ESTABLISHMENT OF PROCEDURES AND TECHNIQUES FOR NUCLEAR FORENSIC INVESTIGATIONS PART II – WORKSHOP ON NUCLEAR FORENSICS INSTITUTO DE PESQUISAS ENERGÉTICAS E NUCLEARES

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INTRODUCTION

The principal objective of this research contract was to implement a comprehensive program of nuclear forensic science in Brazil. The work plan had the following goals:

- Reviewing and upgrading procedures and methods for chemical, physical and isotopic characterization of nuclear materials;
- Demonstrating the reliability of the developed procedures by analyzing reference materials;
- Collecting and analyzing common nuclear material in Brazil; and
- Establishing a database for the nuclear forensic signatures of nuclear material in Brazil.

NETWORK OF LABORATORIES

The first achievement of the project was the creation of the Brazilian Network of Laboratories on Nuclear Forensic Science (BNLNFS) using the scientific expertise of Brazilian National Commission of Nuclear Energy (CNEN) nuclear scientists and existing infrastructure. The BNLNFS partners six laboratories located at Nuclear and Energy Research Institute, São Paulo, an additional laboratory in Poços de Caldas, Rio de Janeiro, and has the support of São Paulo State Police and Federal Police, Brasília. The associated laboratories implement techniques recommended by the IAEA to conduct an examination consistent with the nuclear forensics model action plan. In addition the BNLNFS have also the support of the Department of Radiological Protection, located at the Nuclear and Energy Research Institute, São Paulo.

Based on the IAEA recommendations governing the conduct of a nuclear forensic investigation (i.e., the nuclear forensics 'model action plan'), the procedures and techniques used in the nuclear forensic science were reviewed for their applicability. The action plan incorporates the main steps required during a nuclear security event including operational procedures on radiological crime scene management consistent with BNLNFS's operational plan and the sequence of laboratory analytical protocols.

The first case study was to establish the chemical fingerprint of thorianite, a radioactive mineral containing thorium, uranium, lead and rare earth elements (Fig. 1). During the last decades several tons of this mineral have been seized by Brazilian Federal Police in the north region of Amapa State, Brazil. The current work established nuclear forensic signatures of this mineral to assist in cases of international seizures of this mineral and confirm whether or not the mineral originates from Brazil.

