Laboratory facilities for nuclear forensic investigation in Malaysian Nuclear Agency

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Abstract. Nuclear forensic is a new field and a key element in nuclear security in any country. The purpose of nuclear forensic investigation is to establish the history of nuclear material of unknown origin by analysing the nuclear material in the laboratories. Hence, the results of the nuclear forensic examination will provide the evidence to support law enforcement or nuclear security investigation in the country. The typical analysis used in nuclear forensic investigation is radiological assessment, physical characterization, isotope analysis, elemental/chemical analysis and traditional forensic analysis. This paper will discuss the capability of laboratories in the Malaysian Nuclear Agency and internal arrangement in handling nuclear forensic analysis.

1. Introduction
The use of radioactive sources or nuclear material all over the world is increased, some country also introducing the nuclear power plant then nuclear security aspect should be strengthened. The nuclear security aims in preventing and detecting of and response to theft, unauthorized access, illegal transfer or other malicious acts involving radioactive or nuclear material. It was reported that as of 31 December 2019, a total of 3,686 incidents involving unauthorized activities and events of nuclear and other radioactive material, including incidents of trafficking and malicious use [1]. Nuclear forensic is define as “the examination of nuclear or other radioactive materials or of evidence contaminated with radionuclides in the context of international or national law or nuclear security” [2]. From the nuclear forensic analysis these such questions; what the materials are, how, when, and where the materials were made, and what their intended uses were can be answered. Therefore, nuclear forensics is important tool in the nuclear security [3].

In this regard, countries like Malaysia recognizing to develop the capabilities in this forensic field. An International Atomic Energy Agency (IAEA) expert mission was carried out in 2016 to assess Malaysia’s capability in nuclear forensics. Thus, Malaysian Nuclear Agency (Nuclear Malaysia) as the promoting agency in the country in using nuclear technology and equipped with several facilities and instruments learned that this nuclear forensic could be developed in the agency. Nuclear Malaysia found that nuclear forensic is integration and cooperation among several laboratories and standard operating procedures (SOP) should be documented [4]. The document is purposely to provide guidance for nuclear forensic investigation in Nuclear Malaysia laboratories which technical report from the analysis will help the designated authority in decision making once dealing with the nuclear forensic case in the country.
2. Methodology
The nuclear forensic analysis consists of categorization, characterization, interpretation and reconstruction. The term ‘material signature’ is commonly used in this field. There are several analysis or techniques could be useful to obtain the material signature for example by physical dimensions measurement, analytical techniques, isotopic composition, trace elemental impurities, age determination and of course we cannot left behind the traditional forensic [5]. As mentioned earlier, the development of nuclear forensic in the agency is involvement of several division. Sharing knowledge gained from the training abroad was conducted which lastly the process flow as in Figure 1 was proposed to be used internally in handling the nuclear forensic investigation.

The designated authorities have to send the evidence to the Nuclear Malaysia. Then, the description, classification, categorization of the evidence will be performed. Laboratories will be identified based on the requirement and need from designated authorities before the distribution of evidence for further analysis. Finally, the full report will be written based on finding from the analysis in laboratories and will be submitted to the designated authorities.

![Diagram](image)

**Figure 1.** Proposed process flow for handling nuclear forensic case in Nuclear Malaysia.

3. Result and discussion
The results shows that 5 divisions in the agency could be involved in the nuclear forensic facilities. These division equipped with instrumentations which capable to obtain the “material signature”. Laboratories will be integrated as in the process flow shown in Figure 1 and this development need a secretariat in order to coordinate, communicate and as the central of administrative. The identified laboratories under each division with their assigned task for nuclear forensic facilities is shown in the Table 1.
Table 1. Identified laboratories under each division with their assigned task for nuclear forensic facilities.

| No. | Laboratory(Division)                                                                 | Task                                                                 |
|-----|-------------------------------------------------------------------------------------|----------------------------------------------------------------------|
| 1.  | Health Physic Group (Radiation Safety & Health)                                      | Secretariat: receive evidence, conducting physical radiological assessment and physical characterization, distribution of sample, report writing & communicate to designated authorities |
| 2.  | Radiochemistry and Environmental Laboratory Analytical Chemistry Application Laboratory (Waste and Environmental Technology Division) | Radio analytical measurement & chemical analysis                      |
| 3.  | Material Technology Laboratory Micro Computed Tomography Laboratory (MicroCT) (Industrial Technology Division) | Material characterization analysis                                    |
| 4.  | Reactor (Technical Support Division) Operating Analytical Chemistry Lab              |                                                                     |
| 5.  | Transmission Electron Microscope Laboratory (Radiation Technology Division)          | More advanced analysis: nano-scale microscope                        |

The Health Physics Group under the Radiation Safety and Health Division responsible to plan, prepare and implement health and environmental safety (industrial, radiological and nuclear) programs and activities in accordance with procedures and legal provisions enforced by regulatory bodies. Hence, it seems ideal to be the secretariat in this nuclear forensic facilities. This group equipped with instrumentation used for radiological assessment (dose rate, surface contamination, total activity) which is very important for radiological hazard precaution throughout the various stages during the investigation.

A radio analytical chemistry procedure is to identify the radionuclide of interest and determining its amount in a sample. Chemical analysis will determine the physical properties or chemical composition of samples. Both of this analysis can be carried out by Radiochemistry and Environmental Laboratory (RAS) and Analytical Chemistry Laboratory (ACA). RAS can identify the types of radionuclides (isotopes) present in the material within 24 hours Gamma Spectrometry System while ACA can determine Uranium (U)/Thorium (Th) using Neutron Activated Analysis (NAA) and Inductively Couple Plasma-Mass Spectrometer ICP-MS technique which is very important in nuclear forensic investigation. In addition, these laboratory adopt high quality control and quality assurance practices in order to provide reliable analytical test results, which meet international standards. RAS Laboratory also had been accredited with MS ISO/IEC 17025:2017 since December 2005 by Department of Standards Malaysia for the analysis of gamma emitting radionuclides.

Material characterization analysis is a further method for physical characterization to achieve the goal of nuclear forensic investigation. Material Technology Laboratory which equipped with Field Emission Scanning Electron Microscopy (FE-SEM) techniques, Scanning Electron Microscopy-Energy Dispersive X-Ray Spectroscopy (SEM-EDX), Energy Dispersive X-Ray Fluorescence Spectrocopy (EDXRF), Wavelength Dispersive X-Ray Fluorescence Spectroscopy (WDXRF), and X-Ray Diffraction (XRD), and Micro Computed Tomography Laboratory (MicroCT) under Industrial Technology Division together with
Transmission Electron Microscope Laboratory (Radiation Technology Division) can perform this analysis. Above all, the secretariat plays a role in distributing the sample of evidence for analysis to identified lab based on the requirement and need from designated authorities. Beside that, traditional forensic (fingerprints, fiber, DNA) still have to be carried out. Those techniques describe above is commonly used in nuclear forensic investigation [5]. Hereby, major elements of the IAEA’s recommended pieces of the nuclear forensics ‘model action plan’ are in place in Nuclear Malaysia [4].

4. Conclusion
Currently, there are 10 SOP’s was compiled and will be used in nuclear forensic investigation in Nuclear Malaysia. As nuclear forensic facilities is integration of several division in the agency, practices and familiarization of the process flow is a must. This development could be serve as a reference and guidelines for nuclear forensic analysis not only in Nuclear Malaysia but also could be used in supporting nuclear security system in Malaysia.

5. References
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