**IAEA Coordinated Research Project: Application of nuclear forensics in combating illicit trafficking of nuclear and other radioactive material**

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**Abstract.** Nuclear forensics, as a sub discipline of forensic science, utilizes measurements of physical characteristics, chemical and elemental composition, and isotopic ratios of nuclear and other radioactive material, together with associated traditional evidence to provide information about material origin and history. Data is interpreted to produce findings that may identify associations between people, places and events to deter and respond to a nuclear security event as well as strengthen a nuclear security infrastructure. Research and development is a means to foster innovation applicable to nuclear forensic examinations as well as demonstrate the validity of nuclear forensic methodologies. The challenges posed by a response to nuclear security events to include the illicit trafficking of nuclear and other radioactive materials demands scientific innovation to ensure state of practice methods and techniques are being developed and implemented as a component of national response to nuclear or other radioactive material out of regulatory control.

**1. Introduction**

By analyzing inherent signatures that are intrinsic or imparted during manufacturing and use, materials may be linked to people, places, and events important to a law enforcement investigation, a criminal prosecution as well as assessments of nuclear security vulnerabilities [1]. Because nuclear forensic examinations may involve analysis and interpretation of a range of nuclear and other radioactive material, appropriate methodologies together with high confidence measurements are essential. In addition, the ability to examine traditional evidence (e.g., DNA, fingermarks, hair, and fibers) contaminated with radionuclides may be required as part of an investigation of a nuclear security event. Nuclear forensic analysis and interpretation, presented as nuclear forensics findings, can provide information that may be applied to law enforcement investigations, regulatory inquiries, policy making and assist other relevant stakeholders to make informed decisions to improve nuclear security and prevent future nuclear security events [1]. The integrity of nuclear forensic findings relies upon existing, proven analytical techniques together with the development and validation of novel techniques and applications for nuclear forensic methodologies.

The IAEA promotes research and development *inter alia* to support effective nuclear security through Coordinated Research Activities (CRAs) and in this instance through Coordinated Research Projects (CRPs). Research project proposals are submitted to the IAEA and once the proposal has been positively evaluated, the IAEA may offer institutes in developing countries a research, technical or doctoral contract and institutes in developed countries a research agreement or technical contract. The CRP approach gives an opportunity for a broad range of experts and institutions of a broad range of States to participate at periodic Research Coordination Meetings (RCMs) to report the developments of their research project. Research is completed in the institutes’ countries, with the chief scientific investigator for each project invited to attend the periodic RCMs for face to face discussions, exchanges of information and to facilitate the building of professional bonds that will outlast the lifetime of the CRP.

Nuclear forensic science CRPs are a component of nuclear security capacity building and capability development that contributes to the credibility of findings as well as complements training, education, awareness and exercises. The importance of the science should not be diminished. The use of nuclear forensic science and attribution to identify the source of nuclear and other radioactive material out of regulatory control and to increase the likelihood of assigning responsibility for such acts is discussed in the IAEA Nuclear Security Series Technical Guidance No. 6 on Combating Illicit Trafficking in Nuclear and other Radioactive Material [2]. Tracing seized material via interpretation of nuclear forensics data is increasingly valued and it is recognized that there is a requirement for quality assurance of results to provide confidence in findings. Confidence in analytical results depends upon three factors: 1) validated methods; 2) certified reference materials; and 3) demonstrated competencies.

Nuclear forensics has emerged as an important discipline of forensic science. Research and development is essential to build confidence in nuclear forensic findings and evaluate the reliability of nuclear forensic signatures as a basis to determine origin and history. In particular, research should focus on areas such as improving procedures and analytical techniques for the identification and characterization of nuclear and other radioactive materials, identification of nuclear forensic signatures to aid in determinations of material origins and history, understanding how signatures are created, persist and are modified throughout the nuclear fuel cycle, and how signatures can be accurately measured [3].

