Environmental Sampling for IAEA Safeguards: A Five Year Review

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ABSTRACT

January 1996 marked the beginning of environmental sampling as a new safeguards strengthening measure by the International Atomic Energy Agency (IAEA). Since then, some 2000 swipe samples have been collected from over 100 facilities worldwide and submitted for analysis in the Network of Analytical Laboratories (NWAL). Over this time, the program has been continuously subject to adjustments and improvements in the various areas. This paper will report on the experience gained and improvements made during the first 5 years of implementation.

The implementation of environmental sampling has moved from establishing baseline signatures, to conducting routine sampling in many facilities. Initially, the IAEA concentrated on sampling at enrichment facilities and facilities with hot cells. Recently the types of locations where environmental samples are collected have expanded to include locations without nuclear material inventories, or at mining operations, as part of Additional Protocol measures.

The NWAL has expanded to increase the analytical capacity and the range of available techniques, such as Secondary Ion Mass Spectrometry, fission track analysis on highly active samples, and Scanning Electron Microscopy. The IAEA and NWAL are continuously working to improve the sensitivity of analytical techniques and quality control of analysis. In the area of data evaluation and management an ORACLE database has been developed and put into operation, and the evaluation procedures and reports have been largely standardized.

Although the IAEA has experience in collecting and analyzing several forms of samples such as water, vegetation and soil, swipe sampling has become the preferred method of sampling. Sampling tools have been refined based on inspector and laboratory experience. Sampling procedures have improved through the increased use of composite sampling, which results in fewer samples and a reduction in the analytical workload. Further study has been done in the area of air sampling, a sampling method proposed for wide area environmental sampling (WAES). A Multi-Member State Support Program project evaluated the technical feasibility and costs associated with WAES. Based on its conclusions, an initial air sampling field trial was conducted against reprocessing operations. At this time, analysis results are not complete but an overview of the trial and latest results will be presented. Additional air sampling field trials are planned to be conducted against an enrichment facility.

INTRODUCTION

One of the new safeguards strengthening measures implemented by the International Atomic Energy Agency (IAEA) is environmental sampling. Environmental sampling for safeguards is based on the premise that every nuclear process, no matter how leak tight, emits small amounts of process material to the environment. This material can settle on equipment and surfaces within the buildings and can be transported outside to deposit on vegetation or soil or be carried into the water systems. The quantities of nuclear material emitted are well below concern from a health physics and safety standpoint; however, analytical techniques exist that can detect and

measure these extremely low levels of nuclear material which are indicative of the process from which they derive.

The power of environmental sampling for safeguards was demonstrated through a series of field trials conducted during the IAEA's development programme to systematically evaluate a strengthened and more cost-effective safeguards regime ('Programme 93+2') [1,2]. The overall conclusion from these field trials, conducted in and around 12 nuclear facilities, was that the analysis of environmental samples collected in the immediate environment of a nuclear process or site can provide an effective tool for increased assurance of the absence of undeclared activities at the site. In 1995, the IAEA Board of Governors approved the implementation of environmental sampling as a new safeguards measure. The initial implementation of environmental sampling is focused on swipe sampling in enrichment plants and in installations with hot cells [3,4]. Based on the experience from swipe sample collections and the analytical results, the sampling procedures have been modified. Furthermore, an environmental sampling database was developed and is in operation to facilitate the data evaluations.

A major milestone was reached in the development of a strengthened safeguards system when in May 1997 the IAEA Board of Governors adopted the Model Protocol Additional to Safeguards Agreements, INFCIRC/540 (Corrected). The Additional Protocol expands the IAEA's legal authority with provisions for additional information to be provided by States on their nuclear and nuclear-related activities and for broader access by IAEA inspectors to locations in States. The Model Additional Protocol greatly adds to the value of collecting environmental samples through increased access for inspectors. In addition to the so-called location-specific application of environmental sampling, the Model Additional Protocol also provides for the future application of environmental sampling in a monitoring or wide-area mode. Procedures to implement wide-area environmental sampling require approval by the Board of Governors.

This paper reports on the status of the Agency's environmental sampling programme for safeguards after five years of implementation, describes recent developments in sampling procedures and in the establishment of a central data base, and identifies future needs required under the Model Protocol Additional to Safeguards Agreements [5].

