Establishing Canada's National Nuclear Forensics Laboratory Network

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Abstract. Following the 2010 Nuclear Security Summit, Canada concluded that its existing capability for nuclear forensics should be augmented by establishing a national nuclear forensics laboratory network, which would include a capability to perform forensic analysis of evidence contaminated with radioactive material. At the same time, the need for a national nuclear forensics library of signatures of nuclear and radioactive materials under Canadian regulatory control was recognized. Through the Canadian Safety and Security Program, Defence Research and Development Canada's Centre for Security Science (DRDC CSS) funds science and technology initiatives to enhance Canada's preparedness for, prevention of, and response to potential threats. DRDC CSS, with assistance from Atomic Energy of Canada Limited (AECL), is leading the Canadian National Nuclear Forensics Capability Project to develop a coordinated, comprehensive, and timely national Nuclear Forensics capability. Canada's Nuclear Forensics Laboratory Network will consist of several laboratories having complementary capabilities in areas such as radiological and physical characterization and material handling. Input from law enforcement agencies and other federal departments will ensure that the project outputs are consistent with the requirements and expectations of the user community. The process of building up this integrated laboratory network has commenced, with several tasks already underway, including the identification of requirements for laboratories within the network, cataloguing of current network laboratory capabilities, drawing up of action plans to address any identified capability gaps, and development and delivery of training plans for nuclear and classical forensic scientists. As the project progresses, it will undertake the planning and execution of both inter-laboratory comparisons and an operational exercise geared towards lab network implementation. The paper presents Canada's approach to establishing the laboratory network component of this national nuclear forensics capability, and discusses project tasks in detail, including challenges encountered during implementation of these tasks.

1. Introduction

Ensuring the safety and security of Canadians requires a national capability to respond to all credible threats. An effective response includes prevention as well as mitigation, and may require an ability to successfully interdict, investigate, prosecute, and convict the perpetrators. A gap has been identified in Canada's capability to respond to a radiological and nuclear threat; namely, a coordinated national nuclear forensics capability, such as is required for the investigation of a nuclear security event, does not exist. Such a capability would contribute not only to the safety and security of Canadian citizens, but also to those of North America and the world. The importance of developing and enhancing nuclear forensics capabilities was underscored in the 2012 Nuclear Security Summit Communiqué, fully endorsed by the Canadian government. In addition, Canada made the following statement in its National Report:

"*Canada is finalizing a strategy to enhance its domestic nuclear forensics capabilities, which will include the formalization of the Canadian nuclear forensics laboratory network, the creation of a national library of nuclear and radiological signatures, and the enhancement of Canada's capacity for the forensic analysis of radiologically-contaminated evidence.*"

Efforts to develop a more coordinated national nuclear forensics capability have been underway, led by Defence Research and Development Canada's Centre for Security Science (DRDC CSS). To help establish the scope and requirements of such a national nuclear forensics capability, CSS organized a workshop in September 2011 that brought together nuclear forensic stakeholders to identify how this national capability can be developed. Several areas of work were identified at that time, and formed the basis of the scope of work for the path forward.

2. The Canadian National Nuclear Forensics Capability Project

In 2012, the Centre for Security Science established the Canadian National Nuclear Forensics Capability Project under the auspices of the Canadian Safety and Security Program (CSSP), a joint initiative of DRDC and Public Safety Canada. The project, with Atomic Energy of Canada Limited (AECL) as the lead federal agency, is being implemented with a whole-of-government approach, involving several federal science and technology departments and agencies, with the active participation and guidance of the potential end users of this capability, including law enforcement and international affairs. The project will be building upon existing technology and processes, while also identifying areas where new capabilities may be needed.

With an overall goal of developing a coordinated, comprehensive, and timely national Nuclear Forensics capability within Canada, the areas of work identified during the 2011 workshop were separated into two separate but inter-related project streams:

(1) Stream 1 (Laboratory Network), led by Atomic Energy of Canada Limited (AECL), was mandated to establish a national nuclear forensics laboratory network capable of undertaking comprehensive nuclear forensic analysis of nuclear and other radioactive material, as well as forensic analysis on evidence contaminated with radioactive material as part of the investigation of a nuclear security event.

(2) Stream 2 (Library), led by the Canadian Nuclear Safety Commission (CNSC), was tasked with establishing a national nuclear forensic library (NNFL) consisting of comprehensive descriptions of nuclear and other radioactive materials produced, used, or held in Canada, which will provide the basis for conducting comparative assessments with material encountered outside of regulatory control.

These two streams will proceed in parallel, with the following partner organizations lending their expertise to one or both streams: DRDC's Ottawa Research Centre, the Royal Canadian Mounted Police (forensics and operations), the Royal Military College of Canada, the National Research Council, Health Canada, Public Safety Canada, the Department of National Defence, and the Department of Foreign Affairs, Trade and Development. Over the course of the project, the library stream will identify materials for analysis by the network labs, providing samples where possible, and the labs will carry out analysis to in order to help populate and validate the NNFL. The work of the two streams will culminate in a trial exploitation of this capability at the end of the project. The project is envisioned to take approximately three years to complete, from April 2013 to January 2016. The total commitment of resources to this project, including CSSP funding and partner in-kind contributions, is close to $5 M.

3. National Nuclear Forensics Laboratory Network

A robust nuclear forensics program requires a wide range of expertise found across several government agencies, making it necessary to formalize a network of these organizations, providing a framework for collaboration. Canada's Nuclear Forensics Laboratory Network (the lab network) will consist of several laboratories with complementary capabilities in the fields of radioactive measurements, analytical chemistry (both isotopic and elemental compositions), physical characterization, optical and electronic microscopy, and surface and particle analysis. The laboratories are also expected to have radioactive and nuclear material handling and storage facilities. In addition, law enforcement agencies will work with laboratories in the network to develop procedures for the forensic analysis of evidence contaminated with radioactive material. Partners in law enforcement and international affairs are also providing advice and guidance on the overall direction of the development effort, in order to ensure that the project outputs are consistent with the requirements and expectations of the user community.

The establishment of the lab network has been broken down into a number of key tasks:

(1) Establish requirements for nuclear forensics labs

(2) Catalogue current analytical capabilities in the federal S&T sector

(3) Identify gaps in the lab network capability and determine appropriate actions to close the gaps

(4) Implement appropriate actions to develop technology and standards to address the identified gaps

(5) Develop training plan for nuclear and traditional forensics specialists, and begin delivery of training

(6) Develop protocols for collection, packaging and transportation of RN materials to the labs

(7) Develop appropriate protocols and procedures for the handling of evidence at the RN labs

(8) Plan operational exercise details and establish assessment procedure to test NF capability

(9) Execute operational exercise geared towards lab network implementation

3.1. Nuclear Forensics Laboratory Requirements

Nuclear forensics laboratories must be capable of providing timely, scientifically valid data in a manner that is legally defensible. Access to appropriate resources, and the skills and experience to exploit these resources, is essential to the provision of nuclear forensic data. While resources and expertise are prerequisites to legal defensibility, the operation of a nuclear forensics laboratory according to a defined and documented structure also represents a cornerstone of the nuclear forensics process.

