National Nuclear Forensics Library at Japan Atomic Energy Agency

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Abstract. Japan Atomic Energy Agency (JAEA) has started R&D on nuclear forensics technology from JFY 2011. One of main topics of the R&D project is to develop national nuclear forensics library (NNFL) and evaluation methodology for interpretation of nuclear material attributions. JAEA has developed a prototype system of nuclear forensics library for future NNFL in Japan (prototype NNFL) based on data related to nuclear materials and other radioactive materials that the JAEA has possessed in the past research activities. A concept building of prototype database on nuclear materials and related nuclear fuel cycle facilities was almost completed with its basic data handling system. As the next step of the prototype NNFL project, it is planned to carry out the development of: prototype database on other radioactive materials; image verification function for microscope images; multivaliate analysis function for seizure analysis; and knowledge accumulation system for nuclear forensics analysis. Data gathering on nuclear materials in JAEA has been also continued and they will be populated into the prototype nuclear meterials database. It is expected that the developed prototype NNFL and its operational methods will be transferred to the responsible authorities after the national framework of nuclear forensics in Japan will be constructed in the near future.

1. Introduction

Illicit trafficking of nuclear materials and other radioactive materials has been an issue of concern in international society since early 1990s. Once the unknown nuclear/radioactive materials are detected and seized from a nuclear security event, the questions such as their origins, history and intended use of the seized materials should be addressed. These questions can be answered by nuclear forensics activity, and it supports to identify the deficiencies to be improved in the national nuclear security system [1].

In November 2009, Governments of Japan and Government of the USA were agreed on “Japan-US Joint Statement toward a World without Nuclear Weapons” at the US-Japan Summit meeting. In this statement, it was declared that the governments intend to expand nuclear non-proliferation, safeguards and security cooperation. It includes the area of nuclear forensics together with others such as nuclear measurement and detection technologies, human resource development, training and infrastructure assistance for countries interested in nuclear energy, and coordination of our respective Member States support programs to IAEA safeguards. Also at the Nuclear Security Summit in 2010 (Washington D.C., USA), the Japan Government issued the national statement to develop the technologies related to measurement and detection of nuclear materials for nuclear forensics within three-years timeframe, and to share them with the international community for the contribution on the strengthening global nuclear security system. In response to the two statements, Japan Atomic Energy Agency (JAEA) that possesses sufficient analytical capabilities to fulfil this nuclear forensics mission has initiated an R&D project on nuclear forensics technology from JFY 2011. One of main topics of the R&D project is to

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develop prototype system of nuclear forensics library for future NNFL in Japan (prptotype NNFL) and evaluation methodology for interpretation of nuclear material attributions.

This paper describes the current status and future plan on the development of prototype NNFL.

2. General Concept of NNFL and NNFL Development at JAEA

A nuclear forensics library is an organized collection of data and information about nuclear and other radioactive materials produced, used, or stored within a country [2]. The purpose of nuclear forensics activities is to identify the origin, history and intended uses of nuclear and other radioactive materials found and seized from outside of regulatory control. In this context, a nuclear forensics library enables to compare the seized materials with characteristics of known materials to provide information about a material's origin and history. Therefore, a nuclear forensics library is one of the most important elements in the nuclear forensics activities as a whole (**FIG.I**).

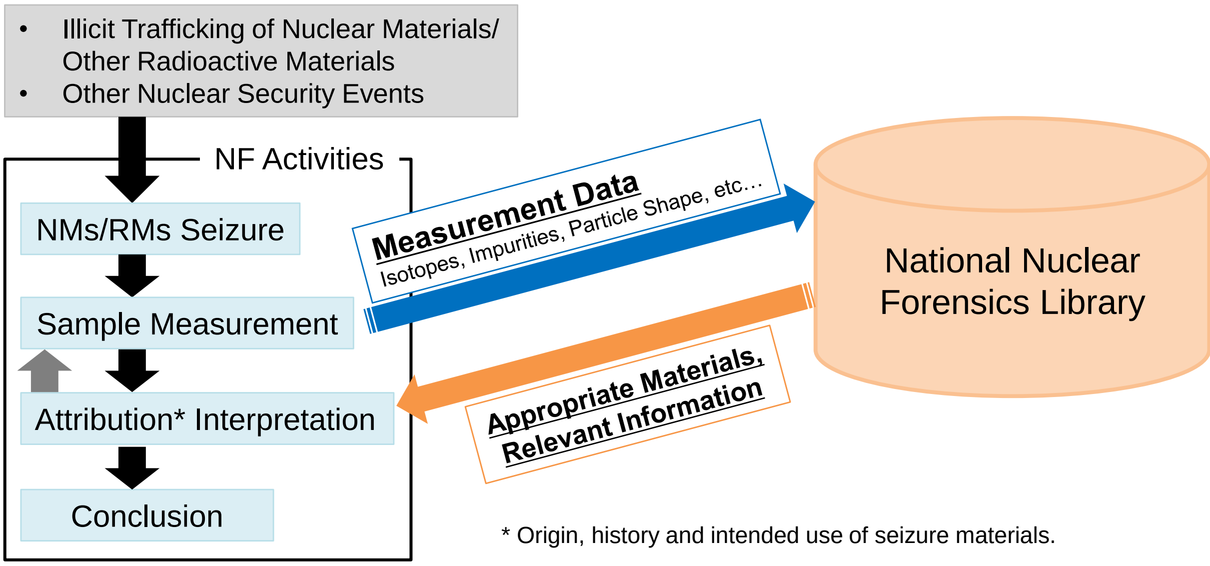

FIG. I. National nuclear forensics library and nuclear forensics activity

Recently, the development of nuclear forensics library has been carried out in some countries and the concept of national nuclear forensics library (NNFL) with point-of-contact (POC) is the most popular in current international society [3]. The prototype NNFL project at JAEA also follows this concept. JAEA has continued to develop a prototype system of NNFL based on data related to nuclear materials and other radioactive materials that JAEA has possessed in the past research activities. This is because JAEA is a nuclear research institute and cannot have access to data of all target materials in Japan. It is expected that the prototype system and the knowledge obtained from the development project will be transferred to the future responsible authority after the national nuclear security regime and national response plan in Japan will be established in the future.

