Overview of Nuclear Forensics in Support of Investigations

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Abstract. In recognition of the benefits of nuclear forensics to the implementation of national nuclear security infrastructures, the IAEA published in 2006 as part of its Nuclear Security Series, "Nuclear Forensics Support (Nuclear Security Series No. 2)," which was based on a document entitled "Model Action Plan for Nuclear Forensics and Nuclear Attribution," developed by the Nuclear Forensics International Technical Working Group (ITWG). The Model Action Plan outlined a generalized approach to the conduct of a nuclear forensic examination. Since the original publication, there have been further advances in nuclear forensics. Nuclear forensic examinations have been successfully applied to a number of reported cases involving the illicit trafficking of highly enriched uranium and plutonium, as well as other events involving nuclear or other radioactive material out of regulatory control. Techniques, similar to those used in nuclear forensics, are also used to support nuclear counter-terrorism and compliance with various international legal instruments. As a result, the IAEA is revising the 2006 document which will be titled "Nuclear Forensics in Support of Investigations." The objective of the revised publication is to describe the role of nuclear forensics in support of investigations of a nuclear security event and provide a context for nuclear forensics within a national nuclear security infrastructure. Additionally, the publication promotes international cooperation by encouraging States to seek or provide assistance, where appropriate, with regard to developing capabilities or during an investigation of a nuclear security event. An overview of the revised publication will be presented.

1. Introduction

In recognition that nuclear forensics is a key component of nuclear security, the IAEA published in 2006, "Nuclear Forensics Support" (Nuclear Security Series No. 2) [1] as Technical Guidance. Acknowledging that there have been further advances in nuclear forensics since 2006, the IAEA is revising the 2006 document with the new title "Nuclear Forensics in Support of Investigations" as draft Implementing Guidance for publication within the IAEA Nuclear Security Series. The objective of this revised publication is to provide national policy makers, competent authorities, law enforcement and technical personnel with guidance on the role of nuclear forensics in the context of investigating a spectrum of nuclear security events involving nuclear or other radioactive material out of regulatory control. Also included are descriptions of nuclear forensic examinations; the role of nuclear forensics in a national nuclear security infrastructure including the investigation of a nuclear security event; and mechanisms for international cooperation and assistance in nuclear forensics. The essential elements of nuclear forensic capacity building including awareness, education, expertise development and training are described. Furthermore, this publication emphasizes that a nuclear forensic capability encompasses more than just instrumentation or analytical measurements. Nuclear forensics involves a comprehensive plan undertaken by States to determine the origin and history of nuclear or other radioactive material in support of law enforcement or nuclear security investigations. Such investigations may include, but are not limited to, illicit trafficking incidents or other encounters with nuclear or other radioactive materials out of regulatory control.

The revised publication does not provide detailed guidance on the design, equipping or staffing of a laboratory where nuclear forensic examinations may be conducted; nor does it provide detailed guidance on radiological crime scene management, the conduct or management of an investigation of a nuclear security event, or traditional forensic examinations, although each of these subjects contributes to the success of a nuclear forensic examination.

2. Role of Nuclear Forensics

Despite the existence of national nuclear security infrastructures, there continue to be cases of material out of regulatory control — whether unintentionally, such as through loss, or intentionally as a result of criminal acts such as theft. Given this information, there is a need for States to develop the capability to prevent, detect and respond to any event involving nuclear or other radioactive material that has nuclear security implications. Events such as these are referred to as nuclear security events. A nuclear forensic examination may be an important component of the response to a nuclear security event.

2.1. A Model Action Plan

The nuclear forensics model action plan [2] shown in Figure 1 provides generalized guidance on the conduct of a nuclear forensic examination and related activities that should be performed in the context of an investigation of a nuclear security event. The plan covers activities undertaken by the authorities requesting nuclear forensic examinations and by the laboratories that may be called upon to undertake the analysis and interpretation.

Nuclear forensic examinations are undertaken to respond to key questions posed by the investigative authority, which may relate to the intended use, history and origin of nuclear or other radioactive material involved in the nuclear security event under investigation. The questions posed by the investigative authority will be influenced by the nature of the nuclear security event and any related legal proceedings that may arise as a consequence of the investigation.

Nuclear forensic analysis and interpretation may lead to findings regarding the material associated with a nuclear security event. When combined with other aspects of the investigation, including traditional forensic findings, conclusions may be drawn about the associations between the material and people, places, events and production processes. States should recognize that although a nuclear forensic capability may not be used on a regular basis, it may play a significant role in the investigation of a nuclear security event.

2.2. National Framework

All States should have a national response plan for nuclear security events, to provide for an appropriate and coordinated response. As nuclear forensics can play a key role in the investigation into a nuclear security event, the nuclear forensics model action plan (Figure 1) should be incorporated into the national response plan to the extent possible.

States should ensure that roles and responsibilities for nuclear forensics in relation to nuclear security events are clearly defined and that expertise, instrumentation and procedures are in place. There should also be provision for the safe and secure storage of seized nuclear and other radioactive material, as well as means to safely and securely transport such material from the scene of a nuclear security event to an evidence storage site. Such a storage site may be a laboratory capable of undertaking characterization of collected material or may be an interim location where seized material can be kept until it is transported to a designated nuclear forensic laboratory for analysis.

Development of a nuclear forensic capability within a State should begin by identifying existing capabilities, including facilities that are already established and relevant expertise that is already used for other purposes, and creating mechanisms for their use in an investigation. Relevant capabilities may exist, for example, at radiation protection institutions, radiochemistry or nuclear physics departments at universities, environmental monitoring laboratories, quality control laboratories of nuclear fuel cycle facilities or security and defence establishments.

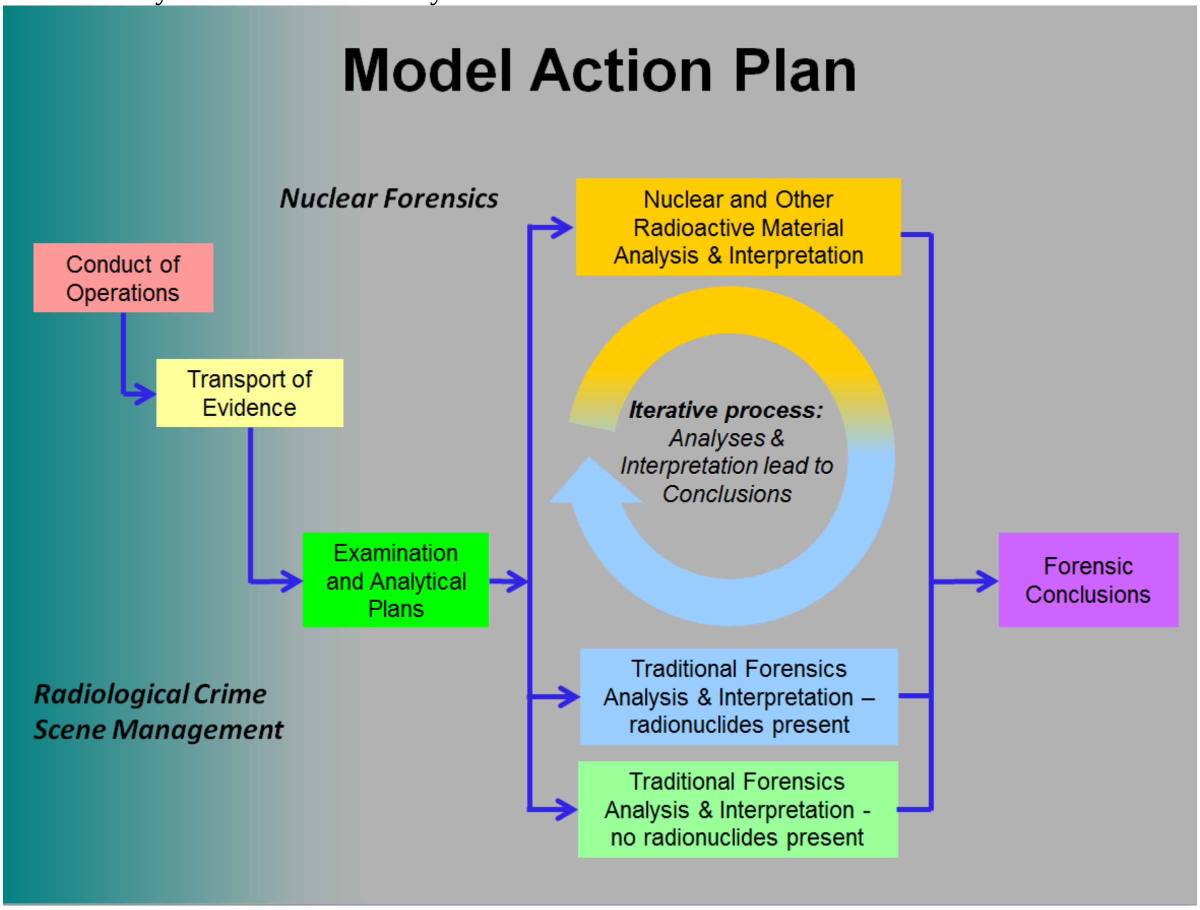

FIG. 1. Illustration of the nuclear forensics model action plan: a process which supports an investigation of a nuclear security event. Background shading indicates the transition from radiological crime scene management to nuclear forensics.

