruments include: the International Ship and Port Facilities Security Code (ISPS); the Convention for the Suppression of Unlawful Acts against the Safety of Maritime Navigation (SUA); the SUA Protocol for Fixed Platforms Located on the Continental Shelf; and the International Code for the Safe Carriage of Package Irradiated Nuclear Fuel, Plutonium, and High-Level Radioactive On-Board Ships (INF).

The IAEA instruments include: the Convention and Protocol of Physical Protection of Nuclear Materials (CPPNM); the International Convention on the Suppression of Acts on Nuclear Terrorism (ICSANT); the IAEA Nuclear Security Series 26-G –Security of Nuclear Material in Transport, Implementation Guide; and the IAEA Nuclear Security Series 27-G –Physical Protection of Nuclear Material and Nuclear Facilities.

The IAEA Safety Standard Requirement (SSR-6) and all the Safety Standard Guides (SSGs) requires that fresh and irradiated fuel are transported in their respective appropriate package types as approved by the competent authorities. As written, the SSR and SSGs were not intended for the transport by sea of small modular reactors (SMRs) in a Floating Nuclear Power Plant (FNPP)-barge containing fresh/irradiated fuel in their reactor cores. In addition, The IAEA SSR and SSGs were developed for water-cooled reactors, they may or may not be applicable to non-water-cooled reactors, such as pebble-bed or molten-salt reactors.

On Civil Liability Conventions for nuclear damages, the 1971 Convention on Civil Liability for the carriage of nuclear material by sea was endorsed by the IMO, IAEA and OECD to regulate liability with respect to damage arising from the maritime carriage of nuclear and radioactive materials. There was a Liability Convention for operators of nuclear-propulsion ships, signed in 1962, but it was not ratified. Hence, both IMO and IAEA should work together to ratify the liability convention for nuclear-propulsion ships, and join together with insurers and re-insurers to establish the insurability of a commercial nuclear-propulsion systems.

To path the way for a viable operation of SMRs in FNPPs (or nuclear-propulsion ships), new nuclear technologies can be employed, and new/modified legal instruments governing the rules and regulations on safety, security, and civil liability by the IMO and the IAEA must be available to support such technologies. This study examines the safety-and-security aspects of several advanced/novel SMR technologies, and identifies the essential challenges in the effort of harmonizing the legal instruments governing the rules and regulations on safety-and-security of maritime-nuclear systems, for both FNPPs and nuclear-propulsion ships, by the IMO and the IAEA.

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The safe transport of radioactive materials is a critical component of nuclear safety, aimed at protecting people and the environment from potential radiation exposure during handling and transit. One of the key safety measures involves the use of concrete as a shielding and containment material. The transport and packaging of radioactive materials, whether from the government or private industry, must adhere to rigorous regulations. These regulations help prevent radiation exposure to the public, transport employees, the surrounding environment and the package must safeguard its contents and provide adequate shielding under typical transportation conditions. In addition, packaging must undergo the specific tests without any release of its contents. These tests including drop test, water spray test and penetration tests, to verify its ability to withstand accidents.

Nuclear and radioactive materials are packed in three different types.

Package Type A: These are standard industrial packages designed for low-activity sources and lower-level radioactive materials

Package Type B: Constructed for high-level waste transport, including spent fuel, integrating dense radiation shielding and reinforced containment to mitigate accident risks.

Package Type C: This is the most robust type, designed to withstand extreme accident scenarios, particularly for transporting high-activity materials by air.

Concrete is widely used in the design of transport containers—known as packages Type B—due to its excellent shielding properties, structural strength, thermal resistance, and cost-effectiveness. These containers are engineered to withstand extreme conditions, including impacts, fire, and water immersion, without releasing radioactive contents. The dense composition of concrete helps attenuate gamma radiation and, when combined with steel liners and lead shielding, ensures robust protection. The CONSTOR registered design was developed as an alternative multipurpose cask concept for transport spent nuclear fuel. This steel cask sandwich concept with heavy concrete as an additional shielding material fulfills the same safety criteria as the CASTOR registered cask design

This paper aim to investigate the radiation shielding properties, physical and mechanical properties of concrete which using in fabrication of COSTOR for transportation of radioactive materials especially spent nuclear fuel. The study program consists of two main partes, the experimental part which conducted to investigate the effect of different nanomaterials on the radiation, physical and mechanical properties of normal weight concrete and heavy weight concrete containing barite aggregate. The theoretical part using the Mont Carlo transport code MCNP5 and XCOM to simulate the linear attenuation coefficient of the two types of concrete containing nano particles. Five nano materials were used (nano titanium (NT), nano hematite (NH), nano silica (NS), nano metakaolin (NMK) and nano ceramic (NC). Nanomaterials were added with 0, 0.5, 0.75, 1, and 2% as a replacement of cement weight. to experimentally investigate the gamma radiation, physical and mechanical characteristics of concrete. Moreover, the scanning electron microscopy technique (SEM) and X ray diffraction analysis (XRD) were used to prove the improvement in the microstructure of concrete as a result of using nano particles and their hybridization.

The experimental results showed that the single addition of each of nano particles and their combination improved the attenuation coefficient, physical properties, and mechanical properties of normal and heavy weight concrete. The results of the hybrid nano addition showed that the synergistic phenomenon occurred in some cases. Furthermore, the scanning electron microscopy technique (SEM) was used to prove the enhancement in the microstructure of concrete as a result of the addition of NS, NH, NT, NMK, Nc and their combination.

In addition, the results of the simulation of the linear attenuation coefficient using the Monte Carlo simulation were in good agreement with the experimental and XCOM program results.

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## modal shipment - A French, Belgian, Dutch and German collaboration

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A Surface Contaminated Object (SCO) is defined as a solid object which is not itself radioactive, but which has radioactive material distributed on its surfaces. The 2018 Edition of the IAEA Regulations for the Safe Transport of Radioactive Material (SSR-6 Rev. 1) introduced the group SCO-III to transport unpackaged large objects.

The two pressurized water reactors of the Fessenheim Nuclear Power Plant, owned by EDF, were shut down in 2020. Previously, for maintenance operations in the year 2002 and 2010, the three steam generators –over 20 metres long, 300 tons –of each reactor were taken out from the reactors, divided in two and stored on site:

- EDF shipped the six upper parts, as SCO-I, to Cyclife, in Studsvik (Sweden), in 2021, to be recycled;
- EDF plans two transports of the lower parts (three parts for each transport), as SCO-III (considering the higher activity due to the NPP primary coolant) to the same facility. Modes of transport are, from consignor to consignee, road, inland waterways and maritime. The countries crossed by inland waterways, from Neuf-Brisach to Dunkerque (France), are France, Germany, Belgium and the Netherlands.

According to the para. 825 of SSR-6 Rev. 1, “multilateral approval shall be required for the shipment of SCO-III”. EDF has submitted to all Competent Authorities an application (para. 827A of SSR-6 Rev. 1), including a transport plan and demonstrations to withstand normal conditions of transport.

Despite SSR-6 Rev. 1, national regulations have their own specificities and each Competent Authority has its own assessment procedures. Nevertheless, involved Authorities agreed for a joint review, which included:

- the understanding of national regulatory requirements,
- the expected level of detail and quality of the safety case,
- the feedback from previous shipments of similar type,
- the contents, including the conditions, of the approvals to be issued.

This joint review demonstrated good coordination between authorities, enabling the application to be processed rapidly, and the various authorities to benefit from each other’s expertise and feedback. This

was of particular importance, as it was the first application for the transport of an SCO-III assessed by the Competent Authorities involved.

Finally, the authorities were able to issue approvals, whose format is certainly in line with their national provisions, but whose content and level of requirements in terms of transport safety are consistent.

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**Harmonizing Nuclear Transport Governance in ASEAN: Legal and Maritime Imperatives****Author:** Samuel Yong<sup>None</sup>**Corresponding Author:** smlyong946@gmail.com

The Association of Southeast Asian Nations (ASEAN) presents a maritime-intensive operational and legal environment that complicates governance of nuclear fuel transport. Nine of the ten ASEAN Member States (AMS) are coastal or archipelagic, and several have overlapping or disputed maritime claims [1], raising questions of jurisdiction, liability, and transboundary risk. As several Member States are planning civil nuclear energy programmes with target timelines in the 2030s, the maritime import of nuclear fuel and related materials will likely remain an essential step until any domestic fuel-cycle facilities are developed, whether front-end or back-end [2].

**Maritime chokepoints and transport exposure**

The Straits of Malacca and Singapore (SOMS) recorded ~94,000 vessel transits in 2024, with the number expected to grow every year [3]. These straits are geographically narrow at points, heightening the risks of congestion, collision, and piracy [12]. Alternative passages such as the Lombok Strait fall within Indonesian jurisdiction but involve longer routes [4]. Any serious incident within these chokepoints would produce transboundary effects, disrupting energy supply chains and raising public safety and environmental concerns across multiple states.

**Dependence on international supply and transport scale**

ASEAN currently has no commercial fuel fabrication or nuclear waste repository infrastructure, and also lacks a clear, regionally accepted waste strategy [13]. Nuclear newcomers will likely rely on imported nuclear fuel from established suppliers in other continents, through maritime transport routes. Without standardized approaches, disparities in national practice could complicate both routine shipments and emergency response, thus underscoring the importance of a harmonized approach.

While limited airborne shipment of small radioactive sources is permitted, international best practice remains to move bulk nuclear fuel and radioactive materials by sea, consistent with IAEA guidance [5][6]. Maritime transport thus remains the globally accepted standard for routine nuclear consignments.

**Fragmented legal and liability framework**

Legal commitments across ASEAN remain patchy for now. To date, the Philippines is the only ASEAN member to ratify a global nuclear liability convention [7], while Indonesia has taken a preliminary step by signing the Convention on Supplementary Compensation [8]. As a result, most ASEAN states rely on general maritime law under UNCLOS and International Maritime Organization (IMO) instruments such as the International Maritime Dangerous Goods (IMDG) Code for hazardous consignments [6]. This fragmented approach generates gaps in liability coverage, transboundary compensation, and coordinated emergency response. Recent initiatives demonstrate growing awareness of these deficiencies, but regional harmonization remains nascent [9][10].

**Recommended harmonization agenda**

This paper argues that ASEAN should move beyond, and establish a regional framework that:

1. Creates explicit protocols for nuclear fuel transport aligned with IAEA safety standards and the IMO IMDG Code.
2. Builds a coordinated EPR mechanism under the ASEAN Agreement on Disaster Management and Emergency Response (AADMER) [11].
3. Develops mutual recognition of port inspections, certifications, and liability provisions across ASEAN Member States.

**Conclusion**

ASEAN's geographic realities - archipelagic structures, congested maritime chokepoints, and the absence of domestic fuel-cycle facilities - mean that nuclear transport will remain unavoidable and

transboundary. A harmonized ASEAN approach would directionally reduce vulnerabilities, improve public confidence in a region still developing its nuclear governance capabilities, and align the region with global best practices. Importantly, it would also allow ASEAN to present itself as a responsible and proactive actor in the global nuclear order, demonstrating that civil nuclear development can proceed in step with robust safety, security, safeguards, and liability frameworks. Moving decisively on this issue is not just beneficial; it is essential to ensuring that the region's nuclear ambitions evolve safely and sustainably.

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## **Assessment of Radiation Levels of $^{99}\text{Mo}/^{99\text{m}}\text{Tc}$ Generator Packages during transport**

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**Abstract:**  $^{99}\text{Mo}/^{99\text{m}}\text{Tc}$  generators are widely used in nuclear medicine to produce technetium-99m for diagnostic imaging. Ensuring safe handling and transport of these generators is essential for protecting workers, the public, and the environment. This study aimed to measure radiation levels for Monorol  $^{99}\text{Mo}/^{99\text{m}}\text{Tc}$  generator packages upon receipt at a nuclear medicine department to verify compliance with international safety standards (IAEA, 2018).

Forty-four generator packages were assessed during 2016–2018. Dose rate measurements were taken using a calibrated survey meter (RADOS RDS-200, calibration factor 0.94) at four positions: direct top surface, one meter above top surface, direct outer surface, and one meter from outer surface. Results were analyzed separately for 30 GBq and 15 GBq generators, and compared with reference studies (Ahasan, 2004) and regulatory thresholds (IAEA, 1999).

All measured values were below IAEA transport limits of 2mSv/hr at package surface and 0.1mSv/hr at one meter (IAEA, 2018).

This study concluded that all generator packages met IAEA and ALARA safety requirements, demonstrating effective shielding and transport practices.

**Keywords:**  $^{99}\text{Mo}/^{99\text{m}}\text{Tc}$ -generators packages, radiation survey meters, and radiation workers

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## **The International Regime for Nuclear Liability: A Key Element of the Legal Framework for the Transport of Nuclear and Radioactive Material**

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The safe and secure transport of nuclear and radioactive material requires not only robust technical and operational measures but also a clear and predictable legal framework. Nuclear third-party liability laws form a critical part of that framework, as they provide legal certainty regarding compensation in the event of a transport-related nuclear incident.

The importance of these liability provisions for transport was recognized at the International Conference on the Safety of Transport of Radioactive Material (Vienna, July 2003), where “It was noted that there are a number of liability conventions to which many States are Parties but to which many others are not, and that the provisions of the liability conventions and the relationships between them are not simple to understand.” Also, as highlighted in the Executive Summary of that Conference, the “lack of broad adherence to a global liability regime creates uncertainty as to the legal consequences of a transport accident.” The Conference concluded that explanatory texts of the nuclear liability instruments should be prepared.

As a consequence, the IAEA Director General established the International Expert Group on Nuclear Liability (INLEX) in 2003 to create a forum of expertise to advise on nuclear liability, to enhance global adherence by nuclear and non-nuclear States to an effective liability regime based on various international nuclear liability conventions, and to assist in the development of national nuclear liability legal frameworks in IAEA Member States.

The international nuclear liability regime has evolved over decades. While the probability of a nuclear accident is low, the potential consequences are significant. As early as the 1960s, suppliers and contractors required governments to indemnify them against nuclear damage before engaging in nuclear activities. In response, governments and industry agreed on key liability principles that became embedded in both national legislation and international conventions, ensuring compensation for victims while enabling nuclear development.

Following the Chernobyl accident, the IAEA launched a review of its 1963 Vienna Convention on Civil Liability for Nuclear Damage, which culminated in the 1997 Protocol to Amend the Vienna Convention. In force since 2003, this instrument expanded compensation amounts, broadened the scope of compensable damage, and extended geographic coverage. It also paved the way for the Convention on Supplementary Compensation for Nuclear Damage (CSC), designed as a global umbrella convention open to all States, regardless of whether they were already party to other treaties. The CSC entered into force in 2015, following Japan’s ratification, reflecting lessons learned from the Fukushima accident.

In parallel, under the auspices of the Organization for Economic Co-operation and Development (OECD), the Paris Convention on Third Party Liability in the Field of Nuclear Energy was modernized and amended through successive protocols (2004, 2022). In addition, the Joint Protocol, which entered into force in 1992, created a bridge between the Paris and Vienna Conventions.

Today, distinct conventions govern nuclear liability. Although built on common principles, their coexistence has contributed to a complex landscape with uneven adherence across States. Against this backdrop, the work of INLEX remains crucial to clarifying these regimes, enhancing understanding of their provisions, including those applicable to transport, and promoting a more coherent and widely accepted global liability framework.

This paper will present the principles of third-party nuclear liability, the provisions applicable to the transport of nuclear and radioactive material, and an overview of the various international nuclear liability conventions. It will also discuss the work of INLEX, particularly its efforts related to transport issues throughout its existence, and its objectives for the future, including its support to IAEA Member States in developing national liability frameworks.

**Country or International Organization:**

**Instructions:**

## **Integrating Nuclear Safety and Security in the Transport of Radioactive Material: Challenges, the Code of Conduct on Safety and Security of Radioactive Sources, and the Role of Security Culture.**

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The safe and secure transport of radioactive material represents one of the most critical interfaces in the broader framework of nuclear governance. The physical movement of such materials across national and international routes not only ensures their beneficial applications in medicine, industry, agriculture, and research, but also exposes them to unique risks related to both safety and security. This is equally relevant for the transport of disused sources, which often present heightened regulatory and operational challenges. The Code of Conduct, together with its supplementary guidance, has become a cornerstone in shaping national and international efforts to minimize risks associated with radioactive sources. Nevertheless, translating these principles into coherent and effective regulatory frameworks remains difficult, particularly when integrating safety and security requirements for transport. This concern was underscored by Member States during the Open-Ended Meeting of Technical and Legal Experts for Sharing Information on States' Implementation of the Guidance on the Management of Disused Radioactive Sources, held in Vienna on 9–13 June 2025.

From a safety perspective, the transport of radioactive material must comply with strict technical standards designed to protect workers, the public, and the environment from radiological exposure. Packaging requirements, dose limits, emergency preparedness, and competent authority oversight are well established through international instruments such as the IAEA Transport Regulations. In parallel, the security dimension focuses on preventing unauthorized access, theft, or sabotage during transport, particularly for high-activity sealed sources. Ensuring that transport routes, carriers, and interim storage points are adequately protected against malicious acts requires tailored regulatory provisions, training, and close coordination with law enforcement and other relevant authorities.

For many countries, one of the principal challenges lies in drafting national regulations that integrate safety and security in a balanced manner. Safety frameworks are often more mature, while security provisions may be considered as supplementary rather than fully embedded. Regulatory fragmentation, overlapping mandates of different authorities, and resource constraints further complicate the establishment of a comprehensive system. Aligning national legislation with the guidance of the Code of Conduct requires not only the adoption of regulations but also the coordination of technical regulators, security agencies, and customs authorities to ensure consistent implementation.

An additional area of concern is the transport of portable radioactive sources, which are frequently moved and used in field conditions. Their portability and widespread applications make them particularly vulnerable to loss, theft, or misuse, especially when transported outside controlled facilities. Addressing these vulnerabilities requires a strong emphasis on security culture. This involves fostering awareness among transport workers, operators, and users about the importance of vigilance, recognizing potential threats, and embedding a “safety and security first” mindset in daily practice. Security culture should complement technical measures by reinforcing responsibility and accountability across all organizational levels. In this regard, recent IAEA publications such as Technical Reports Series No. 1001 (2021), *Managing the Interface between Safety and Security for Normal Commercial Shipments of Radioactive Material*, and Nuclear Security Series No. 46-T, *Security of Nuclear and Other Radioactive Material in Transport*, provide valuable tools for national authorities and operators alike.

The paper will further address the interface between safety and security in the transport of radioactive material, highlighting the need for integrated regulatory approaches. It will examine why national authorities must not only adopt international standards but also adapt them to local realities, strengthening technical capacity and fostering inter-agency cooperation. It will also discuss how embedding security culture in routine practices, with particular attention to mobile sources, can enhance resilience against both accidental and intentional events. Finally, it will consider the importance of sustained capacity building, regional cooperation, and political commitment in ensuring that safety and security measures mutually reinforce each other.

**Country or International Organization:**

**Instructions:**

## Overcoming Denial of Shipment: Regulatory Challenges and Approaches to Facilitate Transport of Radioactive Material

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Impediments to the transport of radioactive material, even when shipments fully comply with international regulations, have become a recurring challenge with significant legal and societal implications. The phenomenon of “denial or delay of shipment” occurs when carriers, ports, or authorities refuse or postpone transport due to liability concerns, political sensitivities, or public pressure. Such impediments can directly affect the availability of radioisotopes for medicine, industry, and research, with serious consequences for public health and economic activity.

From a legal standpoint, these refusals raise complex issues. They can conflict with domestic regulations guaranteeing the free movement of goods, international standards on the safe and secure transport of radioactive material, and broader non-discrimination principles embedded in trade and environmental law. The lack of clear legal frameworks often drives operators and carriers to avoid radioactive consignments, despite compliance with packaging and safety requirements. In several cases, airports have refused to load shipments, shipping lines have declined to carry them, or local authorities have blocked passage through populated areas. These actions can create legal uncertainty and operational disruption, highlighting the need for coherent and harmonized regulations at both national and international levels.

Public concern plays a central role in shaping these impediments. Accidents during transport, such as the loss of a high-activity source or the discovery of radioactive waste or contaminated materials in transit, have heightened perceptions of risk. Even when incidents result in minimal exposure or no radiological harm, societal fears may lead to demands for stricter laws or outright bans on transport through certain regions.

The IAEA identified that denial or delay of shipments occurs even when consignments comply with technical safety and security standards. Its workshops, training, and establishment of National Focal Points are meant to help States implement regulations effectively, respond to denials, and engage in coordinated approaches. This issue was recently highlighted during a side event at the IAEA’s 69th General Conference in Vienna, entitled Facilitation of the Safe and Secure Transport of Radioactive Material. These initiatives, together with the Denial of Shipment Working Group, provide guidance, capacity building, and documentation to help Member States understand patterns, causes, and possible remedies (IAEA, 2006; IAEA, 2025 workshops).

These efforts emphasize the importance of transparency, stakeholder communication, and public participation in regulatory processes to maintain confidence while facilitating safe and secure transport. Clear assignment of responsibilities, harmonization with international transport regulations, and adequate liability provisions are essential to reducing operational reluctance among carriers and authorities.

The paper will further analyze the legal consequences of impeding the transport of radioactive material, examine illustrative cases of denial or delay, and discuss approaches to addressing public concerns without undermining compliance with international obligations. It will also highlight the importance of proactive communication, liability clarity, and consistent regulation in ensuring that radioactive materials essential for health care, industry, and research can be transported safely, securely, and reliably.

**Country or International Organization:**

**Instructions:**

## Review of an integrated safety case for DPCs –experience report

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In 2018 ENSI, as Swiss competent authority for the transport of class 7 material and the licencing of storage casks, received a proposal for a new package design of a Dual Purpose Cask (DPC). This proposal comprises the request for a package approval and the request for a specific storage approval. The fulfilment of the requirements for transports according to SSR-6 and storage, which is described in the Swiss guideline ENSI-G05, is addressed in only one safety file in compliance with the IAEA TECDOC-1938. Therefore, the safety file was called integrated safety case (ISC) and the content is based on the PDSR-Guide as per IAEA SSG-66.

