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FROM CRIME SCENE TO LABORATORY: MANAGING NUCLEAR FORENSIC SAMPLES

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Introduction

Investigating a radiological crime scene is uniquely challenging because of the hazards posed by radioactive materials. Evidence from these scenes can be dangerous to handle, yet it carries the critical forensic signatures needed to solve the case. Safely managing these samples from the crime scene all the way to the lab is essential to protect personnel, preserve evidence, and ensure the integrity of the entire investigation.

Laboratories follow standardised protocols for receiving, assessing, handling, storing, and preparing samples collected from radiological crime scenes, based on established nuclear forensic best practices, including international guidelines, regional frameworks, and established local operational procedures. These protocols support analyses aimed at determining the nature, origin, history, and possible intended use of nuclear or other radioactive materials, while ensuring that scientific findings are reliable and suitable for use as evidence in a court of law (IAEA 2014; Keegan, 2015).

Types of Evidence at Radiological Crime Scenes

Radiological crime scenes may involve a complex mixture of radioactive materials and conventional forensic evidence. In many cases, traditional forensic evidence may be contaminated with radioactive substances, requiring specialised handling throughout the forensic process.
Examples of evidence that may be encountered include:

- Biological evidence such as body fluids (DNA), hair, and fibres
- Impression evidence including fingerprints and shoe or tyre impressions
- Chemical and toxicological evidence
- Environmental indicators such as pollen (for geolocation), soil, dust, and debris
- Toolmarks and mechanical traces
- Digital evidence and electronic devices
- Questioned documents
- Materials evidence such as metal alloys and components
- Design or fabrication residues associated with radioactive material

These diverse evidence types highlight the need for close coordination between radiological protection and forensic examination activities. The wide range of evidence types present at radiological crime scenes underscores the complexity of sampling strategies and subsequent forensic interpretation. Determining sample representativeness remains a major challenge in nuclear forensics, as analytical results must support specific investigative objectives, such as source attribution, with defined confidence levels (IAEA 2015). Given that nuclear and radiological materials are frequently heterogeneous, reliance on bulk analytical approaches alone may fail to capture critical variations within the material. The chemical composition and structural characteristics of a material are essential for uncovering its origin and historical background (Dunn et al. 2025). Consequently, careful sample selection and coordinated radiological and forensic examination are essential to ensure that both radiological signatures and conventional forensic evidence are preserved and interpreted reliably.

Figure 1. Forensic personnel collecting evidence containing radioactive and conventional materials, illustrating integrated procedures for radiological safety and evidence preservation.

Receiving and Verifying Samples

All incoming samples are treated as potentially radioactive and contaminated until proven otherwise. Upon receipt, documentation such as transport records and chain-of-custody forms are verified. Containers are inspected for integrity without opening, and details of the receipt are logged. Samples are only opened under the authorization of a Radiation Protection Officer (RPO), ensuring safe handling at all times.

Initial Radiological Assessment

An initial radiological assessment is performed to determine external dose rates and surface contamination. Ambient radiation levels are recorded to guide handling and storage requirements. This assessment ensures that samples are managed according to their radiological hazard, minimising risks to personnel and maintaining safety within the laboratory.

Figure 2. Radiation detection instruments are used to assess external dose rates and surface contamination before samples are opened or processed.

Maintaining Chain of Custody

Continuous documentation of sample movement is essential to maintain accountability and traceability. Chain of custody documentation and laboratory handling procedures for nuclear forensic evidence are detailed in international guidance (IAEA 2015). Any discrepancies, damage to containers, or deviations in documentation are reported immediately. This process safeguards the integrity of the forensic evidence and supports admissibility in legal proceedings.

Sample Handling and Contamination Control

Samples are processed in controlled laboratory areas. Unknown or potentially dispersible materials are handled within glove bags, glove boxes, or equivalent containment systems. Non-destructive techniques are prioritized to preserve physical, chemical, and radiological characteristics of the samples. Strict contamination control prevents cross-contamination and ensures that forensic signatures remain intact.