IMPLEMENTATION OF ENVIRONMENTAL SAMPLING

Since sample collection began in January 1996, the priority has been on the establishment of a baseline environmental signature for each facility. In this phase, swipe samples are collected from facility locations identified as having the greatest potential for containing traces of past and current operations. The measurement results from laboratory analyses of the samples are used to characterize the nuclear signature for the facility. Once the baseline is established, requirements for sampling as part of routine activities can be determined. By mid-2001, swipe samples have been collected at 104 facilities under safeguards agreements. Sampling as part of routine inspections and design information verification visits, as well as under arrangements provided for by Additional Protocols began in 1998.

NETWORK OF ANALYTICAL LABORATORIES (NWAL)

In addition to the IAEA's Clean Laboratory for Safeguards, specialized laboratories in four Member States with capabilities to analyze environmental samples were certified initially as network laboratories. This network has been and will continue to be expanded. Secondary Ion Mass Spectrometry (SIMS) is now considered a routine analysis method at the IAEA's Clean Laboratory, as well as at three additional Member States' laboratories. One new laboratory is in the process of final certification for newly established capabilities in particle analysis by Thermal Ionization Mass Spectrometry (TIMS) in combination with fission track particle screening. Another new laboratory is presently being certified for analysis of samples by Accelerator Mass Spectrometry (AMS). Another Member State is in the process of establishing a new clean laboratory facility for the analysis of environmental samples. In this case, the laboratory and the IAEA are working in close cooperation at the technical level and the laboratory is expected to join the network once it begins routine operation.

ENVIRONMENTAL SAMPLING DATABASE

Measurement data from the laboratory analysis of the swipe samples at the IAEA Clean Laboratory or in the Network of Analytical Laboratories are reported to the Department of Safeguards where they are evaluated and compared to the expected nuclear signature for the facility sampled. To allow for the seamless integration of sample data from multiple analytical laboratories and safeguarded facilities, the IAEA developed an Environmental Sampling (ES) database. The ES database serves as a tool for analysts in evaluating individual sample series, or investigating trends by country, facility-type, or sample-type (Figure 1). Current development efforts focus on the user-interface with an emphasis on improving search capabilities and standardized reports.

The development of the database consisted of several major steps: developing the structure that organises the data; developing the user-interface; migrating the older data to the new database; back-filling data from previous data sets; and developing output reports. The user-interface retrieves data for a single sampling campaign, as well as searches by country, nuclear activity, facility type, network laboratory, and all samples falling within a certain year. More complex data queries require the user to enter a query using Oracle command syntax. The user form currently has six active tab pages. The first tab page contains sampling campaign information, followed by sample location and screening information on the next page. Each analytical technique (TIMS, SIMS, High Resolution Gamma Spectrometry and Isotope Dilution Analysis) has an individual tab page to display the analytical results and is linked to the active series on the first tab page. The analytical data can be exported to a file with the push of a button for plotting or further data manipulation. Besides evaluating sample data, the database also aids the user in evaluating Quality Control data and comparing data to known standards.