Following points were considered by ENSI for the first time in this way:

- The complete assessment of a Type B package according to SSR-6 Edition 2018. Usually, ENSI has issued package approvals based on the assessment and the licence of a foreign competent authority (country of origin). Therefore, a strategy for the assessment was created, considering the situation of ENSI.
- The new storage guideline ENSI-G05 was used the first time to issue a storage licence. The new guideline includes new requirements for the handling of the DPC.
- The fulfilment of all requirements on transport and storage was documented in only one safety case (ISC). Therefore, the strategy for the assessment was adapted and optimised.

During the project, ENSI identified several points and collected experience, especially the review and assessment of the integrated safety case, for example the dealing with the different criteria of transport and storage, the interaction of the different safety analysis for transport and storage, the optimisation of the assessment for both requirements, the assessment strategy including the integration of independent technical experts. The paper describes these aspects from the view of a competent authority.

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## German regulations on computer security in transport

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Since Germany is a transit country in the middle of Europe there are a lot of transports of radioactive material and of nuclear material in and through Germany. Every year there are more than half a million transports of radioactive material in Germany. Mostly radioactive sources for medical use or measurement tools. In addition to that there is a smaller amount of transports of nuclear material. For example in 2024 there were about 340 transports of nuclear material, only 14 of them didn't cross the borders of Germany.

As computer security is getting more and more relevant for nuclear installations, Germany is currently working on specific regulations regarding computer security for transports of nuclear material. For the transport of radioactive material regulations for computer security are addressed in the "Guideline for the Physical Protection of Other Radioactive Material during Handling and Transport against Malicious Acts" (malicious acts guideline other radioactive material).

The malicious acts guideline other radioactive material came into force in Germany 2022. It contains specific general objectives of computer security and addresses the computer security organization, the computer security concept and requirements for protection measures. Basis to this IT-requirements is the German BSI-Grundschutz, which defines basic standards how to protect computer-based systems. The BSI-Grundschutz meets the international standards ISO/IEC 27001.

To help carriers or other companies related to the organization of transports of radioactive material (e. g. licensees) in Germany implementing computer security to their computer-based systems the Federal Office for the Safety of Nuclear Waste Management (BASE) as the licensing authority together with a TSO wrote a document, which shows how to identify computer systems, which are used during transports and are relevant to security. It gives advise how to protect this computer-based systems and how to write a documentation, which is proofable during a licensing process. This presentation will give an overview of the process to implement computer security measures for the transport of radioactive material. It will show the practical realization in the licensing process and concludes with a short outlook on future challenges in this field in Germany.

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## OVERVIEW OF THE CURRENT SAFE AND SECURE TRANSPORT OF PACKAGES CONTAINING RADIOISOTOPE MATERIAL IN MALAYSIA

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Since Malaysia began developing radioactive material in 1982 using the 1MW TRIGA MARK II research reactor and relies on imports to meet its growing nuclear demands [1], the safe and secure transport of radioactive packages is essential. The transport of packages containing radioactive material is a crucial activity that protects the public and environment from accidental radiation exposure, ensures national security against misuse, and maintains public trust in nuclear technology [2]. This paper reviews Malaysia's current transport system for packages containing radioactive materials by covering its legislative foundation, operational practices, and ongoing challenges. The paper will explore the safe and secure transportation of new radioactive materials, radioactive waste, and radioactive materials used for inspection by operators during non-destructive testing within Malaysia and during international transit. The objective is to demonstrate compliance with both national and international standards.

The transport of packages containing radioactive materials in Malaysia is a highly regulated activity governed by the Atomic Energy Licensing Board (AELB), which operates under the authority of the Atomic Energy Licensing Act 1984 (Act 304) and the Radiation Protection (Transport) Regulations 1989 [3]. As the central regulatory authority in Malaysia, the AELB is responsible for issuing licenses and enforcing compliance with the rules. The AELB also outlines the specific requirements for all parties involved (consignor, carriers, and consignees) along with the necessary specifications for packaging, handling, and documentation [4,5]. Malaysia's system tightly integrates with global best practices by adopting the International Atomic Energy Agency (IAEA) Regulations for the Safe Transport of Radioactive Material (SSR-6, and SSR-6 Rev.1). Furthermore, the International Maritime Dangerous Goods (IMDG) Codes and the International Air Transport Association (IATA) rules also applied to all sea and air transport carried out in Malaysia [3]. The subsequent section of this paper will address the classification of packages and detail the critical logistical requirements necessary for transporting materials with short half-lives, where timely delivery is paramount [4,5].

The paper provides a technical analysis of operational requirements and safety measures for radioactive packages transport in Malaysia [3-8]. It details packaging requirements, which follow a graded approach based on the material's activity, type, and form, and meet testing standards adopted from IAEA guidelines. Key safety measures reviewed include radiation protection, the Transport Index (TI), and contamination control to guarantee containment and shielding during accidents [2,9]. Furthermore, the paper addresses proper marking, labelling, and documentation, and discusses in-transit security through security plans tailored to the radioisotope's category. Transport relies mainly on road transport in Peninsular Malaysia, with air or sea transport for Sabah, Sarawak, and international shipments, requiring compliance with the IATA and IMDG Code [3,6,7,8]. Lastly, the paper concludes by focusing on future initiatives to strengthen the system of transportation of packages containing radioactive material in Malaysia, such as an enhancing public education,

implementing continuous training, and adopting real-time tracking.

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## Recent Experience with the Transport of Large Surface Contaminated Objects as SCO-III in Germany

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The latest revision of the IAEA Regulations for the Safe Transport of Radioactive Material (SSR-6, Rev. 1) introduced a new group of surface contaminated objects (SCO-III) which shall be applied for objects, that –due to their size - can only be transported unpackaged. The classification as SCO-III is typically used for the transport of disused steam generators, that are contaminated on their internal surfaces with activity levels that exceed those permitted for SCO-I, but are below the limits given in §413 (c) in SSR-6, Rev. 1. Furthermore, the classification as SCO-III requires all openings to be sealed in order to prevent the release of radioactive material during conditions defined in para. 520(e), and for the inside of the object to be as dry as possible.

The transport of large contaminated components (as SCO-III or under special arrangement) requires a multilateral approval of the shipment in accordance with the dangerous goods regulations, based on SSR-6, Rev. 1. In Germany, the Federal Office for the Safety of Nuclear Waste Management (BASE) is the competent authority for issuing the approval after verifying compliance with the dangerous goods regulations. The technical assessment of BASE covers, in particular, the radioactive inventory determination carried out by the applicant, and the transport plan including the radiation protection measures for the transport itself and all associated handling operations. After receiving a commission from BASE, the Federal Institute for Material Research and Testing (BAM) assesses the mechanical and thermal properties of the SCO-III in transport configuration in terms of activity retention, as well as the management system including the quality assurance measures for all operations and conditions of the transport (design, preparation, transport).

Since the introduction of SCO-III, three shipments of disused steam generators with high levels of internal surface contamination have touched German territory:

- a transport of two disused steam deformeders from the nuclear power plant Lingen, Germany, by road, inland waterways and sea to the USA in 2024,

- a transport of three lower parts of disused steam generators from the nuclear power plant Fessenheim, France, by road, inland waterways and sea to Sweden in 2025, and
- a transport of four disused steam generators from the nuclear power plant Unterweser, Germany, by road and sea to Sweden in 2025

All of the three shipments were partly accompanied by BASE and BAM, e.g. after preparation and during transshipments.

In this paper, we report on the most important insights gained by assessing the applications for shipment approval and accompanying these transports. These insights concern the preparation of the object, the form and content of the transport plan, the radiological characterization of the object, and the implementation of radiation protection measures.

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## **Class 7 Box: Standardized Packaging to Address Denials and Delays**

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Swiss competent authorities (Swiss CA) were approached by consignors reporting more and more difficulties with the transport of excepted packages (EP). Swiss CA have initiated an analysis of the situation inviting relevant carriers such as postal operator, national airline, and parcel services. Carriers confirmed the difficulties reported by the consignors. Carriers have provided reasons for the non-acceptance of class 7 packages or the acceptance only under very specific conditions. As a result, small quantities of radioactive materials for medicine, industry and research cannot be transported efficiently.

Following the analysis of carrier responses, consignors supported by the Swiss CA started the development of a standardized EP to address variety of EP, training effort for limited number of transported EP, and operators risk perception. The development results in a packaging concept called “class 7 box” (working title) providing a standardised transport solution with improved safety features compared to existing EPs, a clearly understandable packing concept and standardised training and emergency instructions.

The “class 7 box” concept was originally proposed for the last review and revision cycle of SSR-6 (Rev. 1). Due to marking and labelling issues, the adoption of UN concepts such as packing groups (PG) and excepted quantities (EQ), as well as the resulting potential competition with the current EP, the concept could not be included in the revised SSR-6. Nevertheless, the transport community has acknowledged the benefit to have a standardised packaging solution. Hence, the concept is foreseen to be proposed for an ISO standard as a standardised EP only to avoid the conflicts identified during the last SSR-6 review and revision cycle.

The paper provides reasons for denials and delays of EP in the international transport of radioactive materials for medicine, industry, and research. A potential solution is presented in detail: the “class 7 box” as a standardised EP. Follow-up activities such as a proposal to standardize “class 7 box” for an ISO standard will be also presented.

**Country or International Organization:**

**Instructions:**

## Interpretation of the requirements for quality management systems for the shipment of SCO-III objects

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A management system is essential for ensuring the safe transport of radioactive material. Guidance on the implementation of a management system is provided in TS-G-1.4 [1], but the degree of detail depends on the package design and relevant transport activities. A transport comprises all operations and conditions associated with, and involved in, the movement of radioactive material.

How does the - with the transport regulations [2] newly specified - group for large surface contaminated objects "SCO-III" blend in concerning quality management context?

BASE is the German competent authority for issuing approval certificates for shipments of SCO-III. BASE generally refers to BAM for assessment of mechanical and thermal design, containment, and the quality management during approval procedure. BAM as competent authority has from numerous applications over decades expansive experience in the assessment and the surveillance of the quality management systems.

A meaningful interpretation of the recommendations for the quality management system by BAM for the shipment of SCO-III is presented here to help understand the transport regulations. The quality management system for surface contaminated large objects transported as SCO-III may be seen as a three-stage process (Application, Preparation, Transport). All steps should be based on an integrated management system (IMS) of the responsible company for the shipment application (see Figure 1).

Figure 1: Scheme of the Quality-Management-System for SCO-III Shipments

The IMS of the responsible company as basis for an application should be described in corresponding documents. General requirements for quality management systems are given in e.g. ISO 9001 [3] and in the TS-G-1.4 [1].

An application for the transport of SCO-III shall include specific information about quality assurance regarding all activities for the transport [2]. Corresponding measures may be stipulated in form of a comprehensive Quality Management Plan (QMP) to manage all aspects related with the SCO-III transport in terms of the quality assurance, e.g. for the design and the preparation of the closings and bearings.

SCO-III were not built for a transport; they need to be prepared for the transport accordingly. Therefore, comprehensive inspections shall be carried out. A clear determination of the radioactive content and of state of the object itself (materials and construction) is among others important for the transport. Finally, SCO-III shall be inspected according to the QMP after preparation and before commissioning to prove compliance with the design specification.

The QMP shall also consider all activities during the transport. A transport schedule with description of the relevant steps, controls, instruction documents and responsibilities can help to ensure compliance with the foreseen quality assurance measures of the QMP.

The number of SCO-III transports is expected to be increasing in the next decades. The understanding of the requirements, especially for the quality assurance, is difficult since the standards established for packages have to be adapted to SCO-III objects. BASE and BAM provide guidance on a meaningful interpretation of the requirements for quality management systems for SCO -III objects. A corresponding QMP plays a pivotal role in considering all important measures for application, preparation and transport to ensure a safe and secure transport.

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**Country or International Organization:**

**Instructions:**

## Strengthening Capacity to ensure the safe and secure Transport of Radioactive sources: Lessons for Ethiopia and African Region

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### Synopses

In order to ensure the safe and secure transportation of radioactive sources, especially in newcomer nuclear states where their usage is rapidly expanding, it is crucial for every state to take full responsibility. Developing sustainable capacity at both national and regional levels is essential to address transportation risks such as unauthorized access, theft, sabotage, and delays that could compromise safety and security. This study focuses on a capacity-building approach towards enhancing transport security, which incorporates regulatory enhancements, training for operators and first responders, inter-agency communication, and regional collaboration mechanisms.

Ethiopia imports and utilizes a variety of radioactive materials for medical, industrial, and agricultural purposes. Mapping the transit routes revealed gaps in escort services, limitations in GPS tracking, and a lack of awareness among customs officials. These gaps emphasized the necessity for capacity building as a fundamental aspect of sustainable security.

The Method and Model discussed here comprised four key elements and it was recommended by author for Ethiopia and other developing countries:

1. Training and Awareness Programs- Mass training on radiation safety, security protocols, and emergency response for transport operators, regulators, and customs personnel have resulted in an increase in approved operator.
2. Simulation Exercises- Multi-agency drills enhanced communication protocols and decreased emergency response times.
3. Institutional and Regulatory Enhancement-Developing standard operating procedures reduced transport clearance delays while risk-informed route planning enhanced predictability.
4. Regional Collaboration- Ethiopia engaged in discussions with neighboring countries and participated in African Regional Cooperative Agreement (AFRA) activities, laying the groundwork for a regional transport security training center.

These paper underscore the importance of viewing capacity development as an ongoing and sustainable process that must be ingrained within institutional frameworks. Furthermore, this approach aligns with global standards such as the IAEA SSR-6 and Nuclear Security Series No. 9, which emphasize compliance at both international and national levels.

The study concludes with three major recommendations:

1. Institutionalize National Programs by integrating transport security components into the regular training curriculum for customs, law enforcement, and healthcare personnel.
2. Establish Regional Training Centers to facilitate cost-effective and standardized training within the African Union and AFRA frameworks.
3. Address Emerging Threats like cybersecurity in transport security training programs to account for the growing reliance on computerized monitoring systems.

This research indicates that the method discussed here can serve as a model for Ethiopia and African nations. By prioritizing human capital, enhancing institutional readiness, and fostering regional cooperation, achieving secure transport is feasible even in resource-constrained environments.

**Country or International Organization:**

**Instructions:**

## Security of road transport routes for nuclear materials: regulatory framework and implementation procedures

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When constructing a Basic Nuclear Installation (BNI), potential sites are carefully analyzed in order to select the one that guarantees the highest possible level security for the future installation. The same principle applies to the selection of transport routes between different BNIs, as not all routes offer the same level security. The French regulatory framework of the transport of nuclear materials fully address these concerns.

The decree of February 28, 2023 requires that all proposed routes be described in the Implementing Agreement Request submitted by Authorized Transport Operators (ATOs) prior to transport, with six key security criteria that routes must meet:

- Compliance with all applicable road traffic restrictions in France;
- Minimization of total transport duration and the number of stops;
- Identification of vulnerable points along the route, such as mandatory crossing points, bottlenecks, and major engineering structures;
- Identification of areas with weak communication network coverage;
- Identification areas without network coverage;
- Avoidance of urban areas potentially affected by radiological contamination.

In practical terms, the Transport Control Center of the Defense and Security Nuclear Expertise Directorate (DEND) is responsible for verifying the completeness and regularity of the request of Implementing Agreement in accordance with the regulatory framework.

The article explains how route security is integrated into the regulatory framework, how these requirements are applied in practice, and the specific methods and tools developed by DEND to meet them.

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## The evolution of national transport security regulations in Hungary: experience from the regulatory body's perspective of continuous improvement.

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Hungary has a broad nuclear industry, including NPP with four operating units, two research reactors, spent fuel interim storage facility and other radioactive waste treatment and disposal facilities handling the radioactive waste generated by the activities of more than 350 users of nuclear and other radioactive materials. The above described industrial activities result every year in a large number of shipment of nuclear and other radioactive materials at almost all level of materials.

The Hungarian Atomic Energy Authority (HAEA) is the responsible regulatory body for nuclear security, the requirements are described in the Govt. Decree 190/2011. (IX. 19.) Korm. on physical

protection requirements for various applications of atomic energy and the corresponding system of licensing, reporting and inspection entered into force on 4 October 2011

Security related authorization for all type of application of atomic energy is a requirement in Hungary. The commencement of and then any modification in the operation of facilities, as well as the use, storage and transport (as applications of atomic energy) requires a physical protection license. The licensing authority is HAEA in cooperation with the National Police Headquarters, as co-authority.

The transport related physical protection system also requires approval. For majority of shipments, the license is issued for a term of 5 years. Concerning the transport safety related regulation, Hungary implements the IAEA's transport safety provisions through the mode specific international regulations (and their annexes/appendixes, which are aligned with the corresponding IAEA's provisions) for the transport of dangerous goods, including radioactive material.

The aim of the article is to give an overview of the Hungarian nuclear security regulatory framework, especially in relation with transport security, highlighting the advantage of combining requirements for nuclear and other radioactive material security in one single regulation. The paper also covers the lesson learned from two IPPAS missions, international cooperations, national and facility level exercises, to show the mayor steps of gathering experience, knowledge and input for continuous improvement of the national transport security regulations.

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## **Brazilian Nuclear Fuel Cycle (front end): INB's Integrated Approach for $U_3O_8$ and $UF_6$**

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The safe and secure transportation of nuclear materials is a strategic and highly regulated activity for *Indústrias Nucleares do Brasil* (INB). This paper describes INB's integrated approach to the road transport of uranium concentrate ( $U_3O_8$ ) from the mining site to the port in Bahia and the transport of uranium hexafluoride ( $UF_6$ ) from the port to the nuclear site in Rio de Janeiro. These operations, crucial for Brazil's nuclear fuel cycle, involves distinct technical, regulatory, and security challenges, requiring also robust coordination among national authorities such as CNEN/ANSN, IBAMA, the Federal Police, and the Brazilian Navy. By integrating safety, security, and environmental considerations, INB strengthens regulatory compliance, operational reliability, and public confidence.

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## **The Italian National Committee for the Facilitation of the Safe and Secure Transport of Radioactive Material (FATRAM)**

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The Italian regulatory framework for the transport of radioactive material is complex because multiple authorities have safety responsibilities within the safety regulatory framework, and in some cases the responsibilities and functions of each authority are not clearly specified in the relevant legislation. ISIN –National Inspectorate for Nuclear Safety and Radiation Protection is the main Italian authority responsible for nuclear safety and radiation protection and for the safe transport of radioactive material.

Furthermore, the Italian regulatory framework introduces a number of additional requirements to the transport of radioactive material.

In order to address these issues, which at international level can cause delays and denials in the shipment (DoS) of radioactive materials, and possibly to resolve them, in October 2024 ISIN invited all interested parties to join the national committee on the facilitation of safe and secure transport of radioactive material (FATRAM), which will be the national network whose main objective is to overcome the critical issues related to DoS and national regulatory complexity.

ISIN's initiative is based on the IAEA safety requirements: GSR Part 1 (Rev. 1) Requirement 7, SSR-6 (Rev. 1) para 307 and SSG-78 (Rev. 1) para 4.1.

The main objectives of the committee are:

- ☒ planning and coordination for the prevention and tackling of DoS instances, supporting all interested parties

- ☒ supporting the NFP to comply with his objectives to share knowledge on DoS and to prevent DoS by proposing solutions and collecting data about existing situations.

The Committee covers two main areas of action: A) Responsibilities mapping and simplification and harmonisation of the regulatory framework and B) Training, communication and information.

The Committee's activities are divided into four sub-groups, two for each of the Committee's areas of action and each sub-group is coordinated by a chair and a co-chair. Some activities are cross-cutting and involve all Committee participants.

The A.1 Subgroup objectives are:

- ☒ to map the responsibilities in the transport of radioactive material framework;

- ☒ to draft a document that collects the requirements and related procedures to be followed for transporting radioactive material in Italy and identifies any regulatory obstacles or discrepancies between national and international legislation in relation to the various modes of transport;

- ☒ to map ports that accept class 7 materials and the procedures to be followed in relation to specific activities (loading, unloading, transit, etc.).

The A.2 Subgroup objectives are:

- ☒ the assessment and proposals for the simplification and harmonisation of the applicable requirements;

- ☒ launch of consultations with all relevant public and private stakeholders to propose regulatory measures aimed at implementing specific application procedures for the authorisation of transport practices.

The B.1 Subgroup objectives are:

- ☒ training for public administrations and private companies (e.g. ground handling companies at ports and airports);

- ☒ organisation of exercises based on real cases to ensure adequate preparation of the parties involved.

The B.2 Subgroup objectives are:

- ☒ creation of websites and social media profiles dedicated to the Committee activities;

- ☒ preparation of informative brochures on the importance of transporting radioactive material.

The Committee work will be essential to prepare proposals for possible interventions, including regulatory and normative ones, to reduce cases of DoS and to provide the IAEA with shared data and observations, with the aim of aligning the transport of radioactive material with the most recent international standards.

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## **cure transport by road**

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To tackle the issue of delays of and denials in the shipments of radioactive material, one of the main national tools is the identification of regulatory barriers or inconsistencies between national and international legislation, considering the different modes of transport. In this context, the National Committee for the Facilitation of Safe Transport of Radioactive Materials (established in May 2025 by the Regulatory Body) promoted a gap analysis on road transport regulations. This analysis was not limited to formal legal sources but also considered any other acts or practices that, in effect, create administrative obstacles to the shipment of radioactive materials.

The transport of radioactive material is governed by an extensive and complex regulatory framework, which spans general international law, modal law, international nuclear law, regional law, and national law. This framework consists of multiple layers of binding and non-binding standards, regulations, and recommendations. One of its main sources is a non-binding instrument: the IAEA Safety Requirements SSR-6 (Rev. 1). Although the International Atomic Energy Agency encourages Member States to adopt these requirements when formulating and implementing their national regulatory frameworks for the transport of radioactive material, achieving full harmonization still appears, in some respects, as never-never land.