3. Current Status and Future Prospects of the prototype NNFL Development at JAEA

3.1. Concrete Concept of an NNFL

The development of the prototype NNFL at JAEA was initiated from crystalizing its general concept of nuclear forensics library by regarding it as a "library". A library is generally defined as a facility or an organization which collects sources of information and provides accesses to them. In the same manner, a nuclear forensics library can be defined as a system which collects and enables to refer data on nuclear materials and other radioactive materials, and the most basic function of a national nuclear forensics can be isolated as "database" and "data query". The database is an organized collection of data, and it's corresponding to an organized assembly of bookshelf in a library. The structure of database is to be designed according to its objectives and kinds of collected data. The data query function is corresponding to, for instance, book information terminal or librarian in a library. It is to be designed according to the structure of database appropriately so that an user can obtain necessary information from database rapidly and accurately. According to the crystalizing study on the concept of nuclear forensics library, JAEA has addressed the development of nuclear material database and its basic data query functions for the database in the prototype NNFL as the initial step of the project from 2011 JFY.

3.2. Nuclear Material Database and Basic Data Query

The data items included in the database on nuclear material database, which is utilized to identify the origin, history and intended use of seized materials in nuclear forensics, were studied based on three points of view: requirement of nuclear forensics library; “signatures” for nuclear forensics analysis; and available data sources.

TABLE 1 shows the requirements of nuclear forensics library and required information related to nuclear materials which is to meet the requirements. The most important requirement of a nuclear forensics library (or nuclear forensics activities) is to identify the seized materials and its origin, history and intended uses. To achieve it, it is required to make all existing nuclear materials in a country into a “catalogue”. It is important to accumulate information like significant characteristics to identify each material and process/usage record to identify the origin and history. Another important requirement is the accumulation and interpretation for the measurement results of nuclear materials. Sample information, measurement data of many kinds of nuclear forensics analysis and the analytical results based on the measurement data were also important information to be accumulated in a nuclear forensics library.

The second view point on the data item study is “signatures” for nuclear forensics analysis. In nuclear forensics, various kinds of analysis will be made for one seized materials to find out its identity, and the discriminative characteristics of the material is usually called as signature. The discriminative characteristics of nuclear materials in a country can be made clearly by determination of nuclear fuel cycle processes and their product materials [4]. JAEA has various facilities which can cover almost all stages of a nuclear fuel cycle, and it was found that the discriminative characteristics of nuclear materials in each stage can be categorized into 6 classes;

- Physical (e.g. density, colour, transparency and brashness),
- Chemical (e.g. chemical form, major element and chemical homogeneity),
- Impurities,
- Isotope compositions,
- Microstructure (e.g. particle shape, size and crystal structure), and
- Others (e.g. container and serial No.).

TABLE I: REQUIREMENTS OF NUCLEAR FORENSICS LIBRARY

Requirements	**Necessary Data Types**	**Necessary System Functions**
Collection of Information on NMs	• General Information (Facility, Process, Process Duration, Intended Use, History, Shape etc…) • Material Data (Elemental, Isotopic, Chemical, Physical, Microscopic etc…)	• Data Entry, Search, Update
Interpretation and Accumulation of NF Measurement Data	• Sample General Information (Archive, Collected Situation, Transportation etc…) • Measurement Data (Sample Shape, Chemical, Physical, Elemental, Isotopic, Microscopic, Radiation, Analyst, Uncertainty etc…) • Burnup Analysis Data • Age Determination Data	• Analysis Data Entry, Search, Update • Graphing • Age Calculation by Analysis Data • Statistical Analysis

TABLE II shows the example of discriminative characteristics in the stage of uranium fuel fabrication process. A seized material will be analysed and identified by one or some of these characteristics in nuclear forensics analysis.

TABLE II: DISCRIMINATIVE CHARACTERISTICS IN URANIUM FUEL FABRICATION

Process		Uranium Fuel Fabrication
Target Materials		UO_2 Powder, Pellet, Cladding
Key Material Characteristics	Physical	Dimension, Density, Radioactivity, Reflected Color, Transmitted Color, Absorbance, Cladding, O/M, Porosity, Mechanical Properties, Corrosion
	Chemical	Chemical Form/Compound, Homogeneity, Inclusions (Organic Substance), Water Amount
	Impurities	U [Gd (Gd_2O_3), F, Al, Ba, Bl, Ca, Ce, Cr, Fe, K, La, Mg, Mn, Mo, Na, Nb, Nd, Ni, P, Pb, Pr, Sr, Th, Tl, W, Y, Yb, Ru, Zn, Zr, Dy, Dr, Hf, Ho, La, Tb, B, U…] Cladding [Sn, Fe, Cr, Ni, Fe+Cr, Fe+Cr+Ni, O, Al, B, Ca, Cd, C, Co, Cu, Hf, H, Mg, Mn, Mo, Ni, Nb, N, Si, Ti, W, U...]
	Isotopic	U-234/U-235/(U-236)/U-238, U-234/Th-230, U-235/Pa-231, (U-236/Th-232), O-16/O-18
	Microscopic	Powder Av., Max., Min. Sizes, Powder Shape Homogeneity, Powder Aspect Ratio, Surface Roughness, Weld
	Others	Container, Model No., Serial No., He Pressure (Rod)

The third view point on the data item study is available data sources. In many cases, the raw material data to be registered in a nuclear forensics library comes in a variety of formats (e.g., electronic/hard copy, various units). Therefore, to ensure successful data processing and database compiling, it is necessary to perform a preliminary survey on existing materials. A good preliminary survey makes it possible to know the variety and amount of target materials, relevant data, and other related information. The variety forms of data sources in JAEA were collected, and their availability and priority for data-collecting were assessed. Available information for a nuclear forensics library was found out in many kinds of data sources;

- Nuclear fuel design standards,
- QC standard and analysis data,
- Post irradiation experiments data,
- Fuel cycle process and facility information, and
- Material accounting data.