3. Forensics Examination Plan and Corresponding Nuclear Forensics Analytical Plan

For the purposes of investigating a nuclear security event, once the preliminary on-scene assessment has been performed, including categorization[1] of the nuclear or other radioactive material, a forensic examination plan should be prepared by the investigating authority in consultation with the relevant forensic laboratories, including designated nuclear forensic laboratories. The forensic examination plan should describe the requirements of the examinations to be conducted in support of a potential criminal prosecution. Additionally, the development of the forensic examination plan should consider any requirements to retain samples that may be requested by the court if the results of the investigation are used in legal proceedings.

The forensic examination plan should consider the needs of the investigation, the perceived value of the expected results to the investigation, the known or suspected losses of essential characteristics over time if examinations are delayed, and the national level procedures for the conduct of examinations in traditional forensic disciplines and nuclear forensics. In general, priority should be given to examinations where the results are capable of specifically identifying an individual person, (for example, DNA analysis or fingerprint examination) over those where the results are likely to identify only a group or class (for example, shoe or tyre impressions, or the presence of a particular type of explosive). However, the presence of other investigative or intelligence information may enhance the value of class characteristic results, especially where narrowing the range of possibilities is critical to focusing the investigation.

In support of the forensic examination plan, each of the forensic laboratories involved should prepare an analytical plan in consultation with the lead investigative authority. This consultation is important to ensure that key requirements of the examination plan are not overlooked in the preparation of the analytical plans of each of the forensic laboratories.

A nuclear forensic analytical plan should be developed to specifically describe what types of analysis will be performed in order to meet the requirements of the investigation and the sequencing of analyses that pertain to nuclear or other radioactive material and evidence contaminated with radionuclides. An essential element of a nuclear forensic analytical plan includes characterization[2]. The nuclear forensic analytical plan should be prepared by the designated nuclear forensic laboratory or laboratories, with input and ultimately concurrence from the investigating authority such that it meets the needs of the forensic examination plan and the investigation. The nuclear forensic analytical plan should be flexible and adaptable, so that as new information is obtained through the investigation or through sample analysis, the requirements for the forensic examination may be revised. The nuclear forensic analytical plan can be modified as needed, with appropriate consultation and documentation.

3.1. Evidence Contaminated with Radionuclides

The conduct of examinations in traditional forensic disciplines and nuclear forensic examinations should complement each other. Both yield results that may aid in determining whether linkages exist among people, places, events and processes and whether those linkages are indicative of where regulatory control was lost. These results can prove especially useful where they permit association with an individual person, place, thing or event or they allow certain nuclear or other radioactive materials to be excluded from further consideration. The potential for radioactive material to be present as a contaminant on physical evidence presents a particular challenge for examinations conducted in traditional forensic disciplines.

When confronted with the need to conduct examinations in traditional forensic disciplines on evidence contaminated with radionuclides, two approaches are possible. The first approach involves removal of

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[1] Categorization is performed to identify nuclear security implications and the risk of the seized material to the first responders, law enforcement personnel, and the public.
[2] Characterization is performed to determine the nature of the radioactive material and associated evidence.

or separation of the radionuclides from the evidence prior to conducting any examinations. This is often referred to as decontamination of the evidence. The second approach involves the conduct of these examinations directly on the evidence contaminated with radionuclides. Both approaches may require input from multiple agencies, in particular from agencies outside the law enforcement community. For this reason, there may be a need for extensive consultation between the relevant experts for the development of the forensic examination plan and prior to the handling of evidence contaminated with radionuclides. Each approach offers certain advantages and suffers from certain disadvantages that should be evaluated during the course of the investigation.

The decision whether to attempt decontamination of evidence or to conduct examinations on the evidence while it is still contaminated with radionuclides should be addressed in the forensic examination plan and will be dependent on factors such as:

- The nature of the evidence, the contaminant and the examinations to be performed;
- Availability of relevant resources for the conduct of the examinations;
- Information obtained to date through investigative or intelligence methods, and from any related examinations that have been performed;
- National policies and procedures for responding to nuclear security events.

3.2. Nuclear Forensics Laboratory Analysis

Based on categorization and the requirements of the forensic examination plan, characterization of the nuclear or other radioactive material may be necessary. This characterization should take place in a designated nuclear forensic laboratory, and should follow the nuclear forensic analytical plan.

Many of the analytical tools used in the analysis of nuclear or other radioactive material are destructive techniques, i.e., the sample is consumed during the preparation or analysis. Therefore, the proper selection and sequencing of analytical techniques is critical and should be defined in detail in the nuclear forensic analytical plan. The sequencing of analytical techniques should be based upon the questions to be answered from the investigating authority according to the forensic examination plan, taking into account the amount of sample available for analysis, information already available, and the potential signatures (physical, chemical, elemental and isotopic) that may support precise interpretation.

TABLE I. LABORATORY METHODS AND TECHNIQUES WITH TYPICAL TIMESCALES FOR COMPLETION OF ANALYSES

Techniques/methods	**Conducted within**		
	24 hours	**One week**	**Two months**
Radiological	- Dose rate (α, β, γ, n) - Surface contamination - Radiography		
Physical characterization	- Visual inspection - Photography - Weight determination - Dimensional determination - Optical microscopy - Density	Microstructure, morphology, etc. - Scanning electron microscopy (SEM) - X ray diffraction (XRD)	Nanostructure, morphology, etc. - Transmission electron microscopy
Isotopic analysis	- High resolution gamma ray spectrometry (HRGS)	- Thermal ionization mass spectrometry (TIMS) - Inductively coupled plasma mass spectrometry (ICP-MS)	- Secondary ion mass spectrometry (SIMS) - Radioactive counting techniques

TABLE I. LABORATORY METHODS AND TECHNIQUES WITH TYPICAL TIMESCALES FOR COMPLETION OF ANALYSES

Techniques/methods	Conducted within		
	24 hours	**One week**	**Two months**
Radiochronometry	- HRGS (for Pu)	- TIMS - ICP-MS	- HRGS (for U) - Alpha spectrometry
Elemental/chemical composition	- X ray fluorescence	- ICP-MS - Chemical assay - Fourier transform infra-red spectrometry - SEM / X ray spectrometry - Isotope dilution mass spectrometry	- Gas chromatography mass spectrometry
Traditional forensic science disciplines	- Collection of evidence associated with traditional forensic disciplines		- Analysis and interpretation of evidence associated with traditional forensic disciplines

The ITWG, an association of nuclear forensic practitioners, has developed a recommendation on the sequencing of techniques to provide the most valuable information as early as possible in the analysis process. This recommendation is based on expert opinion and on experience gathered from three collaborative analytical exercises undertaken by the ITWG. Table I shows the ITWG's recommended sequence of analyses, broken down into techniques that could be performed within 24 hours, one week or two months from the sample's arrival at the designated nuclear forensic laboratory. Some techniques can also be used at a later time, to achieve more precise analytical results using longer measurement times. The use of such timescales to complete material analyses may also guide the expected intervals of reporting results, corresponding to the 24 hours, one week, and two months analytical intervals, depending on the situation. The duration of the characterization process will depend on the workload of the laboratory, the nature of the sample and the requirements of the investigation detailed in the forensic examination plan, but with a goal of completion within two months after receipt of a sample(s).

3.3. *Nuclear Forensic Interpretation*

Once analyses have been performed, it may be necessary to use additional expertise to interpret analytical results and formulate nuclear forensic findings in response to the forensic examination plan. This expertise may need to be obtained from outside the laboratory that performed the measurements.

Nuclear forensic interpretation is the process of comparing and associating sample characteristics with existing information pertaining to types of material, origins and methods of production of nuclear or other radioactive material, or with previous cases involving similar material. Nuclear forensic interpretation provides context, explanations for the analytical results, and the basis of nuclear forensic findings.

Nuclear forensic interpretation involves comparison of the results from the analyses of the sample in question with information on the corresponding characteristics of existing or known materials. In general, a single signature of a material (e.g., an isotopic measurement) is usually not sufficient to identify a specific sample uniquely from known classes of similar materials. Unlike traditional fingerprint examination, for example, it is impractical for nuclear forensics to rely on a single sample-to-sample matching. However, combinations of signatures, such as isotopic measurements, impurities and microstructure, when used together, can provide increased confidence in associating a specific sample with a known class of similar material. The use of signature combinations may also enable exclusion — the conclusion that a specific sample is not connected with known classes of materials — which can also be valuable for nuclear forensic interpretation.

