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Environmental Sampling Using Location Specific Air Monitoring in Bulk Handling Facilities

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Abstract

Since the introduction of safeguards strengthening measures approved by the International Atomic Energy Agency (IAEA) Board of Governors (1992-1997), international nuclear safeguards inspectors have been able to utilize environmental sampling (ES) (e.g. deposited particulates, air, water, vegetation, sediments, soil and biota) in their safeguarding approaches at bulk uranium/plutonium handling facilities. Enhancements of environmental sampling techniques used by the IAEA in drawing conclusions concerning the absence of undeclared nuclear materials or activities will soon be able to take advantage of a recent step change improvement in the gathering and analysis of air samples at these facilities.

Location specific air monitoring feasibility tests have been performed with excellent results in determining attribute and isotopic composition of chemical elements present in an actual test-bed sample. Isotopic analysis of collected particles from an Aerosol Contaminant Extractor (ACE) collection, was performed with the standard bulk sampling protocol used throughout the IAEA network of analytical laboratories (NWAL). The results yielded bulk isotopic values expected for the operations. Advanced designs of air monitoring instruments such as the ACE may be used in gas centrifuge enrichment plants (GCEP) to detect the production of highly enriched uranium (HEU) or enrichments not declared by a State.

Researchers at Savannah River National Laboratory in collaboration with Oak Ridge National Laboratory are developing the next generation of ES equipment for air grab and constant samples that could become an important addition to the international nuclear safeguards inspector's toolkit. Location specific air monitoring to be used to establish a baseline environmental signature of a particular facility employed for comparison of consistencies in declared operations will be described in this paper. Implementation of air monitoring will be contrasted against the use of smear ES when used during unannounced inspections, design information verification, limited frequency unannounced access, and complementary access visits at bulk handling facilities. Analysis of technical features required for tamper indication and resistance will demonstrate the viability of successful application of the system in taking ES within a bulk handling location. Further exploration of putting this technology into practice is planned to include mapping uranium enrichment facilities for the identification of optimal for installation of air monitoring devices.

Introduction

Since the implementation of safeguards strengthening measures, approved by the International Atomic Energy Agency (IAEA) Board of Governors (1992-1997), international nuclear safeguards inspectors have been able to utilize environmental sampling (ES) (e.g. deposited particulates, air, water, vegetation, sediments, soil and biota) in their safeguarding approaches at bulk uranium/plutonium handling facilities. Enhancements of environmental sampling techniques used by the IAEA in drawing conclusions concerning the absence of undeclared nuclear materials or activities will soon be able to take advantage of a recent step change improvement in the gathering and analysis of air samples at these facilities.

Location specific air monitoring feasibility tests have been performed with excellent results in determining isotopic composition of chemical elements present in actual test-bed samples. Isotopic analysis of collected particles from an Aerosol Contaminant Extractor (ACE) collection was performed with the standard bulk sampling protocol used throughout the IAEA network of analytical laboratories (NWAL). The results yielded bulk isotopic values expected for the operations. Advanced designs of air monitoring instruments such as the ACE may be used in gas centrifuge enrichment plants (GCEP) to detect the production of highly enriched uranium (HEU) or enrichments not declared by a State.

IAEA safeguarding timeliness criteria states that the detection and reporting of HEU receipt should occur within one month after sample receipt for bulk handling facilities unless that facility is under an advanced safeguards approach (Additional Protocol INFCIRC/540). The technique discussed here may offer a means that is complimentary to the current methods used to meet this goal, particularly for GCEPs as particles are concentrated onto the collection surface that is then available for direct analysis. Additionally, this method offers collection of airborne materials before they settle on surfaces, which can be decontaminated, taken into existing duct work and filtered by plant ventilation, or escape via alternate pathways (i.e. drains, doors).

The principal sample collection device discussed herein is a patented Aerosol Contaminant Extractor (ACE) which utilizes electrostatic precipitation principles to deposit particulates onto selected substrates. This device has proven effective in the collection of fuel cycle signatures including an operational demonstration conducted at a Uranium Gas Centrifuge Enrichment Plant (GCEP). One of the primary advantages offered by the ACE system is that the collection substrates may be analyzed directly. This technique is applicable for quick turnaround analysis of samples collected inside operational facilities and may serve as a complimentary method to the gold standard environmental sampling protocol

Figure 1. ACE sampler.

used by the IAEA. Incorporation of tamper resistant and tamper indicating (TRI) technologies into the ACE system would allow collection of samples at uranium/plutonium bulk handling facilities in a manner that verifiably minimizes compromise of sample integrity. This type of sampling also allows for direct analysis of the collected material without modifying the sample. A TRI-ACE would be an important addition to the international nuclear safeguards inspector's toolkit when developing advanced safeguards approaches for the International Atomic Energy Agency (IAEA).