The goal of this task is to produce a document that provides guidance for the minimum quality assurance requirements for facilities conducting nuclear forensics analysis and/or traditional forensics on evidence contaminated with RN material as part of the national nuclear forensics laboratory network. The requirements are to be drawn from those associated with established standards (e.g., ISO 17025), published literature (e.g., guideline documents from the IAEA), and forensics practitioners, including Canadian and international forensic laboratory best practices. Elements of the lab requirements will include laboratory organization and management, sample control (particularly in terms of chain of custody considerations), document and data control, personnel qualifications and training, and analytical methodology.

3.2. Catalogue of Current Analytical Capabilities

To establish the national lab network, there is a need to know the current analytical capabilities of each of the labs. Using IAEA's Nuclear Security Series No. 2, *Nuclear Forensics Support*, as a guide [1], several categories of capability were identified, including on-scene capabilities, radiation detection, imaging (both portable and non-portable), powder characterization, surface analysis, elemental and isotopic analysis, and specialized facilities such as fume hoods, glove boxes, and shielded cells. Input from each of the labs will be consolidated into one catalogue of analytical capabilities. Since the contents of the catalogue are expected to change with time, as new capabilities are developed and established, and old, obsolete ones discarded, the intent is to update this catalogue on a regular basis.

3.3. Analytical Capabilities Gap Assessment

An assessment of current capabilities will be performed to identify gaps in current knowledge and capabilities. During this task, it is necessary to consider the minimum acceptable capability as opposed to the ideal set of capabilities. Part of this assessment is to determine actions to close the identified gaps. A literature review of previous work in Canada and internationally will be conducted to aid in drawing up options for closing these gaps. Another approach that will be adopted is participation in international nuclear forensics meetings and workshops to leverage what is being developed in Canada with other international partners.

3.4. Training of Nuclear and Traditional Forensics Specialists

This task will involve identifying training requirements and potential sources of training for both nuclear forensics and traditional forensics specialists. Effectively, this task will develop a cross-training program, promoting forensic awareness training for RN lab scientists, with an emphasis on chain-of-custody aspects of evidence handling, and RN awareness training for traditional forensic scientists.

3.5. Development of Protocols

Protocols developed under this task will include those for the collection, packaging, and domestic transportation of RN materials to the laboratories, as well as those for the handling of evidentiary material at the labs. Development of these protocols will take into consideration best practices and existing procedures that have been developed for first responders and field personnel. These protocols, intended to be non-prescriptive, will serve as guidelines for each lab to develop their own standard operating procedures.

3.6. Operational Exercise

The coordinated nuclear forensics capability developed under this project will ultimately be demonstrated in an operational exercise geared towards lab network implementation; time and resources permitting, the operational exercise will be preceded by a lab intercomparison study focused on validating the technical aspects of the network's analysis capabilities. Planning of the operational exercise will involve the identification of test objectives and assessment criteria as input to designing the exercise. The exercise will involve the end user community, and will cover the entire "life cycle" of an event, from the incident itself to evidence collection, analysis, and presentation of evidence in a court of law.

4. Project Status

The project charter was signed by all partners in September 2013, and a kick-off meeting for the lab network was held shortly thereafter to initiate work on the first two tasks: the requirements for nuclear forensics laboratories in the network, and the catalogue of current NF analytical capabilities. One major lesson being learned during the early days of the project is that frequent project communication is essential to coordinate a multi-organizational effort such as this.

Thus, the lab network has a regularly scheduled teleconference to discuss status of ongoing work and action items from previous meetings and teleconferences, and a document sharing site has been set up to facilitate collaboration. Realizing the importance of face-to-face interactions to discuss major milestones and resolve any serious issues, project meetings are held quarterly on a rotating basis, where each meeting is hosted by a different lab.

5. Conclusion

Canada has initiated the National Nuclear Forensics Capability Project, taking a two-stream approach to develop a formalized Nuclear Forensics Laboratory Network and a National Nuclear Forensics Library. The Lab Network as a whole will be capable of comprehensive NF analysis, as well as classical forensic analysis on evidence contaminated with radioactive material. Canada's approach to building up the Lab Network is to mobilize and coordinate several federal S&T agencies with complementary capabilities. As active partners in the project, law enforcement agencies and other government departments ensure that the outputs meet the needs of the end user community. The project builds upon existing knowledge, expertise, and facilities in order to provide the greatest possible return on investment.

To succeed, the project requires strong collaboration among nuclear scientists, forensic experts, law enforcement, policy makers, and operational support specialists, and much progress has already been made towards achieving this goal. The ultimate result of this strong collaboration will be the development of a national nuclear forensics capability, which will ensure that Canada is capable of analyzing both seized materials and contaminated evidence in a manner that supports the successful prosecution of crimes involving the misappropriation or misuse of RN materials.

ACKNOWLEDGEMENTS

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REFERENCES

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

The Network of Russian Analytical Laboratories for Support of Nuclear Forensics

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Abstract. Traditional forensics laboratories have not necessary experience in analysis of nuclear and radioactive materials, and they are not able to investigate the conventional evidence together with radioactive materials. Therefore involvement of laboratories which can provide appropriate analysis of nuclear and radioactive materials is necessary for achieving all possible objectives of criminal investigations with nuclear and any other radioactive materials or its trace amounts. Four organizations cover analytical nuclear forensics needs in Russia. No one of these analytical subdivisions can solve all analytical tasks on the highest level. But these four analytical subdivisions together are able to solve all analytical tasks for nuclear forensics with the best possible quality.

1. Introduction

Russia has a well developed system of forensics organizations in the Ministry of Justice, Ministry of the Interior and Federal Security Service. These organizations are staffed by the highly qualified experts and the system is capable to implement the wide range of expert investigations, such as fingerprints, biological traces, microparticles of natural and anthropogenic origin, gunshots and explosions traces, etc.

But investigations, which are usually being implemented by these organizations, not concern radioactivity. Therefore cooperation of these organizations with laboratories which can provide prosecution with appropriate results of analysis of nuclear and radioactive materials is necessary for the solution of entire the diversity of nuclear forensics tasks.

On the nuclear security summit in Haag the Russian minister of foreign affairs S. Lavrov stated that Russia is developing a system of forensic laboratories to identify nuclear and other radioactive materials and radioactive waste removed from illicit trafficking. The purpose of this paper is the clarification of the basic principles that inspired the creation of the system as well as description of this system content.

2. Basic principles of the creation of the system

Criminal prosecution of the incidents with unknown nuclear and other radioactive materials including illicit trafficking of these materials is organized in Russia in correspondence with national laws: criminal code, code of criminal procedure, law about forensic activity in Russian Federation, laws, which determine the handling of radioactive materials, as well as in correspondence with interdepartmental documents.