Nuclear forensic analysis and interpretation involve a deductive and iterative process, as depicted in Figure 2. Implementing the analytical plan produces results that can be compared with information on existing or known materials, and such comparisons lead to interpretation, which puts the analytical results into context. The comparative process involving analytical results and known material information is iterative because each successive comparison may provide new information that can identify further analyses or comparisons that in turn may uncover additional signatures that will help to identify the material more precisely. This comparative process may also be deductive because it can be used to progressively exclude particular processes, locations or other origins as possible sources of the material. For example, comparisons of analytical results from seized nuclear material with known production processes may identify likely production processes that could have made the seized material, as well as those processes that could not have made the seized material.

3.4. Nuclear Forensic Findings

Nuclear forensic findings are the products of nuclear forensic analysis and interpretation. These findings may support law enforcement investigations, regulatory inquiries, and policymaking and assist other relevant stakeholders in improving nuclear security and preventing future nuclear security events. The key questions posed in all scenarios are typically the same: what type of material is involved, what is the possible origin of the material, and what were its probable method(s) of production.

In general, confidence in analytical results depends upon three factors: 1) validated methods; 2) certified reference materials; and 3) demonstrated competencies. Use of validated methods ensures that the analysis is suitable for the material and capable of measuring the analyte(s) of interest. The use of certified reference materials ensures that measurements are benchmarked against known and certified values. Validated methods and certified reference materials provide confidence in findings through demonstrating a measure of reliability in the procedures by which they are obtained. The use of demonstrated competencies provides confidence in the individual(s) performing the analyses.

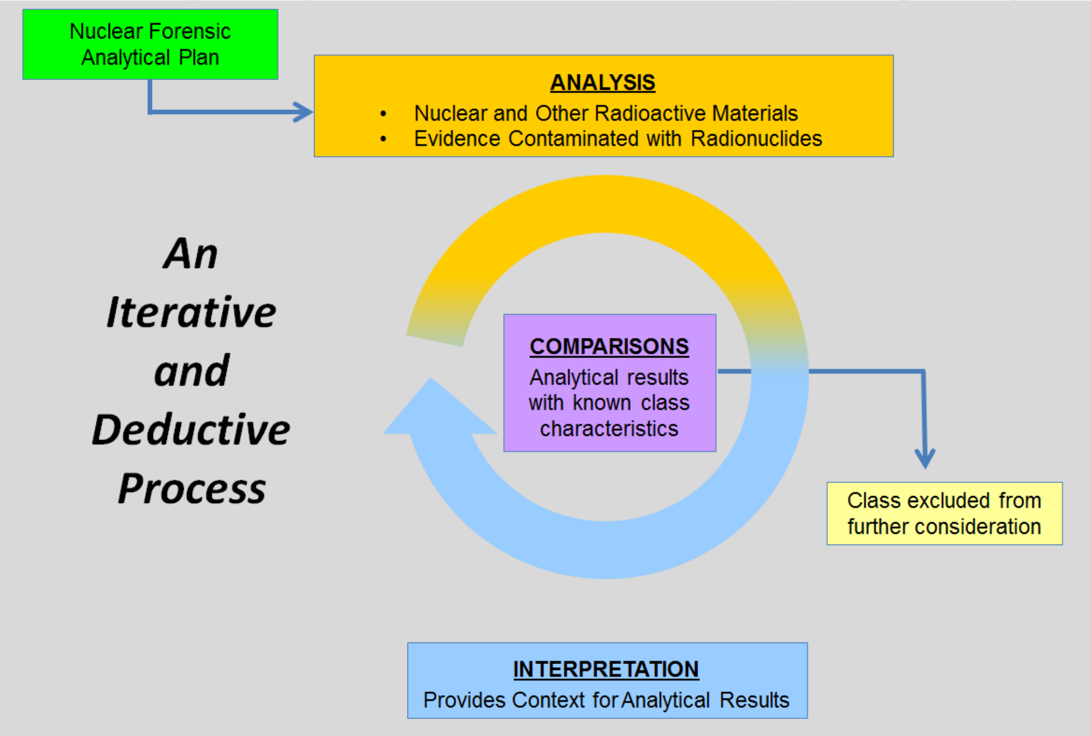

FIGURE 1. Nuclear forensic analysis, comparisons and interpretation: an iterative and deductive process to provide context for analytical results.

All nuclear forensic findings should be communicated in a written report in a timely manner. The reports may be presented in the form of a scientific report or may need to be in a specified standard format required by the national authority or the lead investigative agency.

In the time sensitive environment of a nuclear security event, there may be a need to obtain reliable initial information as rapidly as possible. Nuclear forensic findings will be requested by investigators, as well as decision makers and other officials well before full analysis and interpretation of measurements are completed. Ideally, a method for articulating the confidence levels associated with preliminary reports should be in place. To address information requests from investigators and decision makers, a summary of preliminary nuclear forensic findings should be developed that reports the key findings along with key assumptions, the confidence levels for these findings and any alternative explanations that remain credible in the light of the information available to date.

Given the general need to strengthen the means of conducting nuclear forensic analysis, States are encouraged to share with their counterparts in other States any lessons learned from actual nuclear security events or from the conduct of exercises, where considerations of confidentiality permit.

4. International Cooperation and Assistance

International cooperation and assistance may contribute in advance of, during or following a nuclear security event. The scope of international cooperation and assistance in nuclear forensics includes a range of activities that span raising awareness, research and development, international assistance and capacity building.

A number of international organizations, groups and initiatives promote awareness of the importance of nuclear forensics and provide, on request, various forms of nuclear forensic support. The Global Initiative to Combat Nuclear Terrorism (GICNT), INTERPOL and the ITWG offer various forms of training, guidelines and assistance. States may also choose to cooperate bilaterally or multilaterally in the field of nuclear forensics. In addition, some States have national programmes that can provide support to international partners.

Assistance during the investigation of a nuclear security event may be facilitated through international organizations or through bilateral/multilateral agreements and arrangements. Assistance may include support for evidence collection, optimizing methods of analysis, conducting nuclear forensic analysis, improving confidence in the analyses, collecting data to help in nuclear forensic interpretation or providing other types of information upon request.

As such arrangements involve multiple and complex issues, it is advisable that, within its national response plan, each State defines and includes the arrangements that may be needed in an actual nuclear security event in relation to the provision of or request for international assistance.

5. Nuclear Forensic Capacity Building

Developing and sustaining a nuclear forensic capability is a State's responsibility. Elements such as infrastructure, legal and regulatory frameworks, operations, human capital and specialized equipment and knowledge are critical to an effective nuclear forensic capability. As such, strategies for developing, testing and sustaining nuclear forensic capability and capacity are essential to enabling a suitable response to a nuclear security event. These approaches will include building awareness of nuclear forensics for stakeholders at all levels, appropriate training of existing and future personnel, exercising response actions, designing research and development programmes and effective knowledge management in anticipation of future requirements, and effective education in nuclear science to foster and sustain capabilities.

A key element in developing a State's nuclear forensic capability is awareness of the contribution of nuclear forensics to the State's nuclear security infrastructure. Increasing awareness of nuclear forensics for all stakeholders within the State can help to:

- Promote understanding of nuclear forensics among facilitators and developers of a nuclear forensic capability;
- Clarify roles and responsibilities;
- Increase knowledge of nuclear forensics applied to law enforcement investigations and nuclear security vulnerability assessments;
- Encourage the use of common terminology among different organizations and disciplines.

A State is responsible for ensuring that its national nuclear security infrastructure is supported by appropriately trained personnel. Technical training and human capital development should encompass the complexities of nuclear forensics as a component of preventive measures and as a capability for response. Training is an essential component of a sustainable programme in nuclear forensics by providing essential information on the requirements of an investigation into a nuclear security event, recommended methods for analysis and interpretation, and the role of nuclear forensics in a State's nuclear security infrastructure. Training may also be supported through international nuclear forensics partnerships.

An effective nuclear forensic capability depends upon collaboration between science and technology organizations, law enforcement agencies and other government agencies both nationally and internationally. The development of shared collaboration and cooperation processes and mechanisms is essential for the continued development of nuclear forensic capabilities. The planning, execution and review of nuclear forensic exercises is a key component of bolstering this capability.

Education and expertise development are key elements of an effective, sustainable nuclear forensic capability. A State should have access to technical staff possessing expertise spanning the nuclear and geochemical scientific disciplines most relevant to nuclear forensics. To ensure a sufficient nuclear forensics workforce, it will be critical to develop the next generation of scientists by creating an academic pathway from undergraduate to post-doctorate study in areas such as radiochemistry, nuclear engineering and physics, isotope geochemistry, materials science and analytical chemistry.

Nuclear forensics is a developing 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 the signatures can be accurately measured [3].