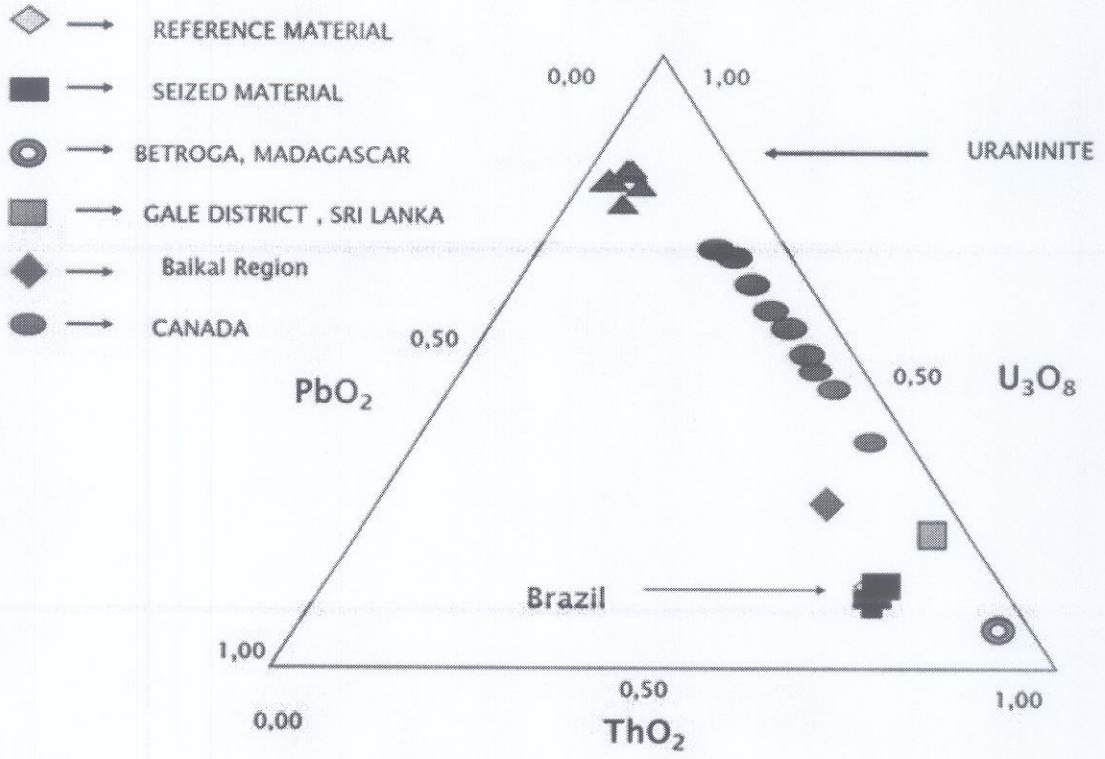

FIG 1: Nuclear forensic chemical fingerprint of thorianite.

The same strategy is now in progress involving other indigenous Brazilian radioactive minerals.

In order to initiate the establishment of a nuclear forensic signatures database, several naturally occurring nuclear materials were collected. Initially, uranium compounds and reference materials from different suppliers were analyzed. The initial results encompass the following data characteristics: visual appearance, density, dose rate, uranium content, particle size, x–ray diffraction patterns to determine mineral identification, and morphology. All of this data will be organized in an appropriate databank to facilitate nuclear forensic analysis and interpretation.

PARTICIPATION IN EXERCISES

The BNLNFS also participated in the Nuclear Forensics International Technical Working Group (ITWG) round robin #3 exercise than was conducted from from 2005 to 2010 and involved analysis of highly enriched uranium samples. Uranium isotopic analyses were performed using high resolution gamma spectrometry (HRGS) and metallic impurities determined by inductively coupled plasma atomic emission spectrometry technique (ICP–OES). All results were in good agreement with comparable analyses obtained by other participating laboratories.

A separate nuclear forensic exercise was planned and conducted involving all laboratories in the Brazilian network. The main objective was to verify the capability of the laboratories to categorize and characterize two samples according to the established action plan. The exercise assumed the existence of a national nuclear forensic library (NNFL) that allows States to make high confidence statements regarding the security of radioactive materials for which it has responsibility. Data —input to the library database — was obtained previously as part of the second objective of the contract.

The exercise simulated seizure of two suspected vials (Questioned Sample 1 and Questioned Sample 2) from a suitcase during a routine customs control in Guarulhos International Airport, São Paulo, Brazil. The exercise commenced with the identification of the presence of a nuclear material and the establishment of a chain of custody. Subsequently, the law enforcement officer at the scene initiated the action plan involving notification to the CNEN's nuclear security officials. Once the presence of

nuclear material was confirmed, the site was secured, and conditions established for the safe and secure transport, the evidence was packed and sent for analysis following the network operational plan as well as the recommended analytical protocols of the IAEA and ITWG.

The data obtained was compared with the data reported in the database and used to tentatively identify the geographical origin. For this purpose, three different statistical techniques were employed utilizing the results analysis of rare earths elements: cluster analysis, principal component analysis and ternary graphs. The main conclusions of the investigation as reported to the authorities were:

- Questioned Sample 1 and Questioned Sample 2 are both U_3Si_2;
- The samples displayed a similar morphology;
- The samples displayed different particle size distributions;
- $^{235}U/^{238}U$ of Questioned Sample 1 was consistent with natural uranium;
- $^{235}U/^{238}U$ of Questioned Sample 2 was consistent with enriched uranium (19.95% ^{235}U);
- ^{236}U was not detected in either sample;
- The chemical signature based on rare earths elements is similar in both Questioned Sample 1 and Questioned Sample 2;
- The forensic evidence suggests the samples represent a similar origin but were produced during different periods;
- The chemistry of the seized samples, based on rare earth patterns, is not consistent with the characteristics represented by the samples reported in the national nuclear forensic library (see Fig. 2);
- The inconclusive results from comparisons with the national nuclear forensic library suggest further analyses are required to include additional elements;
- The geologic age dating of the questioned samples has yet to be determined.