Nuclear forensic has obvious interdepartmental character because criminal prosecution is implemented by law enforcement agencies, but the expert functions should be provided by specialists in the field of nuclear and other radioactive materials. National model incident response plan designed to address the questions of interdepartmental relationship. Now some alignment of Russian response plan with Model plan, which is outlined by [1], is being implemented.

This Response plan consists of several sections, including the section about the support of prosecution by the results of investigation of nuclear materials and other radioactive evidence.

The development of that section of the Response plan and possible scheme of analytical activity is based on several points:

- Illicit trafficking is inherent not only to nuclear and other radioactive materials. It is inherent to drags, weapons, explosives and other chemical reagents, etc. From the point of prosecution the crime investigations of the incidents with all these items are distinguished only by some evidence and consequently by technical experts, which should be involved in investigations.

- Analytical capability of the system should provide the possibility of the solution of any analytical task on the highest analytical level. Accordingly the provision of the record levels for each analytical method should be provided.

- Incidents with nuclear and other radioactivity materials occur relatively rare. It means that involving of high level analytics in the investigation is necessary not so often.

First of these points determines coordination of documents and procedures of nuclear forensics with ones developed for prosecution of illicit trafficking of other mentioned objects. Second point determines the necessity of the developing of any relevant analytical technique up to highest possible scientific level at least in one scientific laboratory. The same point together with understanding of rareness of the incidents mean that it is too expensive and not necessary to have one specialized laboratory, which could to implement any required for nuclear forensics goals analysis, and to use such laboratory exclusively for nuclear forensics analyses. A lot of time such laboratory and accordingly high qualified specialists would have to implement the training and wait the real work.

At the same time these high qualified specialists can implement useful work, which is not concern nuclear forensics, in their laboratories in cooperation with other specialists of their laboratories. Moreover specialists can support their qualification only by implementing real important works. Such works can not be replaced by a lot of trainings.

Therefore the decision was made in Russia – not collect all methods and specialists, necessary for nuclear forensics, in one laboratory, but develop corresponding techniques in laboratories, in which these techniques were developed earlier and are necessary for usual works. Some modifying of early developed techniques is requested in correspondence with possible specific of the evidence, but the major part of working time and efforts are spent by the laboratories and specialists for their routine work. In the case of nuclear forensic investigation the concrete techniques, which should be applied in investigation, are determined. Corresponding laboratories and specialists are involved in the investigation after such of determination.

3. Analytical tasks of nuclear forensics

Solution of the following basic analytical tasks can be required in the process of nuclear forensic investigations for achieving the all possible objectives of criminal investigations:

- Measurement of the content and isotopic composition of uranium, plutonium and other radioactive materials in samples – for identifying the materials and determination of the possible fields of their use;

- Determination of the elemental composition of nuclear and other radioactive samples, including elemental composition of impurities – for identification of possible manufacturer of the materials and, in some cases, designation of materials;

- Determination of morphological characteristics of nuclear material fragments – for identification of possible manufacturer of the materials;

- Detection of the trace amounts of nuclear and other radioactive materials on the clothing, household items, in samples, collected at the crime scene and at the suspected crime scene – for determination of the route of illicit trafficking and the circle of involved persons;

- Detection of the nuclear and other radioactive materials including their trace amounts on the body surface, in the biopsy, autopsy and in the metabolism products – for determination of the circle of involved persons;

- Measurement of isotopic composition of uranium and plutonium in microparticles – for identifying the materials and determination of the possible fields of their use;

- Determination of elemental composition and morphological characteristics of microparticles of nuclear and other radioactive materials – for determination of mechanism of microparticles formation and for determination of possible manufacturer of the materials;

- Measurement of the content of isotopes-chronographs in all types of specimens and samples, as well as in individual microparticles – for determination of the date of production of nuclear or other radioactive materials.

All these analytical tasks are solved by different Russian laboratories in their habitual works. These works concern the study of materials of nuclear technique, IAEA Safeguards, geology, mineralogy and even medicine, including disaster medicine. But laboratories, which demonstrate the highest level of corresponding techniques, should be chosen for the nuclear forensic applications.

4. Laboratories – members of Russian Network

Analytical capabilities of laboratories are the main component of country’s capability in the field of nuclear forensics. These analytical capabilities determine country's ability to implement comprehensive investigation of any incident with illicit trafficking of nuclear materials.

Capabilities of analytical laboratories are determined by:

- Qualification of personal;

- Level of the used analytical equipment;

- Methodological support.

Four organizations cover analytical nuclear forensics needs in Russia. These are: Information and analytical center for identification of nuclear materials, founded on the base of analytical division of the Rosatom’s Bochvar Institute, analytical laboratories of the Rosatom’s Khlopin Radium Institute, analytical laboratories of the Federal Medical Biophysical Center of Russian FMBA, “Laboratory for Microparticle Analysis”.

No one of these analytical subdivisions can solve all mentioned analytical tasks on the level of the highest world standards. But each of them possesses some unique analytical techniques, which correspond to the world level, and these four analytical subdivisions together are able to solve all analytical tasks for nuclear forensics with the best possible quality.

The Bochvar Institute is the main Rosatom’s organization in all matters of nuclear materials and technologies, including the technologies of nuclear materials processing, the technologies of radiochemistry facilities and radioactive waste processing. The Bochvar Institute owns database of Russian and Soviet nuclear materials.

Comparison of the results of analysis of seized nuclear materials with some information about Russian and Soviet materials allows to determine possible samples for further comparative in-depth investigation.

Apart comparison of any information with information from database the Bochvar Institute can provide prosecution with following kinds of analytical investigation:

- Measuring of the content and isotopic compositions of uranium and plutonium in samples of nuclear materials;

- Determination of morphology characteristics of the fragments of nuclear materials;

- Analysis of external details, including inscriptions, symbols and signs, on the surface of the products from nuclear materials.

But analytical equipment of the Bochvar Institute and developed techniques designed first of all for the solution of technological tasks and analysis of relatively large amounts of materials.

For the solution of nuclear forensics analytical tasks, which are connected with characterization of the trace amounts of uranium and plutonium and other radioactive materials, laboratories of Khlopin Institute and "Laboratory for Microparticle Analysis" are designed. Both organizations are the members of IAEA Network of analytical laboratories for analysis of environmental samples. Therefore they are ready to work with the crime scene samples, which contain small amounts of sought-for materials.

Laboratories of the Khlopin Institute measure the content and isotopic composition of picogrammes and femtigrammes of uranium and plutonium. Detection limits for plutonium isotopes as well as for uranium-234 and uranium-236 are the units of femtogramme, for uranium-235 – dozen of femtogrammes, for uranium-238 – about 1 pg.

"Laboratory for Microparticle Analysis" investigates morphology characteristics and elemental compositions of individual particles with sizes down to 0.5 µm as well as isotopic compositions of uranium and plutonium and the content of isotopes-chronographs in particles. Moreover it determines impurities and the content of isotopes-chronographs in the small amounts of the uranium and plutonium materials.