In Italy, the regulatory framework for road transport of radioactive materials derives mainly—but not exclusively—from the transposition of the IAEA Safety Requirements SSR-6 (Rev. 1) into domestic law. More specifically, this occurs through the adoption of the provisions contained in the annexes to the ADR, themselves annexed to Directive 2008/68/EC of the European Parliament and Council on the inland transport of dangerous goods by road. Since its implementation through Legislative Decree No. 35/2010, these requirements have been unequivocally applicable to the domestic transport of dangerous goods, including radioactive materials, both within and between EU Member States.

The transposition process—gradual and carried out within the framework of European rules, which take precedence over national law—left room for the introduction of variations and additional requirements, introduced through a non-binding administrative circular of the Ministry of Transport (Circular No. 162, issued on December 16, 1996).

The paper will present the methodology adopted by FATRAM, which involved broad consultation with competent public administrations and stakeholders, as well as the definition of specific solutions aimed at removing burdens and obstacles to transport, and at ensuring the adoption of practical guidance for the correct implementation of international standards.

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## **ISIN dose assessment to members of the public arising from transport of radiopharmaceuticals to Rome's Hospitals**

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In accordance with paragraph 308 of the IAEA Regulation for the Safe Transport of Radioactive Material, the competent authority is required to carry out periodic dose assessments to members of the public due to the transport of radioactive material.

For the scope of this study ISIN - National Inspectorate for Nuclear Safety and Radiation Protection, which is the Italian regulatory authority for nuclear safety and radiation protection, decided to focus on the transport of radiopharmaceuticals in the province of Rome. This because transport of radiopharmaceuticals is responsible for about 90 % of packages and IT transported all over the Italian territory and the province of Rome is one of the most affected by transport of radioactive material. The dataset is related to road transport of packages in 2022 and it is obtained from STRIMS, the ISIN Traceability System for Radioactive Waste, Nuclear Materials and Ionizing Radiation Sources. This traceability system has been developed to comply with a requirement set Legislative Decree 101/2020, the national implementation of the Euratom Directive n. 2013/59. According to this Decree, ISIN was commissioned to implement the STRIMS traceability system that allows the tracking of the entire life cycle of an ionizing radiation source from its production, placement on the market and until its final disposal as radioactive waste.

The dose assessment was performed using the computer code NRC-RADTRAN 1.0, considering only normal conditions of transport. The dataset is taken by STRIMS, the ISIN Traceability System for Radioactive Waste, Nuclear Materials and Ionizing Radiation Sources. ISIN required the collaboration of transport operators to collect additional information like routes and departure times.

This article presents a description of the methodology used, the analyzed scenarios and a summary of results obtained.

The results show the estimated annual effective dose to residents and to drivers and pedestrians for each route considered in the study. It is clear that the contribution of the transport of radiopharmaceuticals in the province of Rome on the effective dose to the members of the public is negligible.

The estimated effective dose for drivers and pedestrians sharing the road sections affected by the transport of radioactive material is 1000 times lower than 1 mSv/year, which is the dose limit for members of the public. Moreover, the estimated dose is even lower than 10 µSv/year that is the level below which the practices are not radiologically relevant.

For the estimated effective dose for residents, the population living within 100 m of the road sections was considered affected by the transport of radioactive material.

The effective dose to residents is also not radiologically relevant. In fact, it is several orders of magnitudes lower than the dose to drivers and pedestrians.

The difference in the dose to residents and to drivers and pedestrians is due to high daily traffic density on Rome's principal streets, causing two main factors affecting dose to drivers:

- A high number of persons are within a relatively short distance from the transported radioactive packages and hence subject to a potential risk of exposure to radiation;
- A relevant average speed reduction with a consequent raise of travel time, which leads to higher doses to crew members and other drivers.

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## STRIMS - ISIN: Material, Sources and Waste Traceability System

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ISIN - National Inspectorate for Nuclear Safety and Radiation Protection, which is the Italian regulatory authority for nuclear safety and radiation protection, has developed a web based application called STRIMS, which, starting from January 2022, represents the ISIN Traceability System for Radioactive Waste, Nuclear Materials and Ionizing Radiation Sources.

STRIMS has been developed to comply with a requirement set by Italian law (Legislative Decree 101/2020). In addition to registration obligation on ISIN institutional site for all kinds of operators in the nuclear field, anyone who carry out intermediation, trade, detention and transport of radioactive

materials and sources of ionizing radiation, or performing waste management operations, like treatment and/or storage of radioactive waste, after being registered on ISIN web portal (called STRIMS), is required to transmit data relating to each materials, sources and radioactive waste object of the specific activities performed.

STRIMS allows to track every movement that occurs on the Italian territory for each source of ionizing radiation with particular attention to the identification of High Activity Sealed Source (HASS) and radioactive waste. More than 12,700 operators in the sector are already registered and have sent data relating to 230,000 events that include commercial operations, shipping and transportation, production of new waste, detention of new ionizing radiation sources or cessation of a detention.

Main strengths of STRIMS are described below:

1. The high availability of numerous data and guaranteed access to the STRIMS web portal, with any browser, allows ISIN to derive up-to-date and near real time information on subjects authorized to transport radioactive materials;
2. Carriers, through registration in STRIMS, provide a number of items that complete the registry such as, for example, a copy of the transport license granted by the Ministry of the Environment and Energy. The user, at the time of registration, must provide information including the mode of transport, UN numbers, the vehicles used for transport, and the names of the key figures in transport safety and radiation protection (e.g. ADR Transport Advisor, Radiation Protection Expert);
3. Communications on the transport of radioactive material, sent by authorized carriers, are focused on the exact recognition of the consignor and consignee identity, and this facilitates the analysis of the entities who deal with radioactive sources, contributing significantly to the traceability of ionizing radiation sources;
4. Communications, sent by consignors, are formulated prior to transportation and are useful feedback for ensuring the traceability of radioactive sources. Illegal transportation activity can also be highlighted via the communications;
5. Communications on the transport of radioactive waste provide a timely and up-to-date monitoring of the collection activity of such material;
6. In the back-office section of the STRIMS portal, reserved for ISIN, several specific reports are available, which are a useful tool for conducting verification and supervisory actions on the transport activity covered by the communications, data consistency analyses, and data compliance with transport regulations and national regulatory requirements;
7. The flexibility of data input methods, offered by STRIMS, is an important factor contributing to the completeness and consistency of the data. It allows both to send a large quantity of shipping and transport communications (interoperability) or to fill a guided web form;
8. The requirement to include the unique identifier for sources in transport communications, in particular for High Activity Sealed Source (HASS) sources, is a key element to ensure the traceability of relevant sources;
9. STRIMS' special focus on radioactive waste shipments and transports enables tracking of the main flows, and ISIN can exercise effective surveillance of the management and disposal of radioactive waste, including RW from decommissioning nuclear plants and from the industrial, research and medical sector.

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## **Counterfeit, Fraudulent, and Suspect Items (CFSI) in the Transport of Radioactive Material: Risks, Detection, and Mitigation Strategies**

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The global transport of nuclear and other radioactive material is an essential activity that underpins peaceful applications in energy, medicine, agriculture, research, and industry. With more than

20 million shipments annually, maintaining both safety and security during transport is critical to ensuring the uninterrupted use of radioactive materials worldwide. However, the emergence of counterfeit, fraudulent, and suspect items (CFSI) within supply chains represents a growing and underexplored risk to transport safety, security, and reliability. CFSIs—ranging from falsified certificates and unauthorized spare parts to compromised packaging and detection equipment—pose significant threats by undermining regulatory compliance, compromising package integrity, and creating potential vulnerabilities that could be exploited for malicious purposes.

This paper examines the multifaceted risks associated with CFSIs in the context of radioactive material transport. It provides an overview of the typologies of CFSIs relevant to transport systems, including counterfeit transport packages, falsified or incomplete documentation, fraudulent conveyance equipment, and suspect components within radiation detection and monitoring systems. Drawing on lessons learned from nuclear and non-nuclear industries, the paper highlights how such items can infiltrate supply chains due to globalized trade, complex vendor networks, insufficient verification mechanisms, and limited awareness at the operational level.

A structured risk assessment framework is proposed, focusing on the likelihood of CFSI infiltration and its consequences on transport safety and security. Particular emphasis is given to the safety-security interface, where the introduction of counterfeit or fraudulent items could simultaneously compromise physical protection and safety compliance. Case examples are presented to illustrate how vulnerabilities in packaging certification, transport container validation, and equipment calibration may result in regulatory non-compliance, operational failures, or heightened exposure to security risks.

To address these challenges, the paper explores a range of detection and mitigation strategies. Technological approaches include the deployment of Radio Frequency Identification (RFID) systems, Internet of Things (IoT) sensors, and blockchain-enabled traceability to monitor package integrity and authenticate consignments throughout transport. Optimization algorithms for RFID reader placement are discussed to ensure robust coverage in complex transport environments. In parallel, organizational strategies such as supplier vetting, enhanced procurement protocols, and strengthened regulatory oversight are examined. The role of competent authorities in certifying and validating package designs, monitoring compliance, and coordinating with customs and transport regulators is emphasized as a cornerstone of effective mitigation.

Furthermore, the paper proposes a set of mitigation guidelines for Member States, aligned with IAEA recommendations, to enhance resilience against CFSIs in transport systems. These include capacity building for inspectors, training for operators on CFSI identification, cross-sectoral information sharing, and the development of regulatory frameworks that explicitly address counterfeit and fraudulent risks. Emerging technologies such as artificial intelligence and machine learning are also considered for their potential to enhance anomaly detection in supply chain monitoring.

By systematically addressing the risks posed by counterfeit, fraudulent, and suspect items in the transport of radioactive material, this work contributes to ongoing international efforts to ensure safe, secure, and reliable nuclear transport. The findings support the objectives of the IAEA in harmonizing legal and regulatory frameworks, promoting innovative solutions, and strengthening cooperation among stakeholders. Ultimately, mitigating the risks of CFSIs enhances both the safety of operations and the trust of Member States and the public in the secure movement of radioactive material worldwide.

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## **Developing a HALEU Transport Infrastructure –A Collaborative Path to Nuclear Energy Security**

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The UK's Department for Energy Security and Net Zero (DESNZ) has partnered with Nuclear Transport Solutions (NTS) under the High Assay Low Enriched Uranium (HALEU) Fund Phase 3a Transport Solution to develop comprehensive solutions for the safe and efficient transport of HALEU. This proposal, building on the success of Project THOR, outlines key advancements in UK transport capabilities to support the nuclear fuel supply chain.

Team UK is driving critical innovations in HALEU logistics, including the design, licensing, and prototyping of HALEU oxide transport packages to be approved by the Office for Nuclear Regulation (ONR). These efforts encompass road and maritime transport solutions, ensuring seamless domestic movement and facilitating international exports, particularly to North America. Through coordinated industry engagement, Team UK is addressing regulatory challenges, promoting best practices, and fostering strategic collaboration among key stakeholders in the nuclear sector.

The outcomes of this project will strengthen the UK's energy security and nuclear resilience, offering a robust infrastructure for HALEU transport that supports both commercial needs and strategic national interests. This initiative positions the UK as a leader in HALEU transport, underpinning future developments in advanced nuclear technologies and clean energy.

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## **CHALLENGES AND OPPORTUNITIES IN DEVELOPING MALAYSIA'S FIRST CERTIFIED TRANSPORT PACKAGE FOR RADIOACTIVE SOURCES**

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Malaysia's current reliance on imported transport packages for radioactive materials presents several challenges, including high procurement costs, logistical delays, and dependency on foreign suppliers. This issue is particularly critical for time-sensitive applications such as medical isotopes with short half-lives, as well as for industrial non-destructive testing (NDT) and the use of high-activity sealed sources (Category 1 and 2). The absence of a certified domestic transport package limits national flexibility, weakens supply chain resilience, and poses long-term risks to safety and security assurance. In line with Wawasan Nuklear Malaysia 2030, which identifies the development of a licensed radioactive source transport container as a key performance indicator, and the National Nuclear Technology Policy (DTNN) 2030, which emphasises localisation, safety, security and safeguards (3S), and industry capability building, Malaysia is motivated to establish its own certified package design. This effort not only addresses pressing domestic needs but also strengthens compliance with IAEA SSR-6 requirements and positions Malaysia to contribute to regional nuclear transport solutions. This paper aims to present a feasibility study and roadmap that will guide Malaysia in creating its first certified radioactive transport package. The objectives are to establish in-country capability for package development, ensure compliance with IAEA and national regulations, and build long-term capacity for quality assurance, lifecycle management, and re-certification. The study identifies several challenges, including regulatory approval, technical capability gaps, and limited specialised expertise. Nonetheless, Malaysia's readiness is supported by identified stakeholders, including national agencies with suitable testing facilities for drop, leak, thermal, and other qualification assessments, as well as local manufacturers, R&D centres, and Quality Control and Assurance auditors that can play key roles in the development, certification, and life-cycle management process. The project will open opportunities for collaboration with government agencies, research institutions, and international partners to accelerate development and enable technology transfer.

Testing and qualification capacity is available through institutions such as the Standard and Industrial Research Institute of Malaysia (SIRIM), the National Water Research Institute of Malaysia (NAHRIM), and the Malaysian Nuclear Agency (Nuklear Malaysia). These organizations can support critical safety evaluations, including drop, stacking, compression, immersion, and thermal resistance tests. In the future, there may be a need to develop a dedicated Malaysian Standard for quality assurance of transport packages, aligned with ISO/ASME auditing practices, life-cycle management, and re-certification processes.

Malaysia also benefits from the expertise of local research universities and Technical and Vocational Education and Training (TVET) institutions. These universities are recognized for their contributions in design, simulation analysis, and fabrication research, and they represent an important source of innovation and skilled human capital for radioactive transport package development.

From the regulatory side, the Jabatan Tenaga Atom (Atom Malaysia) and the Medical Radiation Regulatory Division (RADIA), Ministry of Health are recognized as competent authorities for package approval and oversight. They maintain close engagement with the IAEA and regional partners, ensuring international alignment. In addition, Malaysia has established competent authorities for each mode of transport. This network of competent authorities reflects Malaysia's readiness to coordinate across multiple modes of transport and to integrate transport safety with emergency preparedness. In conclusion, this initiative represents Malaysia's strategic move toward self-reliance in the nuclear transport sector. It has the potential to strengthen regional nuclear safety and security transport capacities and capabilities, and to position Malaysia as a credible contributor to international best practices. While the transport package is primarily intended for use within Malaysia and neighbouring regional countries, it fully supports both national policy goals and IAEA objectives. The project will therefore make a significant contribution to the global effort to ensure the safe, secure, and efficient transportation of radioactive materials.

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## **Building an Integrated Safety–Security Culture in the Transport of Radioactive Material through Management System Standards: Strengthening Indonesia's Framework**

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### **Abstract**

The safe and secure transport of radioactive material poses critical challenges, particularly for Indonesia as an archipelagic nation on international trade routes. Risks of radiation exposure, theft, or sabotage demand a robust regulatory framework supported by strong safety–security culture. This paper explores Indonesia's approach in aligning national regulations, such as Government Regulation No. 58/2015 and its derivative, with international standards to strengthen radioactive material transport safety. Integrating ISO 9001:2015, ISO 31000:2018, ISO 28000:2022, and ISO 22301:2019 improves quality management, risk assessment, supply chain security, and business continuity. The study emphasizes that management systems and culture must reinforce each other: systems without culture risk becoming formalities, while culture without systems lacks consistency. Adopting ISO's Annex SL high-level structure makes IAEA TS-G-1.4 more compatible and efficient. Key recommendations include applying risk-based thinking, enhancing supply chain traceability, embedding continuity planning, strengthening audits, and expanding competence, ensuring Indonesia contributes to a harmonized global framework.

Key words: transportation of radioactive material, security–safety culture, standardization, global harmonized management systems.

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## **STRENGTHENING THE REGULATORY FRAMEWORK FOR SAFETY AND SECURITY FOR TRANSPORT OF NUCLEAR AND RADIOACTIVE MATERIALS IN CAMEROON: DIFFICULTIES ENCOUNTERED RESULTS AND PROSPECTS**

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Improving a State's national regulatory framework for transport of radioactive materials remains the cornerstone of the nuclear security regime. The National Radiation Protection Agency set up in 2002 was changed to Radiological Safety and Nuclear Security Authority in 2024, and aims to regulate nuclear and radioactive materials within in Cameroon. One of its aims amongst others is to ensure adequate application of radiological safety and security measures by the licensees. To fully advance its nuclear security mission, Cameroon enacted Law n°2019/012 of July 19, 2019, repealing the previous Law No. 95/08 of January 30, 1995. A key provision of this new legislation is the formal introduction of regulations governing the transport of radioactive materials. To facilitate its implementation, regulatory guides on the safe and secure transport of these materials have been developed and disseminated to licensees. This initiative aims to ensure a comprehensive understanding of the requirements and to strengthen the protection of nuclear and radioactive materials. Inspections conducted since 2019 have revealed a significant improvement in licensees' compliance with safety and nuclear security measures during transport. The paper presents the actions taken by Cameroon to strengthen its national regulatory framework on safety and security of transport of radioactive materials. It shares the country's experience, origins and motivations behind these actions, the results obtained, difficulties encountered and outlooks.

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## **The Implications of a Risk-Informed Transportation Package Approval Process for Highway Transport of Microreactors on Transportation Security**

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Microreactors are compact reactors capable of producing less than 50 megawatts of electrical energy. Typically, these reactors are factory-fabricated and designed to be transportable by truck, rail, vessel, or air. Microreactor designs often assume that the reactor can be transported containing either unirradiated or irradiated fuel. The interest in microreactors is driven by several factors, including the need to generate power at remote locations, at military installations, at facilities such as data centers, and in areas recovering from natural disasters.

The report *Development and Demonstration of a Risk Assessment Approach for Approval of a Transportation Package of a Transportable Nuclear Power Plant for Domestic Highway Shipment* lays out and demonstrates a risk-informed transportation package approval process by which a factory fueled microreactor containing its irradiated or unirradiated fuel could be approved by the U.S. Nuclear Regulatory Commission (NRC).

In the traditional non-risk-informed transportation package approval process, compensatory measures are not typically required as a condition of transportation package approval. However, when implementing a risk-informed transportation package approval process, compensatory measures may be required. Potential compensatory measures include:

- The use of interstates, beltways around cities, and state identified preferred highway routes
- Specific heavy haul truck or superload permit requirements, e.g., the use of warning signs and lights
- Increased exclusion zone around the microreactor because of possible radiation dose rate increase
- Real time health/fitness onboard monitoring/diagnostics of reactor package
- Escorting of the reactor forward and aft for the entire route
- Rolling road closures
- Travel at reduced speeds
- Choosing a route that avoids bodies of water (balanced by quality of road)
- Controls for bridges over bodies of water (bridge inspection, speed reduction, close bridge to other traffic)
- Judicious use of time-of-day and day-of-week restrictions
- Avoid shipping during severe weather
- Conduct training for emergency responders along the route.

These potential compensatory measures have been shown to be effective from a safety perspective and are often used when shipping non-radioactive hazardous materials or when shipping overdimension or overweight commodities. However, the security implications of many of these potential compensatory measures are not well understood for radioactive materials shipments.

Many of the compensatory measures listed above would have positive impacts on security; for example, rolling road closures, and judicious use of time-of-day and day-of-week restrictions would have the potential to increase security. Several of the compensatory measures listed above have the potential to decrease security depending on how they were implemented. An example of this is the use of interstates, beltways around cities, and state identified preferred highway routes, where the use of these alternative routes would have to be examined to determine their effect on transportation security.

The purpose of this paper is to evaluate these potential compensatory measures to determine their effect on transportation security where the commodity being shipped is a microreactor containing its unirradiated or irradiated fuel where the transportation package approval has been obtained through a risk-informed transportation package approval process. A companion paper presented at this conference examines potential compensatory measures from the perspective of maritime transport of a microreactor containing its unirradiated or irradiated fuel.

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## Transport and Disposal of a Gammacell 40 Irradiator containing Cs-137 Sources

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This technical intervention involved the dismantling, packaging, transport, and disposal of a Gammacell 40 irradiator unit containing two sealed Cesium-137 (Cs-137) sources, each with an activity of 29 TBq. The irradiator was installed within the radiation-shielded bunker of a hospital facility and had reached the end of its operational life. The objective of the intervention was the safe removal of the sources and their return to the original manufacturer for final disposal, following all applicable national and international safety and transport regulations.

The operation was conducted using a certified Type B(U) container, model PO-02, which meets all international standards for the safe transport of high-activity sealed radioactive sources. Given the complexity and radiological risk involved, the intervention was carried out by specialized personnel with experience in the handling and transport of radioactive materials, under the supervision of radiation protection experts.

The process began with the preliminary securing of the work area, including radiological surveys and the setup of protective equipment and monitoring systems. Technicians first dismantled the outer metallic shielding (carter) of the irradiator, followed by the removal and disconnection of all internal electrical, mechanical, and control systems that served the unit. This phase also included the disassembly of auxiliary instrumentation and service components connected to the irradiator, ensuring that all potentially hazardous connections were safely deactivated.

Subsequently, attention turned to the core elements of the irradiator—the two source heads containing the Cs-137 sources. These components were carefully stabilized and secured to prevent any movement or risk of accidental exposure. The source heads were then disassembled using tools and procedures designed to minimize radiation dose to personnel, with continuous real-time dosimetry and shielding in place throughout the operation.

The sources were extracted from their original housing and each left in its respective head, in safe transport position. Once extracted they were immediately placed into the approved PO-02 transport container. The container was pre-verified for compliance and integrity, and the loading of the sources was executed following strict radiological protection protocols. After placement, the container was sealed and underwent a final series of radiological and structural checks to ensure that all regulatory conditions for transport were met.

The final phase of the operation consisted of the preparation and execution of the road transport of the radioactive package to the facility of the original source manufacturer. The transport was carried out in compliance with the specific authorizations obtained from the competent authorities. This included the submission of a prior notification as required by Article 186, paragraph 7, and Annex XXXIII of Italian Legislative Decree 101/2020, and the request for road transport authorization in accordance with paragraph 3.3 of Circular 162/96, which regulates the movement of radioactive materials in Italy.