It was found that the first three types of information are especially useful as the data source of a library because many discriminative characteristics of nuclear materials are summarized in them. The material accounting data, on the other hand, was found to be comparatively unuseful for nuclear forensics purpose since the data is limited to the fissile isotopes for safeguard program. Furthermore, some of the other data, which cannot be collected from existing data sources for some reason like storage limitation, could be complemented by computation analysis and additional analysis of remaining material samples.

FIGURE II shows the overview structure of the nuclear material database [5] and the example of user interface of the prototype system of the NNFL developed in JAEA was shown in **FIGRE III**.

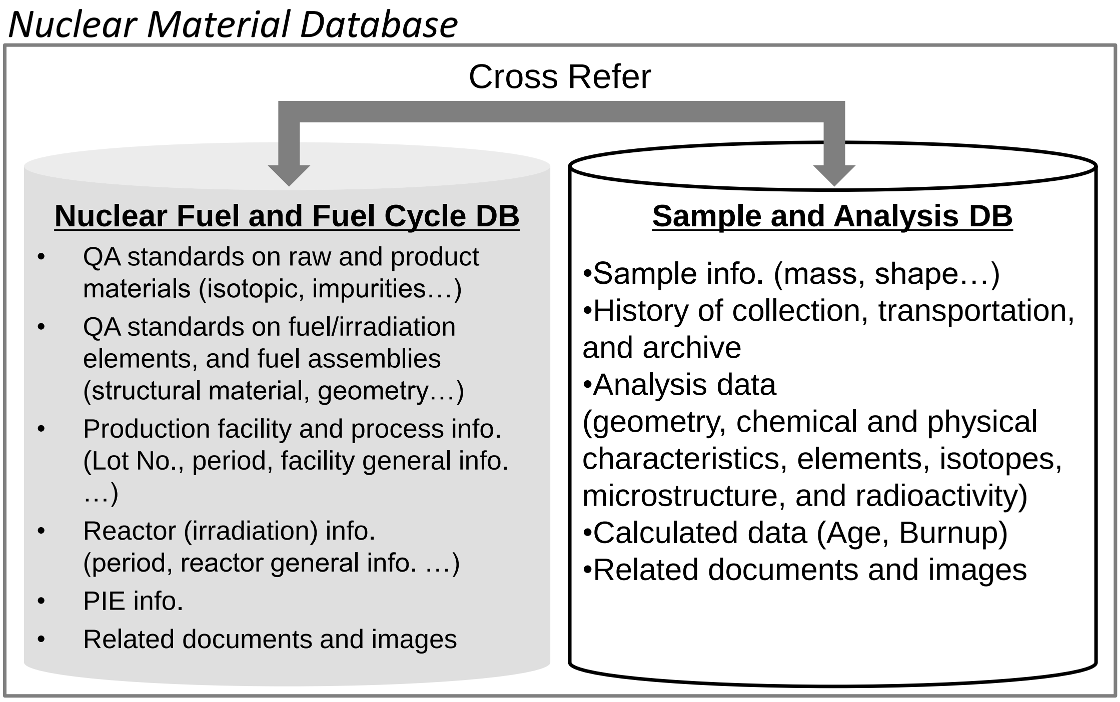

FIG. II. Overview structure of the nuclear material database

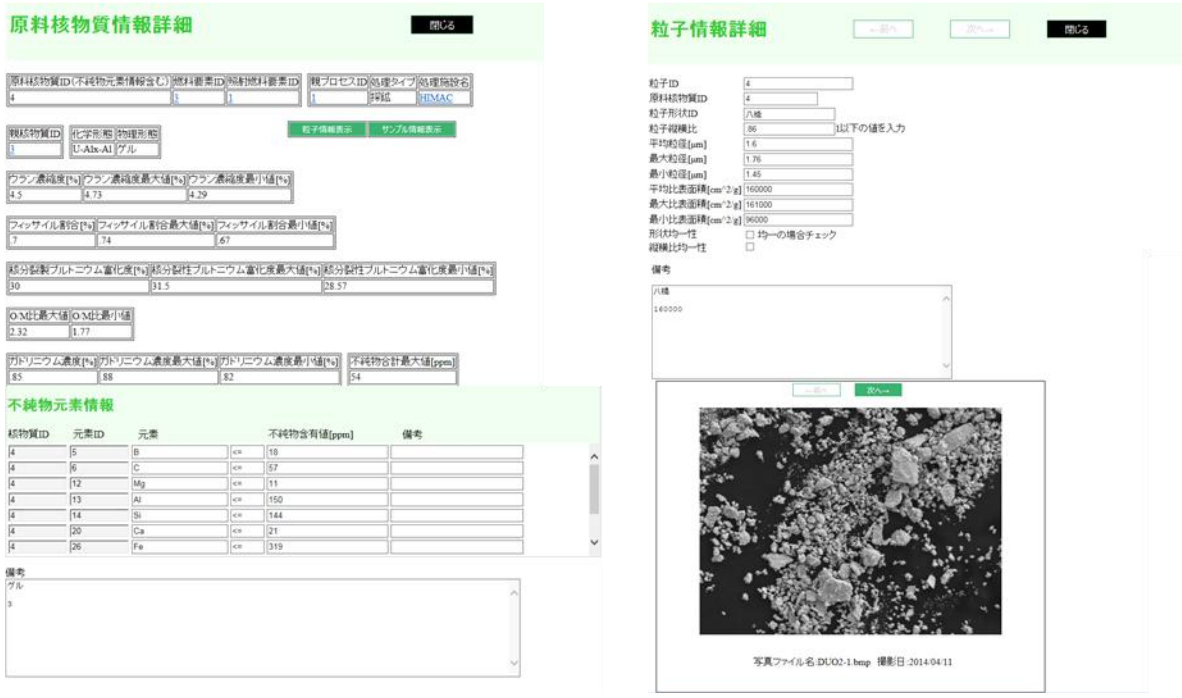

FIG. III. Prototype system of the NNFL at JAEA

The number of data items in the nuclear material database is about 550 items, and they are divided into about 70 tables. The data structure was designed based on relational database structure and it consists of two small databases. The first of these databases was named Nuclear Fuel & Fuel Cycle DB and stores raw nuclear materials data and product nuclear fuels in addition to information on their parent processes and parent fuel cycle facilities. The second database was named Sample & Analysis DB, which stores analysis results of nuclear forensics data, quality control, material accounting, and other datasets.

3.3. Future Plan

Currently, the development of nuclear material database and its associated system for data query has been almost completed and the prototype system of NNFL at JAEA will be improved by some development items as follows:

- Computational evaluation tool for nuclear forensics analysis (e.g. multicomponent analysis tool),
- Database of other radioactive materials, and
- “Knowledge base” for the NNFL system.

The data-collecting in JAEA will be also continued. Although it is expected that the present prototype system will be transferred to the future national responsible authority for nuclear forensics activities in Japan, the establishment of national nuclear security system including national response plan is remained as a big challenge.

4. Conclusion

JAEA has continued to develop a prototype system of nuclear forensics library for future NNFL in Japan based on data related to nuclear materials and other radioactive materials that JAEA has possessed in the past research activities as one of main topics of the R&D project for nuclear forensics technology. The nuclear material database in the prototype NNFL has been developed with its associated system for data query from 2011 JFY and it has been almost completed. It is expected that the prototype NNFL will be transferred to the future national responsible authority for nuclear forensics activities in Japan, but the establishment of national nuclear security system including national response plan is remained as a big challenge.

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Resources and Forensics Signatures to Help Determine the Origin of Sealed Radiological Sources

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Abstract. In a crime scene that involves radiological material, analysis of the source capsule and the radiological material could provide law enforcement with valuable clues to the sources manufacturer. Identification of the source manufacturer has the potential to provide further leads on where the radiological sealed source was obtained, including when the loss of regulatory control might have occurred. These signatures include materials of construction, dimensions, weld details, and the elemental composition and isotopic abundances of the radioactive material.