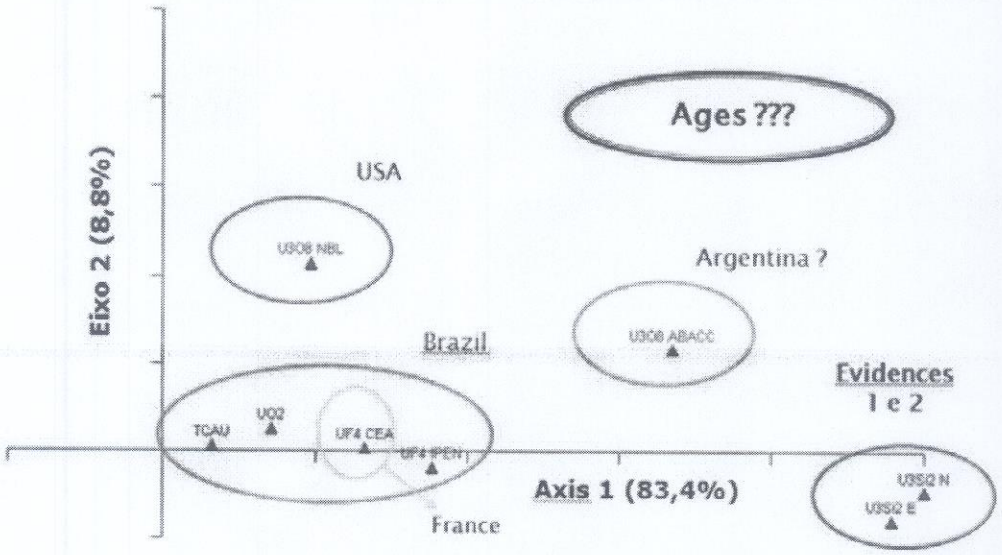

FIG 2. Principal component analysis (PCA) for rare earth elements measured in the Brazilian nuclear forensic exercise.

CONCLUSIONS

The results demonstrated that the laboratories belonging to the Brazilian network are capable of performing the full spectrum of analysis required in the conduct of a national investigation utilizing nuclear forensics. The establishment of an analytical plan facilitated the conduct of the exercise. However, lessons learned indicate improvements are necessary to the procedures for the distribution and reception of questioned samples, the standardization of documentation, and chain of custody associated with the nuclear forensic investigation. The determination of sample ages is paramount for the better interpretation of the results. The national nuclear forensic library is a very important tool for nuclear forensic interpretation. However, the library needs more comparative data to be reliable. Future exercises should seek to enhance the engagement of the law enforcement experts and better exploit classical forensic evidence.

LESSONS LEARNED AND FINAL COMMENTS

The principal objective of the contract was to establish a working group in Brazil dedicated to nuclear forensic science. The creation of the BNLNFS, the subsequent use of this infrastructure for analyzing several uranium compounds and reference materials, and the conduct of the first national nuclear forensic exercise is a direct result of this contract. The available infrastructure, as well as Instituto de Pesquisas Energéticas e Nucleares's nuclear experts, demonstrated that the network was able to support a nuclear forensic investigation. A networked system is the most effective way to initiate a nuclear forensics program and avoids the high cost required to implement infrastructure dedicated to this activity. However, it is necessary to implement continuous training of all teams involved in the nuclear forensic analysis, establish a well–defined model for the nuclear forensic analytical plan, and standardize all the analytical documentation to include a chain of custody.

The experience of Brazil has emphasized the importance of IAEA training courses and workshops to promote nuclear forensic awareness and understanding, disseminate technical guidelines concerning analytical and interpretative methods, and promote the exchange of best practice among experts required to work together on real cases of nuclear or other radioactive material out of regulatory control.

Despite the progress in the program, further work remains to be done. The entire plan of action, as well as the analytical plan, needs to be documented in greater detail. Additional technical procedures have to be implemented while, for others, a better understanding of the analytical results is necessary. A comprehensive national nuclear forensic library must be developed for Brazil; as well, new chemical signatures of nuclear materials and minerals need to be studied prior to their inclusion in the library. In conclusion, the participation in this CRP research contract contributed to the improvement of the knowledge of the principles and procedures used in nuclear forensic science and, as a consequence, the improvement of the nuclear security infrastructure within Brazil.