Throughout all phases of the intervention, continuous radiological monitoring, environmental controls, and documentation were maintained to ensure full compliance with safety standards and to guarantee the protection of workers, the public, and the environment. This operation is a representative example of best practices in the decommissioning and secure transport of high-activity sealed radioactive sources, demonstrating the effective application of regulatory frameworks, technical expertise, and radiation protection strategies in the field of nuclear waste management.

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## Sellafield Transport Emergency Arrangements - Progress and Challenges

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#### Background

Sellafield is a large industrial nuclear facility in the north west of England. It has been part of the UK Nuclear industry since the 1950s. The Sellafield Site contains a large variety of facilities with nuclear inventory, employs >10,000 employees and is a complex and hazardous site.

Our current activities relate to decommissioning, remediation, and environmental clean-up. To enable delivery of our mission and to support national strategies, we routinely transport Class 7 radioactive material both within the UK and abroad.

The Carriage of Dangerous Goods and Use of Transportable Pressure Equipment Regulations 2009 sets out responsibilities to dutyholders. The amendment in 2019 was a result of the Basic Safety Standards Directive (BSSD) 2013 and it emphasised the legal requirements to have suitable emergency plans. The legislation also sets out key duties for Consignors and Carriers.

Sellafield acts as both a Consignor and a Carrier and our consignment travels by Road, Rail and Sea. The distance of travel is substantial. To enable timely emergency response, Sellafield is a full member of RADSAFE, which is a GB mutual aid scheme with 24/7 response capability. If there is a transport incident anywhere within GB where the package may be damaged, the geographically closest member will provide emergency response on behalf of the Consignor, before the Consignor attends the scene and undertake package retrieval and environmental remediation and clean-up. All RADSAFE responders are trained Radiation Protection Advisers (RPAs) and provide expertise Radiological Protection advice to the Emergency Responders at the scene.

#### Engagement with Local Authorities

Sellafield maintains routine communications with Local Authorities and Emergency Services in Cumbria to raise awareness about Transport of Radioactive Materials from the Sellafield Site. A CDG Task and Finish Group was formed within Cumbria Local Resilience Forum and a series of workshops was held in 2022-2023. Government agencies like the Fire Services, Police and Ambulance Services were actively involved. Other operators within the region also took part. This series of workshop was positively received and clarified responsibilities and promoted collaboration at a regional level in North West England.

Sellafield has promoted this piece of work through national forums, namely the Radioactive Materials Transport User Committee (RAMTUC) and encouraged other members to engage with their respective local authorities and local resilience forum.

Sellafield, in conjunction with Cumbria Local Resilience Forum and EDF, undertook a desktop emergency exercise in 2023 where multi-agency partners were present. Sellafield also ran a live play exercise in 2025 where emergency services and other agencies were involved. These were successful demonstration that different parts of the industry collaborate and enhance our emergency preparedness for such incidents.

#### Challenges Ahead

Sellafield is working closely with our partners who have significantly improved awareness of the topic. There are still challenges ahead. Public perception of radioactive material means that even a minor incident could cause disproportionate interests in the public domain with potentially extensive media, and social media, coverage. This is further complicated by the fact that personnel from the consignor organisation may take a significant amount of time to reach the scene to undertake package retrieval and environmental clean-up.

Onward consignment involves approval from competent package design capability and dispatch paperwork produced by Dangerous Goods Safety Adviser in consultation with the Office for Nuclear Regulation. This require significant amount of time and can cause disruption to the road or rail network.

There are opportunities that better technological solutions like the use of drones could contribute to effective and efficient emergency response. We are continuously working closely within the industry which will further contribute in preserving the confidence and trust that our stakeholders have in our industry.

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## Safe and Secure Transport supported by Regulations

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The Argentine Nuclear Activity Law (Law No. 24,804) establishes that the Nuclear Regulatory Authority (ARN), Argentina's regulatory body, shall have among its functions, attributions and obligations the issuance of regulations related to radiological and nuclear safety, physical protection and control of the use of nuclear material, the licensing and surveillance of nuclear facilities, international safeguards, and the transport of nuclear materials as far as radiological and nuclear safety and physical protection are concerned. The ARN is responsible for establishing regulations, in harmony with the international parameters; primarily related to the international transport by air, land or water of nuclear materials, materials of interest to the ARN, radioactive sources, and systems, components and equipment for nuclear activity.

In this regard, the National Regulatory Framework issued by the ARN includes a regulation on the transport of nuclear material and two regulations on nuclear security. Regarding nuclear security, one of the regulations addresses the physical protection of nuclear materials and other materials of interest to the ARN, and the other addresses the security of radioactive sources. Both regulations include provisions for physical protection during transport.

The ARN issued Regulation AR 10.16.1, Transport of Nuclear Materials, on September 18th, 2025, which fully adopts the provisions of the IAEA Regulation SSR-6 Rev. 1 for the Safe Transport of Radioactive Material, 2018 Edition. Additionally, on September 26th, 2025, the ARN issued, for public consultation, the draft update of regulation AR 10.13.1, Revision 2, entitled Physical Protection of Nuclear Materials and Facilities, which establishes the requirements for establishing a physical protection system during transport. Regarding the update of Regulation AR 10.13.2 on Security of Sealed Sources, the revision process is already underway.

The presentation will focus primarily on the updated system for physical protection during transport, in accordance with the Convention of Physical Protection and its Amendment. In particular, according to Fundamental Principle B of the Amendment, concerning responsibilities during international transport, any State Physical Protection Regime associated with a Physical Protection System must include the responsibilities of all stakeholders, including transit States, for maintaining safety, security, and adequate means of transport, as well as the integrity of the consignment, in order to ensure that responsibility for planning and response capabilities is defined and fulfilled. Furthermore, the communication process plays an important and crucial role during transport.

The development and maintenance of a shared global physical protection system for transport in countries with nuclear activity boosts the international nuclear industry and ensures the exchange not only of nuclear materials and radioactive sources, but also of equipment, systems, components, and facilities. At the international level, achieving consistent quality in items transferred to the nuclear industry is an asset that must be fundamentally supported by a robust global supply chain verification system, integrated into a physical protection system for transport.

The aforementioned aspects will be addressed in the oral presentation, taking into account current national regulations and international safety standards published by the IAEA. The advantages of developing a Global Supply Chain System, along with a Physical Protection System for Transport, will be analysed to raise awareness and get support among Member States for this goal, promoted by the IAEA.

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## Use of a Risk-Informed Transportation Package Approval Process for Maritime Transport of Microreactors and Its Impact on Transportation Security

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In the United States (U.S.), a risk-informed package approval process has been developed to address the regulatory challenges of safely transporting microreactors that may contain irradiated nuclear fuel. Regulatory approval of such a transportation package based on quantitative risk information would be groundbreaking and could help pave the way for general use of microreactors in both commercial and defense applications. Previous work demonstrates the viability of a risk-informed regulatory approach developed by a Pacific Northwest National Laboratory (PNNL) led team for domestic highway transport of a U.S. Department of Defense microreactor design.

The implementation of this risk-informed approach was endorsed by the U.S. Nuclear Regulatory Commission (NRC) as an acceptable way to seek microreactor transportation package approval. Given that possible uses include multiple modes of transport (e.g., highway, maritime, rail and barge), that study is being taken a step further in a second study by demonstrating its viability for maritime transport. A draft report of the study has been submitted to the U.S. NRC for review. Unlike the first, the second study addresses international implications, since maritime transport may involve routes through international waters as well as the territorial waters and ports of other countries.

In the first study, the risk informed approach developed for domestic highway transport was based almost entirely on U.S., nuclear regulations, guidance and applications. In the second study, an evaluation was performed to investigate whether the risk-informed approach aligns with international maritime agreements and the nuclear regulations and expectations of other countries. This alignment is expected to be successful given the deliberate international harmonization of regulations on radioactive material packaging and the consistency of risk-informed application metrics across U.S. and foreign regulations. Beyond regulatory alignment, applying this approach also has important implications for transport security, particularly given the potential attractiveness of microreactor fuel to threat actors.

This paper takes a preliminary look at how applying this risk-informed regulatory approach could affect the security of transporting microreactors that may contain irradiated fuel. It's notable that many microreactor designs will be fueled with uranium oxycarbide (UCO) tri-structural isotropic (TRISO) particles containing high-assay low-enriched uranium (HALEU). This higher assay fuel could raise the attractiveness of the transported microreactor fuel as a target for threat actors.

The preliminary assessment of the potential impact on security of the use of this risk-informed regulatory approach to safety contrasts two approaches: transporting the nuclear fuel in a microreactor package that relies primarily on the robustness of the reactor vessel and integral shielding as containment and transporting fuel in traditional Type B thick-walled steel casks. The assessment considers transport security measures applied to the vessel itself, including tamper-indicating devices, tracking systems, intrusion detection, locks, barriers, and other delay measures. Besides physical security, the preliminary assessment looks at procedural measures such as use of an escort ship, communication capability, and the use of security personnel. Perhaps of special interest is the concept of compensatory measures allowed under Title 10 of the U.S. Code of Federal Regulations, which parallel the IAEA's transport provisions known as "special arrangements." These measures must be assessed for their interface with transportation security. For example, compensatory measures might require an escort ship to help avoid collisions with other vessels or obstacles, a requirement that may also need to be integrated with the security-related escort provisions.

The purpose of this paper is to describe the viability and international relevance of a risk-informed regulatory approach to package approval for maritime transportation of microreactor packages that could contain irradiated fuel in terms of safety and security.

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## Lessons learned on deployment of Security and Tracking Technology –A regulators' perspective on enhancing transportation security through technology integration, challenges, and opportunities

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The implementation of new technology to support enhanced transportation security is more than just implementing the technology itself. The integration of technology into the existing regulatory framework, including adoption by shippers, carriers, and response agencies can be challenging. This paper will describe how a competent authority can work with its licensees, and other stakeholders involved in transportation of radioactive material to embrace new technology and procedures, to ultimately provide a higher level of security during the transportation of radioactive materials. In 2025, a system called the Transportation-Security, Tracking, and Reporting system (T-STAR) was implemented by Nigerian Nuclear Regulatory Authority (NNRA) and Romanian National Commission for Nuclear Activities Control (CNCAN) for use on shipments of radioactive material to provide in transit visibility and cargo intrusion detection. Developed by the Department of Energy, Office of Radiological Security, the T-STAR system can augment and strengthen existing transportation security by providing near real time tracking and detection of theft and also provide regulators and shippers with the opportunity to review operational data such as routes, stopovers, and delays. Understanding the differences in planned shipments vs actual operations can help inform all parties on needed changes to reduce unnecessary risks. However, integrating technology is not without challenges, and this paper will highlight the experiences of NNRA and CNCAN in implementing T-STAR including information security, integrating with existing transportation control centers, questions from shippers and carriers, training, and development of standard operating procedures related to both normal and off normal events. Finally, recommendations on best practices and opportunities will be provided that can inform how other regulatory bodies may prepare for and then integrate tracking technology into their transportation security regime.

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## Design and lessons learned from the consolidation of Co-60 sources and their contribution to updating the Regulations for the Security Transport of Radioactive Materials in Colombia

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Colombia gained significant practical experience from two Cobalt-60 source consolidation processes carried out in 2016–2017 and 2020–2021. These operations made it possible to evaluate, under real

conditions, the effectiveness of the procedures applied by the regulatory authority, operators, and law enforcement agencies, as well as the application of physical security requirements during transport. Based on the lessons learned, the need for updated transport regulations was identified, given that the country's current regulatory framework, issued in 2004, did not incorporate the most recent international recommendations or establish clear criteria for defining the physical security levels applicable to these activities.

The purpose of the regulatory update was to establish clear, practical, and proportionate criteria for assigning

security levels in transport, maintaining consistency with the recommendations of the International Atomic Energy Agency and adapting them to the operational reality of the country. Although IAEA Guide No. 9 (NSS-9) proposes an approach based on activity thresholds ( $A_2$  and D-parameters), Colombia opted for a more practical approach, focusing on the classification of packages according to their type (excepted, BAE, IP, Type A, Type B/C). In this way, the definition of security measures becomes more simple and understandable for shippers, carriers, and the authorities that oversee these operations.

The country's experience in consolidation was key to supporting this decision. Based on this experience, a specific chapter on security was designed within the new transport regulations, explaining the methodology for assigning protection levels and defining measures related to detection, delay, and response. This approach, aligned with the principles of defense in depth and the practical application of the graduated approach, ensures that regulatory requirements are proportionate to the risk and feasible to implement in the field.

The consolidation exercises also showed that organizing security based on the type of package facilitates the standardization of requirements and reduces the administrative burden without compromising physical security. At the same time, it allowed for the identification of additional measures —such as real-time tracking, the use of specialized escorts, and notification and recovery protocols —that are necessary in certain higher-risk scenarios.

Several conclusions can be drawn from this experience: the practice of consolidating sources is a fundamental input of operational experience for adjusting security levels and measures; classification based on packages improves the applicability of the regulation; combining a graduated approach with defense in depth ensures an appropriate balance between proportionality and effectiveness; and successful implementation requires continuous investment in training, interagency exercises, and verification systems. All of this reinforces the importance of having a robust regulatory framework that, in addition to aligning with international recommendations, offers practical solutions that facilitate compliance and strengthen the confidence of institutions and users.

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## **Legislative and Regulatory Framework: Implementation of International Atomic Energy Agency (IAEA) Safety Standards for the Safe and Secure Transport of Radioactive Material in Nigerian**

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Title: Legislative and Regulatory Framework: Implementation of International Atomic Energy Agency (IAEA) Safety Standards for the Safe and Secure Transport of Radioactive Material in Nigerian  
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**Abstract:** The transport of radioactive material within international and national boundaries poses unique safety and security challenges that necessitates a strong regulatory framework to ensure the protection of people, property, and the environment from its harmful effect during transport. In Nigeria, the overall regulation of transport activities with regards to radioactive material is primarily the responsibility of the Nigerian Nuclear Regulatory Authority (NNRA). This paper explores the regulatory framework and compliance mechanisms guiding the safe and secure transport of radioactive material in Nigeria, with a focus on the implementation of the International Atomic Energy Agency (IAEA) Safety Standards and Security Recommendations which serves as the foundational guidelines for Nigeria's domestic transport safety and security regulatory control regime. Nigeria, as a Member State of the IAEA, has consistently demonstrated its commitment to incorporating these safety standards and recommendations into its national legal and regulatory framework. The NNRA has made significant progress in domesticating the IAEA Safety Standards and Security Recommendations through the promulgation, development, implementation and enforcement of national legislation and regulations. The Nigerian legal and regulatory framework provides the NNRA with the statutory mandate and authority to oversee, control, and regulate all activities related to the safe and secure transport of radioactive material. The law establishes a licensing regime, prescribes technical and administrative requirements and empowers the NNRA to conduct inspections and enforce compliance as well as the establishment of security measures. The implementation of IAEA standards in Nigeria has been facilitated through capacity building, training programs, and technical cooperation with IAEA and other international partners. These efforts have led to improved awareness, reporting systems, and emergency response capabilities. Despite these remarkable achievements, Nigeria faces several challenges in fully implementing and sustaining IAEA safety standards. Key issues include insufficient inter-agency coordination, and a need for greater public awareness about the risks and safety measures related to radioactive materials. Moreover, the informal transportation network and porous borders raise concerns about the potential for illicit trafficking and unregulated movement of radioactive material. To address these challenges, the paper recommends strengthening inter-agency collaboration through the establishment of a national transport safety and security coordination framework that includes Customs, Police, Civil Defence Corps, Emergency Services, and the NNRA. Investment in transport infrastructure and radiation monitoring equipment is also crucial to enhance the physical protection and real-time tracking of radioactive shipments. Also, continuous periodic review of national regulations in line with IAEA and other international best standards are necessary to reflect updates and emerging global best practices. In conclusion, Nigeria regulatory framework for the safe and secure transport of radioactive material is rooted in the IAEA and other international best standards and it has consistently demonstrated a clear and genuine commitment to global radioactive material transport safety and security regime. While notable progress has been made in implementing IAEA Safety Standards, sustained efforts are needed to address institutional and awareness-related gaps. Strengthening compliance mechanisms and enhancing national capacity will not only ensure the safe and secure transport of radioactive material within Nigeria but also contribute to international safety and security of radioactive material in transport.

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## **Nuklear Malaysia Mobile Hot cell Facility: Enhancing Transportation Security of High-Activity Radioactive Sources**

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The secure transport of Spent High-Activity Radioactive Sources (SHARS), particularly those contained within disused industrial and medical equipment such as irradiator and teletherapy units represents a critical and pervasive challenge to global nuclear security. The unauthorized access to

or malicious use of SHARS during transit poses a significant radiological and security threat. Addressing this imperative, the Malaysian Nuclear Agency (Nuklear Malaysia) has pioneered the development and deployment of a Mobile Hot Cell (MHC) Facility dedicated to the safe and secure end-of-life management of SHARS. This paper presents a comprehensive analysis of the Nuklear Malaysia MHC Facility, focusing on its design, operational methodology, and pivotal role in strengthening the security of SHARS transportation. The MHC is a highly shielded, relocatable containment system engineered to perform remote handling, dismantling, conditioning, and secure packaging of SHARS into certified transport and storage containers known as Long-Term Storage Systems (LTSS) at the source owner's site. This on-site conditioning capability eliminates the high security risks associated with transporting unconditioned, bulky, and often vulnerable equipment containing SHARS over long distances to a disposal waste facility. The methodology adopted includes a detailed discussion of the structural integrity, shielding performance, remote operation mechanisms, and the rigorous Quality Management System (QMS) established for the MHC operation, which was developed in collaboration with the International Atomic Energy Agency (IAEA). The paper concludes that the Nuklear Malaysia MHC Facility is a vital national asset significantly mitigating the security risks of SHARS by facilitating their safe transfer from insecure operational environments into secure, robustly shielded transport and storage packages. Its implementation enhances compliance with international security recommendations and sets a new standard for a secure, flexible, and responsive approach to the cradle-to-grave management of high-risk radioactive material.

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## **From Cyclotron to Clinic: Experiences and Challenges in Packaging, Transport, and Importation of Radiopharmaceuticals at KUTRRH**

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The expansion of nuclear medicine in Kenya has created both opportunities and new responsibilities in the safe handling and transport of radioactive materials. At Kenyatta University Teaching, Referral & Research Hospital (KUTRRH), the only public hospital with a cyclotron, we not only produce fluorodeoxyglucose (FDG) for our in-house PET/CT services but also package, label, and transport doses to other hospitals across Nairobi and beyond. This process involves specialized packaging under KNRA regulations, careful labelling, and time-sensitive distribution given the short half-life of FDG. In practice, ensuring that the calibrated activity reach at the destination on time, and radiation shielding remain intact during road transport is challenging, particularly when faced with traffic delays or last-minute dose requests. At the same time, Kenya still depends on imported isotopes such as Technetium-99m generators for SPECT, Iridium-192 for brachytherapy, and calibration sources. Here, customs clearance often presents hurdles, with delays at entry points affecting timely delivery to our facility. These experiences highlight that while the science of transport is well-regulated on paper, the lived reality involves balancing regulatory compliance, logistical challenges, and patient needs under time pressure. By sharing our journey, we aim to contribute lessons learned on safe packaging, secure labeling, local distribution, and navigating customs processes for international shipments, while highlighting areas where collaboration and training can enhance efficiency and safety in the transport of radiopharmaceuticals in Kenya.

**Country or International Organization:**

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## BRIDGING POLICY AND PRACTICE: ENHANCING EMERGENCY PREPAREDNESS FOR RADIOPHARMACEUTICAL TRANSPORT IN KENYA

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As Kenya's nuclear medicine capabilities expand, the safe and secure transport of radiopharmaceuticals particularly fluorodeoxyglucose (FDG) produced at Kenyatta University Teaching, Referral & Research Hospital (KUTRRH) to multiple PET/CT centers within the Nairobi region has become a critical component of national emergency preparedness and response (EPR) arrangements. KUTRRH's critical role in this supply chain, no simulation exercises or drills have been conducted since the hospital began routine FDG distribution to external facilities, leaving a significant gap in transport safety preparedness. Effective response planning for transport-related incidents is essential to protect public safety, ensure service continuity, and maintain regulatory compliance.

To address this gap, this paper proposes a joint exercise simulating a radiopharmaceutical transport emergency in Nairobi's high-density central business district during peak traffic hours. The proposed scenario involves a courier vehicle transporting FDG from KUTRRH being immobilized following a road accident, resulting in minor injuries and temporary loss of control over the radioactive shipment. This exercise would provide a valuable platform to test emergency communication protocols between transport personnel, hospital nuclear medicine teams, and receiving PET/CT centers; coordination with traffic police and emergency responders; real-time radiological risk assessments and dose viability decisions; activation of backup delivery procedures; and public risk communication strategies, particularly for managing misinformation on social media.

Conducting such a simulation would allow healthcare institutions and national authorities to evaluate the robustness of their emergency SOPs, close procedural gaps, and strengthen inter-agency collaboration. This aligns with IAEA guidance on transport safety and supports Kenya's national EPR framework. The paper concludes by advocating for the institutionalization of regular, inter-facility exercises as a practical, scalable approach to bridging policy and operational readiness, offering a replicable model for other Member States seeking to strengthen radiological transport safety within rapidly evolving nuclear medicine systems.