Determinations of nuclear and other radioactive materials on the bodies of the people as well as in materials of biopsy and autopsy are implemented by Federal Medical and Biophysical Center. This Center posses unique experience of investigation of human organs, which were contaminated in the result of different incidents with nuclear and other radioactive materials. Specialists of this Center posses of information about possible accumulation of nuclides in specific human organs. Besides they have invaluable experience of analyses of biological samples by using different analytical techniques.

For some kind of nuclear forensic tasks these four laboratories organize and implement joint investigations, including Round Robins. The similar techniques as well as the different methods are used in these experiments for the determination of the same characteristics of nuclear and other radioactive materials.

REFERENCES

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

Development of Nuclear Forensics Capabilities in Japan

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Abstract. According to the IAEA technical guidance for nuclear forensics (NF) starting from incident response and going to sampling, distribution, analysis and finally interpretation in illicit trafficking of nuclear and other radioactive materials [1], NF laboratory has to enable the identification of unique characteristics in the seized materials, to provide investigative leads and support prosecution outcomes and then to enhance State security. Japan Atomic Energy Agency (JAEA) has started the development of analytical techniques for establishment of the NF laboratory with responsibilities to accomplish the analytical techniques such as isotope ratio measurement, impurity measurement, particle analysis, uranium age determination, and development of a prototype national NF library against illicit trafficking of nuclear and radiological materials. In this paper, capabilities of the NF technologies in Japan are presented in order to share our experience with international NF community. Need to establish international cooperation regime on realistic NF approach is also discussed.

1. Introduction

In accordance with Japan's national statement at the Washington Nuclear Security Summit (2010), development of technology related to measurement and detection of nuclear material and nuclear forensics (NF) has been started based on international cooperation for the contribution to the identification of the sources of the nuclear material illicitly trafficked or used in terrorist attacks. Japan has made increased contributions to the international community by establishing these technologies with more precise and accurate capabilities in detection and forensics within an approximate three year time frame and sharing the fruits of these new technologies with the international community.

According to IAEA reports and other security documents, the threat of nuclear terrorism is still increasing. From the point of view of security and maintenance of public peace in Japan, the domestic technologies against illicit trafficking of nuclear material and radioactive substances must be established for criminal specification and prosecution. When illicit trafficking of nuclear material happens in a third-country in future, there is possibility that the nuclear material is suspected to be stolen in Japan because we have various nuclear facilities and multiplex nuclear materials. Japan's own technology for NF should be retained in order to keep reliance of our nuclear activities.

Japan Atomic Energy Agency (JAEA) has engaged in research and development activities of NF for strengthening nuclear security. The JAEA implements joint researches with the US including uranium age dating measurements, characterization of nuclear fuel for forensics purposes, and establishment of a proto-type national NF library. Analytical methods for measurement of isotopic abundance and impurity in nuclear material are also developed to identify its source and determine the point of its origin and routes of transit. In this paper, capabilities of the NF technologies in Japan are presented in order to share our experience with international NF community. Need to establish international cooperation regime on realistic NF approach is also discussed.

2. Development of nuclear forensics technologies

Fundamental technologies for NF have been developed from 2011 to 2013 at JAEA, where the objects to be analysed are isotopic abundances of nuclear material by means of Thermal Ionization Mass Spectrometry (TIMS), abundance of impurity contained in the nuclear material by Inductively Coupled Plasma-Mass Spectrometry (ICP-MS), particle image by Scanning Electron Microscope (SEM) and/or Transmission Electron Microscope (TEM), and uranium age determination. National NF library is under construction by collecting several kinds of data and analysing various uranium samples as an NF database.

Actual uranium samples have been measured by the methods mentioned above. Isotopic abundance of an imported yellow cake was analysed by TIMS and the result is shown in TABLE I. High reliability of the isotopic abundance measurement has been accomplished by analysing the NBL standard materials of CRM U050 and U500, where their relative standard deviations (1 RSD) are 0.022% and 0.030%, respectively. Particle image of the same sample measured by SEM is given in FIGURE. 1. Specific future of the image can be observed from this figure, which is very useful information as an NF evidence.

TABLE I: ISOTOPIC ABUNDANCE OF A URANIUM SAMPLE (YELLOW CAKE).*

Sample No	^{234}U (%)	^{235}U (%)	^{238}U (%)
1	0.00576	0.7206	99.2736
2	0.00527	0.7206	99.2742
3	0.00565	0.7199	99.2744
4	0.00545	0.7202	99.2744
5	0.00547	0.7207	99.2739
Mean Value	0.00552	0.7204	99.2741
1 SD	0.00019	0.0003	0.0004

* Five specimens from one sample were measured for uncertainty evaluation.

Impurity analyses were carried out for five samples of natural, depleted and enriched uranium by ion exchange separation and ICP-MS measurement and the result is shown in FIG. 2. The contents of impurity elements are quite different among the samples, because the points of their origins and routes of transit are varied.

The age of nuclear material is essential information to identify the source of the material, and ^{234}U-^{230}Th chronometer is widely applied to NF. We conducted procedure exchange and inter-laboratory comparison exercise on uranium age dating between Department of Energy (DOE) of US and JAEA, where the same NBL standard materials of CRM U050 were independently analysed. The analysis of age determination on uranium oxide standard was already performed and the time of its purification can be estimated to be July 31 of 1957 from the JAEA's result. Inter-comparison with other laboratory's results is now in progress [2].

The JAEA has developed a prototype system of National Nuclear Forensics Library (NNFL) based on the data related to nuclear materials and other radioactive materials possessed at the JAEA facilities. A concept building of the database for NNFL was almost completed with its basic system of data handling. The data gathering on the nuclear materials at JAEA has been continued. The present prototype system will be transferred to the future national responsible authority as a real NNFL which will support the nuclear security activities in Japan. The JAEA participated in the first international table top exercise of NNFL "Galaxy Serpent," held by the International Technical Working Group (ITWG) as a part of our NNFL development project [3]. FIGURE 3 shows an isotope correlation plot in order to evaluate the seizure. The seized material (green) strongly associated with the PWR-2 reactor (blue). Status of our NNFL development will be also presented in this IAEA Conference [4].

3. Nuclear Forensics Capabilities in Japan

In the Statement of Principles committed to the participants in the Global Initiative to Combat Nuclear Terrorism (GICNT), they implement eight principles on a voluntary basis: One of the principles is "Improve capabilities of participants to search for, confiscate, and establish safe control over unlawfully held nuclear or other radioactive materials and substances or devices using them." In view of the importance of nuclear security and international impetus to construction of NF regime, the pertinent agencies in Japan (Nuclear Regulation Authority, National Police Agency, Japan Coast Guard, Ministry of Foreign Affairs, Ministry of Finance Japan, Ministry of Education, Culture, Sports, Science and Technology, Ministry of Defense, and so on) must cooperate with one another. It is necessary to organize Japan's own system for NF by establishing a national NF laboratory and collaborating with traditional forensics which targets the evidences of finger prints, DNS, and so on.

