"We can obtain a truly amazing amount of information from a tiny amount of material in samples."
D. Donohue, Safeguards Analytical Laboratory

Tools for Nuclear Inspection

IAEA nuclear inspectors have a range of high-tech tools at their disposal. Over the last decade, there have been significant improvements in the technology they use, mostly software advances that make equipment more powerful and provide faster results.

As they gather evidence, inspectors use a broad array of technologies, such as hand-held radiation detectors and measurement instruments. Some small instruments are used to search for nuclear and radioactive materials known to be associated with weapons-making. Others, known as multi-channel analyzers, can identify specific radioactive elements in samples that inspectors collect for fuller analysis in laboratories.

Analysis of samples can determine "nuclear fingerprints", and reveal indicators of past and current activities in locations handling nuclear materials, particularly those associated with uranium conversion, fabrication, and enrichment. Determining such cases, however, requires expertise and the right equipment — the fingerprints of different isotopes, for example, can overlap, and an abundant constituent of one element can mask a rare one. Reaching conclusions can be tricky, often requiring multiple dimensional analytical approaches. The IAEA has its own experts and facilities, through its Safeguards Analytical Laboratory in Austria, experienced in sample measurement and analysis, including hundreds of samples from the 1990s Iraq inspections. Fully operational since then is a "Clean Laboratory" equipped with highly sensitive instruments, including electron microscopes and mass spectrometers. Experts can precisely measure even tiny nanogram (one-billionth of a gram) particles and detect traces of nuclear materials collected in the environment of known or suspected nuclear facilities.

Swipe Sampling. Environmental sampling for safeguards means the collection of environmental "dust" from the vicinity of a known or suspected nuclear facility to look for tell-tale elemental or isotopic "signatures". These signatures are expected to match the declared activities of the location as well as reveal any clandestine production or handling of nuclear materials. The best way to collect environmental dust is by wiping surfaces using a 10 × 10 cm square of specially-clean cotton cloth — a "swipe" sample. The Clean Laboratory for Safeguards in Seibersdorf prepares certified clean sampling kits that contain 6 of these swipes, special gloves, plastic bags, a sample data form and a pen. A safeguards inspector uses one such kit to collect an environmental sample in a chosen location. The reason why each kit contains 6 swipes is so that multiple swipes can be sent, in parallel, to different analytical laboratories for measurement. Similar results obtained on these parallel swipes will give a high level of confidence that the signatures detected were genuine and can be used to draw valid safeguards conclusions.

Multi-channel analyzers (MCAs). These standard and portable tools for IAEA inspectors register the energy emitted by a radioactive source. MCA´s use software that reads the pattern of the energy output, matches it to a signature, and displays the result. One portable analyzer is designed for detection of gamma radiation from radioisotopes and the presence of neutrons for enhanced detection of plutonium, which is produced in a reactor by irradiating uranium-238. Unlike typical radiation detectors, the device can be used to search for and locate an unknown source of radiation, determine the relative dose rate, and isotopically identify the source. Results are displayed on a digital screen. Uranium and plutonium isotopes, for example, are a good indication of whether nuclear fuel has been reprocessed. Another type, a portable gamma spectrometer, is specifically designed to measure uranium and whether it has been enriched. It can perform accurate and rapid uranium verification measurements in laboratories, at facilities, or in other industrial environments. The ratio of certain isotopes can yield valuable information — for example, the type of enrichment that was used.

Alloy detectors. Faced with a yard filled with metal objects, the inspectors use another portable device, known as ALEX, short for the brand name "alloy expert". Nuclear activities use exotic steels and unusual elements such as zirconium. ALEX allows rapid identification in the field and gives the opportunity to intensify inspections when something important is discovered. For example, UF_6 (uranium hexafluoride) is a highly corrosive material used in uranium enrichment. The special alloys required in its production apparatus would be quickly identified by ALEX. Technically, the device is an X ray fluorescence spectrometer. It generates X rays to penetrate the material being inspected. ALEX matches the response pattern of elements in the alloy to the X rays against a library of information in its software and displays the results.

Environmental monitoring instruments. A nuclear weapons development programme, despite best efforts to conceal it, is likely to leave its fingerprints on nature. Water monitoring uses a system that draws raw water through a filter for one hour, the equivalent of testing a large volume of water. Laboratory analysis of the filter is able to find the most minute traces of materials in the water with pinpoint accuracy. Air samples and samples of vegetation can be tested for tritium, an isotope of hydrogen. Finding tritium in waterways or the air strongly suggests reactor operations, for example.

Digital video surveillance systems. Tamper proof and digital video systems are used for surveillance and monitoring at facilities. They could include factories where dual purpose activities could be conducted — for example, the potential use of machine tools to manufacture components for a nuclear programme. Data is fed into powerful computer systems that inspectors use to review and analyze images and related data.

Satellite imagery. For monitoring purposes, images obtained by commercial satellite imaging sensors can greatly help inspectors track activities. These imaging sensors range from medium resolution imagery, that provide the ability to perform broad area searches in instances where exact location information may not exist, to very high, 61 cm resolution imagery, that permits the imagery analyst to provide very detailed analysis of a facility's infrastructure. Resolution of 61 cm refers to the size of objects that can be distinguished from their background. In support of inspection activities, the IAEA has the option of tasking the satellite sensor to acquire imagery within a specific time frame to facilitate current issues, as well as taking advantage of an enormous archive of historical imagery datasets. Some archives date back to 1960 and can provide a unique insight of past activities. The IAEA has also taken advantage of recent developments in 3D analysis that permits volume measurement and the generation of 3D models from a single high-resolution satellite image. While labour intensive, the creation of detailed facility layout can support pre-inspection planning and offers unique facility viewing that may not otherwise be possible to obtain.

Inspection Database. Alongside the full suite of radiation-detection gear and other monitoring equipment, a key tool inspectors rely upon is the IAEA's confidential database. It contains comprehensive and exceptionally detailed information obtained from past inspections, country declarations, defector disclosures, intelligence information, and other multiple sources about nuclear-related activities. Inspectors can find out, for example, that a device has been moved from one side of a room to another, and learn why.

Safeguards Analytical Laboratory (SAL)

"We've come a long way since the 1990s," says David Donohue, who heads the Clean Laboratory Unit of the IAEA Safeguards Analytical Laboratory, one branch of the multi-purpose Seibersdorf Labs near IAEA headquarters in Vienna, Austria. "Our Lab is fully operational, with state-of-the-art methods for detecting elements like uranium and plutonium. Newer, more powerful methods are constantly being developed. We can obtain a truly amazing amount of information from a tiny amount of material in samples."

The IAEA's Lab serves as the centre of a global network of analytical laboratories equipped for the measurement and analysis of nuclear and radioactive materials. Sophisticated tests help analysts screen "swipe samples" that IAEA inspectors collect with small cotton swabs using specialized kits. They swipe walls, floors, or pieces of equipment at inspected sites.

Inside the secure and contamination-free Clean Lab, Donohue and his team screen the samples, using techniques such as X ray fluorescence and gamma spectrometry, and coordinate the network's analysis of replicate samples. Any uranium and plutonium particles in samples can be detected down to a picogram, or trillionth of a gram. Network Labs involved are in Australia, France, Germany, Japan, Russia, United Kingdom, and the United States. Though the immediate focus is on dust samples, labs are equipped for analyzing various types of environmental samples, including water, soil and vegetation.

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