**Country or International Organization:**

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## Legislative and regulatory framework for safe and secure transport of radioactive material in Cameroon

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In Cameroon, radioactive materials in categories 1 to 5 are used in medical, industrial and research settings. The transport of radioactive materials is a reality there, and several stakeholders are involved, such as the Radiological Safety and Nuclear Safety Authority, which is the Regulatory Body; the Ministry of Transport, The Customs, the Police and Gendarmerie, the Cameroon Civil Aviation Authority (CCAA), The National Port Authority (APN). The transport of radioactive materials in

Cameroon is currently regulated by a number of legislative and regulations such as Law n° 2019-012 of 19 July 2019 on the general framework for radiological and nuclear safety, nuclear security, civil liability and the application of safeguards, several decrees such as Decree n° 2024/00163/PM of 22 January 2024 laying down the procedures for implementing certain provisions of Law n° 2019/012 of 19 July 2019; Decree n° 2024/599 of 19 November 2024 on the change of name and reorganization of the National Radiation Protection Agency (ANRP), which creates the new Regulatory Body and strengthens its powers, decrees of the Ministry of Transport on dangerous goods. The Guide of Authorization for the Transport of Radioactive Materials was developed through collaboration between the Regulatory Authority radioactive's transport institutions. It should also be noted that Cameroon has been a member of the International Atomic Energy Agency (IAEA) since 1964 and has signed and ratified certain international treaties and conventions relating to nuclear safety and security. From 2010 to date, the Regulator Authority, now known as the Radiological Safety and Nuclear Security Authority (ASRAN), has given approvals to six (06) companies to transport of radioactive materials in Cameroon. Approvals are issued when the applicant meets the followings requirements: possessing authorization from the Ministry of Transport for dangerous goods, technical and organizational capabilities, and trained personnel in radiation protection and in emergency response and demonstrate ability to comply with all regulatory requirements relating to the transport of radioactive materials. A transport authorization is issued for each shipment. A study conducted between September 2022 and September 2025 counted twenty-nine (29) authorizations for the transport issued by ASRAN. This article will present information on the laws and regulations relating to the safe and secure transport of radioactive materials, authorization procedures, roles and responsibilities in transport, and roles and responsibilities in case of an accident or security event during the transport of radioactive materials and the flow of radioactive material transport between 2020 and 2024. Conclusions will be presented on the compliance of Cameroon's current regulatory framework for the transport of radioactive materials with the Recommendations on the Transport of Radioactive Materials published by the IAEA (NSS14 and NSS9) and the perspectives with the draft regulatory text on the transport of radioactive materials developed with the support of the IAEA.

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## **PREPARATIONS FOR TRANSPORTING URANIUM OXIDE CONCENTRATE FROM THE UNITED REPUBLIC OF TANZANIA**

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On July 30, 2025, Tanzanian President Samia Suluhu Hassan launched uranium pilot processing plant in Namtumbo District, Ruvuma region in Southern Tanzania, approximately 470 km South West of Dar es Salaam and 120.46 km North East of Songea town. This is the first uranium processing plant in the country serving as a crucial step toward large-scale industrial operations. Although the pilot plant is expected to produce a small quantity of uranium oxide concentrate (yellow cake) per annum, the need for enhanced capacity to deal with such materials especially during storage and transportation emerges. From regulatory point of view, the United Republic of Tanzania (URT) has a number of enabling legislations which include but not limited to: the Atomic Energy Act No.7 of 2003 and its amendment 2025; Atomic Energy (Protection from ionizing and non-ionizing radiation) Regulations, 2023 and its amendments and the packaging and transport of radioactive materials regulations, 2011. The URT's regulatory capacity with respect to transportation of radioactive materials has been established for several years through the IAEA TC projects such as RAF 9046 –Strengthening Effective Compliance

Assurance for the Transport of Radioactive Material, RAF 9060 (Building Competent Authority Effectiveness in Regulating the Safe Transport of Radioactive Materials); and RAF 9063 (Strengthening

Competent Authorities for the Safe Transport of Radioactive Material), among others. Regulatory capacity was further enhanced through the European Union (EU) Project titled “Support to the Regulatory Authority of Tanzania” which was implemented between 2017 and 2020. In terms of transport infrastructure, there is a good road network from the uranium mining and milling site to Mtwara Port. This port was recommended in the “Fact Finding Mission Report for Tanga and Mtwara” conducted in January 2018 under the aforesaid EU project. Despite of these achievements, some limitations may exist due to lack of practical experiences in transporting radioactive materials, particularly uranium oxide concentrate (U<sub>3</sub>O<sub>8</sub>) commonly known as the yellowcake. Also, there remains a need to enhance the regulatory capacity by equipping the regulatory body with the necessary tools and equipment. Furthermore, strengthening interagency collaboration is essential to further support and improves the overall regulatory effectiveness. Last but not least is the need for improving the regulatory staff succession plan to take care of the aging workforce.

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## **Strengthening Stakeholder Engagement and Trust in the Safe and Secure Transport of Nuclear and Radioactive Material. A Ugandan perspective.**

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The safe and secure transport of nuclear and radioactive material is a critical aspect of nuclear security, as it directly protects people, the environment, and infrastructure. Transport operations take place in the public domain, often involving multiple transfers, different transport modes, and interactions with diverse actors. This complexity introduces unique vulnerabilities that require not only technical safeguards but also strong stakeholder engagement to ensure effective risk management. In Uganda, regulatory and technical frameworks have been established in alignment with international standards to govern the transport of these sensitive materials. While these measures form the foundation of safety and security, their success ultimately depends on stakeholder confidence and trust in the system.

Building this trust requires deliberate strategies that strike a balance between transparency and the protection of sensitive information. On one hand, stakeholders must be assured that adequate security measures are in place; on the other hand, excessive disclosure of operational details could increase the risk of malicious exploitation. Achieving this balance depends on cultivating a shared understanding of the potential threats, as well as the roles and responsibilities of different actors within the transport security framework. Trust is not a by product of regulation alone but must be intentionally fostered through inclusive engagement, communication, and collaboration.

Uganda’s experience demonstrates that effective engagement involves a broad spectrum of stakeholders, including regulators, operators, law enforcement agencies, emergency responders, local government authorities, and communities. Each plays a complementary role: regulators set and enforce standards; operators implement security measures; law enforcement provides physical protection and intelligence; emergency responders prepare for and mitigate incidents; and communities contribute by remaining informed, vigilant, and cooperative. This multi-actor aspects requires deliberate coordination mechanisms to facilitate information exchange, harmonize security practices, and ensure rapid, collective response when incidents occur.

Key approaches to strengthening engagement include structured risk communication, targeted awareness programs, collaborative planning exercises, and multi-agency coordination platforms. Risk communication builds understanding and reduces uncertainty by ensuring that stakeholders have accurate and accessible information about both potential threats and protective measures. Awareness programs, particularly at the community and local authority levels, empower stakeholders with knowledge to recognize and appropriately respond to risks without causing undue alarm. Collaborative planning fosters trust between agencies by creating shared ownership of security strategies,

while multi-agency coordination ensures that institutional silos do not undermine collective security efforts.

Integrating technical safeguards with trust building initiatives provides a more resilient security posture. While compliance with regulations ensures baseline protection, the addition of trust and engagement mechanisms enhances adaptive capacity, facilitates early detection of emerging threats, and strengthens preparedness for deliberate attacks such as theft or sabotage. The Ugandan perspective underscores that without public trust, even the most advanced technical systems may be perceived as inadequate, thereby weakening overall security. Conversely, when stakeholders are engaged, informed, and confident, they contribute actively to the success of the nuclear security regime.

This paper therefore argues that the safe and secure transport of nuclear and radioactive material cannot be achieved through technical measures alone. A holistic approach anchored in stakeholder engagement, transparency, cooperation, and trust is essential for reinforcing compliance, enhancing resilience, and strengthening Uganda's nuclear security regime against threats with potentially severe radiological consequences.

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## **Computer security for safe and secure transportation of nuclear materials –leadership and the whole of organisation approach**

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Information Technology (IT), Operational technology (OT) and Sensitive Information assets all have critical roles in the safe and secure transportation of nuclear materials. IT systems drive logistics and communications; OT ensures the safety and reliability of transport vehicles and monitoring systems and information assets such as schedules, routes and protective measures represent prime targets for adversaries. A compromise in any of these domains could trigger operational failure, reputational harm and the loss of public trust.

This paper highlights the importance of leadership in embedding cybersecurity as a core component of safe and secure nuclear transport operations through the whole of organisation approach. Building on the 2024 Green rating of NTS from the ONR's thematic inspection of Governance, Leadership, Culture and Risk Management, it describes how board understanding and executive team commitment have been developed and cascaded through the business and how cybersecurity and information governance risk exposure is communicated to decision makers through clear governance and concise management information. The importance and appointment of key cyber security leadership roles such as Senior Information Risk Owner (SIRO), Chief Information Security Officer (CISO) and a Non-Executive Director (NED) responsible for Information Security are also highlighted and how these have positively shaped cybersecurity culture, clarified risk ownership and ensured cyber security is a business priority from the board room to engine room.

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## **SAFE AND SECURE TRANSPORT OF A DISUSED SEALED HIGH ACTIVITY COBALT-60 SOURCE IN TANZANIA**

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In Tanzania, nuclear technology plays a pivotal role in improving healthcare, industrial and agricultural productivity. One of its benefits is the use of the sterile insect technique (SIT) to eradicate tsetse flies, which spread diseases to humans and livestock. This technique was successfully used at the Vector and Vector Borne Disease Centre (VVBDC) in Tanga using a Gamma-cell 200, Cobalt-60 (60Co) irradiator. Once the source became disused and could no longer serve its purpose, the next challenge emerged: how to safely dismantle and move it to long-term storage. This paper describes a successful transportation security plan and execution of sealed high-activity radioactive source (SHARS) in accordance with the legal and regulatory framework in Tanzania. Tanzania Atomic Energy Commission (TAEC), in collaboration with VVBDC and the US Department of Energy, carried out a special mission of removing the disused Co-60 source from Tanga to the central radioactive waste management facility (CRWMF) in Arusha. The entire operation involved detailed coordination among radiation experts, transport authorities, emergency responders, and security forces. The irradiator was secured in its original accident-resistant transport container and moved under an approved transport security plan. The 450 km journey was conducted at night to avoid high traffic and reduce public radiation exposure. The source was continuously monitored using real-time radiation survey instruments, and security command communication was enhanced by radio systems. Upon arrival, the source was inspected, confirmed to be intact, and placed in a secured, designed interim storage facility. This case highlights Tanzania's commitment to the cradle-to-grave management of radioactive sources and demonstrates the national capacity to safely manage high-activity radioactive material, in line with the IAEA safety and security guidelines.

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## **SAFETY-SECURITY INTERFACE IN CIVIL NUCLEAR TRANSPORT The influence of leadership, management, and organisational culture**

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The 1950s saw the advent of the international civil nuclear sector. In 1954, the former Soviet Union's Obninsk nuclear power plant was the first to be connected to an electricity power grid. Two years later, in 1956, Calder Hall Nuclear Power Station was the first commercial nuclear power plant to be connected to the UK's national electricity power grid. Nuclear safety has always been prioritised in the civil nuclear sector. However, since the 1950s, there have been several high-profile nuclear safety incidents. This includes the 1957 Windscale radiological release in the English county of Cumbria; the 1979 partial nuclear core meltdown at the USA's Three Mile Island Nuclear Generating Station in Pennsylvania; the 1986 reactor explosion at Chernobyl Nuclear Power Plant, in the former Soviet Union; and the 2011 damage to reactors at Japan's Fukushima Daiichi Nuclear Power Plant caused by the Tōhoku earthquake and ensuing tsunami. Amongst others, these incidents have driven development of stringent approaches to nuclear safety by the IAEA.

The IAEA have produced an extensive catalogue of nuclear safety standards. This includes a Fundamental Safety Principles document highlighting leadership, management, and the promotion of

effective safety culture as key principles for nuclear safety. In the aftermath of the Chernobyl incident in 1986, the IAEA's approach to nuclear safety culture was significantly influenced by the Swiss/American Professor of Management, Edgar Schein. Schein's Model of Organizational Culture (hereafter referred to as Schein's Model) hypothesised that organisational cultural was influenced by three levels: 1. Artifacts, which describe visible structures, processes, and observed behaviour; 2. Espoused Beliefs and Values, which are defined by ideals, goals, values, aspirations, ideologies, and rationalisations; and 3. Basic Underlying Assumptions, which relate to unconscious beliefs and values that are taken-for-granted. Influenced by Schein's Model, the concept of nuclear safety culture gained increasing acceptance during the 1980s.

The IAEA acknowledged the need for a legally binding framework for international nuclear security when it developed the Convention on the Physical Protection of Nuclear Material and its Amendment (CPPNM/A), which includes the need for effective transport security. However, the concept of nuclear security culture, and its correlation to the physical protection of nuclear facilities, transport, and operations, did not gain traction until the late 1990s. To an extent, this may be indicative of civil nuclear security considerations advancing at a slower rate and being less prominent in comparison to nuclear safety approaches. Potentially, this may create leadership and management challenges in relation to cohesive approaches to nuclear transport security and safety and this is the main issue this paper examines. Certain academics have asserted that approaches to nuclear security are not as mature as those concerned with nuclear safety. They suggest this may be partly attributable to nuclear security and safety not being integrated and developing in isolation. Arguably, this is an important topic as the IAEA maintain that integrated nuclear security and safety approaches will influence the future development of the civil nuclear sector. Safe and secure nuclear transport capability will underpin this.

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## **Transport of Environmental Instrumentation Containing Sealed Sources: Critical Issues in the Application of the Decree Implementing Directive 2013/59/EURATOM**

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Increased awareness of environmental issues has driven the widespread use of beta absorption-based air particulate analyzers. These instruments utilize the radiometric principle with beta ray sealed sources, typically <sup>14</sup>C, <sup>63</sup>Ni, or <sup>85</sup>Kr (with activities from 0.45 MBq up to 75 MBq), to continuously measure the concentration of airborne particulate matter (PM).

These instruments are used both at stationary observatories on the Employer's premises and in external environmental campaigns (e.g., supporting the Fire Brigade following major incidents) at sites that cannot be determined a priori.

This work examines the case study of an Employer who holds multiple sources used in a fixed mode, initially falling under the Practice Notification regime (pursuant to Italian Legislative Decree 101/2020 and Directive 2013/59/EURATOM). The critical issue arises when the Employer needs to move a single device for temporary monitoring at an external site.

Following the transfer, the single source may fall outside regulatory control. This is because the activity of the source, when installed on a mobile unit, can drop below the thresholds established for Practice Notification (Table I-1A) and for the road transport of radioactive materials (Table I-4). This situation creates a scenario of "non-radiological relevance" for the practice. However, upon returning to the original location, the source is once again considered "held" under the notification regime.

This mobility creates three primary challenges:

1. The movement of the source raises questions about the necessary communication to supervisory authorities. Since the original practice was subject to communication, a modification of communication is required to declare the temporary cessation of holding the source at the initially declared location. However, the legislation does not clarify whether this communication must also be sent to the destination supervisory authorities to inform them of the source's presence in their territory, especially when the source itself no longer requires notification.

2. Since the source activity is below the values specified in Table I-4, the mandatory provisions for the transport of radioactive materials do not apply. This means that packaging, markings, or the use of an authorized carrier (ADR) are not required.

However, performing the transport privately exposes the transporter to a significant insurance risk. If the source is involved in theft, loss, or serious events (e.g., fire, major car accident), insurance companies may refuse coverage for "accidents occurring during the transmutation of the atom." While a highly cautious approach involves the a priori use of an authorized ADR carrier, this solution incurs an additional cost that may not be justifiable, as the decree does not legally require it.

3. Ambiguities also exist in managing the transport and holding registration on the Sistema Tracciabilità Rifiuti Materiali e Sorgenti (STRIMS).

- To register the transport, the Employer might be required to list themselves as an authorized transport carrier, even though they are not legally designated as ADR.
- The cessation of holding requires specifying the final destination. This destination is often not owned by the Employer, being an external and temporary monitoring site.

The disparity between the source activity in fixed and mobile modes risks turning these sources into regulatory "ghosts" during transit. It is essential for the Employer and the Radiation Protection Expert to establish clear procedures for communication, transport, and STRIMS registration to avoid penalties from local supervisory authorities.

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## **INNOVATIVE PROTECTIVE MONITORING APPROACHES FOR THE CIVIL NUCLEAR INDUSTRY A Case for a New Approach to the Protective Security of Nuclear Facilities**

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The use of new and innovative monitoring technologies in the civil nuclear industry is being explored to enable more efficient and cost-effective security of material, facilities, and premises. These advancements are being strongly considered in relation to the nuclear renaissance, in particular with emerging Small Modular Reactor (SMR) technology. However, new protective monitoring approaches can also be utilised in decommissioning where the category of nuclear material has been reduced or nuclear material removed, justifying a proportionate reduction in security posture. The benefits of these innovations include better situational awareness, more effective deployment of security personnel, reduced insider risk, and cost savings.

States have obligations under the Convention on the Physical Protection of Nuclear Material (CPPNM) and its Amendment (CPPNM/A) to maintain appropriate physical protection of nuclear facilities and material in domestic use, storage, and transport. This means that security arrangements that include innovative protective monitoring technologies may be an option for licensees. The UK Government has indicated that these new monitoring approaches are within their risk appetite, subject to regulatory approval, and they may provide a solution to challenges regarding armed police resource

for SMR development and eventual deployment. This paper will therefore make the case for innovative monitoring technologies to be considered more widely across the nuclear lifecycle. These technologies will be aligned to IAEA requirements such as the CPPNM/A and provide a vision of how innovations in security monitoring can enable the growth of civil nuclear.

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## **Polish nuclear regulations governing transport of nuclear and radioactive material in light of international standards and IAEA guidelines**

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In 2009 Poland launched large-scale nuclear new build programme aimed at construction of the country's first nuclear power plants. When developing its nuclear legal framework the top priority of Poland is to ensure that it not only implements applicable international legal instruments but also reflects all relevant IAEA recommendations and guidelines (as well as good practices of other experienced nuclear countries) –also with respect to regulations governing transport of nuclear material. From that perspective particularly useful tools for every nuclear newcomers are IAEA review that address the above issue and help to enhance national nuclear legal framework in the subject matter.

Given the above the aim of the paper is to present:

- 1) the evolution and current state of Poland's legal and regulatory framework applicable to transport of nuclear and radioactive material (incl. Atomic Law Act);
- 2) the Poland's approach to develop its nuclear legislation so that it remains in line with the IAEA recommendations and guidelines;
- 3) special legal instruments developed in Poland to streamline nuclear licensing procedures in the given area (in the context of nuclear new build programme);
- 4) the role of IAEA review missions, such as INIR, IPPAS and IRRS for nuclear newcomers in enhancing their respective nuclear legal framework.

The paper will consist of the following main parts. In the first part the overview of international legal instruments and IAEA recommendations and guidelines applicable to transport of nuclear and radioactive material will be given (including the role of relevant IAEA review missions, such as INIR, IRRS, IPPAS with these regards). In the second part the evolution and the current state of national regulations governing transport of nuclear and radioactive material in Poland, contained in the primary (Atomic Law Act) and the secondary nuclear legislation will be discussed in detail; preceded by brief overview of institutional and legal framework for nuclear activities. To give broader perspective of nuclear transport regulations, in the third part the impact of the aforementioned regulations on the licensing process for nuclear installations, including nuclear new build projects in Poland, will be explained. Particular focus will be given to special legal instruments of Polish nuclear law aimed at streamlining and accelerating nuclear licensing procedures, including those contained in the Atomic Law Act and Nuclear Investment Special Act.

Main findings and conclusions (including the identified good practices of Polish legal framework in the subject matter) could be useful to various stakeholders, especially in embarking countries on nuclear power programmes.

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**Jordanian Experience in the Safe and Secure Transport of High-Activity Radioactive Sources and Nuclear Materials****Author:** Saad Abdullah<sup>1</sup><sup>1</sup> *Jordan Atomic Energy Commission***Corresponding Author:** saad.ata@jaec.gov.jo**Scope**

This study describe the safe and secure transport of two (cat. 2) Tele-therapy devises (Phoenix, T780C), which contained Depleted Uranium (DU) used as shielding material and have previously been applied for cancer treatment. The project describes the complete processes, from preparation of heads to their successful delivery to Hungary.

**Background**

This project is very important to Jordan, providing new experience in the field of transporting radioactive sources to abroad. It aims to gain practical experience in this field, in addition to enhancing efficiency and skills for operators.

**Objectives**

1. Ensuring safety of radioactive sources with high activity.
2. Protecting environment and future generation.
3. Reducing the volume of radioactive materials stored at CSF
4. Promoting the use of new technology in medical treatment

**Methodology**

According to the national policy and strategy for radioactive waste & spent nuclear fuel management, a permit was granted to transport these sources to another country, in accordance with the regulations and instructions in Jordan issued by Energy and Minerals Regulatory Commission (EMRC) including:

1. Regulations on the Transport of Radioactive Materials, No. (32) and its Instructions, 2016.
2. National Policy for Radioactive Waste & Spent Nuclear Fuel Management, 2015.
3. Instructions on the Management of Radioactive Waste, 2015.
4. Law of Radiation Protection, & Nuclear Safety & Security No. (43), 2007.
5. Regulation of Radiation Protection No. (108) and its Instructions, 2015.

The priority was to precisely define the roles and responsibilities of the relevant parties and develop clear plans to facilitate the process. Jordan Atomic Energy Commission (JAEC) is responsible for implementing the plans related to transport, safety and security, while the Transport and Radioactive Waste Management Directorate was responsible for preparing for transport and storage of sources at the central storage facility (CSF). All plans were approved by EMRC.

- Prepare the sources inside CSF and receive the empty type B(U) packages from Hungary.
- Place the sources in the packages inside the facility according to safety and preparation procedures.
- Perform accurate dose rate measurements, check for surface contamination, and ensure package labeling.
- Transport the packages to the airport according to a specified schedule and safe routes.
- Repeat all safety-related procedures.
- Ship the packages to Hungary.

The IAEA supported the project through a dedicated international fund. The warhead removal process was carried out by a licensed and professional service provider under IAEA Contract No. 202204058. It should be noted that the (DU) material was handled according to established procedures and reported to the International Atomic Energy Agency (IAEA) nuclear safeguards department

**Conclusion**

Throughout the operation, the Radiation Protection Officer (RPO) controlled and monitored the entire process. The measured dose rate at the surface of each devise were less than 11  $\mu\text{Sv/h}$ . The occupational exposure of workers involved in the project did not exceed 5  $\mu\text{Sv}$ , and no radiological contamination was detected during the mission.