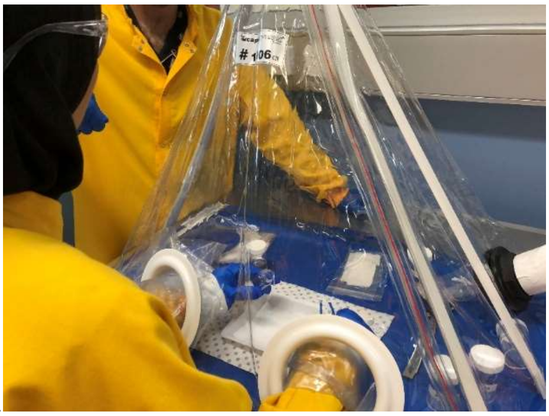

Figure 3 Nuclear analysts carefully handle nuclear forensic samples within glove bags or glove boxes, preserving forensic integrity while minimising radiation and contamination risks.

Storage and Preparation for Analysis

Samples are stored in shielded, secure, and access-controlled facilities. Uncharacterised or high-risk samples are quarantined until radiological clearance is granted by the RPO. Preparation for analysis follows method-specific procedures while maintaining forensic integrity. This ensures that analytical results are accurate and can reliably support investigative outcomes.

Figure 4. Samples are stored in shielded, access-controlled facilities to ensure safety, security, and evidence integrity.

Safety and Personnel Competency

Personnel are trained in radiation protection, contamination control, and nuclear forensic principles. ALARA (As Low As Reasonably Achievable) principles of time, distance, and shielding are applied in all activities. Personal protective equipment (PPE) and dosimeters are worn at all times, and controlled laboratory areas strictly prohibit eating, drinking, or smoking. Procedures for incident management and non-conformance address abnormal radiation readings, damaged containers, or any deviation from standard protocols.

Key Equipment

- Radiation Detection and Identification Devices – Instruments such as Geiger-Müller counters, scintillation detectors, and gamma spectrometers for detecting and identifying radioactive materials.
- Dosimetry Devices – Thermoluminescent Dosimeters (TLDs), Optically Stimulated Luminescence (OSL) rings, or electronic personal dosimeters to monitor personnel radiation exposure.
- Sample Handling and Containment – Glove bags, glove boxes, and remote handling tools (tongs, forceps) for safe manipulation of unknown or potentially dispersible samples.
- Radiation Shielding and Storage – Shielded boxes, lead bricks, shielded containers, and secure storage cabinets to protect personnel and preserve sample integrity.
- Contamination Control and Monitoring – Surface contamination monitors, portable survey meters, wipe test kits, and work surface mats for contamination prevention.
- Personal Protective Equipment (PPE) – Gloves, lab coats, shoe covers, safety goggles, and respirators where required.
- Sample Transport and Packaging – Tamper-evident, shielded transport containers compliant with safety regulations.
- Waste Management Equipment – Designated containers for radioactive or contaminated waste, both solid and liquid.
- Documentation and Security Tools – Chain-of-custody forms, evidence labels, barcoding systems, and secure logbooks or storage.
- Auxiliary Laboratory Tools – Fume hoods, small analytical balances, and sample preparation tools for safe, precise sample handling.

Regulatory and Legal Context

In many jurisdictions, handling and analysis of nuclear and radiological materials are regulated under national law and licensing frameworks. For example, the Atomic Energy Licensing Act 1984 establishes requirements for the possession, transport, and management of radioactive materials to ensure safety and compliance with regulatory obligations (Malaysia,2011).

Figure 5. Radiation survey meters commonly used in nuclear forensic laboratories to assess dose rates and surface contamination.

Conclusion

From collection at a radiological crime scene to analysis in the laboratory, standardised procedures are essential for the safe and effective management of nuclear forensic samples. Following these protocols ensures the protection of personnel, preservation of forensic evidence, and reliability of analytical results. By drawing on internationally recognised guidance, regional frameworks, and established local practices, laboratories can maintain high standards of nuclear forensic investigation worldwide.

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