Argonne and Idaho National Laboratories have for the past 11 years been working on identifying signatures that could be used to identify specific source manufacturers. These signatures have been collected in a library that now contains the most complete forensics information on radioactive source signatures than any other database in the world. In addition to the collection of signatures from a variety of sources, both laboratories have developed and validated procedures for age dating of common radiological materials. These activities are described.

1. Introduction

In a crime scene that involves radiological material, analysis of the source capsule and the radiological material could provide law enforcement with valuable clues to the sources manufacturer. Identification of the source manufacturer has the potential to provide further leads on where the radiological sealed source[1] was obtained, including when the loss of regulatory control might have occurred. These signatures include materials of construction, dimensions, weld details, and the elemental composition and isotopic abundances of the radioactive material.

A database or library of known signatures is needed by the law enforcement community. Many countries have regulations in place to track or document the radiological sealed sources that are used in their country, but these databases are typically focused on regulatory requirements and not for forensics purposes. We know of two organizations that maintain a database of forensics signatures of sealed sources: the International Atomic Energy Agency (IAEA) and Argonne/Idaho National Laboratories.

[1] A radiological sealed source can be defined as a radiological material that has been sealed into a metal container that can then be safely handled without fear of spreading contamination. Specifics of these sources depends upon the final use the manufacturer and the country of origin.

The IAEA has developed and maintains a database called the International Catalogue of Sealed Radioactive Sources and Devices (ICSRS).[2] The second is housed at Argonne National Laboratory and is referred to as the Radiological Sealed Source Database (RSSD); details on this database are described in this paper.

Argonne National Laboratory, with support from the Idaho National Laboratory, maintains the RSSD and includes sealed radioactive sources and the devices that house them. The purpose of the database is to aid U.S. government agencies, including law enforcement and first responders, in identifying radioactive sources or devices, including the manufacturer and distributor. The RSSD houses a searchable collection of pictures, construction diagrams, dimensions, and chemical compositions of sources and devices sold anywhere in the world. The information encompasses both currently distributed source and device models and historical, discontinued ones. The latter are necessary because the half-life of many nuclides in sealed sources and radioactive devices is beyond that of most current commercial products.

Currently, the RSSD is the most complete compilation of its kind in the world. Argonne and Idaho National Laboratories have worked together for the past 11 years to populate this database with relevant signatures that could then be used to identify specific sealed source manufacturers.