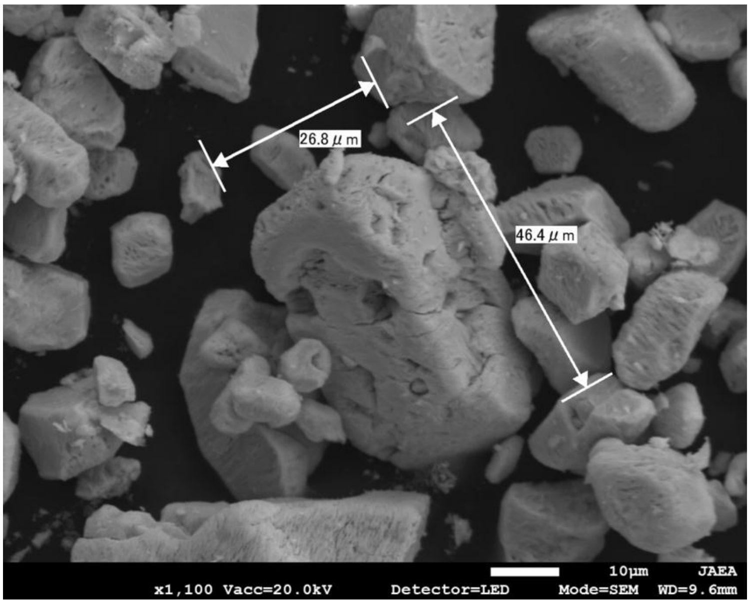

FIG. 1. Particle image of the yellow cake observed by SEM.

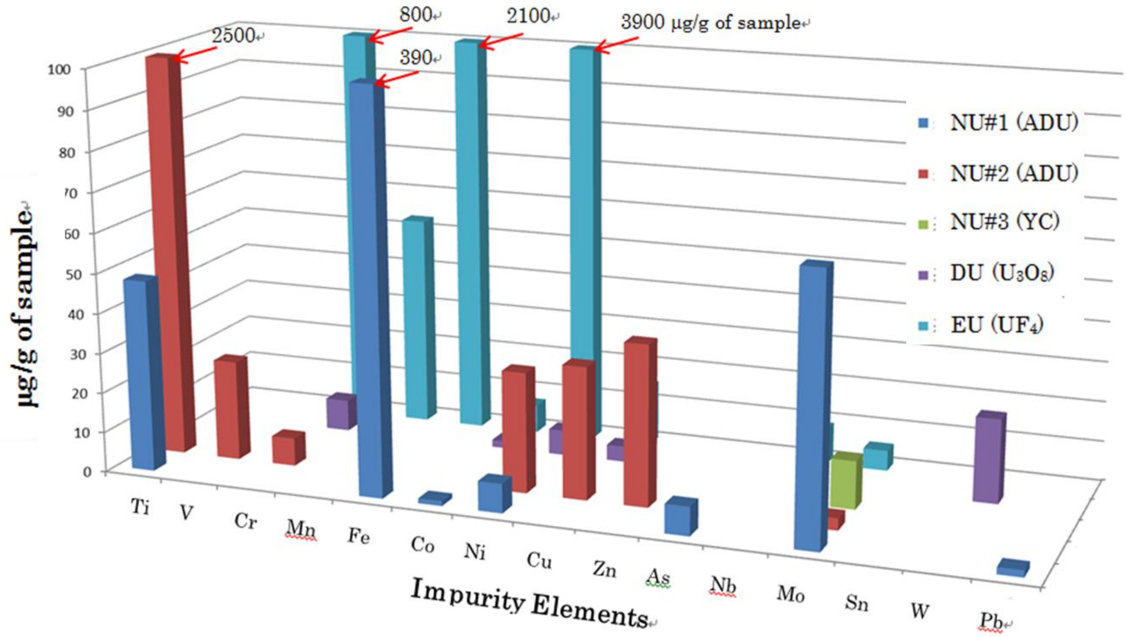

FIG. 2. Impurities contained in the uranium samples.

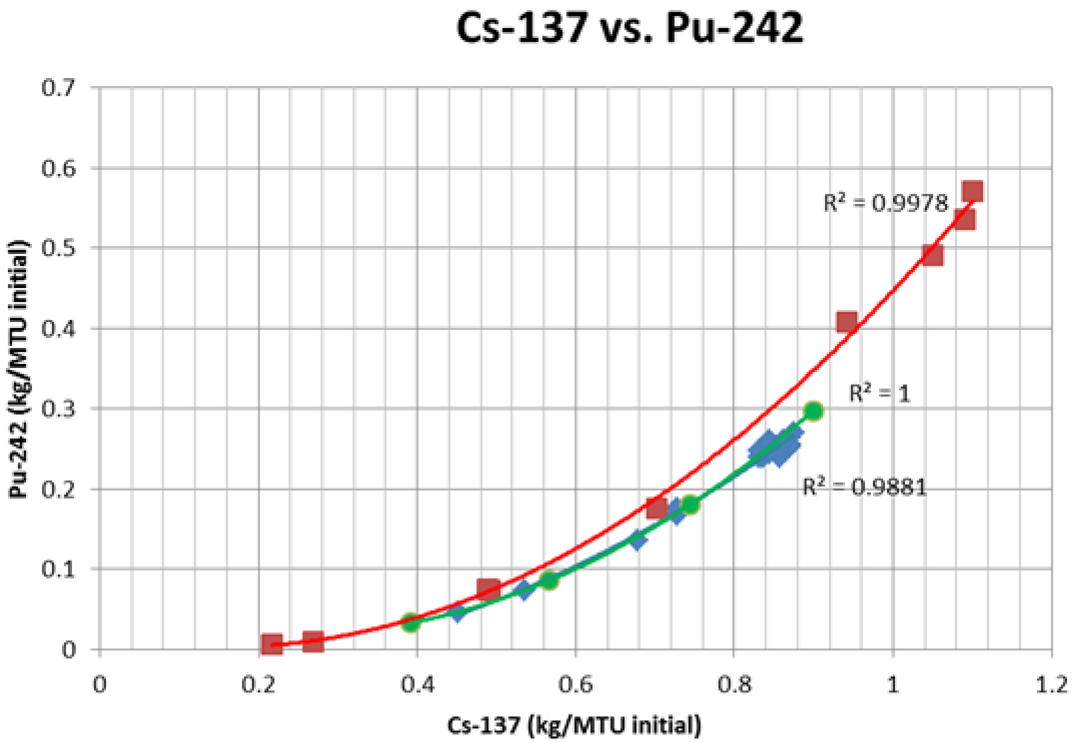

FIG. 3. Isotope correlation plot of ^{137}Cs vs. ^{242}Pu for international table top exercise of NNFL "Galaxy Serpent." The data of red squares belong to spent fuel of PWR-1, blue squares to PWR-2 and green circle to seizure, respectively.

The NF laboratory consists of analytical and storage facilities for seizure materials and NNFL. The laboratory should have ability to secure the reliabilities of evidence analysis techniques, guarantee of quality to the results analysed as evidence, database and its comparison with evidence. Because the JAEA has developed the fundamental technologies for NF as mentioned above, it is possible for us to take charge of the analysis for nuclear materials as a work of NF laboratory. In the NF analysis of seizure and the database construction of NNFL, the judicial reliability of the data is required on the basis of standardization of the analytical scheme and inter-laboratory round-robin exercises. We enhance our analytical skills for the sake of international progress of the nuclear security.