Extracting relevant information from material seized in a criminal context, together with information about the perpetrators of criminal or unauthorized acts, may also help contribute to an analysis of the flow of radioactive material into and through illegal markets. High confidence measurements of nuclear and other radioactive material and their resulting interpretation may allow for patterns in activities such as perpetrators of criminal or unauthorized acts and the movement of radioactive material through illegal markets to become evident. Consequently, nuclear forensics is an increasingly important tool in determining the source of contraband radioactive material [2].

The goal of CRPs, to include those in nuclear forensics, is to promote improvements in current technology, encourage international best practice, stimulate confidence building via peer-to-peer networking and increase competence among nuclear security practitioners. In this regard the IAEA has organized two CRPs in nuclear forensics. The first CRP was implemented from 2008 to 2012 and focused on the requirements of state of practice measurements of seized materials, techniques to collect and preserve evidence, and improvements to interpretative capacities for law enforcement and nuclear security purposes. The second CRP commenced in 2013 and will continue for three years. The CRP is titled ‘Identification of high confidence nuclear forensic signatures for the development of a national nuclear forensics library’. Through its contractual conditions, the IAEA ensures that the research results are freely available worldwide for use of its Member States, with the IAEA publicising widely on the research.

**2. Coordinated Research Project: Application of Nuclear Forensics in Combating Illicit Trafficking of Nuclear and Other Radioactive Material**

The first CRP ran from 2008 to 2012 and focused on the requirements of state of practice measurements of seized materials, techniques to collect and preserve evidence, and improvements to interpretative capacities for law enforcement and nuclear security purposes. Conclusions of the first CRP focused on the areas of 1) instrumentation and field collections, 2) laboratory methods and techniques and 3) modeling and interpretation and demonstrated that the CRP provided a forum for sharing improved techniques and procedures (to include radiation detection and mass spectrometry techniques), the importance of a staged nuclear forensics analytical plan with nondestructive analysis proceeding destructive analysis, the value of predictive signatures in the analysis of irradiated materials, the considerations to preserve evidence contaminated with radionuclides, and the necessity for research activities to be commensurate with State’s requirements for nuclear forensics.

The following seven projects were undertaken as part of this CRP and are summarized in Table I together with the principal research topic.

Table I. Participating research institutions of Coordinated Research Project: Application of Nuclear Forensics in Combating Illicit Trafficking on Nuclear and Other Radioactive Material.

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| Research institution | Title | Research topic |
| Australian Nuclear Science and Technology Organisation, Australia | Exploiting critical evidence contaminated with alpha emitting radionuclides | Laboratory methods |
| Instituto de Pesquisas Energéticas e Nucleares, Brazil | Establishment of procedures and techniques for nuclear forensic investigations Part II – workshop on nuclear forensics | Laboratory methods; modeling and interpretation |
| IDEA System GmbH, Germany | Identification, localization, and categorization of RDD | Instrumentation and field work |
| Democritus University of Thrace, Greece | Determination of the origin of unknown nuclear material through an isotopic fingerprinting method | Modeling and interpretation |
| Centre for Energy Research, Hungarian Academy of Sciences, Hungary | Development of nuclear forensics methods and techniques for combating illicit trafficking of nuclear and other radioactive material | Laboratory methods |
| Korea Institute of Nuclear Safety, Republic of Korea | The development of IT-based in-situ mobile response supporting system for deterring illicit trafficking of nuclear and radioactive materials | Instrumentation and field work |
| Institute for Transuranium Elements, European Commission | Procedures and techniques for nuclear forensic investigations | Laboratory methods; modeling and interpretation |

**3. Coordinated Research Project: Identification of High Confidence Nuclear Forensic Signatures for the Development of a National Nuclear Forensics Library**

The second CRP entitled ‘Identification of high confidence nuclear forensic signatures for the development of a national nuclear forensics library’ commenced in 2013. This project recognizes a national nuclear forensics library as one possible tool to aid in nuclear forensics interpretation through enabling the comparison of material characteristics and signatures with materials used, produced or stored within a State.