2. Data Collection

The RSSD contains technical information compiled from manufacturers and distributors of radiological sealed sources. Data collection involves various strategies, including vendor catalogs (Figure 1 displays the cover of a Mayak catalog), web pages, technical publications, interactions with foreign governments and companies, attendance at technical meetings, and site visits to foreign and domestic source production and distribution facilities, and interactions with the US Nuclear Regulatory Commission. For the RSSD, the Nuclear Regulatory Commission's Source and Device Registry was the primary resource for collecting signatures.[3] Non-disclosure agreements are used to protect information obtained directly from source producers and distributors. Information obtained through all of these methods is contained in a searchable database and in company profiles, country summaries, isotope summaries, and individual source reports.

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[2] The IAEA has developed a database of sealed radioactive source models and models of devices containing sealed radioactive sources. The International Catalogue of Sealed Radioactive Sources and Devices (ICSRS) contain key manufacturing data for source and device models. Like Argonne’s database, the ICSRS does not contain a list of actual physical sources or devices with their serial number, owner or location. But it can help identifying the model for a given (or "found") individual source or device and provide manufacturer, application area and the level of threat associated with a source model. An effort to update this database with more current information from member countries has been proposed.

[3] Regulations in the United States (10 CFR Part 35) require NRC licensees to use only sources and devices as approved and listed in the Sealed Source and Device Registry. Therefore, starting with information from this database enabled Argonne/Idaho to get detailed signature information on sealed sources that are used and/or manufactured in the United States. Since the Registry’s primary use is regulatory, the forensics information was not in a searchable form and had to be manually extracted.

Figure 1. Example of manufacturers catalog (Mayak) with useful forensics information.

A ^{137}Cs capsule from a major source producer is shown in Figure 2. It is important to capture design features that could differentiate this source from other manufacturers. Some potential signatures that differentiate manufacturers are shown in Figure 2 and include labels, engravings, number of capsules, dimensions, weld details, and materials of construction.

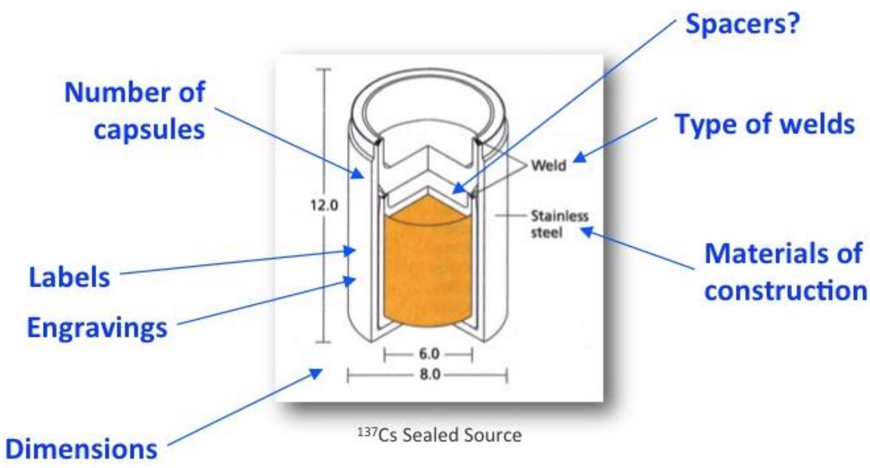

Figure 2. A ^{137}Cs sealed source with design features that could differentiate this capsule from other manufacturers are noted.

3. Chemical Analysis

Although the shape and dimensions of source capsules may help identify the manufacturer, additional information from the analysis of the radiological material would be helpful to better pinpoint the manufacturer or supplier of a particular source (see Figure 3).

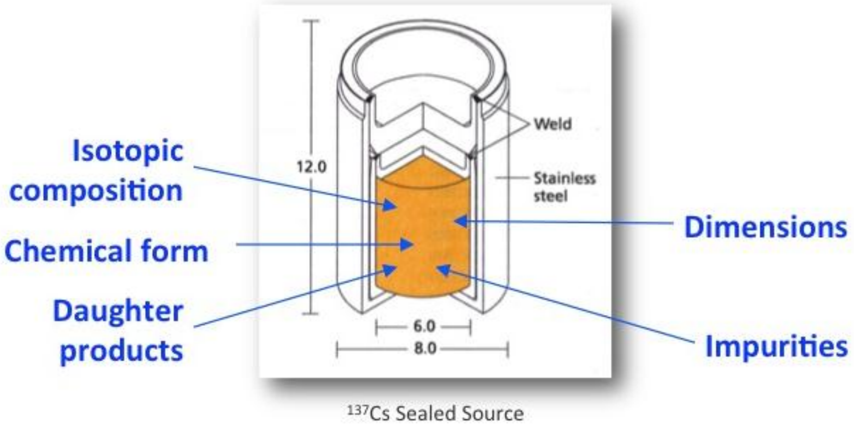

Figure 3. Analysis of the radiological material in a sealed source could provide additional information about the sources origins.

The careful analysis of parent-daughter decay pairs can provide the "time since purification" or time since the "end of irradiation" of the radioactive material. This apparent age of the source, therefore, provides an estimated date when the source material/capsule was manufactured. Knowing the manufactured date information and the manufacturer could lead to sales records and/or to exclude other manufacturers based on company histories. Analysis of trace elements or impurities in the radioactive material may also lead to an understanding of the processing history, including purification methods, type of reactor that was used to generate the material, and the original source of the target material.

This "age dating" technique requires analysis of both radioactive and stable isotopes. For the analysis of stable isotopes mass spectrometry measurements are essential, however the parent-daughter decay pairs used in age dating often have the same atomic mass and require chemical separations to eliminate isobaric interferences in the mass spectrometric measurement. For example, the parent Cs-137 interferes with the measurement of the stable daughter Ba-137 (see Figure 4) by mass spectrometry; similarly Co-60 interferes with the measurement of the daughter Ni-60.