No incidents or accidents occurred during the project's implementation and the packages arrived safely in Hungary and all activities were completed according to the schedule, despite the challenges

associated with the high risk cross border transport. This participatory experience provided valuable experience and lessons learned that can support other countries in managing similar operations involving high-activity radioactive sources and nuclear material transport.

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## Adapting Physical Security Considerations to Mobile Marine Nuclear Applications

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The International Atomic Energy Agency's Nuclear Security Series provides guidance to support Member States as they develop comprehensive nuclear security regimes. Within each Member State, multiple federal stakeholders collaborate to establish security frameworks for the transport of nuclear and radioactive materials. The foundation of nuclear security governance is that Member States maintain this responsibility to establish, implement, and maintain physical protection regimes.

Mobile nuclear power plants (MNPPs) and transportable nuclear power plants (TNPPs) are emerging applications for advanced nuclear technologies, especially considering rising global energy demand and decarbonization goals. Floating nuclear power plants (FNPPs) and nuclear-propelled vessels are maritime industry examples of these applications that will provide reliable power to coastal operations and help decarbonize global shipping. Deployment models envision centralized production and maintenance factories to manufacture and integrate the reactors onto the maritime platform (ship or barge) before they are transported to their operational site or utilized for commercial shipping. While operational models will differ, initial fueling and commissioning, as well as any refueling and decommissioning, are expected to occur at the central factory prior to transport to the final operational location. This will likely include transport of irradiated fuel onboard.

International guidance documents and regulatory frameworks provide a foundation for security regimes to inform the physical protection of nuclear and radioactive materials. However, there are unique considerations for mobile marine deployments of advanced reactors. These deployments introduce threats not completely addressed with security requirements and threat assessments developed for terrestrial power plants. Successfully deploying floating nuclear applications will require adaptable security designs that can respond to threats as they emerge, in addition to updates for regulations and guidance that inform member state responsibilities specific to floating nuclear applications.

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## Behavioral Drivers of Radioactive-Material Delay and Denials: Insights from Prospect Theory

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Delays and denials of radioactive materials pose serious challenges, impacting their beneficial applications, particularly in healthcare, industry, and other sectors. This poster explores the key factors causing such delays and denials, emphasizing the role of human psychological behavior. Additionally, it offers practical tips to help reduce these issues and ensure the timely and effective use of radioactive materials.

Delays and denials in the shipment and use of radioactive materials—especially radioisotopes for diagnostics, therapy, industrial gauging, sterilization, and research—undermine time-critical applications and generate cascading costs for patients, providers, and supply chains. This poster examines why delays and denials occur—and how to address them—by focusing on a human psychology factor that is often overlooked. This poster synthesizes the technical, regulatory, and behavioral contributors to these disruptions, with particular emphasis on the human psychological dynamics that shape gatekeeping decisions throughout the materials' lifecycle. The methodology of the paper is a questionnaire, mainly from stakeholders. This poster synthesizes the technical, regulatory, and behavioral contributors to these disruptions, with particular emphasis on the human psychological dynamics that shape gatekeeping decisions throughout the materials' lifecycle. Drawing on case reviews, stakeholder interviews, and a rapid scan of guidance from competent authorities, we map choke points. Organizational culture amplifies these tendencies when incentives penalize false approvals more than harmful delays, and when training emphasizes hazard without balancing benefit. In conclusion, safety and speed can coexist. By making compliance legible, aligning incentives, and keeping the human stakes visible, we can cut needless delays and denials. That means more patients treated on time, more reliable industry processes, and smoother science—without compromising the safeguards that keep everyone safe.

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## Cybersecurity as an essential aspect of transport and maritime nuclear systems

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Data-driven decision-making is a key aspect of the nuclear industry. Yet this data does not exist within a vacuum. Instead, digital systems are utilised at every stage of the nuclear lifecycle, from conceptual design to transport to daily operation and ultimately decommissioning, with accurate and reliable data an essential aspect of nuclear operations.

Due to the vast amount of data collected on a daily basis, the sensitivity of some of the data transmitted, and increased reliance on digital systems, it is critical that these systems are built to include cybersecurity. This is essential to ensure appropriate safety, security, and safeguards for both operational technology and information technology.

The increase in cyber incidents affecting energy infrastructure, including operational technology attacks and ransomware attacks regarding company information, underline the importance of strong

cybersecurity/defence. It is crucial for actors across the sector to understand and establish systems which counter the risks posed by weak cybersecurity.

The IAEA has long been involved in establishing cybersecurity guidelines for industry, offering guidance for operators as well as providers across the supply chain. This is supported by efforts by the International Electrotechnical Commission (IEC) to establish international standards on cybersecurity for operational technology and fixed installations. Yet domestic regulations on cybersecurity and transportable systems vary by jurisdiction, creating a patchwork assessment structure for firms looking to ensure international compliance. This is further complicated by non-uniform data protection regulations, limited worker expertise in cybersecurity for nuclear, and differences in design basis threats.

Amidst this complex regulatory landscape, nuclear innovation continues. Floating Nuclear Power Plants (FNPPs) and future maritime civil nuclear propulsion applications pose distinct cybersecurity dilemmas. The modular nature of the reactors, advanced technology which relies on increasingly digital operating systems including remote control, and options for international operation all present challenges. Building upon existing standards for terrestrial applications, as well as adapting existing best practices from other sectors, will be necessary to guarantee cybersecurity for maritime nuclear applications.

It is essential that these practical solutions are supported internationally through collaboration on cybersecurity standards and assessments. This should include incorporating cyber into baseline security assessments as well as cybersecurity incident reporting. Any approach should ensure a technology-agnostic approach which allows for future-proofing as technology advances. These measures are necessary to establish the groundwork necessary for integration of advanced technology, including artificial intelligence (AI).

The establishment of standards and regulations are only as effective as those who implement them. There is a distinct need for upskilling and increasing knowledge and understanding within the sector when it comes to cybersecurity. Creating a cybersecurity culture across the sector which is built upon systems prioritising safety, security, and safeguards by design will be indispensable to ensuring lasting impact and effectiveness of any regulation.

As technology advances to include advanced digital solutions, international standards and baseline operating approaches are needed to ensure safe, stable, and reliable nuclear systems.

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## **Establishment, evolution and competency development of competent authorities and compliance assurance mechanisms for safe and secure transport of nuclear and radioactive materials in Myanmar**

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The widespread applications of radioactive materials and radiation generating equipment in the field of industry, medicine, agriculture and research in Myanmar necessitated establishment of an efficient regulatory framework and consequently the Department of Atomic Energy (DAE) constituted

to exercise regulatory control over the safe and secure transport of the nuclear and radioactive materials.

DAE promulgated Atomic Energy law on 8th July 1998 for safe use of radiation source in the country. It was mainly based on radiation safety and does not cover nuclear safety, nuclear security and safeguards (3S strategies). In order to strengthen its national nuclear related legislation, DAE has just recently completed the drafting of the Myanmar Nuclear Law as DAE acts as the regulatory body under the atomic energy law and is responsible for all aspects for control, security and safe management of radioactive materials used in Myanmar.[1]

In Myanmar, Users of radiation sources must submit storage design and emergency procedures when they apply for licence and also transporters needs permission from inspectors of DAE to get transport certificate.[2] All the radioactive sources are registered and sources having activity above the exemption levels are licensed both for safety and security point of view. DAE is using Regulatory Authority Information System (RAIS) since 1998 and now using RAIS 3.3.[3]

Inspectors from DAE are implementing safety and security culture in every practices and transport of radioactive sources which they inspect. Their safety and security points are for carriers, radiation workers, public and environment. They measured the radiation levels around the radioactive sources transport vehicles with instruments provided by International Atomic Energy Agency (IAEA) and United States Department of Energy (USDOE) to ensure the safety for the vehicle crew and public. Ministry of Health and Sport is producing and sharing some part of short half-life radioisotopes from its cyclotron to private hospitals by using modified transport vehicle with radiation shields around transport package.

Challenges in Myanmar is well developed and implemented safety and security culture is essential. To achieve that, DAE in collaboration with stakeholders, has been conducting workshops and trainings to exchange information, knowledge of radiation safety, experience and good practices on the system of radiation protection at the national level and regional levels with the help of IAEA and other international organization.

IAEA is providing assistance to Myanmar by giving appropriate trainings for inspection of specific practices and also support new instruments for inspections such as neutron detectors to inspect linear accelerators and other neutron producing facilities. The DAE is also trying to strengthen its human resources by recruiting new staffs to enhance the ability of performing the necessary activities in safety and security of radioactive sources and nuclear materials more effectively. DAE is also planning to conduct radiation protection officer (RPO) training.

This paper will present an overview of the Legislative and Regulatory Framework for Safe and Secure Transport to fulfill the demands of radiation and nuclear safety in various sectors in Myanmar. With the support of IAEA and other developed member states, Myanmar is looking ahead to working with emerging technologies and innovative graded approaches.

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## **Anomaly Detection in Radioactive Material Transportation Using Isolation Forest**

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### **Introduction**

Each year, approximately 20 million radioactive material transports occur worldwide. These radioactive materials can pose significant risks to humans and the environment. Despite stringent oversight, the CNS Global Incidents and Trafficking database recorded more than 1,500 incidents involving the transport of radioactive materials reported from 2013 to 2021. This data can be used to develop secure practices for the transport of radioactive materials. Using artificial intelligence, this data can be analyzed to uncover proliferation risks by predicting successful material recovery and detecting anomalous events, aiming to support regulators and law enforcement with proactive analytical tools.

### **Methodology**

This analysis utilized the CNS Global Incidents Database, which contains structured records of nuclear and radiological incidents worldwide. This data records Incident Type, Detection Method, Material Use, Isotope, Country, and other related data. After the data cleaned, Random Forest applied to predict whether lost or stolen material could be recovered. Finally, cross-section validation was used to evaluate the recovery outcome and achieved 87% accuracy and a ROC-AUC of 0.92.

Isolation Forest algorithm applied for anomaly detection to detect anomalies in the transportation process. The result is an “anomaly score” for each incident based on how isolated it was from the overall data pattern; incidents with the highest anomaly scores were flagged for further examination.

#### Results

The Random Forest classification yielded strong predictive performance (87% accuracy, AUC 0.92), indicating that incident characteristics can reliably predict whether lost nuclear material has been recovered. The most important features are Application, RSG-19 Category, and Incident Type. In particular, incidents involving industrial materials or materials with unknown intended uses are significantly associated with recovery outcomes. These features suggest that incidents related to theft and unclear material characterization need special attention. The unsupervised Isolation Forest model identified 76 anomalous incidents. Specifically, the flagged anomalies included cases of unauthorized possession of radioactive material, lost shipments, and misrouted shipments.

#### Discussion

This research demonstrates how AI can enhance the security of nuclear material transportation. For example, authorities could use its predictions to identify high-risk thefts or losses with a low likelihood of recovery, thus prioritizing these cases for aggressive investigation and resource allocation. Anomaly detection could be used as an automated alert system for anomaly response, flagging irregular incidents that might otherwise be missed in routine reporting. Such early detection of anomalies allows for faster incident response and corrective action, potentially mitigating security breaches.

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## From Analog to Digital: Enabling the Next Generation of Nuclear Material Transport Packaging

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The U.S. Department of Energy’s National Nuclear Security Administration (DOE/NNSA) has worked cooperatively with global partners to advance proliferation-resistant fuel cycle technologies and nuclear material management since its inception, successfully removing or confirming the disposition of more than 7.3 metric tons of weapons-usable nuclear material from 49 countries and Taiwan. This experience working within existing regulatory frameworks, combined with deep expertise in advanced modeling and simulation used to maintain the safety, security, and reliability of the U.S. nuclear weapons stockpile for decades, provides unique insight into both current limitations and transformative opportunities in nuclear material packaging.

As the United States rapidly expands nuclear energy deployment, demand is surging for advanced fuels with higher fissile contents in quantities that dwarf previous requirements. Yet while the technologies and processes underpinning the nuclear renaissance have evolved dramatically, the lifecycle for nuclear material packaging remains stubbornly analog. The resulting global framework for

testing, licensing, and validation of nuclear material packages has proven robust and safe, but comes at the cost of flexibility, speed, and sustainability.

Current practice for the design of new packages predominantly relies on physical testing protocols despite IAEA regulations (TS-R-1, paragraph 701(d)) and national frameworks (e.g 10 CFR 71.41(a)) permitting computational methods. This analog approach, combined with limited business volume, has created a fragile supply chain with high innovation risks and significant inefficiencies. Meanwhile, cutting-edge modeling and simulation capabilities—already proven in stockpile applications—can model atomic-level processes in three dimensions at nanosecond timescales with high fidelity, and advanced manufacturing techniques have proven their value in nuclear applications.

Drawing on lessons learned from decades of DOE/NNSA's nuclear material management and advanced simulation experience, this paper examines how a comprehensive digital framework could revolutionize nuclear material packaging by integrating computer-aided design, advanced simulation, and new manufacturing techniques. We propose specific opportunities for government to 1) catalyze innovation while maintaining safety standards and reducing regulatory burdens, and 2) demonstrate how this integrated approach can extend from design and testing through fabrication to deliver high-reliability packages efficiently and consistently. The result: alignment between government and industry to better meet growing nuclear packaging demands for decades to come.

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## **Communicating during Emergency Response & Security Incidents IN THE CIVIL NUCLEAR SECTOR**

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Nuclear Transport Solutions is the leading global provider of safe, secure, and reliable transport of nuclear material. NTS has conducted over five million miles of nuclear rail transport in the UK and shipped over two thousand flasks of nuclear material internationally, with a 100% safety and security record, often in challenging operational environments. In an ever-developing world, the way we communicate relies more on technology than ever before. This has been beneficial in terms of speed of communication, the distances modern communications technology can cover, and the ease with which we can communicate internally within organisations and with external stakeholders worldwide.

But what happens when communication technology is compromised? How do we still communicate and receive critical information without putting our people, operations or assets at risk, and how do we balance safety with security to achieve this? This paper aims to explore scenarios where this has occurred. It will look at what the best practices are in business-as-usual instances as well as examine the challenges of communicating during critical incidents during nuclear transport operations in complex environments. It will also explore possible solutions and approaches that can be considered to manage such events.

**Country or International Organization:**

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## Interfaces between Safety and Security during the Transport of Radioactive material including NORM in Madagascar

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Radioactive material is transported every year for peaceful applications in medicine, industrial exploration and development, as well as in basic scientific research and education in Madagascar.

Transport safety and security of radioactive material within the country is regulated.

Madagascar has adopted the IAEA Regulations for the Safe Transport of Radioactive Material (SSR-6) to regulate transport of radioactive material from safety perspective. Radioactive material from security point of view has been defined under the Convention on the Physical Protection of Nuclear Material (CPPNM) and its Amendment. The Code of Conduct and the Guidance on the Import and Export of Radioactive Sources has been implemented in this regard.

Moreover, Madagascar has an abundance of resources suitable for mining and as a result has large mining and transportation industry sectors devoted to the extraction and transport of nickel, cobalt, ilmenite, monazite, zirconium and chromium ore. All of these materials contain varying concentrations of radionuclides of natural origin. Depending on the concentration of the radionuclides of natural origin, the ores and byproducts may be considered naturally occurring radioactive material (NORM) for which safety controls must be established and enforced for the handling of the materials. The Radiological Safety and Nuclear Security Directorate (DSRSN) of the "Institut National des Sciences et Techniques Nucléaires" (INSTN) has responsibility for the radiological safety of these products and operations. Additionally, the DSRSN has responsibility for nuclear security within Madagascar.

Certainly, safety and security measures are different during the transport of radioactive material. Madagascar establishes an approach to manage the interface between safety and security during transport, so that relevant measures are implemented in a harmonized way that does not compromise safety and security.

This paper aims to describe the main aspects in the regulatory implementation of Safety and Security issues related to the transport of radioactive material by the DSRSN, which is the Competent Authority for regulating transport of radioactive material in Madagascar. Experiences and lessons in the detection and control of cargoes containing radionuclides of natural origin will be discussed from both security and safety perspectives, especially in the context of NORM.

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## Validation practices and consequences on international transport

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Swiss competent authorities (Swiss CA) were approached by consignors reporting more and more difficulties with the international transport of approved packages, which are subject to validations. Further investigation and discussion on international level provided significant issues with respect to national implementation of validation procedures and requirements. As a result, transports must

be cancelled or have to be prepared right in advance.

From the operational point of view, the country-of-origin approval is usually valid for five years. The revision process starts earlier, at least one year before the expiration date. If a transport through multiple countries is prepared, each transit country and the country of the consignee has to be approached for a validation. The assessment scope and the necessary time for review of validation applications have increased in recent years. If the country-of-origin approval is already running, the time for getting validations and following authorizations for the transport might be too short. A revision of the country-of-origin approval starts the process again.

This identification and the following discussion in international networks such as the European Association of Competent Authorities (EACA) provides different national practices and reasons for the extended assessment scope: the extent of the existing country-of-origin assessment results to be considered during validation varies between authorities, the scope of assessment varies due to the needs and the resources of authorities (do not approve each content specification), full scope assessments due to administrative reasons take place (requirements of national laws or international agreements), assessment of boundary conditions in addition to the main focus of assessment (mechanical and thermal inputs for criticality safety assessments)

Additional issues are the use of the identification mark to clarify differences between the country-of-origin approval and the validation, the format of certificates or the evolution of shock absorber dimensions and handling attachments in country-of-origin approvals with consequences on operational aspects such as routing restrictions for road and rail mode and proper handling of the package. The contributions during international discussions result in a questionnaire, which is launched within the European authority network EACA. The questionnaire will be presented including the background of the individual questions. Other means to facilitate the preparation of transports will be addressed. They are also related to international cooperation.

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## Application of Transport Regulations to NORM: Practical Guide

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This paper provides an update on the issues associated with the transport of naturally occurring radioactive materials (NORM) in the mining and mineral processing industry and is an update of an earlier publication on the same topic, prepared by two of the authors from the original 2007 paper [1]. The update is required due to regulatory changes and several identified inaccuracies in the earlier publication.

Furthermore, the arguments in the 2007 publication were based on the 2005 IAEA Regulations for the Safe Transport of Radioactive Material and the 2002 Advisory Material for the Regulations. In the interim, both the International Regulations and the Advisory Material were reissued several times, with documents [2] and [3] being currently applicable. Also, since the time of publication of the previous version of this paper, the regulations in Australia have also changed three times with document [4] being currently applicable.

A preliminary assessment of the applicability of the current Transport Safety Regulations to NORM was carried out by Calytrix Consulting in 2016-2019 and an informal technical reference note was published online in August 2019, together with a NORM Exemption calculator created in MS Excel

**Country or International Organization:**

**Instructions:**

## The Eldorado-8 Re-Source: Mastering Safety, Security, and Logistics in the Transport and Installation of a High Activity Cobalt-60 Source

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### 1. Introduction

The safe and secure transport of high-activity Category I radioactive sources presents complex challenges requiring meticulous planning and rigorous adherence to safety protocols. This paper details the comprehensive safety and security framework implemented for the replacement of a Co-60 source in the Eldorado-8 teletherapy calibration machine at the Secondary Standard Dosimetry Laboratory (SSDL) of Malaysian Nuclear Agency (NUKLEAR Malaysia). The operation involved the transport and installation of a new 2,188 Ci source, transported using a Type B(U) package over a 50 km inland distance from Kuala Lumpur International Airport (KLIA) Cargo Hub.

### 2. Objective

The primary objective is to share a successful, real-world case study, highlighting integrated protocols developed to meet both IAEA Regulations (SSR-6) and national regulatory requirements by Malaysian Department of Atomic Energy (ATOM Malaysia) for the safe and secure transport of radioactive material.

### 3. Integrated Safety and Security Methodology

The entire operation from import approval to final source installation was meticulously segmented into three critical phases, designed and executed under the supervision of the Radiation Protection Supervisor (RPS) of NUKLEAR Malaysia.

#### 3.1 Pre-Transport Planning and Licensing

This phase ensured comprehensive regulatory compliance and risk mitigation:

- **Regulatory Compliance:** Approvals for the import, ownership, and transport of the Category I source were secured from the ATOM Malaysia. The source was procured from the Institute of Isotopes Co. Ltd., Hungary.
- **Transport Risk Assessment:** The detailed Work Implementation Plan defined the preferred 50 km transport route and meticulously documented height limitations to prevent vehicular accident.
- **Physical Security Plan:** Due to the Category I nature of the source, enhanced security was mandated, detailing the use of Armed Guard to provide armed escort. All transport and installation personnel were vetted for reliability.

#### 3.2 Transportation Phase: Safety and Security in Transit

The road transport phase was executed under strict physical security and radiation protection controls.

#### Key Implementation Details (December 2022):

- **Armed Escort:** Transport occurred at night and was protected by a convoy including the Armed Guards, RPS, and the contractor. The transport vehicle maintained a minimum of two personnel and was continuously guarded.

- **Package Verification & Control:** Upon arrival at KLIA Cargo Hub, the Type B(U) flask was verified for document conformity, integrity, and labelling (UN 2916). Mandatory Leak Testing was performed, and RPS continuously monitored dose rates to ensure ALARA compliance.

### 3.3 On-Site Movement and Installation Phase (Delayed Execution, January 2023)

The source replacement, initially planned for 16 January 2023, was completed on 18 January 2023 due to a critical technical delay.

- **Logistical Challenges (Bunker & Technical Delay):** Initial site constraints (narrow corridors, ramps, and a raised threshold) necessitated specialized lifting equipment. However, the primary delay was a technical challenge: the holes on the Eldorado-8 machine head did not align correctly with the transfer tool required to safely move the old source (81 Ci) into a temporary storage head, requiring specialized effort and time to resolve while maintaining strict radiation protection.

- **Radiological Safety and Accountability:** The source exchange utilized remote operation by specialized engineers. Continuous radiation monitoring by Health Physics Group personnel ensured ALARA was upheld. Post-installation, the depleted source was safely repackaged and transferred to NUKLEAR Malaysia's waste storage, ensuring full chain of custody and accountability.