Exchange of the newest NF information through international cooperation is important for each State, because the NF activity has a global side of criminal investigation. Japan implements joint researches with the US for forensics purposes at the JAEA. The Integrated Support Center for Nuclear Nonproliferation and Nuclear Security (ISCN) under the JAEA has been providing training courses to support domestic and international capacity building for regulators, mainly from Asian countries in cooperation with the IAEA. The IAEA Regional Training Course on Introduction to Nuclear Forensics was hosted by the ISCN in May 2012 and received total 24 participants from ten Asian countries. Japan will continue to promote such coordination and cooperation through the IAEA and other international fora [5].

4. Conclusion

The JAEA has developed fundamental and reliable technologies for NF (Nuclear Forensics) and is now measuring actual uranium samples to make a NF database. A prototype system of NNFL (National Nuclear Forensics Library) is under construction on the basis of international cooperation. The pertinent agencies in Japan must cooperate with one another to organize Japan's own system for NF by establishing a national NF laboratory. The laboratory should have the reliabilities of evidence analysis techniques, guaranteed quality of the evidence, and database and its comparison with evidence. Another important subject of ours is domestic and international capacity building of nuclear security, especially for Asian countries, in cooperation with the IAEA.

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REFERENCES

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

[2] A. OKUBO et al., to be submitted (2014).

[3] Y. KIMURA, N. SHINOHARA, Y.FUNATAKE, Lessons Learned from the International Table Top Exercise of National Nuclear Forensics Library at JAEA, Journal of Nuclear Material and Management (in press).

[4] Y. KIMURA, N. SHINOHARA, Y.FUNATAKE, M. WATAHIKI,Y. KUNO, National Nuclear Forensics Library at Japan Atomic Energy Agency, International Conference on Advances in Nuclear Forensics, IAEA, Vienna (2014).

[5] NUCLEAR SECURITY SUMMIT 2014, National Progress Report Japan, http://www.mofa.go.jp/dns/n_s_ne/page18e_000059.html, Hague (2014).

Armenian Nuclear Forensic Lab

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Abstract. After disintegration of the USSR, a situation developed in Armenia when control over sources at the enterprises which use radioactive sources was extremely weakened due the following reasons:

1. The majority of the industrial enterprises and scientific research institutes of federal submission, including the so-called "enterprises of military department", from the end of 80th practically did not work. Further process of production renewal was accompanied by active alienation of the equipment without taking into account radioactive sources of scientific and industrial purpose.

2. In the beginning of 90th in Armenia, there was no corresponding state body of radioactive sources management supervision. The centralized lists for accounting and control of industrial and medical radioactive sources were lost. Therefore, actual process of accounting by Regulatory body of the RA was carried out on the basis of own studies within the framework of the developed statutory acts. This procedure is still in process.

3. Considering that the enterprises were shutdown, the appropriate control over the sources was not possible because of unavailability of the:
   - means,
   - experts of corresponding qualification,
   - corresponding knowledge on the sources management, and special devices.

1. Introduction

A number of facts exists which prove the abovementioned (see Appendix A). In particular, many cases are known, when sources (and highly active) have been found in possession of private persons who knew practically nothing about the danger they and their environment were posed. The situation is even more complicated when radioactive sources become a potential subject of illegal trade or are used by people who do not suspect any danger, in other purposes.

Many cases are known when during transportation through border, radioactive sources and radioactive materials were found in cargoes of scrap metal (See Appendix A).

The current situation represents a real danger for workers of the enterprises, population and environment. It is necessary to note one more (though also improbable, but still possible) aspect of this problem. It concerns the radiation terrorism considering the established situation – a potential for radioactive sources theft is rather high. Cases (in particular in the Czech Republic) are known when terrorists threatened to use the radiation weapon against the population.

According to IAEA, for the period since January 1, 1993 to 2003, 335 reported incidents with radioactive materials, other than nuclear materials, are known. In most cases they were in the form of closed radioactive sources.

According to the data in the work by V.Orlov [IIIicit Nuclear Trafficking and the new agenda, IAEA BULLETIN, v. 46, N_o 1, June 2004, p.53], since 1993 the reported incidents with nuclear materials have sharply gone on a loss. At the same time the number of incidents with radioactive materials has increased for more than twice compared with 2003.

The incident which occurred in January 2009 at Meghry custom-house (the border with Iran) is remarkable. During transportation of lead waste, the excess above the limit was fixed on the transport monitor. 3 bags with lead waste were delivered to laboratory. The further analysis showed that the waste contained Am-241 source. Neutron power of the source was 10^7 neutron/s. This incident was notable because the owner knew about the source presence and tried to hide it from the customs officers, carefully packing it in some layers of sheet lead.

In May 2009, during routine radiation monitoring in the village of Noraduz, it was revealed that the premises for repair of trucks and the territory adjoining them (an area of 300 square meters) were polluted with radioactive isotope Cs-137. Gamma radiation intensity in the premises ranged from 900 to 1200 μSv/h. Gamma radiation intensity in the surrounding area was 600-800 μSv/h. Four persons (the owner of the truck repair shop, his son and two technicians) received radiation doses exceeding the normally established limits. The dose for the owner's son was 128 mSv/year, and another person's internal dose was estimated from 7 to 12 mSv/year.

In Fig. 1, the statistics of incidents is presented, related to the illicit trafficking of radioactive sources and materials, which were followed by court examination. For these incidents the FL performed expert examinations and issued expert reports. In Appendix A, some photos illustrating the above-mentioned situation are presented.

In summary it should be noted that the activity on searching, identification and bringing radioactive and nuclear sources and materials to safe condition is to be continued, as there are a lot of enterprises and territories in Armenia where monitoring is necessary.