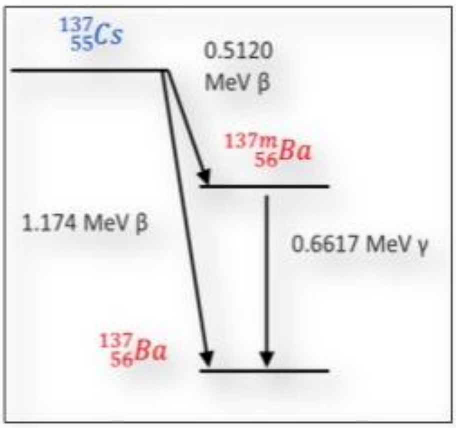

Figure 4. Radioactive decay of radioactive ^{137}Cs to the stable ^{137}Ba atom.

Sample dissolution methodologies and separation procedures for age dating analysis have been completed for ^{137}Cs [1,-4], ^{90}Sr [5], and ^{60}Co [6] sources. The process typically involves dissolving a representative sample and then using extraction chromatography to separate the parent isotope from the daughter. Separation schemes using Gas Pressurized Extraction Chromatography (GPEC) have been developed for Cs/Ba (Figure 5) and Sr/Zr methods as well as separations using Omnifit column system with DOWEX 1x8 resin that was used for Co/Ni separations (Figure 6). Analysis is completed using analytical techniques such as inductively-coupled-plasma mass spectrometry (ICP-MS), thermal ionization mass spectrometry, or by gamma counting the radioactive fraction. Details are described elsewhere [1-6].

With careful analysis to prevent environmental contamination of the samples, source ages can be determined. An example of this using the GPEC system for a ^{137}Cs sample is shown in Figure 7. Two laboratories conducted these analyses over a five-year period on a sealed source capsule that was dated 27 October, 1965.

Figure 5. Gas Pressurized Extraction Chromatography (GPEC) that was used for Cs/Ba separations.

Figure 6. Omnifit column system with DOWEX 1x8 resin that was used for Co/Ni separations.

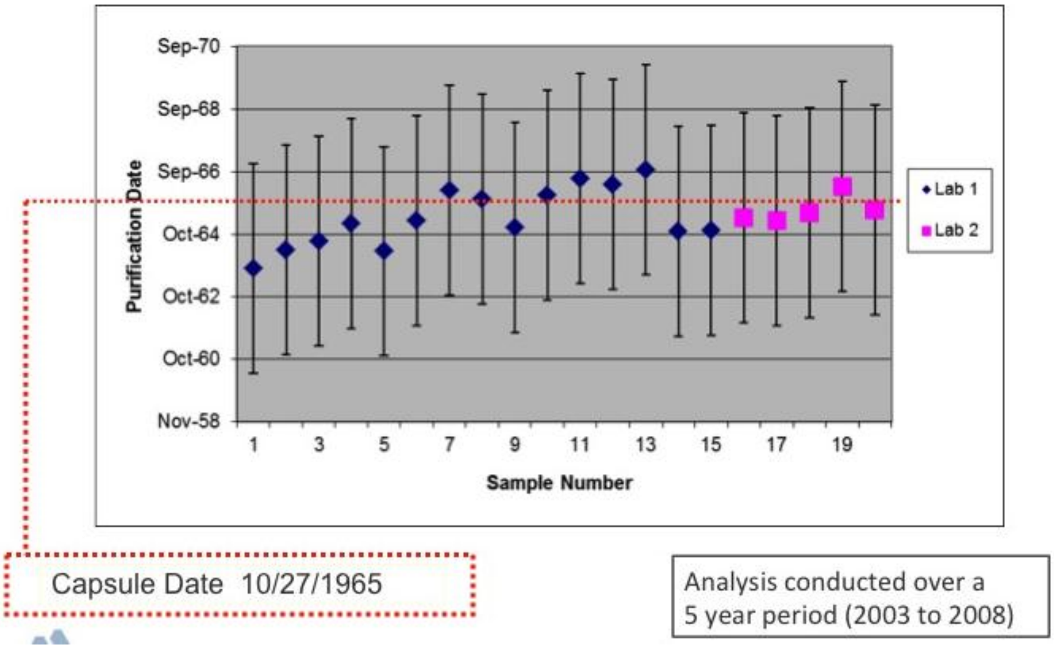

Figure 7. Summary of age dating results of a ^{137}Cs source with expanded uncertainties using GPEC system by two laboratories.

4. Summary

Argonne and Idaho have compiled the most complete database of forensics signature information on radioactive sealed sources in the world, with over 10,000 models currently documented. Information is contained in a searchable database and includes company profiles, country summaries, isotope summaries, and individual source reports. This information can be used to aid law enforcement personnel in their investigations to help identify the manufacturer and original owner of the source.

We do not expect that examination of a sealed source and the radiological material will always lead to a specific source model or manufacturer. But it is likely that these examinations will reduce the number of possibilities to be considered for further evaluation. For example, using information contained in the RSSD, knowing that the radiological material is ^{137}Cs reduces the number of possible source models from over 10,000 to just under a 1000 possibilities. Further details such as the source strength, number of capsules, and/or capsule dimensions can further eliminate possible models.

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Mechanism of Interpretation of Seized Materials without Creation of Nuclear Forensics Library

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Abstract. Approach to interpretation of unknown nuclear or other radioactive materials by using national nuclear forensics libraries is characterized by a set of inherent deficiencies. These deficiencies force to use other approaches to interpretation of seized unknown nuclear or other radioactive materials. Alternative approach is considered. It is based on the results of experienced experts' estimations and analyses of measured characteristics of seized material or its trace amounts as well as on the subsequent implementation of comparative investigation of both: seized and suspected materials at the same time in nuclear forensic laboratories.

