Nuclear forensics: The Science behind illegal activities involving radioactive materials. Materials, instrumentation and law 2020

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Illicit trafficking of radioactive materials is known to exist from the early days of radioactive era. The nuclear forensics deals with recognizing the materials and processes of the radioactive industry. The properties of the materials can give a hint about the source of material and its original use.

The most common radioactive material involved in illicit trafficking is uranium. Uranium is a common natural element which can be found everywhere. The cosmogenic uranium is well known and defined. The natural enrichment of uranium is varying within a small range around 0.72 % and is indicative to its source. The enrichment of the anthropogenic uranium can vary much depending on the purpose and use of the material. Different enrichments are known for individual nuclear power plants, research reactors and military uses.

Measuring the uranium properties can indicate its enrichment, presence of other elements or impurities and can help in finding its attribution, namely its origin.

To learn more about the history of found material accurate isotopic measurements are needed. The ratio between $^{230}$Th and $^{234}$U can give a good estimation of how much time passed from the last chemical cleaning of the material. This technique is called radio-chronometry or age dating.

Presence of other isotopes like $^{236}$U indicates that this material was once in a nuclear reactor since its amount in nature is almost negligible.

Nuclear materials or radioactive materials like $^{235}$U, $^{238}$U, $^{239}$Pu, $^{137}$Cs or $^{60}$Co $^{90}$Sr etc. can be used in RDD (radioactive dispersion device). The regular radioactive materials are much easier to get since they are very common in medicine and industry.

Nuclear forensics is dealing with masses of material in the range of kilogram to picogram. Dealing with such wide mass range requires different collection techniques and sensitivity of the equipment.

All that work should be done in clean laboratories which are authorized to deal with radioactive and nuclear materials.

First-responder's teams all over the world are trained to collect those samples with high efficiency and avoid cross-contamination.

The samples can be collected before the detonation or after the detonation depending on the event.

New sensitive techniques were developed to increase the sensitivity and resolution of the radioactive measurements.

The technique of FTA (fission track analysis) will be described in detail showing how we can find picograms of nuclear material in our samples. The result of this kind of analysis is shown in figure 1.
Laser Ablation, ICP-MS, SEM, TIMS and SIMS are some examples of new sophisticated techniques used in the nuclear forensic research. Large variety of experiments, indoor or outdoor, in large or laboratory scale, where done in the last years to investigate the behavior of radioactive materials in RDD event. The most famous ones are green-field and red-house which yield new model of radioactive cloud disperse from RDD event which was implanted in Hotspot [2] Health Physics codes provided to emergency response calculations.

Analytical equipment like TOF-SIMS (Time Of Flight - Secondary Ion Mass Spectrometry) and ICP-MS (Inductively Coupled Plasma - Mass Spectrometer) together with new FTA software can give new frontiers to the nuclear forensic research, see figure 3.

New ideas of image data processing included AI and new TOF-SIMS data analysis for very small particles will be presented.

References