Engaging in research and development that promotes the science of nuclear and radioactive material analysis can maintain and improve a national nuclear forensic capability. Additionally, peer review through the scientific process promotes acceptance of and confidence in techniques for nuclear or other radioactive materials analysis and interpretation. Acceptance by the scientific community allows these tools to be adopted for use during an actual nuclear forensic examination.

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South Africa's Nuclear Forensics Response Plan Step 1 - In Support of Nuclear Security Investigations

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Abstract. In South Africa, the nuclear forensics approach and its functions as hosted and managed by Necsa, in support of any nuclear security investigations, start from the incident scene when the nuclear or radioactive material (that is out of regulatory control) is being handled and handed over to Necsa Emergency Control Centre by the South African law enforcement Agencies in the presence of NOMS Department official. The main objective for this approach is to increase the credibility status of the chain of custody on the handling of the material during incident (crime) scene management process (for both nuclear forensics and traditional forensic evidence collection) and its transportation from the scene to the suitable storage facility at Necsa. Aspects to be looked into during the response process include interactions between law enforcement agencies, Necsa relevant departments and the National Nuclear Regulator of South Africa. This paper focuses on the entire whole response process and associated prior arrangements in order to show and provide a set of requirements attached to the material and also the scope of critical relevant technical and law enforcement information to be acquired by all parties involved and participating in the nuclear/radiological incident or event response process before the material is authorized for storage at a suitably qualified Necsa's nuclear forensics' dedicated storage facility on Pelindaba site.

1. Background Information

South Africa abandoned its nuclear weapons program, joined the Treaty on the Non-Proliferation of Nuclear Weapons (NPT) as a non-nuclear weapon state in 1991 **[4],** and allowed international inspections of its former nuclear weapons program. Since abandoning its nuclear weapons program, South Africa has emerged as a champion of both global nuclear non-proliferation and equal access to peaceful nuclear energy. However, South Africa's remaining dual-use nuclear capabilities have made it both a possible exporter of nuclear technology and know-how, and a target for state and non-state actors seeking assistance for nuclear materials handling, protection and storage facilities.

South Africa is a producer, possessor, and exporter of nuclear materials and technologies for peaceful purposes. Radioactive/nuclear materials find uses in various sectors of this country's economy and these include the mining industry, health sector, research and development and energy sector. Necsa operates the 20 MWt Safari-1 reactors at its Pelindaba nuclear research centre. Safari-1 is the main supplier of medical radioisotopes in Africa and can supply up to 25% of the world's molybdenum-99 needs. By 2009 the reactor was converted from using HEU to low enriched uranium (LEU) fuel **[1],** and conversion of the targets used for radioisotope production from HEU to LEU was achieved in 2010.

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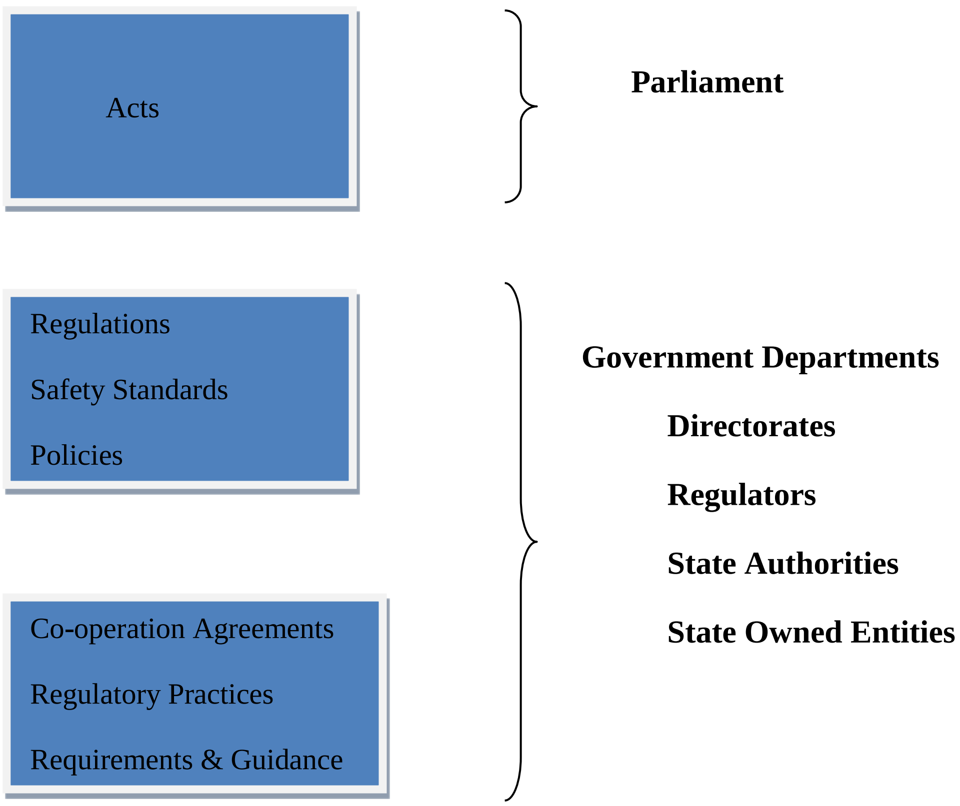
Uranium production in South Africa has generally been a by-product of gold or copper mining. In 1951, a company was formed to exploit the uranium-rich slurries from gold mining and in 1967 this function was taken over by Nuclear Fuels Corporation of South Africa (Nufcor), which in 1998 became a subsidiary of AngloGold Ltd. It produces over 600 tonnes of U_3O_8 per year from uranium slurries trucked in from various gold mines and Palaborwa copper mine. Eskom, the South African electricity utility, operates two nuclear power reactor units, that is Koeberg 1 and 2 respectively, which together produce 1,800 MWe.

Major security concerns for radioactive materials usage include theft of radioactive sources, illicit trafficking in nuclear and radioactive material, etc. It should be noted that the safety and security of these materials is guaranteed through an effective national regulatory control infrastructure. However, nuclear or radioactive materials that is out of regulatory control form the integral part of the nuclear terrorism or crime threat across the country and also in other parts of the Southern African region.

2. National Competences, Statutory and Regulatory Framework

Although the prevention of nuclear and radiological terrorism is a global issue or initiative, the establishment of an efficient and well defined system for combating illicit nuclear material is understood to be a national responsibility. In this regard, the Republic of South Africa has an effective nuclear regulatory framework which is derived from a set of well detailed comprehensive legislation which include Nuclear Energy Policy of 2008, Nuclear Energy Act, 1999 (Act 46 of 1999) and the National Nuclear Regulatory Act, 1999 (Act 47 of 1999). Other related legislation includes Non-Proliferation of Weapons of Mass Destruction Act, 1993 (Act 87 of 1993); National Radioactive Waste Disposal Institute Act, 2008 (Act 53 of 2008); the Hazardous Substances Act, 1973 (Act 15 of 1973); National Strategic Intelligence Act, 1994 (Act 39 of 1994); National Key Points Act, 1980 (Act 102 of 1980); Disaster Management Act, 2002, (Act 57 of 2002); and the Protection of Constitutional Democracy Against Terrorist and Related Activities Act, 2004 (Act No. 33 of 2004).

RSA Regulatory Framework



3. Nuclear Forensics in Support of National Nuclear Security

Ministerial roles and responsibilities are integrated into a national nuclear security response plan, for prevention and detection of and response to theft, sabotage, unauthorized access, illegal transfer or other malicious acts involving nuclear material, other radioactive substances or their associated facilities. Role players include Department of energy as custodian of the deployed Nuclear Security plan, National Nuclear regulator, Department of Health, State Security Agency, South African Police service and Justice, Defence, IAEA guidelines, etc. In addition, nuclear forensics is now one component in a support of on-going national nuclear security investigations. Nuclear forensic science (used in this paper as Nuclear Forensics) aims at providing clues on nuclear or other radioactive material which are out of regulatory controls or involved in illicit trafficking incidents. Credible nuclear forensics can only be achieved if all evidence and case history are preserved and made available for data interpretation and source attribution. Hence, in the context of the South African nuclear security events or incidents investigations, nuclear forensics investigations have to start at the ‘crime scene’. As a consequence, a comprehensive response plan is required, clearly describing the responsibilities of the authorities involved and the roles of the individual actors in the event(s).

