Revealing facts through science for nuclear verification

By Nicole Jawerth

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> *— Steven Balsley, Head, Nuclear Material Laboratory, IAEA*

Keeping track of the facts is an important part of nuclear verification. Receiving hundreds of samples each year, staff at the IAEA's safeguards laboratories verify data through spot checks and analysis of the uranium and plutonium content of nuclear material samples.

"We use highly sensitive equipment to analyse samples collected by safeguards inspectors, sometimes even down to the nanogram," said Steven Balsley, Head of the IAEA Nuclear Material Laboratory. "It's a highly accurate process that plays an important part in the IAEA's work to verify whether nuclear material and facilities are being used peacefully."

The laboratory scientists analyse environmental swipe samples and samples of nuclear material from various points of the nuclear fuel cycle collected by safeguards inspectors during physical inspections of nuclear facilities. The samples are screened, processed, distributed to laboratories in the IAEA network of laboratories, and analysed and archived by scientists at the IAEA's laboratories in Seibersdorf, Austria. These laboratories consist of two modern facilities: the Nuclear Material Laboratory (NML), which handles samples of nuclear material, and the Environmental Sample Laboratory, which receives and screens all environmental swipe samples for traces of nuclear material. (see article, page 14).

Once the samples are recorded and distributed to the labs in the IAEA network, scientists use instrumentation such as gamma spectrometers and mass spectrometers (see The Science box on page 15), to determine the amount and type of uranium or plutonium in a given sample.

"Uranium and plutonium are the two main fissionable elements used for generating power in nuclear power reactors, but are also the fissionable elements most commonly used in producing a nuclear weapon," explained Balsley. "We're most interested in keeping a very close eye on where the fissionable isotopes of those two elements are moving around in the nuclear fuel cycle."

On average, more than 600 samples of nuclear material are received and analysed each year. They are kept in small containers labelled with anonymous barcodes to ensure confidentiality throughout the evaluation process. The sample sizes can vary from as small as an eyelash to several grams. The information they contain may help uncover clues about past and current activities at the site where the sample was taken.

"While the samples collected by safeguards inspectors may just be a tiny fraction of the tonnes of material in a facility, we can look at certain characteristics of the atoms in a given sample to evaluate its overall nature," Balsley said. "By extrapolating data from the analysis of a small sample, scientists can determine the composition of tonnes of material — and improve the accuracy of nuclear material accounting."

Samples for verification

The main purpose of collecting nuclear samples is to verify the declared quantities and isotopic composition of material in facilities under safeguards. The IAEA then compares the declared values with its own independently measured values.

"A small discrepancy is normal when working with large inventories in any sector, be it banks, grocery stores or nuclear facilities. There is either an excess or deficit when book values are compared to physical items," explained Balsley. One of the main goals of safeguards is to make sure the discrepancies are small compared with what is known as a 'significant quantity', the amount of material required to develop a nuclear explosive device, he said.

Significant differences between declared and independently measured values are known as defects and come in three types: a gross defect, when one or more bulk items of nuclear material cannot be accounted for; a partial defect, when a significant portion of a bulk item is siphoned off; and a bias defect, when a small fraction of a bulk item is shaved off periodically over time.

Unlike gross and partial defects, which are more easily spotted by an inspector at the facility due to the larger quantities involved, the small-scale nature of a bias defect requires high-precision chemical and physical measurements to improve nuclear material accountancy.

With homogenous bulk material, like barrels of uranium oxide, for example, this is done by first carefully and precisely weighing the original, randomly selected bulk item using a specialized system called a load cell (learn about this and other equipment on page 18). Then representative gram-sized samples are taken from the bulk item by the operator, under the watchful eye of an IAEA inspector. These gram-sized samples are then also carefully weighed at the facility.

Once delivered to the NML, the samples are re-weighed and then analysed to reveal the percentage of uranium, as well as its isotopic composition. By measuring the percentage of uranium in the sample and the weight of both the samples and of the original item, IAEA specialists can calculate precisely the quantity of uranium in the bulk item. They then compare these findings to the declared information from the facility and also to the historical record of analytical results from samples taken from the same physical area where nuclear material quantities are overseen, known as the material balance area.

For some products that cannot be easily sampled, or inhomogeneous materials from which representative samples cannot be taken, other methods are used to verify their chemical or isotopic composition.

Accuracy, quality, confidence

Quality control is essential to maintaining confidence in analytical findings used for safeguards verification. Being part of an internationally certified laboratory, staff use validated analytical methods to perform analyses. Certified reference materials are used to monitor the quality of measurements in the labs, and participation in inter-laboratory comparison programmes ensure that standards of measurement and instrument calibration are on point. Lab staff also train safeguards inspectors in procedures to properly collect and handle samples, from how to avoid cross-contamination to sampling nuclear material items in such a way so as to achieve representative samples.

Experts in the Nuclear Material Laboratory use specialized tools to carefully analyse samples of nuclear material as part of the safeguards verification process.

(Photo: D. Calma/IAEA)

Staying up-to-date with the latest technological developments also contributes to higher levels of accuracy and precision for ensuring quality. The laboratories keep pace with these developments through frequent consultations with experts in the field, support from Member States, and continually improving methods and upgrading instrumentation.

Modern facilities

A major modernisation project, costing around 80 million euro at the Seibersdorf laboratories was completed on time and on budget at the end of 2015. The ‘Enhancing Capabilities of the Safeguards Analytical Services’ project included a new Clean Laboratory Extension for the Environmental Sample Laboratory and a new Nuclear Material Laboratory that replaced the Safeguards Analytical Laboratory built in the 1970s.

This project, among other things, increased the laboratories’ sample capacity, improved the sensitivity of analytical methods, and provided more infrastructure for training inspectors and staff from Member State laboratories.

“Successfully completing this project underlines the IAEA’s readiness to cope with the increasing workload of safeguards,” said Balsley. “Being up-to-date and modern will enable the IAEA to continue to meet safeguards’ analytical requirements for decades to come.”