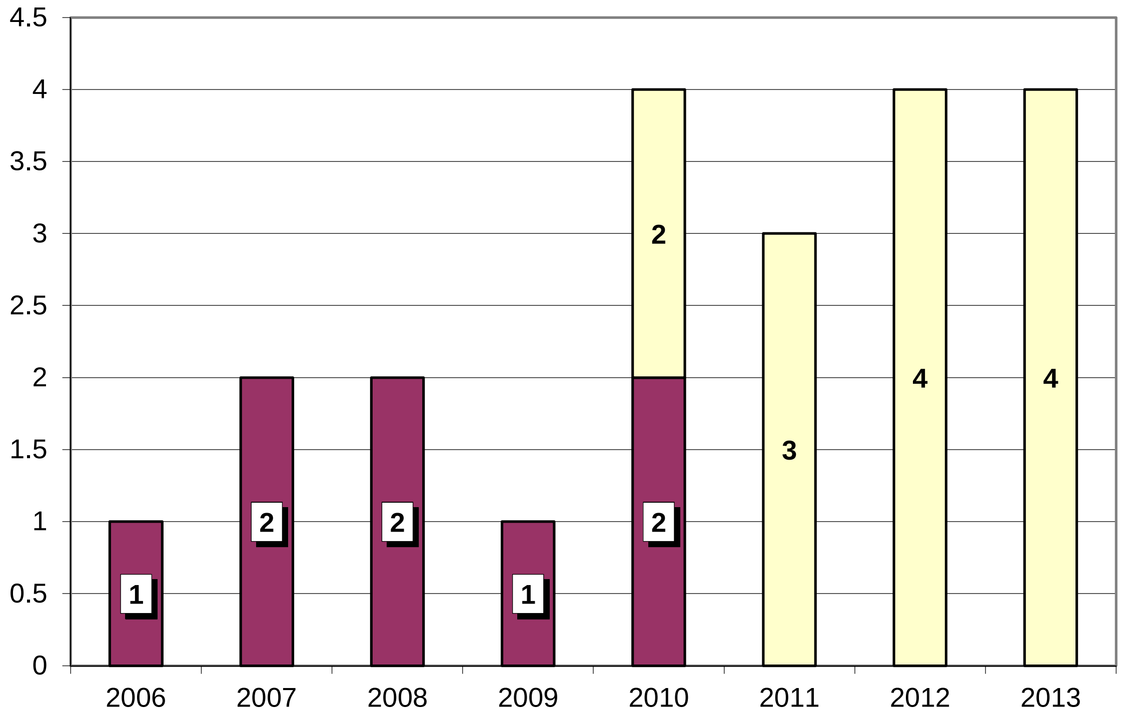


Fig. 1 Statistics of incidents, related to illicit trafficking of radioactive sources and materials, which were followed by court examination. For these incidents the FL performed expert examinations and issued expert reports. CRDF Project # PNCP 8210 was started on October 1, 2010 (the expert examinations performed within project are yellow colored).

2. Project Implementation

For all cases of revealed illegal manipulations with radioactive sources and materials it is necessary to identify and implement the established procedures connected with these sources description and provision of the data for prosecution and execution of judicial actions.

So far Armenia had no a specialized laboratory intended for solution of such problems. Therefore, the initiative group from Radiation Protection Department (Laboratory of Radiation Monitoring) of the Armenian Nuclear Power Plant made a decision to carry out radiation monitoring of the enterprises and territories of Armenia with the purpose of detecting orphan radioactive and nuclear sources and materials. During the whole period of monitoring the initiative group closely cooperated with bodies of national security, internal affairs and nuclear regulatory body.

The laboratory of radiation monitoring received licenses for:
- export of radioactive and nuclear sources and materials.
- storage of radioactive and nuclear sources and materials.
- transportation of radioactive and nuclear sources and materials.

Besides, we developed a program for safe transportation of ionizing radiation sources (SIR), and also, emergency procedures. Members of the initiative group participated in the training course on searching and detection of radioactive and nuclear materials in August, 2006, organized by Sandia National Laboratory of the USA, and received corresponding certificates. Two members from the initiative group are licensed experts in the field of the dual purpose goods (the state licenses ## 0411, 0412).

In October 2010, the Laboratory received the CRDF grant for the project “Establishment of the Laboratory for Technical and Forensic Analysis of Nuclear and Radioactive Materials in the Republic of Armenia” (FL) in the framework of Preventing Nuclear Smuggling Program, US. Total project cost is US $384,116.

2.1. International Collaboration

During project implementation, and until now, we have been continuously supported by curators of the project (Ms. Antsiferova, Ms. Dace Sarma and Mr. Matthew Fargo from CRDF Global) and by scientific collaborators (Dr. Michael Palian and Dr. Kevin McLeary from The Chemical, Biological, Radiological, and Nuclear Sciences Unit, Federal Bureau of Investigation).

2.2. National Collaboration

We successfully collaborated with the National Security Service (NSS) of the Government of the Republic of Armenia, and the Police of the Republic of Armenia in the field of illegal trafficking of radioactive and nuclear materials. The Laboratory provided forensic expert support to the law proceedings in this area. Three times the staff of the FL participated in trials/court examinations to clarify the hazard posed by radioactive material and their potential use in illegal trafficking.

The Laboratory organized two training courses (total duration -18 hours) for the staff of the Academy of the National Security Service (22 attendees) and NSS Armavir Department (4 attendees). Topic 1 - "*Nuclear and radioactive materials/sources and the instruments where they are used, potential threats*" (12 hours), topic 2 - *"Sources of human exposure"* (6 hours). These lectures contributed to a better understanding of the threats related both to illegal trafficking of radioactive and nuclear materials and their transport across the borders of Armenia.

The staff of the Laboratory performed calibration of the radiation monitors at the customs points (Meghri, Bagratashen, Bavra, Gogavan, Gyumry airport, Zvartnots airport) once per year, which enabled improving significantly the quality of radiation monitoring at the borders of Armenia.

Below-listed are the Armenian State Bodies with which we maintain regular relations:

- Relevant Law Enforcement Agencies
- National Security Service
- Armenian Nuclear Regulatory Authority
- Customs Service
- Ministry of the Environment Protection
- National Academy of Science

Fig. 2 presents the scheme of Armenian Nuclear Forensic Lab's interaction with Armenian ministries to strengthen the national nuclear security infrastructure

For the period of the project implementation:

1. The full set of the documents was prepared, defining the statute of the laboratory, regulating its activities and duty regulations. 22 documents were issued.

2. The laboratory was equipped with the up-to-date high-sensitivity equipment necessary for performance of gamma spectrometric analyses (both in laboratory conditions, and in situ) and, partially, for performance of alpha measurements.

3. "Database of Incidents Linked with Radioactive and Nuclear Sources and Materials on Territory of Republic of Armenia" was developed including detailed description of the discovered radioactive souses and materials from 1999 up to now.

4. Some areas in Armenia were monitored, and, as a result, the radioactive materials were discovered.

5. During the project implementation two experts were trained in the FL, and they participated in the training course "Radiological Crime Scene Management and Way to Nuclear Forensics" held in Karlsruhe, Germany, Transuranium Elements Joint Research Center, European Commission, 17-23 June, 2013. Four project participants (Vovik Atoyan, Vazgen Melikyan, Ashot Avagyan - training course "Radiological Crime Scene Management and Way to Nuclear Forensics" held in Karlsruhe, Germany, Transuranium Elements Joint Research Center, European Commission, 2-6 July, 2012, and Konstantin Pyuskyulyan - International Nonproliferation Export Control Program, INECP, University of Georgia - "Center for International Trade and Security", USA, two weeks in March 2013) were trained in the area of combating the illegal trafficking of nuclear and radioactive materials and sources.

3. Future Plans

- Continue monitoring activities: searches, transportation, analysis, and secure storage of orphaned sources.

- We plan to continue our work in close cooperation with the National Security Service of the Government of the RA and Juridical Authorities, and render expert support to the State Committee for Nuclear Regulations (ANRA), Customs Service of the RA.