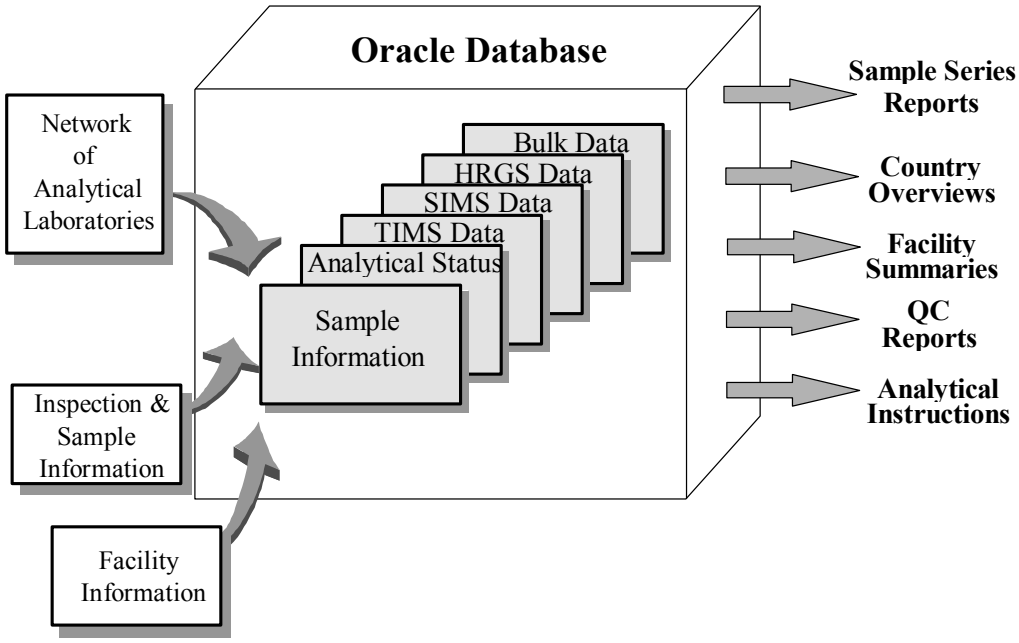

Figure 1. Environmental Sampling Database Schematic

The IAEA migrated the older environmental sampling data from a MS-Access application to the Oracle application. Although the Oracle platform offers robustness and advanced security capabilities not available in the original MS Access database, the Oracle development has proven a challenge. The design of the first generation ES database was completed and became operational in early 2000. Future development efforts are focusing on improving the functionality of the user-interface and data sharing with other databases within the Agency.

SAMPLE COLLECTION PROCEDURES

In general, samples are taken by trained inspectors using standardized sampling kits and approved sampling protocols according to the facility-specific sampling plans. Based on the experience from baseline swipe sample collections and the measurement results from sample analysis, sampling procedures have been modified. For most sampling locations cotton swipes are used (Figure 2).

The standardized cotton swipe kit is pre-labeled with an IAEA identification number and normally contains seven cotton swipes individually packed in mini-grip bags. A kit also includes larger mini-grip bags for double bagging, labels, two pairs of clean-room gloves, a pen, and a sample collection sheet with sampling instructions. The cotton swipe material has a low uranium background, is durable and is relatively easy to process for analyses.

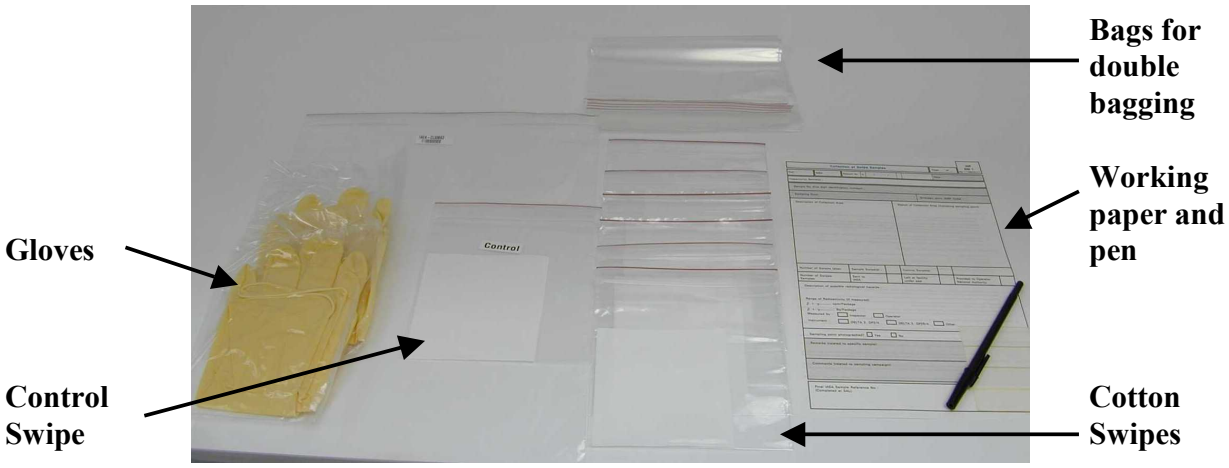

Figure 2. Standardized Cotton Swipe Kit (one sample)

A different sampling kit is used for sampling within hot cells. Based on the field experience and recommendations provided by the operator of a hot cell facility, the original sampling tool has been redesigned. The original tool was relatively large and required a large amount of lead shielding for shipment. Furthermore it could not be used in pneumatic transfer systems. The new sampling tool, consisting of small cellulose wipes and plastic bottles that can be used in pneumatic transfer systems, has been successfully used in all hot cell facilities since its implementation (Figure 3). It is smaller for easier introduction into and removal from the cell, and requires less lead shielding.