1. Introduction

Interpretation of seized nuclear or other radioactive materials, determination of its origin and possible designation are the essential parts of any investigation, which is associated with illicit trafficking of such materials. This investigation includes comparison of characteristics of the seized material or the detected trace amounts of unknown material, which are determined in the result of its analysis, with the data about known materials.

IAEA nuclear security publication [1] recommends establishing national nuclear forensics libraries (NNFL) for inventory of nuclear and other radioactive material. These libraries should include databases of all material produced, used and stored in the State, and considered by several experts as a tool for nuclear forensics data interpretation. Another IAEA publication [2] requests States to consider establishing a programme that compiles libraries of inventoried/registered nuclear and other radioactive material as one of main elements of the national nuclear security infrastructure. Furthermore, IAEA is developing a special nuclear security guidance document on nuclear forensics libraries [3], where the role of such libraries in interpretation of seized material data seems overestimated.

2. Interpretation of seized material like one of the main elements of incident investigation

Interpretation of nuclear and other radioactive materials, determination of its origins, deterrence of potential criminals, facilitating to development of international cooperation in the nuclear forensic field are mentioned and listed like the tasks, which can be solved by using NNFL. At the same time possibility of solution of these tasks without creation of NNFL is hushed.

But it should be noted that deterrence of potential criminals is determined only by inevitability of solving the crime. Consequently for such deterrence only the possibility of right interpretation and attribution of seized material is important. And it does not matter how this possibility is provided. May be NNFL can facilitate to right interpretation and attribution, may be right interpretation and attribution can be implemented without NNFL. For example, right interpretation and attribution can be implemented by using the databases, which are not combined in NNFL, or by using comparative analyses of seized material and reference materials from materials archive.

Living aside political component of the issue, international cooperation is organized for the best investigation of the incidents and crime solution. It is also directed on the right interpretation and attribution of seized material. So, only one NNFL's task is really important for investigations practice – facilitating to right interpretation and attribution of seized materials. At the same time it is necessary to note that NNFL is defined, as "an administratively organized collection of information on nuclear and other radioactive materials produced, used, or stored within a State that may come from different and diverse sources" [3]. It means that NNFL is administratively organized collection of databases. Therefore working instruments of NNFL are databases. Nevertheless right interpretation and attribution of seized material depends on quality of databases, but not of their inclusion in NNFL.

3. Deficiencies of databases and NNFLs for investigation goals

All other structural parts of NNFL, which should be created above databases, are not important for the conclusion about the origin of seized materials. Therefore the interpretation of seized unknown nuclear or other radioactive materials by using NNFL or by using scattered, not organized in NNFL, databases contain the same inherent deficiencies:

- Comparison of the results of analysis of seized material or trace amount of material with information from data bases. Obviously such comparison allows to withdraw from the suspicion a lot of materials, characteristics of which are very different from characteristics of seized material.
  But it is known that several similar materials can be manufactured at different facilities or produced by fuel irradiation in different reactors. Investigation of incidents with such materials is most complex for prosecution. On the other hand analyses of the same material in different laboratories can provide not the same results. Moreover, analyses of the same material in the same laboratory, but in different times and/or by using different techniques can sometimes provide not the same results also. But comparison of the result of analysis of the seized material and suspected materials implies the comparison of the results, which are obtained likely in different laboratories and obviously at different times. Therefore material cannot be undoubtedly attributed on the result of such comparison.

- List of characteristics, which should be measured for undoubted interpretation of nuclear or other radioactive materials, is not determined until now. Moreover it is very likely that different lists will be required for investigation of different incidents. Characteristics, which will be really necessary for nuclear forensics investigation goals, can be determined after first steps of the investigation. It is clear [4] also, that databases, which are created for technological control, only contain at best a small part of forensically significant information. On the other hand there is considered for instance the possibility of measuring of the contents of a lot of chemical elements (up to 64) for identification of UOC [5]. Therefore, creation of comprehensive database is very labour and resource intensive process. Due to the low frequency of nuclear security events such a creation may be unreasonable;

- The concept of national nuclear forensics libraries, presented in [3], reflects simplified understanding of forensic database. "Forensic database" not only means that it is used during criminal investigation. A set of specific requirements is inherent to forensic database. First requirement is periodic actualization of database for the whole range of materials, which are currently manufactured. Secondly, database should contain information about intermediate products of manufacturing, etc.

One more deficiency concerns the NNFLs, but does not concern scattered databases. Accumulation of a lot of information, including sensitive information, in additional point of storage enlarges the circle of knowledgeable people and increases the risk of unauthorized sharing of information.

These disadvantages of any databases as well as NNFLs for prosecution goals force to use other approaches to interpretation of seized unknown nuclear or other radioactive materials.

4. Another approach – involvement of experts and comparative analyses

As indicated in IAEA nuclear security publication [6], "nuclear forensics does not consist of routine procedures that can be universally applied to all evidence". Direction and scope of each subsequent step of nuclear forensics analysis should be selected in accordance with the results of previous steps. Another interpretation mechanism based on the involvement of experienced experts to estimation of measured characteristics of seized materials or its trace amounts as well as to subsequent implementation of comparative investigation of both: seized and suspected materials at the same time in the same analytical laboratory (laboratories). Several nuclear forensic laboratories can be involved firstly for supporting the conclusions of one laboratory and secondly for measuring entire set of requested characteristics if all of them can not be measured satisfactory in one laboratory.