4. Nuclear Forensic Capacity Building

Since nuclear forensics approach and its functions have become increasingly important tools in the fight against the illicit trafficking in nuclear and radiological materials, The South African government has committed itself to develop the country’s nuclear forensics capability in order to support the prevention, investigations and response to nuclear security events. Nuclear forensics is established to be a key technical capability of the national response plan to address nuclear and radioactive material out of regulatory control. To achieve this, South Africa is in a process of finalising the establishment of national nuclear forensics capabilities which include national nuclear forensics laboratory to analyse the evidence contaminated with radioactive material and establishing the procedures to respond to nuclear security events including those for the collection and transportation of evidence linked to nuclear or radioactive material. The South African Nuclear Energy Corporation Limited (Necsa) is authorized to fulfil the commitments of nuclear forensics since it acts as the National Authority (National Key Point in nuclear) and contact point for the following IAEA conventions:

- Convention on early notification of a nuclear accident
- Convention on assistance in the case of a nuclear accident or radiological emergency

Responding plan to these incidents involves many organizations, (of highly specialized law-enforcement and technical expertise) which may include agencies such as police (criminal investigations), intelligence unit, prosecuting authorities, national nuclear forensics laboratories, nuclear regulatory authorities, etc. Hence the plan should be able to describe the roles and responsibilities of the relevant national agencies and authorities involved in response situation to these incidents. Therefore in order to be effective, the response plan to a call must be well coordinated to preserve the evidence from contamination [2] which should also provide guidance for responding to this kind of incidents when nuclear forensics investigations are required.

Nuclear incidents (nuclear related illicit trafficking) have been defined as incidents which involve unauthorized acquisition, provision, possession, use, transfer or disposal of nuclear materials with or without crossing international borders including thwarted and unsuccessful events [3]. This paper focuses on the entire response process and associated prior arrangements in order to show and provide a set of requirements attached to the material. The scope of critical and law enforcement information to be acquired by all parties involved and participating in the nuclear/radiological incident or event should be clear to all parties to avoid confusion or conflicting ideas as these may also pose a contributing factor and some implication on the credibility of overall chain of custody pertaining to the event itself.

4.1. Response

The response team is led by any law enforcement agency, (Fig. 1.). In case of a suspected nuclear /radiological incident, or there is an object found or seized which is assumed to be radioactive/nuclear material or has been contaminated by such materials the police or any law enforcement involved, after conducting initial assessment whose results will determine whether a nuclear event has occurred or not, must prevent individuals from accessing the area or object (crime scene). The police should be informed in parallel as they have the detective administrative action powers against crimes concerning nuclear and radioactive materials that are out of regulatory control.

The notified crime investigating unit (in this case being the SAPS Bomb Disposal Explosive Section) will report the incident to the Necsa ECC, which is in principle the first contact point on all incidents involving illicit radioactive and nuclear materials brought into Necsa site. Necsa ECC representatives are on a call 24 hours per day and are well trained and dedicated to technically assess the incident using dedicated tools to detect radiation levels, quantitative measures to a certain extent.

If the incident is confirmed to be a nuclear event ECC assumes the responsibility of attending/responding to the incident to ensure that any radiation protection measures are in place to control and protect the public and the response teams. They will also initiate the process of sending relevant experts to the scene for operations and collection of the material. In addition to notifying its own responsible units, ECC will notify Nuclear Obligations Management Services (NOMS) department (In the event that the material is serving as criminal evidence) before initiating the process of sending relevant RPO/RPS to the scene for operations and collections. Following this notification NOMS then informs the following departments:

- Security Services Department of Necsa (in the case in which the material is brought into Necsa site)
- The National Nuclear Regulator (NNR) through Safety & Licensing Department of Necsa
- The South African Nuclear Safeguards
- Nuclear liabilities management Department of Necsa
- National intelligence agency through Necsa Security Services Department (Threat assessment)

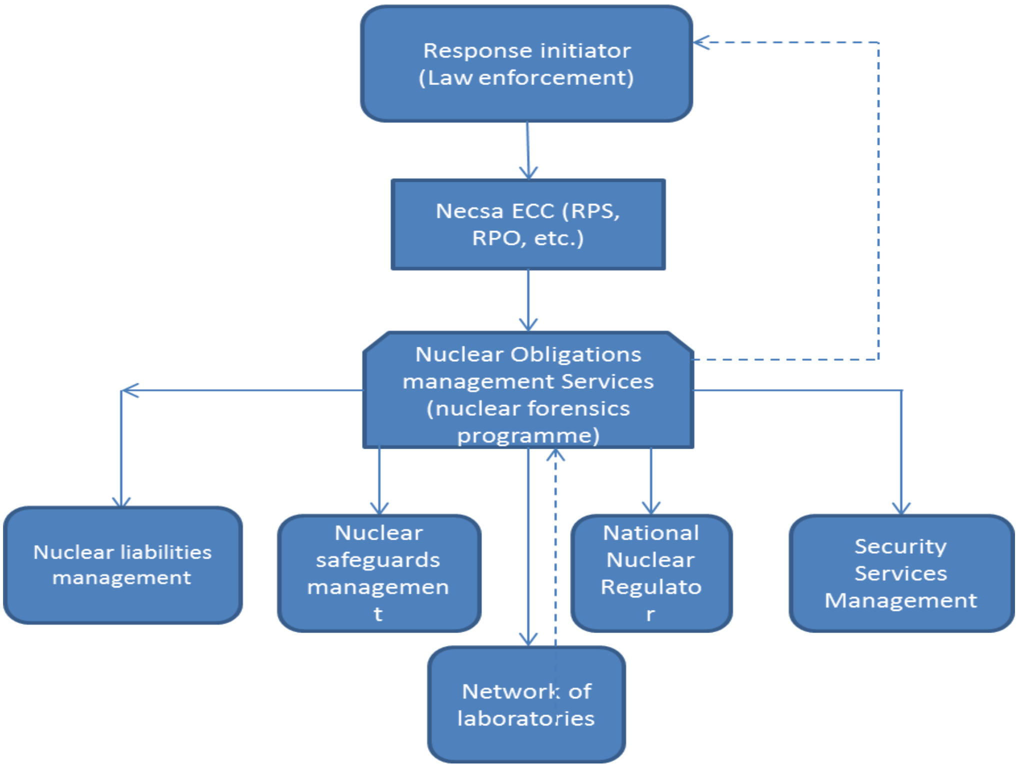


Figure 1. The NOMS response hierarchical communication model structure to a nuclear or radioactive event in South Africa.

<u>Legend</u>

: Event call & communication line.
: Dotted line: Official Results & Reports communication line.

The NOMS Department of Necsa is responsible for, amongst other nuclear forensics roles, the evidence collection and management, chain of custody management, nuclear material sampling, required analyses, results interpretation, full report preparation and submit reports to the South African Police Services (SAPS), building the National Nuclear Forensics database (library), submit information to Nuclear Safeguards Department for reporting to the IAEA (on the IAEA's ITDB).

For consistent and credible chain of custody information on the evidence of the event, the Necsa ECC and NOMS Department representatives are required to attend or react to a police response call out to ensure the proper handling and collection of the sample/material from the environment to the radiological controlled areas (facilities) at Necsa.

4.2. What happens at the nuclear event scene

At the scene, all conventional safety measures, radiological protection measures and proper handling of the materials to preserve evidence credibility for both nuclear forensics and traditional forensic investigations are critical steps to overrun the event scene management. As a result the following steps will be followed to ensure that compliance to the above critical steps is met:

Collection of traditional forensic evidence and evidence contaminated with radioactive material will be performed in a manner consistent with radiological safety practices.

If the experts (RPO and RPS) determine that it is probable that the found or seized material is radioactive, then a preliminary inventory will be taken. A Pro-forma form (Annexure A) will be issued to all officials who will be attending to the response call-out and collect the material, determining the quantity of the material, and an inspection made of the packaging, and the materials collected. Officials who will attend to the scene from Necsa include ECC (RPO/RPS), NOMSD, NLM. They will fill in the form and sign it for handing the material from the law enforcement agencies to Necsa. Pro-forma form (Annexure A) will record material information such as the type of material and its dose rates, visual inspection information (package type, contents colour, material form (powder, liquid, solid etc.).

In the event that the material is serving as criminal evidence, the regulations governing the handling and recording of objects seized in criminal proceedings will be observed when taking samples of the material, as well as during the testing and storing of such.

The material will then be transported in a specialized transport to Necsa storage facility (currently temporary storage facility of NLM Department or any other suitable facility within Necsa) designated for this purpose by Necsa ECC, NOMS Department in consultation with NLM Department or any other responsible Department as the facility owner.

4.3. Handling of evidence contaminated with radioactive material on Necsa site

Upon receiving the illicit nuclear or radioactive material on Necsa site, NOMS assumes interim ownership and control over the material for the sake of internal Necsa chain of custody credibility and also coordinates the process of attaining all the necessary and relevant information about the material. It is the responsibility of NOMS department to make the relavant departments aware that the material is on site and subsequently provides a brief description of the activities to be performed by each department. The NOMS performs or does screening measurements (Non-Destructive Analysis or Assay - NDA) on every material in question before submitting samples for the destructive analysis (DA) in the laboratory. The report, based on the NDA (screening) results with a short description on the intepretation of the results, is then sent over to relevant Law Enforcement Agencies, National Nuclear Regulator, Nuclear Safeguards and lastly most importantly populate our national Nuclear forensics database with the data/information.