## 4. Conclusion

The successful transport and installation, despite confronting significant technical challenges, confirmed the effective integration of IAEA transport regulations (SSR-6) with stringent national security protocols. This experience underscores the critical role of the RPS in managing complex, multi-agency operations and executing flexible solutions for both predictable logistics and unexpected technical failures, thereby guaranteeing the safety and security of Category I radioactive material.

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## Mutual Recognition of Professional Qualifications (MRPQs) to increase engagement and upskilling for transport and maritime nuclear sectors

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With 90% of the world's youth, the next generation of workers, living in developing countries, it is more important than ever to invest in industries which offer sustainable and reliable employment opportunities. Global economic growth requires engagement across countries, skill level, and age groups. This increase in engagement and outreach from local populations leads to a simultaneous increase in economic impact through increased employment, inclusion in financial markets, and attention and commitment to the community.

The nuclear maritime and radioactive materials transport sectors offer the potential to support upskilling youth and traditionally underserved populations in a way which allows them to access newly created well-paid roles which provide highly transferrable skills. Alongside offering direct routes to employment, these sectors can:

- drive investment in distressed and underserved coastal areas

- provide reliable access to energy to underserved areas
- operate under strict governance standards based on long-standing nuclear standards and operating culture, and
- increase local and direct engagement with an area of technology which is often surrounded by superstition and misunderstanding.

Through regular engagement and support of local communities, these sectors offer the chance to continue to drive increased development economically and socially, directly and indirectly.

As transport of nuclear materials is inherently international, it has identified skills and abilities that ensure transports are conducted safely globally, although formal international certifications do not currently exist. Development of mutual recognition of professional qualifications (MRPQs) for transportation through everything from information sharing led by experts to formal training and qualification programs would greatly assist this sector. Similar approaches will be needed to develop maritime nuclear skills and understanding that are supported globally. Though requiring in-depth and collaborative approaches from national regulators and inter standard setters, supporting a drive for MRPQs in these nuclear sectors will enable workers to operate as the sector does – internationally.

This report will provide an outline of the potential societal and local economic benefits for MRPQs offered by the radioactive materials transport and nuclear maritime industries. Included in this are the direct economic impact of increased investment and skilled jobs and the indirect impacts of increased understanding of nuclear sector and more reliable green energy. Additionally, the report will underline the existing international certification pathways and recognition agreements and areas for increased international collaboration to expand MRPQs in this space.

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## Computer Security in Nuclear Material Transport: Digital Attack Surfaces and Mitigation Strategies

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**Title:**

*Computer Security in Nuclear Material Transport: Digital Attack Surfaces and Mitigation Strategies*

**Themes:**

Threats and risks / Computer security by Design

**Abstract:**

Nuclear material transportation occurs in public spaces, exposing it to unique safety and security challenges compared to stationary facilities. The theft or sabotage of nuclear material during transport could have catastrophic consequences, including the potential for radiological exposure, environmental contamination, or its use in malicious acts such as the construction of improvised nuclear devices. With the increasing reliance on digital technologies in modern transport vehicles, computer security vulnerabilities have now emerged as a key concern, further amplifying the risks associated with unauthorized access or cyber-attacks targeting these systems.

Collaboration between NNSA's Office of International Nuclear Security (INS - United States) and Direction de l'Expertise Nucléaire de la Défense et de la Sécurité (DEND - France) aims to research the sensitive digital assets related to safety, security, and emergency preparedness of nuclear material

transport. Specifically, our research strives to identify critical functions of vehicle computer security, their attack surfaces, and corresponding mitigation strategies. Efforts will focus on common vehicles, trailers, and fleet management software utilized in North America and Europe. Based on findings, a paper will be written to serve nuclear security stakeholders with a framework for identifying and protecting sensitive digital assets critical to nuclear security transport. A scanning device will also be developed to map these assets by interrogating on-board equipment.

This submission will focus on our initial findings and challenges related to ongoing research efforts via an oral presentation. Presenting this work to partners in the nuclear material transport domain will allow us to foster additional collaboration, understand unique considerations, and solicit feedback from key experts related to the field.

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## Safe Transport of Decommissioned Radiotherapy Co-60 Source from Amazonia to the Source Repository in Southeast Brazil

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The decommissioning of a Co-60 source from a radiotherapy unit at a public hospital in Rio Branco (High Complexity Oncology Unit –Unacon) in Acre State, located at Brazilian Amazonia region, required complex multimodal transport to the Center for Development of Nuclear Technology repository in Belo Horizonte, Minas Gerais.

Due to limited infrastructure in the Amazonia region, the transport involved road transport (~3500 KM) via BR-364 and a waterway transport crossing on the Madeira River at Abuna (RO), facing challenges unique to the Amazon region, such as poor road infrastructure, river piracy risks, and remote logistics. This multimodal transport was authorized under the UN 2919 special arrangement (Radioactive Material Transported under Special Arrangement, Non-Fissile or Fissile-Excepted), in compliance with international IAEA regulations (SSR-6, GSR Part 7, NSS No. 9) and national CNEN standards (Norm CNEN-NE-5.01 for Transport of Radioactive Materials, Nota tecnica conjunta IBAMA-CNEN 01-2013).

This work presents a case report on the safe transport of a disused radiotherapy Co-60 source with an initial activity (calibration date 2005) of 6000 Ci (222 TBq). The obsolete radiotherapy equipment decommissioning process began with the dismantling of the shielded head (approximately 2 tons), conducted in July 2019 under the supervision of a medical physicist and radioprotection team, in compliance with Brazilian National Nuclear Energy Commission (CNEN) standards NE-6.02 and NN 3.01. The source was extracted with the original manufacturer shielding to minimize gamma radiation exposure. To keep stability during transport the shielded Co-60 source was transferred to a “cradle” support.

The destination selected was the radioactive source repository at the Center for Development of Nuclear Technology (CDTN) in Belo Horizonte, Minas Gerais, the primary national repository for low- and medium-level radioactive waste, licensed by CNEN for receipt, treatment, and temporary storage of radioactive materials.

The transfer was executed under a special arrangement (UN 2919), in accordance with international transport regulations for radioactive material. The multimodal route combined road and river segments, including a fluvial crossing by ferryboat over the Madeira River between the states of Acre and Rondonia—an essential link due to limited road infrastructure in the region.

Security and operational coordination involved multiple agencies: the Institutional Security Office of the Presidency of the Republic (GSI), the Brazilian Federal Highway Police (PRF), and different State Military Highway (PMRE). These entities provided tactical escort, route surveillance, and contingency support throughout the journey. Notably, aerial monitoring using drone was employed to enhance situational awareness, verify convoy integrity, and support real-time decision-making in

remote or high-risk segments of the route, aligned with physical protection guidelines for radioactive material transport (CNEN NN 2.05).

This operation exemplifies Brazil's commitment to nuclear safety and security, demonstrating the effectiveness of Special Arrangement frameworks, highlights the importance of inter-agency coordination and the integration of advanced technologies—such as drone surveillance—in the transport of high-activity radioactive devices.

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## Data-Driven Resilience: Integrating Culture, Capability, and Frameworks for Safe and Secure Transport of Radioactive Material

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### Abstract

Malaysian Nuclear Agency (NUKLEAR Malaysia) manages over 200 annual transports of high-activity Category I radioactive materials. To achieve durable resilience against accidents and malicious acts, NUKLEAR Malaysia employs a strategy centred on integrating safety and security cultures, supported by quantitative assessment and formal frameworks. A security culture survey of 430 workers yielded an average score of 3.84/5, identifying critical weaknesses in Communications and Training & Qualifications (3.78). This quantitative data is validated by operational deficits revealed in multi-scenario drills, where physical security responders demonstrated uncertainty in using radiological monitoring equipment (survey meters/EPD) at incident sites. In response, NUKLEAR Malaysia has formalized its integrated approach by establishing the Nuclear Safety and Security Group (2024) and implementing mandatory joint drills, transparent reporting processes, and targeted training programs. This synthesis of cultural diagnosis, operational testing, and structural reform is essential for maintaining a robust, responsive transport system in an evolving threat landscape.

#### 1. The Safety-Security Interface and Operational Challenge

NUKLEAR Malaysia operates key facilities, including a research reactor and over 800 radioactive sources (highest activity up to 400,000 Ci). The integrity of its ≥200 annual RAM transports depends on harmonizing Safety (compliance with Act 304 and minimizing accidental exposure) and Security (preventing theft or sabotage). The interface goal is clear: ensure neither domain compromises the other during emergencies.

#### 2. Cultural Assessment and Deficiencies

NUKLEAR Malaysia employs continuous assessment to diagnose cultural vulnerabilities among its workforce.

##### 2.1 Nuclear Security Culture (Transportation of Radioactive Material) Findings:

A comprehensive survey confirmed that while Security Awareness scored highly (3.93/5), the organizational components supporting execution fell short, notably in Communications and Training (3.78/5). Demographic analysis highlighted a need for specific intervention for younger and less experienced staff, whose security perception scores were generally lower, and for Management & Professional personnel whose scores lagged behind technical and support staff.

## 2.2 Safety Culture and Preparedness:

A separate assessment showed good overall worker awareness of emergency preparedness (5.65/7), yet the lowest scoring area was Training (4.89/7). This consistency between safety and security assessments indicates a systemic need to strengthen training programs.

## 3. Frameworks for Robust and Responsive Systems

NUKLEAR Malaysia has developed robust frameworks to translate cultural awareness into durable, responsive capability:

### • Integrated Drills and Lessons Learned:

Mandatory, complex, multi-site drills test the system against combined security threats (intrusion, confinement) and radiological risks (source theft, contamination). These drills repeatedly exposed the Operational Integration Deficit, specifically the lack of proficiency among initial security responders in performing immediate radiological assessment upon securing a compromised package.

### • Structural and Procedural Reforms:

Based on drill findings, NUKLEAR Malaysia implemented foundational changes:

**i. Organizational Merger:** The creation of the Nuclear Safety and Security Group (2024) formally mandates integrated leadership and procedural alignment.

**ii. Transport Control:** Standardized documents, such as the Radioactive Material Transport Document (for Category 1 radioactive materials) and the internal Movement Notification Form, ensure comprehensive safety checks, security protocols (armed escort, personnel vetting), and real-time communication tracking.

**iii. Targeted Training:** The way forward includes mandatory joint safety-security drills and specialized workshops (e.g., National Workshop on Security Culture Self-Assessment) to close the identified gaps in communication and training across all staff levels.

## 4. Conclusion

Achieving a robust, durable, and responsive transport system requires continuous quantitative cultural diagnosis validated by operational stress testing. NUKLEAR Malaysia's experience demonstrates that merging safety and security groups, institutionalizing joint exercises, and focusing targeted training on organizational weaknesses (Communications and Training) are crucial steps toward building integrated resilience that protects personnel, the public, and the integrity of radioactive material transport.

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## The regulatory landscape for electric-powered vehicles (EVs) in South Africa

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The regulatory landscape for electric-powered vehicles (EVs) in South Africa

Introduction

Vehicle safety in the transportation of radioactive materials is crucial to protect public health, the environment, and national security by preventing releases, limiting radiation exposure, and deterring malicious acts. This is achieved through stringent regulations from competent authorities. Some

member states prefer to follow the IAEA transport requirements rather than prescribe their own. These requirements dictate specialized packaging, vehicle marking, route planning, and security measures, ensuring that the inherent hazards of radioactive materials are contained and controlled during transit. This, however leaves a gap in ensuring that the vehicles themselves, in terms of their design and manufacture, are safe.

South Africa's EV regulatory framework is evolving from fragmented, sectoral measures toward a coordinated industrial and regulatory strategy. The Department of Trade, Industry and Competition (dtic) published an Electric Vehicle White Paper that sets out a comprehensive roadmap for a just transition of South Africa's automotive sector, covering manufacturing, incentives, skills, and infrastructure. The White Paper is the base document guiding many subsequent regulatory and fiscal proposals.

South Africa is shifting from policy design to implementation —finalising regulations stemming from the White Paper, rolling out standards for charging infrastructure, and operationalising fiscal incentives for manufacturers. This paper provides an in-depth examination of the south African regulatory landscape for electric-powered vehicles and identifies gaps that need to be addressed in the regulatory framework.

**Battery Safety: South Africa's Regulatory & Technical Requirements**

**Relevant Standards & Testing Regimes**

Occupational health & safety, environmental law (e.g. for disposal / recycling of batteries), transportation regulations all intersect with battery safety. Though EV-specific battery safety regulation are not yet as comprehensive, resulting in testing/labs employing requirements other member states. Some requirements can be found in national standards; others are emerging via policy documents or still in draft form. South Africa is still in a phase of aligning its regulatory infrastructure with best global standards.

Current standards in the area of EV batteries are specific to “battery swap” systems (where batteries are removed and replaced/swapped between vehicles). These standards address safety requirements for these systems, including safety and interoperability for both the removable battery systems and the infrastructure or systems that swap them.

EV batteries, battery packs and related components are currently subject to testing against internationally recognized safety standards. International Organisations like SGS and TÜV SÜD offer testing services for batteries/cells/modules/packs under IEC, ISO, UN, and other such standards.

**Gaps / Areas for Development**

One key gap is that there is not yet (as publicly visible) a fully unified set of EV battery safety regulations that cover the entire lifecycle (from manufacture to in-vehicle safety to disposal / recycling). The reliability of grid, charger safety, local Battery Management System (BMS) certifications, and mandatory local compliance testing remain areas needing more regulatory clarity or enforcement. Adding battery safety into the broader regulatory framework means:

- Policy documents (e.g. the EV White Paper, industrial incentives) must consider mandated safety certification (for manufacturers, importers) as part of conditions.
- Trade / import tariffs and duties should incentivize only those battery systems that meet safety and testing standards.
- Standards bodies (SABS / SANAS) will need to issue or adopt more SANS standards for battery safety and ensure test labs are accredited and available locally.
- Transport & storage regulation: ensuring that when EV batteries are stored, transported (especially in bulk, or replacement/spare batteries) the dangerous goods rules are respected.

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## **Implementing Safety and Security Measures during for he Transport of Radioactive Sources in Cameroon**

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The transport of radioactive materials in Cameroon is carried out in accordance with the International Atomic Energy Agency (IAEA)'s Transport Regulations. These regulations are reflected in national legislation and regulatory texts, in particular Law No. 2019012 of July 19, 2019, establishing the general framework for radiological safety, nuclear security, civil liability and the safeguards enforcement, Decree No. 2024/00163 of January 22, 2024, establishing the modalities for the application of certain provisions of this law, and Decree No. 2024/0599 of November 19, 2024, changing the name and missions of the National Agency for Radiological Protection (ANRP), which became the Radiological Safety and Nuclear Security Authority (ASRAN). ASRAN ensures the implementation, throughout the national territory, of safety and security measures relating to the transport of radioactive materials. However, the effectiveness of this activity depends on the contribution of stakeholders in the transport chain, law enforcement agencies, security forces, justice, and providing the Authority with the resources required to carry out its missions.

Key words: radioactive materials, IAEA transport regulations, national legislation and regulations, security, carrier, enforcement, regulatory authority

**Country or International Organization:**

**Instructions:**

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## **Competency Management for the South African National Nuclear Regulator**

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See the attached synopsis.

**Country or International Organization:**

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## **FROM BORDER DETECTION TO REGULATORY REFORM: ADDRESSING THE SAFETY AND SECURITY OF NORM TRANSPORT IN AN ERA OF CRITICAL MINERAL EXPANSION IN ZIMBABWE**

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Legislative gap in the transport of naturally occurring radioactive material

**Country or International Organization:**

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**TRANSPORT OF NORM: HEAVY MINERALS CONCENTRATES MINERALS IN SOUTH AFRICA****Author:** Theresah Kekana<sup>None</sup>**Corresponding Author:** tkekana@nnr.co.za**Background and Objectives**

The regulated activities involving Naturally Occurring Radioactive Material (NORM) in South Africa (SA) include the mining and processing of Gold, Copper, Uranium, Heavy Minerals Concentrates, Phosphate rock, Manufacturing of Fertilizers, Recycling of scrap material contaminated by NORM, Small users (i.e. laboratories) conducting tests of small quantities of NORM samples for verification of proposed and existing actions, including samples from prospecting activities and Service providers (i.e. storage warehouse). The regulation of these industries is through the issuance of two types of nuclear authorisation depending on the associated radiation risk, i.e. the Certificate of Registration (COR).

**Materials and Methods**

The mining of Heavy Mineral Concentrates (HMC) which includes zircon, rutile, monazite which are radioactive in nature and includes the minerals that are not radioactive such as garnet, and ilmenite occurs within South Africa (SA) along the western to the eastern coast. The maximum activity concentration of the radioactive HMC has reached about 9 Bq/g, making them exempted from transport regulations. However, studies have shown that in some cases the limit of 10 Bq/g limit for some radio nuclides can be exceeded (SSR-6). Therefore, the authorisation holder must constantly prove that their material is exempted from the transport regulations. HMC miners have taken a precautionary approach to conduct more analysis prior dispatching their consignments. The most effective and efficient method in terms of turnaround time is through XRF-analysis and at a lesser frequency by full radionuclide analysis. These analyses are conducted at accredited laboratories.

Other NORM industries handle material that is exempted from transport regulations as is evident from their laboratory analysis results. The waste material produced in all industries including the HMC can be decontaminated to below Surface Contaminated Objects (SCO) –1 levels and therefore transported as cleared waste.

**Results and Discussion**

The HMC industry handles radioactive material that sometimes falls under transport regulations and will therefore constantly need to analyze their consignments to know when to apply the regulations as per SSR-6. Other NORM industries need to ensure that materials although radioactive but not falling under transport regulations are transported in a secure manner. Based on the outcome of their assessment, authorisation holders are required to draft their transport procedures to detail the process to follow for their material will be transported considering the available regulations.

**Conclusion submission**

It is the responsibility of the authorisation holders to constantly analyze and determine if their material needs to be transported under SSR-6 requirements or provide a justification that their material is exempted. Records for justification for exemption need to be maintained to ensure that they are available for review by the regulator.

**Country or International Organization:**

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## Lessons learned from one year of implementation of the new French regulatory framework for the security of nuclear material transport

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### Background :

Since the security of nuclear transports is concerned, in France, it is the state responsibility and the ministry of energy duty to design security regulations, to license authorised carriers, to authorize each shipment and to approve transport vectors. Having a large nuclear industry imposes France to have a robust and up-to-date nuclear security regime. In this regard, France renewed its nuclear security regulatory framework for nuclear material transport in 2023.

### Philosophy of the new French regulation: what has changed?

Fourteen years of effective practice of the previous regulatory framework have highlighted certain needs for improvement, for example:

- The need for a clearer vision between state's and carriers's respective responsibilities;
- The need to adapt to new threats (cyber, sabotage);
- A more "operational oriented" rather than an administrative writing of the regulation;
- A better security continuity between installations and transports;
- The need to clarify some concepts to avoid misunderstandings;
- A better integration of information protection.

The new regulation, issued in 2023, reaffirmed the concept of movement as a guarantee for security and reinforced previous provisions regarding, in particular, sensitivity on stops and during changes of mode. Moreover, in the 2023 regulatory framework, France implemented specific provisions for transshipment platforms to give them a specific status and to define an appropriate physical protection system.

To accompany carriers in the implementation of the new regulation, the nuclear security authority provided guidance to specify some aspects of the regulation and ensure an homogeneous implementation (e.g. for unpredictability criteria).

*The extended synopsis will provide additional examples of the new 2023 regulatory framework's provisions.*

### Feedback after one year of implementation

Since the full entry into force of the new regulation, in January 2025, some authorizations have been renewed or are under examination based on updated files from carriers and more than 60 inspections and exercises have been conducted by the nuclear security authority. Inspections have been carried out "during" transport operations or at the carriers' headquarters. Also, in January 2025, carriers were asked by the authority to provide a document assessing their compliance with the new regulation.

The observations made during the authorization files examination and the different types of inspections, as well as through reported incidents, brought to the conclusion that, on one hand, certain aspects of the new regulation have been well implemented by the carriers (e.g. the reinforcement of certain transport vectors, the provision of security files for stops and transshipment areas). On the other hand, more efforts are still expected on other topics (e.g. the centralized monitoring of transports by the carrier, carrier's exercise policy).

*The extended synopsis will provide more detailed information on the progress made and the residual areas for improvement.*

### Future challenges

Work is still ongoing to update the regulation with regard to the technical control and approval of conveyances.

Moreover, the threat is evolving, as is the nuclear landscape with projects for new reactors, facilities and the associated transports of nuclear material. Challenges are high, as materials concerned, modalities, and volumes to be transported are still unknown. In parallel, emerging technologies can bring security advantages as well as constitute new threats.

The nuclear security authority upcoming challenge is to ensure that the regulatory framework remains adapted to these new concerns. In the future, nuclear security regulations could go further and address topics like:

- Security by design of the casks;
- New sensor reporting on temperatures, pressures, shocks, radiations;
- New technologies to reinforce surveillance during short duration stops.

*In conclusion, the extended synopsis will develop further the new challenges for transports security regulation.*

**Country or International Organization:**

**Instructions:**

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## **The Feature of Transfer a Responsibility for the Physical Protection of Nuclear Material in International Transport**

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This paper presents an overview of current issues related to ensuring the physical protection of nuclear material during international transport. By analyzing international legal framework of physical protection regulation, as well as other international legally binding documents related to international transport of goods, the author explores the main point and content of the notion of «responsibility for physical protection».

The paper provides a list of potential participants of the international transport of nuclear material and their functions with respect to its physical protection. A description of a transfer of responsibility for physical protection at various stages of the international transport process is provided.

Particular attention is given to the readiness of forces and resources of each participant of an international transport of nuclear material. The author analyzes the elements of the transport process requiring special attention and provides examples of international best practices that have an aim to achieve continuous physical protection of nuclear material during international transport.