Within the context of nuclear forensics, signatures are the characteristics of a given sample of nuclear or other radioactive material that distinguishes that material from other nuclear or radioactive material. Analysis of these signatures may aid in the identification of the origin and processing history of the material.

The project also recognizes that the comparison of material characteristics and signatures would benefit from the identification of peer reviewed and validated signatures across the nuclear fuel cycle and the manufacture of radioactive sources.

The objectives of this CRP seek to address the data requirements of a national nuclear forensics library for stages of the nuclear fuel cycle and for the manufacture of radioactive sources, as well as promote research into novel signatures that are indicative of nuclear processing and important to high confidence interpretation and nuclear forensics findings. Of interest, for example are resolving intrinsic signatures of natural uranium from those that are introduced as a result of production and manufacturing processes during milling, isotopic enrichment, fuel manufacture and reactor operations.

A fundamental question to be considered by this CRP is how signatures are imparted and how they persist. The outcomes of this project will be used to provide technical guidance to States for the development of a national nuclear forensics library and the measurement of material characteristics and signatures. Table II summarizes the following ten projects included in this CRP together with the principal research topic.

Table II. Participating research institutions of Coordinated Research Project: Identification of High Confidence Nuclear Forensic Signatures for the Development of a National Nuclear Forensics Library.

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| Research institution | Title | Research topic |
| Australian Nuclear Science and Technology Organisation, Australia | Investigation of various signatures and their application to the provenancing of material at the front end of the nuclear fuel cycle | Laboratory methods; modeling and interpretation |
| Instituto de Pesquisas Energéticas e Nucleares, Brazil | Identification of nuclear forensic signatures in environmental samples | Laboratory methods; modeling and interpretation |
| Chalk River Laboratories; Atomic Energy of Canada Limited, Canada | Nuclear forensics signatures of irradiated CANDU fuel | Modeling and interpretation |
| Democritus University of Thrace, Greece | Parametarisation of unknown spent nuclear fuel from nuclear reactors in view of identifying its origin | Modeling and interpretation |
| Centre for Energy Research, Hungarian Academy of Sciences, Hungary | Establishment of a national library for nuclear forensics purposes in Hungary | Laboratory methods; modeling and interpretation |
| Bhabha Atomic Research Centre, India | Mass spectrometry, radiometry and other analytical techniques for nuclear forensics | Laboratory methods |
| Center for Nuclear Science and Technology, National Nuclear Energy Agency, Indonesia | Identification of high confidence nuclear forensic signatures for mining, milling and conversion process | Laboratory methods; modeling and interpretation |
| Swedish Defence Research Agency, Sweden | Measurement of lanthanides in uranium matrices | Laboratory methods; |
| Institute for Transuranium Elements, Joint Research Centre, European Commission | Propagation of nuclear forensics signatures at the front-end fuel cycle | Laboratory methods; modeling and interpretation |

**4. Communication of Research Outcomes**

The premise of IAEA coordinated research projects, to include those in nuclear forensics, is to promote improvements in current technology, encourage international best practice, stimulate confidence building via peer-to-peer networking and increase competence among nuclear security practitioners. The CRP ensures that technical advancements in nuclear forensics are shared for maximum benefit for all States [3]. The IAEA, through a programme of developing technical guidance and provision of outreach and training, assists States to promote the awareness and understanding of nuclear forensics as well as their development of technical capability. The IAEA’s programme of CRPs offers a mechanism for collaborative international scientific research and confidence building.

**References**

[1] INTERNATIONAL ATOMIC ENERGY AGENCY, Nuclear Forensics Support, IAEA Nuclear Security Series No. 2, IAEA, Vienna (2006).

[2] INTERNATIONAL ATOMIC ENERGY AGENCY, Combating Illicit Trafficking in Nuclear and other Radioactive Material, IAEA Nuclear Security Series No. 6, IAEA, Vienna (2007).

[3] INTERNATIONAL ATOMIC ENERGY AGENCY, Application of Nuclear Forensics in Combating Illicit Trafficking of Nuclear and Other Radioactive Material, IAEA-TECDOC-1730, Vienna (2014).