4.4. Security Services

The working principle for the nuclear security event material transported to Necsa for storage and nuclear forensic analysis is that, at the Necsa site entry point (gate) , the security services department official shall aknowledge by signing the pro-forma form that the material has been taken into Necsa. And also if required, assist with the escort services in cases where SAPS officilas are transporting the material on site. Following all relevant officials signatures, NOMS official will accept the material together with Pro-forma to the storage facility and sign for the interim ownership and control of the material.

4.5. Nuclear Safeguards Management department

The Nuclear Safeguards Department will be informed of the material as usual and Safeguards Officials will perform the following activities for their records:

- Preliminary NDA measurements in order to characterize the material
- Record the material information its system for control and reporting to IAEA. Although Safeguards Department is primarily not resposnible and directly involved in the investigaations of the nuclear security events, all findings related to the events are ussually submitted to them for updating the IAEA.

4.6. Nuclear Liabilities Management (NLM)

This is the main Necsa' Storage facilities Department. Due to Necsa not having a special storage facility specifically for the nuclear forensics material or samples, the NLM Department licensed storage facilities are used temporarily as interim storage facilities to keep some nuclear security events material. Therefore since the storage facility is falling under Necsa's NLM Department then the facility manager or any assignee shall sign the Pro-Forma form indicating that the materail has been stored in that facillity under the name of MOMS department.

5. International Cooperation in Combating Illicit Trafficking

For South Africa to be able to develop credible and advance capabilities in nuclear forensics there should be co-operation and collaboration initiatives. As a key nuclear R&D organization in South Africa, Necsa and the USA national laboratories (Lawrence Livermore National Laboratory and Los Alamos National Laboratory (LLNL & LANL) have entered into and signed a Memorandum of Understanding (MOU) in 2011 for collaboration (work together) in the field of nuclear forensics. The collaboration aims mainly for the establishment of nuclear forensics capabilities in South Africa which include the development of a national nuclear forensics laboratory and the national nuclear forensics database (library).

In this regard, a national nuclear forensics laboratory (Pic. a), which will include a nuclear security response training component, is at a final stage of construction and thereby entering the commissioning stage. The laboratory and the nuclear forensics associated training achievements are the result of the existing collaboration between Necsa (The South Africa's Nuclear Energy Corporation) and the LLNL-LANL of the US DOE. Several training phases have already been undertaken, such as nuclear forensics analysis training course in the US at LLNL in 2012.

South African representatives participated in numerous training courses, workshops, meetings and conferences that were funded and organized by US government and the IAEA.

South Africa is a Participating State in the IAEA's Incident and Illicit Trafficking Database (ITDB).

As a reflection of good international relations and co-operation South Africa has, the IAEA and the US Department of Energy donated the nuclear security equipment's (Figure. b) that were utilized during Major public events from 2010 – 2013 on the effort of strengthening the nuclear security system in the country.

Picture a: Part of Necsa's new nuclear forensics laboratory under construction.

Picture b: Some of the equipment donated by IAEA & US DOE to South Africa in 2010.

6. Experience on Illicit Trafficking of Nuclear and or Radioactive Material

Very few illicit trafficking incidents reported in South Africa were associated with criminal cases under SAPS custody. The following are incidents handled by NOMS-NFP for nuclear forensic analysis.

- On the 14th October 2011 the material was brought to the Necsa site by the police official. This was a 5L bottle that contained yellow sediment and a clear supernatant liquid. The bottle was labelled as uranium trioxide. Analysis confirmed it to be uranium material with 11.52 g U-235.

- On Tuesday 10 Jan 2012 two containers containing uranium were confiscated in Sandton area. These weighed about 1.2kg and 0.5kg respectively. On Friday 13 Jan 2012 one container containing uranium was confiscated again in Sandton area and delivered to Necsa for NFP, this weighed about 0.8 kg.

- On 14 November 2013 South African Police Services arrested two men on a suspicion of possessing uranium and some tablets which were stored (packaged) in a plastic bag. The package was sent to Necsa for analysis. On receiving the material, Non Destructive Analysis (NDA) screening has indicated that the material consisted of depleted uranium with the radiation dose of approximately 0.58μSv.

7. Conclusions

South Africa continues to enhance measures for strengthening the national and regional nuclear security regimes in the country and nearby countries respectively by developing and executing the national nuclear forensics capabilities. All these capabilities are grouped together under a National Nuclear Forensics Programme within the NOMS Department of Necsa (NOMS-NFP). The Nuclear Forensics Laboratory and the National Nuclear Forensics Library (Database) are the first two technical capabilities to be developed through our co-operation and collaboration with the IAEA and the US DOE National Nuclear Security Agency (NNSA) which includes LLNL and LANL. The IAEA together with the US Department of State and the US DOE's NNSA (LLNL and LANL) have been and are still playing a very critical role in supporting our efforts towards establishing the national nuclear forensics capabilities and the associated international participation in nuclear forensics training, workshops, meetings and conferences which form a significant part of international co-operation in general.

ANNEXTURE A.

	A. Safety & Licensing Department (Necsa ECC)		
1.	Purpose of a Call-Out		Remarks
2.	To: Name of Necsa's S&LD (ECC) Official receiving a Call-Out:		Signature:
3.	From: Name of a Caller/origin (eg, Mr. Yes Goodman of SAPS):		
4.	Call-Out Date & Time:		
5.	Date for informing Necsa NOMS Official about Incident:		
6.	Necsa RPS/RPO Names sent to the Incident/Event		
	B. Necsa NOMS Department (Compliance Support Section)		
1.	Name of NOMS Official informed about the call-out & incident:		Signature:
2.	Necsa NOMS Official accompanying RPS/RPO (optional):		
	C. Information Obtained on the Incident/Event Scene **Date:**		
1.	**Observations by Visual Inspection**	Police Case No:	
a.	Describe container & its contents (color, size, etc.):		
b.	Form/state of material (powder, solid, liquid, crystals, etc):		
2.	**Measurements Taken (In field Screening)**		
a.	Radioactivity (Bq) or Radiation dose (uSv) levels or Dose rates (uSv/hr) from the package (material/source):		
b.	Identification of material/source (eg. U, Pu, Co, Ir, etc):		
c.	Material/source Isotopic state (eg, U^{nat}, U^{235}, Co^{60} , Ir^{192}, etc):		
d.	Application category of material/source (eg, Industrial, Medical, etc):		
3.	**Process for Material Handing-Over to Necsa**	Date:	
a.	From: Name of Law-Enforcement Official: Explosives Section:		Signature:
b.	Circle or Cross a Phase showing information needed from Necsa NOMS Dept by the Law-Enforcement agency for purpose of prosecution process:	**Phase 1:** Only Screening Results from NDA Techniques **Phase 2:** Screening + Full Material Characterizatio, Results from DA Techniques	
c.	Date (Deadline) for Law-Enforcement agency to get the information/report:		
d.	To: Name of Necsa Official accepting the Material from Law-enforcement agency Official:		Signature:
	D. Materials/Sources Arrivals at Necsa for Storage		
1.	Name of Security Official (Access control)	Name: Date:	Signature:
2.	Name of NOMS Official Receiving Material/Source	Name: Date:	Signature:
3.	Name of Necsa Official (eg, NLM or NOMS or other Necsa Department's Official) Authorizing Storage of the Material/Source under NOMS Department's name & Supervision	Name: Date:	Signature:
4.	Name of NOMS Official certifying that Material/Source is stored in the facility under NOMS Department's name and Supervision.	Name: Date:	Signature:
	NB: Access to the storage facility and the Materials/Sources under Law-Enforcement processes shall be through NOMS Department's permission and supervision.		

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Lessons Learned from Moleta Incident

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Abstract. Moleta is a small region in Upper Nile State in South of Sudan, very close to Palouge oil base ,with distance about more than 300 Km from the capital "Khartoum". A projector that contains a radioactive source (Ir- 192) of about 1.9 TBq (51.35 Ci), belongs to a Sudanese NDT company was been stolen due to poor security measures. Mobile Experts Team (MET) from the regulatory body flew to the region after one day from the case, immediate meeting was held with security and HSE personnel of Palouge and Moleta regions, as a result un action plan was planned to manage the situation and mitigate the consequences , the plan depends on surveying using detection instruments, informing the public through their local language (*Dennka*), beside dissemination of posters contain other source photo (similar to the stolen source) , more over FM Mirraya Radio was used to inform the public about the case, in addition to that the people movement was supervised in the exist and entry to the region beside that the doctor in the main hospital was been informed about the symptoms of exposed to radiation. After five searching days the source was found by truck driver not far from Moleta region. Based on the recommendation from the MET, more physical protection barriers were implemented to enhance the security levels around the radioactive sources storage. Another round of field works was conducted by the MET to collect the posters around the region in order to get the public confident, safe and secure.

Despite the hard effective efforts that has been performed by the MET, but, it doesn't include an expert from criminal evidence directorate in order to supervise the crime scene area to take the finger prints.

