Contribution ID: **33** Type: **ORAL**

ADVANCING TRANSPORT SAFETY OF NUCLEAR AND RADIOACTIVE MATERIALS THROUGH EMERGING TECHNOLOGICAL INNOVATIONS

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.

Country or International Organization

Instructions

Author: Mr NINYIO, Noel (Nigeria Atomic Energy Commission)

Co-authors: Dr GODWIN, Ini (Nigeria Atomic Energy Commission); Mr OJEWOLE, Oladokun (Nigeria Atomic Energy Commission)

Presenter: Mr NINYIO, Noel (Nigeria Atomic Energy Commission)

Track Classification: Track 4 Computer Security and Emerging Technologies