- In addition, we plan to cooperate with the Ministry of Environment Protection of the RA and Academy of Sciences of the RA. Both organizations rely upon the FL staff's expertise, and need our support.

- Train new experts from the staff of the National Security Service in examination of nuclear and radioactive material, and continue training and competency improvement of the FL staff, as well

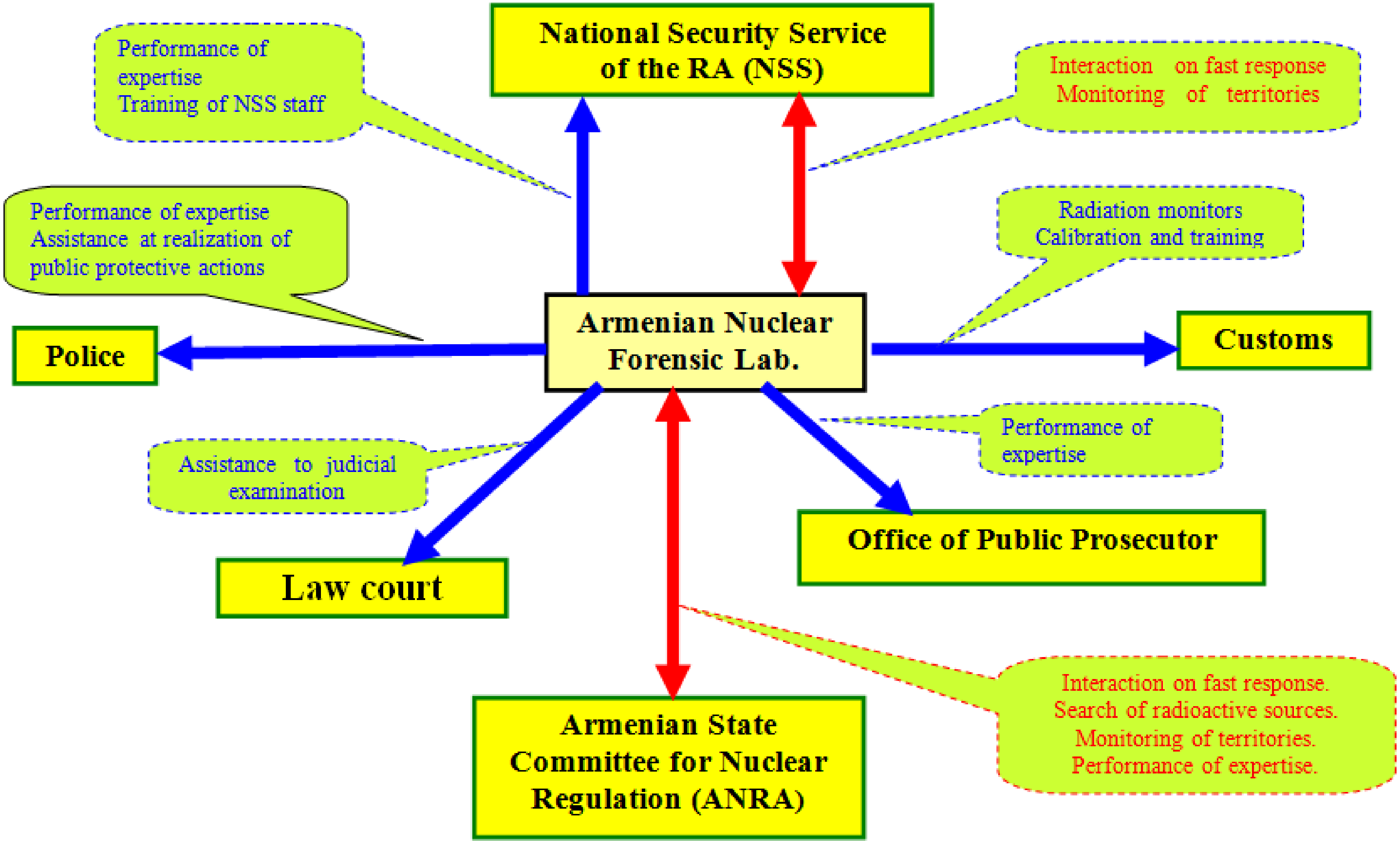
- We are also interested in implementing new methods of expert examinations of nuclear and radioactive material and learning from other international experience in this area.

- We are extremely interested in the expansion of our international network of experts in the field of Preventing Nuclear Smuggling.

- Serve as partners and contributors to regional and international efforts with the aim of countering radiological terrorism and smuggling of radioactive sources.

- ANPP and Armenian Nuclear Forensic Lab look forward to discussing new projects and opportunities for cooperation with international colleagues and partners.

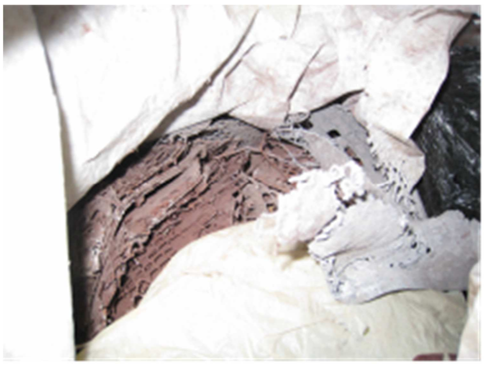
Fig. 2 The scheme of Armenian Nuclear Forensic Lab interaction with other ministries to strengthen the national nuclear security infrastructure



Appendix A

Some Examples of Illicit Incidents with Radioactive Sources.

1. Customs point in Meghri (border with Iran), January 2009, Radioactive source ^{241}Am



A bag with lead scrap

Layers of lead in which the source was packed

The neutron source

2. Institute of Physics of the Academy of Sciences of Armenia. Theft attempt March, 2010 (^{60}Co - 1,7×10^{13} Bq).

3. RITEG facility activity 1,1×1016 Bq, Found in Khosrovi reservation.

4. April 2012. 6 containers with ^{60}Co, measured activity of 3×10^{11} Bq, were found during monitoring of the woodworking factory located in Masis city.

5. ^{137}Cs, 5×10^{12} Bq, Tavush Regional Branch of the Noyemberyan Police Department

6. 21-M (Gammarid 21-M) radiograph found during monitoring of the municipal landfill area of Armavir town, November 2012

7. Results of monitoring of Vanadzor Chemical Combine. Source with isotope ^{192}Ir placed in container. February2012

8. In May 2009, during routine radiation monitoring in the village of Noraduz, it was revealed that the premises for repair of trucks and the territory adjoining them (an area of 300 square meters) were polluted with radioactive isotope Cs-137. Gamma radiation intensity in the premises ranged from 900 to 1200 μSv/h. Gamma radiation intensity at the surrounding area was 600-800 μSv/h. Four persons (the owner of the truck repair shop, his son and two technicians) received radiation doses exceeding the normally established limits. The dose for the owner's son was 128 mSv/year, and another person's internal dose was estimated from 7 to 12 mSv/year. The fixed dose limit for the public is 1 mSv.