Figure 3. New Hot Cell Sampling Kit (one sample)

Initially many point samples were taken for each sampling campaign. Lately mainly composite samples are collected from larger areas in a sampling location. This procedure allows a reduction in the number of samples collected and subsequently optimizes the analytical effort without sacrificing sensitivity in detecting signatures of nuclear operations.

ADDITIONAL PROTOCOL

The Agency first implemented environmental sampling under the legal authority of the existing comprehensive safeguards agreements, which limits the collection of samples in facilities and at locations where inspectors have access during inspections and design information visits. The approval of the Model Additional Protocol in 1997 [5] greatly expanded the IAEA's legal authority to conduct its safeguards activities. The Additional Protocol provides for increased inspector access to all aspects of a State's nuclear fuel cycle including locations involved in fuel cycle-related R&D and manufacturing activities not involving nuclear material. Environmental sampling is one of the activities the Agency may carry out during access to these sites and locations. In addition, the Additional Protocol provides the authority to collect environmental samples wherever the IAEA deems such collection to be necessary, even if the location has not been declared by the State. The Additional Protocol also provides for the future application of environmental sampling in a wide-area mode. As of September 2001, 57 States have signed an Additional Protocol and the first sample collection under the Protocol was conducted at a site in April 1998.

WIDE AREA ENVIRONMENTAL SAMPLING (WAES)

A technical study evaluating the feasibility, practicability, and costs associated with Agency implementation of wide area environmental sampling in the context of the Protocol was completed through a Multi-Member State Support Programme project in 1999 [6]. The Multi-Member State Support Programme study [6] provides a technical evaluation and assesses the potential feasibility and approach of wide area environmental sampling (WAES) for use in the detection of undeclared nuclear facilities. The term 'wide area' has been used to mean the collection of environmental samples that are not targeted around a suspect facility or geographic location, but instead over regions containing much larger areas (e.g., on the order of hundreds of thousands of square km).

The study involved estimating the potential levels of environmental releases from enrichment and reprocessing facilities, assumed to be producing 8 kg of plutonium or 25 kg of highly enriched uranium per year, and determining the maximum distances at which such releases might be detectable from an analysis of environmental media. Attention was focused on detecting a nuclear operation at an undeclared site. Both enrichment and reprocessing operations were considered in the study. In general, it was assumed also that no known nuclear facilities would be operating within or near the area subject to WAES monitoring.

The study concluded that atmospheric sampling appeared to be the technique with the greatest detection probability per-sample of those sampling methods that were considered. Screening techniques can be utilized to identify areas of a region of primary focus for a WAES programme, i.e. those areas most capable of supporting an undeclared facility. But even under the best conditions, the cost of operating a WAES network could be high.

The study made a number of assumptions, most notably relating to the size of source terms of signatures, but also including factors affecting atmospheric and aquatic transport, pathways into aquatic systems, and the background levels of potential signatures. Different assumptions in

this regard, as well as in other instances, could affect the overall outcome of the feasibility study. The study participants believe it would be prudent first to conduct a small-scale field trial to validate some of the key assumptions used as input to this study and on which the results heavily depend, such as the variability in background levels of target signatures. In an attempt to validate some of the key assumptions, and gain experience in fielding and analyzing air particulate samples, a series a field trials are planned starting in July 2001 in the United Kingdom and possibly in the Russian Federation.

CONCLUSIONS

The implementation of swipe sampling for routine IAEA safeguards under existing safeguards agreements is well underway. By mid-2001, swipe samples have been collected in over 100 facilities under safeguards. Based on field experience the swipe sampling procedures have been optimized. A central environmental sampling database is operational to facilitate the evaluations. Data are being evaluated and discussed with Member States to establish baseline environmental signatures for individual facilities to provide a basis for comparison during routine sampling. Since ES was implemented five years ago, the network of analytical laboratories has expanded in numbers and capabilities.

The approval of the Model Additional Protocol by the Board of Governors in May 1997 provides the Agency with complementary legal authority to apply safeguards. Environmental sampling may eventually include the collection of other types of samples (e.g., vegetation, soil, water) exterior to facilities and sites.

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