Involved experts should have knowledge and experience of handling with materials of corresponding type. Range of experts can be determined after first identification of seized material or its trace amounts. Experts will be able to determine the group of materials, which can be suspected as the origin for seized material. They will be able also to choose materials for comparative investigations, to assess the significance of differences in measured characteristics of seized and suspected materials. By the way scattered material databases or any information of NNFL can be useful for choice of suspected materials for comparative analyses. Samples of these materials can be requested from corresponding material archive.

Only coincidence of all measured characteristics in seized material and in one or in several suspected materials provide the prosecution with undoubted conclusion about origin of seized material (possible origins in the case of coincidence of characteristics of seized material and several suspected materials).

If requested sample is absent in material archive and it is impossible to find corresponding sample anywhere, experts are forced to use any information about such materials, including information from all suitable databases. In these cases expert evaluation should be based on the knowledge of the details of manufacturing technologies, operational features, knowledge of the sources of raw materials for different manufacturing, etc. But expert evaluation should contain additional expertise of real and all possible differences of the results of measurement as well as all possible variations and uncertainties of the published data.

Such approach is realized, for example, in Russian Federation. Russian Federation has a large range of nuclear and radioactive materials and owns a lot of technological databases, which are not concentrated on one site. This approach focuses on the Russian legislation and does not require additional management and centralization.

5. "Galaxy serpent" exercises – confirmation of necessity of expert involvement

The virtual table top exercise "Galaxy serpent" held in 2013 confirmed that assessment of the significance of differences between the results of analysis and information from database can require involvement of experts even if the comprehensive database is accessible [7]. "Laboratory for Microparticle analysis" participated in the final round of this exercise in February-March 2014. Conclusion had to be elaborated about the possible pertaining of the "seized material" to the spent fuel of one from three reactors on the result of comparison of "the results of analysis of the seized material" and the data about spent fuels of reactors. Comparison had to be implemented on the set of spent fuel parameters.

On the result of comparison two reactors were qualified like reactors, which can not be the origin of "seized material". Spent fuel of one of them is characterized by concentration of uranium-235 of 2.04% at the burn-up of 5.88 GWD/MTU, while that concentration in "seized material" is significantly higher, 2.37%, even at the larger value of burn-up – 6.41 GWD/MTU. Spent fuel of another reactor is characterized by concentration of uranium-235 of 1.26% at the burn-up of 16.00 GWD/MTU, while that concentration in "seized material" is significantly higher, 1.65%, at the larger burn-up of 18.08 GWD/MTU. Uncertainties of the measurements do not compensate the differences in concentrations.

At the same time comparison of "the results of analysis of the seized material" with available characteristics of the third reactor could not identify significant differences for "seized material" and spent fuel of the third reactor. This spent fuel should be considered like possible origin of the "seized material". Nevertheless definite conclusion can not be stated that this spent fuel is the origin for "seized material" because any database con not be overall. And it can not be guaranteed that there is no another reactor, spent fuel of which is characterized by the same parameters at some burn-ups.

For example, concentrations of uranium-235, uranium-236 and plutonium for reactors of different typs are presented on the fig.1 [8]. Only initial enrichments are almost the same.

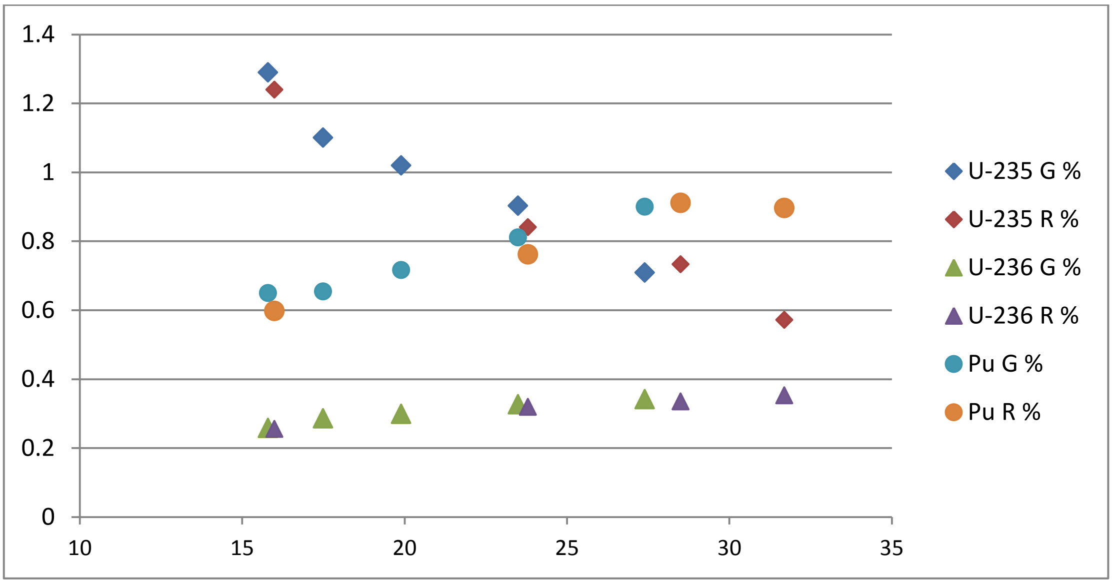

FIG. 1. Concentrations of plutonium and isotopes of uranium in spent fuel (%) of reactors BWR Gundremmingen (G)and PWR Robinson (R) at different burn-ups (GWD/MTU).

One of them is installed in Germany, another – in USA. It can be seen that isotopic composition of spent fuel depends on burn-up rather then on the power reactor parameters.

So, "Galaxy serpent" held in 2014 confirms again that databases can be successfully used for exclusion of some materials from the list of suspicious ones, but for attribution of material they are not sufficient. Of course this conclusion is true for both: scattered databases as well as databases, which are associated with NNFLs.

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