**Country or International Organization:**

**Instructions:**

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## **Mediterranean Region - Competent Authorities Cooperation for the Oversight of the Transport of Radioactive Material**

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In October 2025, the Mediterranean Network of competent authorities (CAs) for the transport of radioactive material (MedNet) marked its 10th anniversary since its official establishment even though activities had started since late 2013. The International Atomic Energy Agency (IAEA) has been continuously supporting MedNet with both financial and technical resources. It is pertinent to mention that the initial financial support came from the European Commission (EC).

During these years, several achievements have been reached, starting from the buildup of confidence and sharing of regulatory and operational experience. Other achievements include establishment of working links for sharing information, development of common guidance material, training activities, several meetings both in person and virtual, and recently development of train the trainer material.

Achievements and actions were communicated at international level in conferences such as PATRAM 2016, 2023 and 2025, RAMTRANS 2018 and 2024, IAEA's International Conference on the Safe and Secure Transport of Nuclear and Radioactive Materials, 2021 and now 2026.

MedNet also held joint meetings with the European Association of Competent Authorities for the safe transport of radioactive material (EACA) in 2019, 2024 and 2025. It is also pertinent to mention that in 2022, a cooperation agreement was signed between the two groups. EACA has always been seen as a model for MedNet given the long-term cooperation experience among CAs in Europe and the advanced infrastructure in EACA member states. During these meetings MedNet member states not normally exposed to the whole Transport phases of radioactive or nuclear material, became aware of how complex issues are faced by experienced colleagues. MedNet members also intent to enhance their experience in transport security and the management of safety-security interface and it is hoped that future co-operation with EACA, international organizations and experienced regulators in other regions will be beneficial.

Significant examples of operational experience build up are the joint inspections conducted in Belgium in 2023 and in United Kingdom in 2024; the two EACA countries hosted several representatives of MedNet members. Key themes included collaborative strategies for information sharing, harmonization of inspection procedures, development of protocols for effective communication between regulatory authorities and stakeholders. Based on the information gained, training material for a train the trainer program was developed and a course already took place to ensure that all MedNet MS get the same exposure as was received during the visits to the two EACA Member States. Most of the mentioned activities have been made possible through the IAEA TC Interregional Project INT9184.

This is in line with MedNet's long term goal of achieving harmonization in the Mediterranean region and ensuring that the next generation of transport experts is well-prepared to address and resolve challenges that may impact transport safety and security.

This paper presents the outcomes and the progress achieved by MedNet in the last years, as well as, the challenges ahead, including transportable nuclear power plants, small modular reactors and

climate change effects, and the way forward. It also aims to address the significance of exchanging information through its established contact channels for e.g. shipments being detected as contaminated in a MedNET Member State going to in another MedNet Member State.”

**Country or International Organization:**

**Instructions:**

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## **Mitigating the risk: Improving Insider Threat Mitigation, Ensuring Security of Cat. 1 and 2 disused sealed radioactive sources during transport, and lessons learned from implementation**

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The National Nuclear Security Administration’s (NNSA) Office of Radiological Security (ORS) strengthens US national security, as well as global security, by eliminating the threat of disused sealed radioactive sources (DSRS). To ensure that this mission is carried out successfully, LANL, INL and ORNL recognized a strong case for improvements in insider threat mitigation which led to the authorization, development and implementation of a stand-alone Insider Threat Mitigation Program (ITMP) for the Off-Site Source Recovery Program (OSRP).

The OSRP insider threat program’s goal is to ensure that the risks to OSRP-funded recoveries and transports from actions taken by insiders, whether malicious or inadvertent, are understood and mitigated. The challenges to this are different than in mitigation of insider threats within a single organization or employer: OSRP projects involve numerous different stakeholders from NNSA, the national laboratories, as well as subcontractors for commercial industry, other academic or government institutions, and end user sites, as well as local law enforcement agencies, each with different awareness of insider threats, and different perspectives on insider threat risks and security needs. The removal projects require a high level of coordination and information sharing across these stakeholders to ensure success and strengthen security during operations, but this adds cross-organization challenges to mitigating insider threats.

The success of the OSRP ITMP program relied heavily on an in-depth assessment of OSRP work processes from the frontline practitioners who have been involved in recovery operations, in order to identify security-sensitive activities where ITMP mitigations could be implemented. Additionally, a Working Group (WG) was formed comprised of subject matter experts from the DOE national labs responsible for OSRP operations with nuclear transport security and insider threat mitigation experts that fostered a strong collaborative relationship with stakeholders to facilitate improvements in mitigations within their unique organizations, and improve communication and information sharing across organizations. Lastly, the establishment of communication and information sharing mechanisms that improved the awareness of insider threats across all stakeholders, provided assistance with insider threat mitigation resources, capabilities of the participating organizations.

Early “lessons learned” from ITMP implementation showed that Engagement in the field was incredibly powerful and effective. Having OSRP ITMP working group members attend recovery operations adds an ITM component real time with active discussions. These discussions allowed for scenario building and resolution as well as open and frank discussion on ITM.

As program implementation grows through greater interactions with OSRP subcontractors and the material transport industry, a broader acceptance of ITMP goals and objectives is anticipated, leading to new lessons learned for sharing with government and industry participants.

**Country or International Organization:**

**Instructions:**

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## **Navigating the Safety & Security Interface: safety and security by design and in operations for the NNSA ORS Type B Packages**

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National Nuclear Security Administration's (NNSA) Office of Radiological Security (ORS) enhances global security by preventing IAEA Category 1 and 2 quantities of radioactive material from being used in acts of terrorism. One strategy ORS employs to achieve this mission is the recovery of disused sealed radioactive sources (DSRS) that pose a potential risk to public health, safety, and national security. Under ORS's direction, the Off-Site Source Recovery Program (OSRP), consisting of Los Alamos National Laboratory (LANL) and Idaho National Laboratory (INL), share the responsibility for removing irradiators containing Category 1 or 2 quantities of cesium-137 or cobalt-60.

Category 1 and 2 DSRS are most at risk while in transport, where physical protection systems are more difficult to develop and implement relative to fixed facilities, such as hospitals. Addressing this gap is what LANL and INL have been focusing on by direction of ORS. Several factors are attributed to this effort including regulatory changes in the United States.

In 2004, the U.S. Nuclear Regulatory Commission (NRC) revised their regulations in 10 Code of Federal Regulations (CFR) Part 71 to harmonize with the IAEA's 1996 edition of "Regulations for the Safe Transport of Radioactive Material" (IAEA Safety Standards Series No. TS-R-1). In doing so, a number of Type B packagings used by the OSRP and industry for shipments of Type B quantity were phased out of use on October 1st, 2008. In anticipation of this change and subsequent lack of certified Type B packaging for compliant shipments, ORS directed LANL OSRP to design, test, certify, and fabricate new Type B package models, thus ensuring that source recovery operations weren't interrupted.

This new design effort allowed ORS and OSRP to approach package design with deliberate consideration of safety and security factors. The safety of packages is a well-established metric in which packages must meet criteria defined by the IAEA and the competent authority under which the package is evaluated and certified. The security-by-design of packages is an area where ORS and OSRP determined additional measures could be taken. OSRP worked with the package design agency and packaging engineers to ensure a security mindset during the design of the packages. This allowed OSRP to ensure better security of the packages through inherent design features without sacrificing safety or operational efficiency.

Through these efforts, ORS OSRP movements of IAEA category 1 and 2 DSRS are safer and more secure. OSRP project managers and shippers are able to track conveyances from the end user to DOE/NNSA contracted facilities, and in the event of a security incident can immediately initiate a response from local law enforcement agencies. These efforts make OSRP transportation of high consequence material safer for the general public and increase national security through removal of DSRS.

**Country or International Organization:**

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**Designing a Secure Conveyance: Cyber-Physical Security Risk Mitigation Leveraging In-Vehicle Computers****Author:** Samuel Hollifield<sup>1</sup><sup>1</sup> *Oak Ridge National Laboratory***Corresponding Author:** hollifieldsc@ornl.gov

Modern vehicles increasingly rely on electronics and small, embedded computer systems called Electronic Control Units (ECUs), which act as central hubs for sensing, computation, and control. Typical automobiles contain dozens of ECUs that connect to internal vehicle networks, typically Controller Area Networks (CANs). These systems, embedded within passenger cars, commercial fleets, and heavy-duty trucks, enable advanced driver assistance, infotainment, telematics, and autonomous capabilities.

Commercial vehicles and heavy-duty trucks benefit from a high-layer network protocol, SAE J1939, which defines CAN message encodings and enables deciphering of vehicle state information. For instance, by monitoring network parameters such as wheel speed, brake pressure, and gear position, it is possible to detect physical events like unauthorized towing or theft. While these insights can enhance visibility into vehicle and driver status, the networks were not designed with modern cybersecurity provisions. A severe lack of authentication and encryption makes CAN/J1939 traffic susceptible to spoofing, replay, and denial-of-service attacks, which can directly translate into safety-critical failures. As a result, nuclear and radioactive transport vehicles have become both security assets and risks.

This paper proposes an in-vehicle, network-centric architecture that treats these pre-existing in-vehicle networks as both a source of actionable cyber-physical security intelligence and a resource that must be actively defended. Using experience gleaned from research and development projects at Oak Ridge National Laboratory, we present three interoperable approaches that can be deployed to improve situational awareness and threat resilience by leveraging sensor-state information communicated through in-vehicle networks.

The first effort, Controller Area Network Transport Security Tracking and Reporting (C-STAR) aims to secure a myriad of heavy-duty, high-risk vehicle shipments by leveraging onboard telemetry and vehicle sensors on a modular and flexible-edge computing platform. This technology intakes automotive network data to make determinations on the physical security of the vehicle. The second effort, CAN-based Driver Identification, aims to fingerprint driver behavior and mental state through continuous two-factor authentication based on their interaction with the vehicle. This technology allows stakeholders to utilize side-channel methods for driver identification where camera systems are unreliable or unavailable. Finally, to address potential cybersecurity issues arising from manipulation of the J1939 network, our Automotive Secure Hijack, Intrusion, and Exploit Layered Detector (Auto-SHIELD) technology is deployed to detect and alert for network intrusions and vehicle sensor anomalies.

This paper will detail our development processes and key findings, including deployment of technologies on real vehicles using aftermarket hardware. We will summarize our findings, capabilities, and how the implementation of Artificial Intelligence could improve operational security in the near future.

**Country or International Organization:****Instructions:**

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## Innovative Protective Monitoring Approaches for the civil nuclear industry: A Case for a New Approach to the Protective Security of Nuclear Facilities

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The use of new and innovative monitoring technologies in the civil nuclear industry is being explored to enable more efficient and cost-effective security of material, facilities, and premises. These advancements are being strongly considered in relation to the nuclear renaissance, in particular with emerging Small Modular Reactor (SMR) technology. However, new protective monitoring approaches can also be utilised in decommissioning where the category of nuclear material has been reduced or nuclear material removed, justifying a proportionate reduction in security posture. The benefits of these innovations include better situational awareness, more effective deployment of security personnel, reduced insider risk, and cost savings.

States have obligations under the Convention on the Physical Protection of Nuclear Material (CPPNM) and its Amendment (CPPNM/A) to maintain appropriate physical protection of nuclear facilities and material in domestic use, storage, and transport. This means that security arrangements that include innovative protective monitoring technologies may be an option for licensees. The UK Government has indicated that these new monitoring approaches are within their risk appetite, subject to regulatory approval, and they may provide a solution to challenges regarding armed police resource for SMR development and eventual deployment. This paper will therefore make the case for innovative monitoring technologies to be considered more widely across the nuclear lifecycle. These technologies will be aligned to IAEA requirements such as the CPPNM/A and provide a vision of how innovations in security monitoring can enable the growth of civil nuclear.

**Country or International Organization:**

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## Closing the Transport Gap: Mobile Conversion of HEU-UF<sub>6</sub> into Legally Shippable Forms

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The safe recovery and transport of highly enriched uranium hexafluoride (HEU-UF<sub>6</sub>) remains a critical challenge for nuclear security operations. At present, there are no legal means to ship large quantities of HEU-UF<sub>6</sub> in its native volatile form, creating both regulatory and safety barriers to international material removal. To address this issue, Oak Ridge National Laboratory (ORNL) developed a system for the U.S. Department of Energy's National Nuclear Security Administration's Mobile Uranium Facility (MUF) to convert HEU-UF<sub>6</sub> into uranyl fluoride (UO<sub>2</sub>F<sub>2</sub>), a chemically stable solid compatible with U.S. Department of Transportation-certified ES-3100 shipping containers. This process enables secure, regulation-compliant transport of material previously considered unshippable.

The MUF's system uses activated  $\gamma$ -alumina to adsorb UF<sub>6</sub> vapors under negative pressure, converting them into UO<sub>2</sub>F<sub>2</sub> and hydrogen fluoride (HF). Both products are immobilized within the alumina matrix, yielding a stable, nonvolatile form suitable for packaging. The system, contained within a single CONEX unit, features four adsorption traps operated in series or parallel to maximize capacity. Once saturated, uranium-bearing alumina is HEPA-vacuum-transferred into Teflon bottles and

then into an ES-3100 qualified container for shipment.

A phased testing program demonstrated readiness for field deployment. Bench-scale studies confirmed alumina's loading capacity of ~50% by weight. A half-scale two-trap system using HEU-UF<sub>6</sub> validated materials compatibility and process scalability, while full-scale demonstrations with water vapor surrogates provided operator training and confirmed heat-of-reaction monitoring and sorption kinetics. Together, these results confirm that the MUF can safely process a full 5A (~25 kg) HEU-UF<sub>6</sub> cylinder.

By converting volatile HEU-UF<sub>6</sub> into a legally shippable solid, the MUF eliminates a long-standing regulatory gap, enhances transportation security, and provides a mobile capability supporting international nuclear material removal missions.

**Country or International Organization:**

**Instructions:**

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## TRANSPORT CONCEPT FOR THE BALDER PROJECT AT PSI

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Copenhagen Atomics has entered a collaboration agreement with the Paul Scherrer Institute (PSI) to initiate the BALDER project for licensing, construction, and operation of molten salt experiments at the Villigen site in Switzerland. The Copenhagen Atomics Molten Salt Experiment (MSE) is the first planned experiment, to be conducted within a purpose-built Nuclear Test Facility (NT).

The MSE, a self-contained criticality experiment, uses low-enriched uranium fluoride molten fuel salt and heavy water as a moderator to generate heat through fission. As a short-term criticality experiment based on Molten Salt Reactor (MSR) technology, it is planned to generate 1 MW of thermal power for 30 days. The design incorporates inherent and passive safety features, including negative reactivity feedback for temperature, low-pressure operation, and significant margins to prevent fuel salt boiling. Comprehensive autonomous control and monitoring systems ensure robust management of key parameters to prevent incidents and accidents.

All MSE systems, structures, and components (SSCs) will be shipped from the Copenhagen Atomics facility in Denmark to the PSI Villigen site. These SSCs are not classified as dangerous goods and can therefore be transported conventionally. In contrast, the fuel and blanket salts will require appropriate packaging and arrangements in fresh fuel transport casks due to their radioactivity. These packages and arrangements require approvals from relevant authorities, as well as the transport of heavy water.

After the operational phase, the MSE will undergo a period of safe shutdown to allow for substantial radioactive decay prior to dismantling and subsequent transport. End-of-life transport of SSCs and materials will follow a similar process, but with additional measures to address increased radioactivity. Most notably, the irradiated fuel and blanket salts will require spent fuel transport casks. Once the MSE has been shut down, decontaminated, and released at PSI Villigen site, SSCs and materials are planned to be reused under regulatory control at the Copenhagen Atomics facility.

Copenhagen Atomics is engaging with suppliers to define technical solutions, including license extensions for the cask to contain a package of a storage tank with solid salt, transport routes, safety assessments, and final storage options. Appropriate packages have been identified based on the activity and inventory of the irradiated materials. All salt material handling and transport are performed with the salt solidified and near ambient temperature to facilitate operations. The solidified salt is contained in custom stainless steel tanks that are used to melt and transfer the content during the MSE operation. The selected transport cask requires re-licensing of the package, demonstrating that the package fulfills the requirements for packages containing fissile materials including package arrays under accident conditions for transport. Different approaches to fulfilling this requirement are being considered.

Beyond these preparations, compliance with international regulations for the transport of radioactive materials will require additional effort. Anticipated challenges include securing approvals for novel fuel salt compositions, demonstrating package performance under regulatory testing, and coordinating authorizations across several national authorities. Addressing these aspects will be critical to ensure safety and avoid delays in project implementation.

Copenhagen Atomics will initiate a series of feasibility studies with established European suppliers to address all aspects of MSE transport, supporting the BALDER project's licensing applications. These studies will be led by established suppliers within the nuclear transport domain in ongoing collaboration.

At the appropriate stage, permits will be sought from the Swiss Federal Office of Energy, the Danish Health Authority, and the competent authorities of the relevant transit states. These applications will be supported by the necessary safety-related assessments.

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## **Beyond Visual Line of Sight (BVLOS) Drone use in Transport Security**

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Project Falcon

Beyond visual line of sight (BVLOS) drone use in transport security

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Synopsis

“Project Falcon” or “Drones in a Box”, refers to the British Transport Police’s (BTP) new remote drone capability using Beyond Visual Line of Sight (BVLOS) technology to increase operational policing capability on the United Kingdom’s rail network. The use of BVLOS drones addresses the limitations of existing Visual Line of Sight (VLOS) drone capability by increasing range and coverage to assist a policing response to live incidents, crime scenes, public events and search & rescue. By having BVLOS assets at major rail locations, it aims to minimise rail disruption, reduce response times and increase public safety. This is the first time that such technology has been utilised by a British Police service. Project Falcon deploys drones as a “State Aircraft” under article 3 of the Chicago Convention and therefore they are not subject to UK Civil Aviation Authority (CAA) Rules.

This has been achieved by framing each rail corridor as an Atypical Air Environment (AAE) and as such the CAA class this as airspace as rarely used by other aircraft. Altitude is capped at 120 metres, and the operating safety case incorporates geofencing, emergency kill switches and parachutes to enable controlled landings if the communication link is lost. As with new technology there are cost implications for nationwide coverage as well as training competence, but also distance and flight path limitations. For the transport of nuclear and other radioactive material, this may be beneficial in the longer term by enabling faster response times in an emergency and providing proactive patrols of critical locations. In future, the aspiration is that this technology will become increasingly

widespread. There will be a need to educate the public and stakeholders across the rail transport and civil nuclear sector to increase awareness and highlight the benefits BVLOS drones will bring.

Current Police Drone use by the British Transport Police and other United Kingdom Police entities are limited to drones and pilots situated in patrol vehicles that will respond to incidents and pre-arranged events. These assist responding officers on the ground in searching areas for suspects, crowd dynamics and missing persons. This can be resource intensive and not pro-active.

**Country or International Organization:**

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**Instructions:**

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## **Floating nuclear power units: features of ensuring safety during transportation**

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Will be submitted

**Country or International Organization:**

**Instructions:**

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## **Floating nuclear power units: life cycle features and approaches to their transportation**

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**Country or International Organization:**

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## Mobile Plutonium Facility Packaging Operations Rev C

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Paper being submitted by the DOE/NNSA Mobile Packaging Program

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**Instructions:**

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## Improving RASIMS profile, success story from Sudan

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**Introduction: Legal Framework**

Through Agency legislative assistance and staff training provided under previous TC projects, Sudan received support in drafting and promulgating a comprehensive Nuclear Act that covers radiation safety and nuclear security, safeguards of the facilities, nuclear materials, radiation sources, and all activities involving peaceful uses of nuclear energy and radiation technology in Sudan. The new Nuclear Act cited as "The Nuclear and Radiological Regulatory control Act, 2017" came into force on the date of signature by the President on 26/02/2017 and was published in the gazette issue No 1863 KH on 15 April 2017.

**Radiation and Nuclear Safety Services**

These services are provided by the Radiation and Nuclear Safety Institute (RNSI) of the Sudan Atomic Energy Commission (SAEC) to meet national regulatory requirements. The key achievements of the past IAEA TC projects comprise continuous capacity building support, establishment of personnel and workplace monitoring services, secondary standard dosimetry laboratory (SSDL), radioactive waste management facility, and foodstuff monitoring capabilities.

**RASIMS profile**

To facilitate the assessment of progress made in strengthening radiation safety infrastructure, country profiles for TSA 1, TSA 2, TSA 3 and TSA 7 in the IAEA's RASIMS database are extensively being updated and almost complete awaiting review by the relevant IAEA Department. Regarding the status of the other thematic safety areas: TSA 4 profile is 80%, TSA 6 is 26% completed. TSA 5 is no longer part of RASIMS.

**Objectives**

The country aims at achieving high compliance with IAEA safety standards for all thematic areas by 2027.

**Methodology**

A committee has been established in 2016 by the D. G of SAEC to coordinate, edit, update and endorse the information uploaded to RASIMS.

This committee chaired by the Director General of SAEC and, co-chaired by the Secretary General of SNRRA, the RASIMS national coordinator as a reporter and the members include the director of RSNI-SAEC, AFRA NC, and 14 members; two for each thematic area, one from the Regulatory body (SNRRA) and the other from the service provider (RSNI-SAEC). The committee used to meet every two month to follow up the progress made by the designated CPs for each thematic area.

**Results**

As a result of the mechanism explained in the methodology section, the profile of Sudan has improved in general and in particular for thematic areas 1, 2 and 3 as shown in the following figure.

#### Discussion

The mechanism of coordination between regulatory body and service provider was found to be very efficient and effective in improving the RASIMS profile of Sudan in few years and this mechanism is now adopted by AFRA project RAF9070 during the first coordination meeting in 2024, all participating member states assigned two CPs for each thematic area.

**Conclusions** The close coordination and strong partnership relation will change the shape of profiles to a better position and reflects the national commitment to ensure safety in all the peaceful applications of nuclear technology.

#### Recommendations

To national institutions in Sudan; to maintain this mechanism of coordination to achieve the stated objective in time.

To AFRA community; to adopt the mechanism effectively to ensure achieving the same results obtained in Sudan.

#### References

RASIMS platform

The Committee profile

Report of the First coordination meeting of RAF9070 Enhancing the Radiation Safety Infrastructure (AFRA)

**Country or International Organization:**

**Instructions:**