1. Practical experience with storage from "*pit*" type

According to the experiences gained from the case, the *"pit*" storage are easily to be broken, and that is due to the poor design measures of the storage which are weak and didn't provide any mode of advanced physical protection such; i.e. defense in depth, so that, it didn't played any role against possible access to the stored radioactive material and thus; the intension of sabotage, steel, damage and terrorism activities against the public or to the environment are expected. Thus; more arrangements are taken, fence, container fixed to the ground with concrete, door locked with special design to delay possible access are performed.

2. The role of information dissemination in the intervention process

As one of the important element; dissemination of information and public communication rounds among peoples as field work has been conducted to convey information about the case are assumed as stone corner in the intervention process, which take place in form of four monitoring team with radiation detector, this take four days, where general public ,army personnel ,police personnel , security personnel and petroleum companies employees had been informed about the harm and potential risks of radiation exposure, through posted printed papers contain a photo of radiation source (similar to the stolen source) was disseminate in all areas around the location where the radioactive

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source has been stolen , also public have been instructed through their local language “*Denkka*” using loud speakers and FM “*Mirraya*” radio , using a very simple words, that; a dangerous ,harmful and strong radioactive sources had been stolen and could causes risk to you and your families . Moreover; local transport has been monitored, and posted with the printed photo in order to inform others in their travel, in case, the source is get out of the incident location and their passengers has been informed about the associated risk of the radioactive source. In addition to that; the official employees i.e; army, security and police who supervised the entry and exit of the location, has been informed about the source size, shape and weight, if they observed anything suspected .also the only one medical doctor was instructed to contact the MET or the representative of the official employees if he receive a patient his diagnosis shown a clear radiation symptoms.

3. Readiness for army, security and police employees

The support group from the participated bodies in the intervention; i.e. police, Sudan and South Sudan’s joint-army and petroleum security has to be trained about how to act, in case they found the stolen radioactive source, thus; they have to be train, practice, and exercise different scenarios and arrangements with regard to response to radiological emergency or provision of nuclear security specialists, if force is needed for the retrieval process.

Thus, when the radioactive source has been founded, some technical measures have to be conducted; for the source; e.g. verification of the source serial number, check that the source is still inside the container by measuring the dose rate, no failure in the source lock or no attempting to open or damage the source container, also, if its possible, fingers print or blood could be taken as samples for nuclear forensic. In addition to that, suitable arrangements and procedures has to be performed for safe transportation to the re-constructed storage; i.e. car marked with radiation sign, security guard, radiation detector and radiation worker or the company’s RPO.

4. The role of surrounding atmosphere and stress factor in the case management:

From the area study you have to take in your consideration the surrounding circumstances with the case you manage, taking in your mind the security condition in the case area are unstable, and that implies more efforts and stress on the regulatory body personnel, which would be reflected on their performance by affecting their ways of thinking, and their assessing and evaluation of the case which would result in taking right decisions and quick actions.

Although, you have to prepare yourself for receiving false communication when they are waiting for any contact or information about the stolen radioactive source ,because the calling one could be mad, joking, lie or eager to collect money which provided by the petroleum company as prize for the source founder.

In addition to that, when you work in a team, and act as team leader or member, by the end of any searching day, you need to send written or verbal report to the security committee in the region, which would be busy, a way, drank or didn’t take the case as serious as you consider. All these factors put more stress on the MET and they needs to be trained on the different scenarios about how to overcome those difficulties.

5. Meetings and logistical support and good administration

It’s very important to held meetings with different partners; i.e. security personnel, HSE employees and the contractors or sub-contractors managers, in order to listen to their information and observation about the case and the current situation in the case area, through formal report or oral discussion, gathered information would be necessary for developing suitable action plans and that leads to quick response. Although, meetings is a good opportunity to define responsibilities and tasks of other intervention parts and to form teams beside arrangement for logistical support; e.g. cars, security, food, equipment (survey meters) … etc. Although, meetings are important; but, meeting time should be minimized as possible for time consuming.

6. Get the Public trust and confident after the case:

The hard efforts that has been conducted during the survey time, information dissemination and public communication is not enough, a very important task has to be performed, so another round of public communication is needed, in order to collect back the posted posters and to inform the public, police, army and companies employees, that, the stolen radioactive source has been found in safe status, the situation is safe for them and the emergency preparedness situation is ended. In the same way it's very important to communicate with other employees within different disciplines in the petroleum company about radiation and its safe application and with details on the case and how it had been managed, in order to get them trusted, confidant and safe and secure.

7. Conclusion and recommendations:

- The National Nuclear Security Committee (NNSC) that has been formed in 2003 by the decision of the Minister of Science and Technology needs to be re-engineered and activated.

- The National Emergency Preparedness and Response Committee (NEPRC), which has been formed in 2007 by the Minister of Interior, also need to be re-engineered and activated.

- National response action plan needs to be developed containing all the expected scenarios.

- Currently, effort, time and resources are made available in order to build the human resources in the field of nuclear forensic with national and international assistance through IAEA/ AFRA TC-project.

- Relevant institutions, other regulators and relevant partners that have relation to regulatory processes, nuclear security and emergency preparedness and response should be trained on radiation, radiation applications, radiation protection and the associated risks and consequences.

- Storage from "*pit*" type is not any more secure storage for radioactive material.

- Information dissemination and public communication is very effective and efficient tool in solving such case, if it is implemented with careful attention and good cooperation with other parties.

- The radiation detectors are not always the only one tool to find out radioactive materials**.**

- It's very important to keep the source special key with the company's RSO or his technologists, in order to avoid the intention to open it.

- Qualification, education and expertise are necessary for regulators to dealing with this type of cases, taken in account managerial, technical and personal issues.

- Regulators should be able to work with team from different background and interpersonality.

- Important of coordination and cooperation between different parts in order to ensure proper defining of responsibilities and tasks.

- The convention of early notification about radiation accident has been implemented by send a detailed report to the IAEA.

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Opportunity and Challenge of Nuclear Forensics in Indonesia

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Abstract. It is important for Indonesia to prevent, detect and response to incidents involving the illicit trafficking of nuclear materials and other radioactive sources. More importantly, Indonesia is a part of the global community in combating nuclear terrorism. Nuclear forensics is one element of nuclear security regime that should be viewed as the opportunity and challenge for BAPETEN and/or Indonesia.

The objectives are to overview the opportunity and challenge of nuclear forensics in Indonesia. Indonesia will take part on Enhancement of a Global Nuclear Security Framework Program and Risk Reduction and Security Improvement Program in nuclear security plan 2014-2017. Also Indonesia will organise activities under these programs. Indonesia has an intention to apply nuclear forensics for responding nuclear security event and nuclear security threat. Indonesia assumes nuclear forensics is a powerful tool to identify the origin of the seized nuclear material and provide feedback on potential security weaknesses. But, Indonesia does not have their own nuclear forensic capabilities, lack of quality human resources and sustainability of knowledge management in nuclear forensics. Opportunity of Nuclear Forensics in Indonesia will be beneficial for law enforcement; uses systematic approach for analysis and attribution; benefits from reference data; provides clues on the origin of the material; assures sustainability in combating illicit trafficking; calls for International cooperation; and methodology applicable in other areas. While the challenges are the methods "environmental sampling", i.e. the collection of particles within (or outside) nuclear facilities using swipe sampling, the need for laboratory analysis facilities and new technology; the need for quality of human resources; attribution process; knowledge management; nuclear forensics is an important part of nuclear security regime in Indonesia; experience on inspection and law enforcement in nuclear energy utilisation are the ways of controlling and enforcing nuclear security implementation in Indonesia as parts of nuclear security infrastructure has to be manage at the best and maintained their qualities. In conclusions, nuclear forensics to be one of nuclear security infrastructure that has to be planned and strengthened in order to respond to nuclear security events in Indonesia. Also, to develop international cooperation in the area of nuclear forensics through IAEA and relevan institutions is an important matter for Indonesia.

1. Introduction

Indonesia concerned with the physical protection of nuclear material and nuclear installations, nuclear material accountancy, detection and response to illicit nuclear trafficking, the security and safety of radioactive sources, emergency response measures, including pre-emergency, and the promotion of adherence to relevant international instruments.

It is important for Indonesia to prevent, detect and response to incidents involving the illicit trafficking of nuclear materials and other radioactive sources. Indonesia itself is the victim of several terrorist bombings, and certainly it is unthinkable if the terrorist have had the access to such dangerous materials, such as nuclear material. Currently, Indonesia operates 9 international airports and 20 international seaports. it is necessary for us to ensure that we can effectively reduce the risk of the smuggling of nuclear materials and radioactive sources in these international gateways.

More importantly, Indonesia is a part of the global community in combating nuclear terrorism. As our president mentioned during the Second Nuclear Security Summit in Seoul early 2012, Indonesia fully supports international cooperation to enhance peace and security in the world.

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Indonesia, in this case BAPETEN other relevan institutions have the responsibility for combating illicit trafficking and the inadvertent movements of radioactive material. Nuclear forensics is one element of nuclear security regime that should be viewed as the opportunity and challenge for BAPETEN and/or Indonesia.

2. Objectives

The objectives are to overview the opportunity and challenge of nuclear forensics in Indonesia

3. Methods

Methods used are SWOT analysis and study of literatures. In SWOT analysis, we identify strenght, weaknesses, opprortunities, and threats. The methodology of is descriptive analytic, namely to identify opportunity and challenge of nuclear forensics in Indonesia based on the current status.

4. Results and Discussions

4.1. From Nuclear Security Plan 2010-2013 to Nuclear Security Plan 2014-2017

It has been mentioned in Nuclear Security Plan 2010-2013 [1] that one of activities in contributing to the Enhancement of a Global Nuclear Security Framework Program is completing and considering options for further broadening the participation in ongoing and new CRPs aimed at developing improved, user-friendly and effective radiation detection instrument, for risk methodology development and for nuclear forensics.

Also, in that plan, one of activities in Risk Reduction and Security Improvement Program is supporting the development of nuclear forensics capabilities and making such capacity available to all States.

Development of nuclear forensics capabilities for Indonesia is a matter of concern. Author believes that capacity on nuclear forensics has to be enhanced in order to build a better nuclear security infrastructure. So, author hopes that these programs and activities could be sustainably continued in nuclear security plan 2014-2017 [2]. Indonesia will take part on these programs. Also Indonesia will organise activities under these programs.

4.2. The SWOT Analysis

SWOT analysis is a tool to identify the strenghts, weaknesses, opportunities and challenges on nuclear forensics in Indonesia. Strenght and weaknesses are internal factors. While external factors are opportunities and challenges. In order to overcome threats then we have to see them as challenges (Threats Challenges). Table 1 shows nuclear forensics in Indonesia that has been mapped into SWOT analysis.Table 1. The map of SWOT Analysis of Nuclear Forensics in Indonesia

Strength	Weaknesses
1. Indonesia has an intention to apply nuclear forensics for responding nuclear security event and nuclear security threat. 2. Indonesia assumes Nuclear forensics is a powerful tool.	1. No capability on nuclear forensics. 2. Indonesia concerned with national nuclear security matters 3. Lack of quality human resources.
Opportunities	**Threats**
1. Nuclear forensic science is closely related to the phenomenon of illicit trafficking, nuclear security and nuclear safeguards. A border crossing threat is associated with it, hence calling for an internationally coordinated response. 2. to establish broad international cooperation appears highly recommendable in view of the threats of nuclear terrorism, which is unavoidably linked to illicit trafficking of nuclear material.	1. Terrorists attacks/nuclear terrorism 2. Border crossing threats, illicit trafficking, orphan sources and nuclear security at major public event. 3. The exchange of information on nuclear materials as well as on analytical methodologies is often restricted, due to commercial sensitivities and for national security reasons.

4.2.1. Strength

Indonesia has an intention to apply nuclear forensics for responding nuclear security event and nuclear security threat. Nuclear security event is an event that has potential or actual implications for nuclear security that must be addressed. Nuclear security threat means a person or group of persons with motivation,intention, and capability to commit criminal or intentional unauthorized acts involving or directed at nuclear material, other radioactive material, associated facilities or associated activities or other acts determined by the State to have an adverse impact on nuclear security.

Indonesia assumes nuclear forensics is a powerful tool to identify the origin of the seized nuclear material and provide feedback on potential security weaknesses. Nuclear forensics is the analysis of intercepted illicit nuclear or radioactive material and any associated material to provide evidence for nuclear attribution. The goal of nuclear analysis is to identify forensic indicators in interdicted nuclear and radiological samples or the surrounding environment, e.g. the container or transport vehicle. These indicators arise from known relationships between material characteristics and process history [3]. Thus, nuclear forensic analysis includes the characterization of the material and correlation with its production history. The purpose of the nuclear security regime is to prevent, detect and respond to nuclear security events (e.g. illicit trafficking of nuclear material or a nuclear terrorism attack). Nuclear forensic analysis is a key technical capability that utilises signatures inherent to nuclear or other radioactive material to provide information on its source, production and history. It can be used as part of the response to the nuclear security event, as well as to help prevent it.

4.2.2. Weaknesses

(1) Indonesia does not have their own nuclear forensic capabilities.
(2) Indonesia concerned with physical protection of nuclear material and nuclear installations, nuclear material accountancy, detection and response to illicit nuclear trafficking, the security and safety of radioactive sources, emergency response measures, including pre-emergency, and the promotion of adherence to relevant international instruments. These concerns can be weaknesses.
(3) Lack of quality human resources and sustainability of knowledge management in nuclear forensics.

4.2.3. Opportunity of Nuclear Forensics

Opportunity of Nuclear Forensics are discipline between science, law enforcement; uses systematic approach for analysis and attribution; benefits from reference data; provides clues on the origin of the material; assures sustainability in combating illicit trafficking; calls for International cooperation; and methodology applicable in other areas.

There is an important difference between nuclear forensics as it is practiced today and the analysis of foreign nuclear test as it was practiced during cold war and for some time thereafter, eventhough both rest on the same scientific base. Nuclear forensics for attribution involves comparing data and analysis samples from identified sources. Forensics analysis for attribution therefore reqiures that data concerning foreign origin material be available. Therefore, nuclear forensics analysis would benefit from as much international cooperation as possible.

4.2.4. Threats on nuclear security - Challenge of Nuclear Forensics

The risks of the smuggling (illicit trafficking) of nuclear materials and radioactive sources in international gateways, border crossing, nuclear terrorism, orphan sources and nuclear security at major public event have been emerged. These threats pose serious challenges for governmental organizations, users of nuclear technology and society in all regions of the world. Although most States have recently adopted enhanced measures to address threats, further sustained efforts will be necessary to meet this threat in the future. Many States, particularly those in regions of political instability or with underdeveloped economies, are experiencing difficulties in establishing national capabilities to mount an effective response to illicit trafficking. In general, these difficulties can be traced to a basic lack of resources — human, technical and financial. Specifically, the following difficulties were emphasized: — Lack of sufficient trained personnel with adequate technical competence; —Lack of equipment for the detection of radioactive materials at borders and for prompt and accurate analysis of detected materials. —Inadequate legal or regulatory frameworks; —Weak enforcement or sanction measures; —Poor coordination among relevant national agencies and organizations; —Lack of awareness of the threat by officials, users, the public and other stakeholders[4].

The need for nuclear forensics support on measures to enhance law enforcement capabilities to address those threats, especially illicit trafficking, is a must. So, the challenges of nuclear forensics are:

(1) the methods safeguards inspectors use to verify compliance with treaty obligations is "environmental sampling", i.e. the collection of particles within (or outside) nuclear facilities using swipe sampling.
(2) The need for laboratory analysis facilities and new technology; including field equipment and numerical modelling, software of code.
(3) The need for quality of human resources with relevan capabilities and competencies.
(4) Nuclear forensics remains a technically complex challenge for the scientific and law enforcement communities. The difficulty in kin succesful forensics work, especially an attribution process, should not be underestimated.
(5) Knowledge management: the future problem of declining pool of technically competent scientists. The underlying scientific disciplines, radiochemistry, nuclear physics, and others are understood adequately for the purpose of forensics.
(6) Indonesia has National Legislation Implementation Kit for Nuclear Security [5] to deal with the threat of nuclear and other radioactive material out of regulatory control, namely illicit trafficking, orphan sources and major public event. It was mentioned in the kit that nuclear forensics is an important part of nuclear security regime. In Nuclear Security Summit 2014 (Den Haagh, 24-25 March 2014) Indonesia delegates stated that “Since 2013 the Government has started the process of drawing up a draft law on nuclear security with the view to submit it to the parliament in 2015. The Government of Indonesia sees the importance to strengthen its national legislation which in turn can reinforce and complement existing law such as the Law No. 10 Year 1997 on Nuclear Energy. The law

is expected to cover, inter alia, total prohibition of the use, possession and transfer of nuclear weapons; strengthening transfer control and licensing for the possession and transfer nuclear and radioactive materials, and enhancing national nuclear security architecture." Indonesia has submitted the National Legislation Implementation Kit as house gift in the 2014 Nuclear Security Summit with the objective to help States with building blocks to develop comprehensive national legislation in accordance with their own respective legal cultures and internal legal processes[6].
(7) Experience on inspection and law enforcement [7] are the ways of controlling and enforcing nuclear security implementation in Indonesia as parts of nuclear security infrastructure has to be manage at the best and maintained their qualities.

5. Conclusions

Nuclear forensics to be one of nuclear security infrastructure that has to be planned and strengthened in order to respond to nuclear security events in Indonesia. Also, to develop international cooperation in the area of nuclear forensics through IAEA and relevant institutions is an important matter for Indonesia.

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