Air Monitoring vs. Sample Swipes: Sampling Plan

Augmenting swipe samples with an aerosol collection system such as the ACE, which could operate in a mode to collect discrete, timed samples or continuously draw samples from the atmosphere of uranium handling areas of bulk facilities, would improve the probability of diversion detection. The presence of air sampling systems in enrichment facilities, for example, near the feed and take-off areas and cascade hall equipment mezzanines, would allow constant sampling of the uranium process area. Quick connections, hot taping into piping, and/or valve or compressor leakage could be detected by a continuous air sampling system and provide IAEA inspectors with additional confidence in their conclusions of the absence of HEU production.

In order to assess the performance and thus the applicability of air monitoring for safeguards applications, ORNL will conduct experiments to (i) ascertain the relative effectiveness of ACE collection versus swipe collection in a relatively high U-air-loading scenario and (ii) ascertain the effectiveness of HEPA filters at capturing trace airborne uranyl compounds. Experimentation will be carried out using ORNL's UF_6 Test Loop (Figure 2) designed to simulate low level fugitive emissions of UF_6. This system allows for minute quantities of UF_6 to be released into air and the reaction products collected and subsequently characterized. It is comprised of a small volume (~7L), static release chamber and a side stream sampling capability wherein an ACE collector will be incorporated. Environmental conditions are monitored, but are minimally controlled. A small battery operated ACE has been used in this system in the past and a similar unit, being fabricated at SRNL for this project, will be deployed in the chamber for release experiments. The ACE unit will be used to actively collect the dispersed UF_6 reaction products inside the chamber, while layout coupons will be used for passive collection (i.e., swipe sampling). The passive deposition coupons will be made of several common materials of construction (e.g., aluminum, stainless steel, painted steel, plastic) surfaces that might be found in an operating facility and be used as targets for swipe samples.

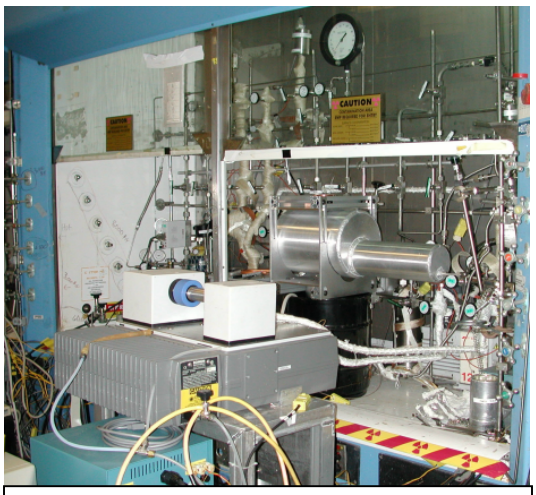

Figure 2. ORNL's UF_6 Test Loop.

The quantity of material collected by the ACE will be compared with the quantity found on the passive deposition samples. The layout sample will be swiped and analyzed using the standard IAEA environmental sampling protocol. The layout sample will then undergo a more aggressive leach in order to assure that all deposited material is removed. The efficiency of the swipe method can then be assessed by comparison of the quantity of isotopically perturbed U detected in the swipe and in the post-swipe leach. The ACE collection substrate will be analyzed using the aggressive leaching technique. The isotopic abundances of the materials and the relative concentrations will then be compared. The density of the material will be used to determine the equivalent concentration of the deposition material per unit of air for direct comparison of the material loadings for the swipe relative to the ACE collections.

A more stringently controlled environmental chamber will be used primarily for the HEPA efficacy test. This system generates lower airborne concentrations of reaction product in an environmentally controlled, moving airstream. As currently configured, the release of UF_6 takes place at the upstream end of a ~400L main chamber. The chamber air (with particulates produced by the release) drifts at a controlled flow rate through and out of the chamber and then passes through a series of ACE units into which a HEPA filter will be positioned. Deposition on the ACE plates (Figure 3) will be examined by scanning electron microscopy (SEM) (and possibly by transmission electron microscopy) for morphology, and by mass spectrometry for the determination of total U content. The quantity and character of material captured by the ACEs (and in particular, differences between the ACE samples collected on either side of the HEPAs will be one measure of the effectiveness of the HEPA at capturing the release particulates. The HEPA itself will also be leached and analyzed for total U to directly determine the quantity it captured.

Figure 3. Example of a typical ACE collection plate.

Development of a Tamper Resistant/Indicating Aerosol Contaminant Extractor (TRI-ACE)

The active ACE collector will be made more viable for safeguards-applicable air monitoring through inclusion of tamper resistant/tamper indicating features incorporated into the collection scheme. Figure 4 depicts the initial concept for the TRI-ACE design. In the category of tamper resistance, the TRI-ACE could utilize passive systems such as a welded stainless steel shell structure with no exposed fasteners, a keyed and sealed access door, inlet/outlet air baffles with water drains, and a mounting mechanism secured from inside the enclosure. Active tamper resistant features could include power line filters, variable inlet-constant outlet power supplies, electrostatic discharge and magnetic

shielding, self-resetting fuses, and a 72-hour internal battery back-up. In the category of tamper indicating, the TRI-ACE could utilize active systems including inlet voltage monitoring and ambient light detectors, vibration/tilt detectors, access door switches, airflow sensors, ambient particle sensors, inlet/outlet obstruction sensors, and external proximity detectors to sense if the unit is being covered.

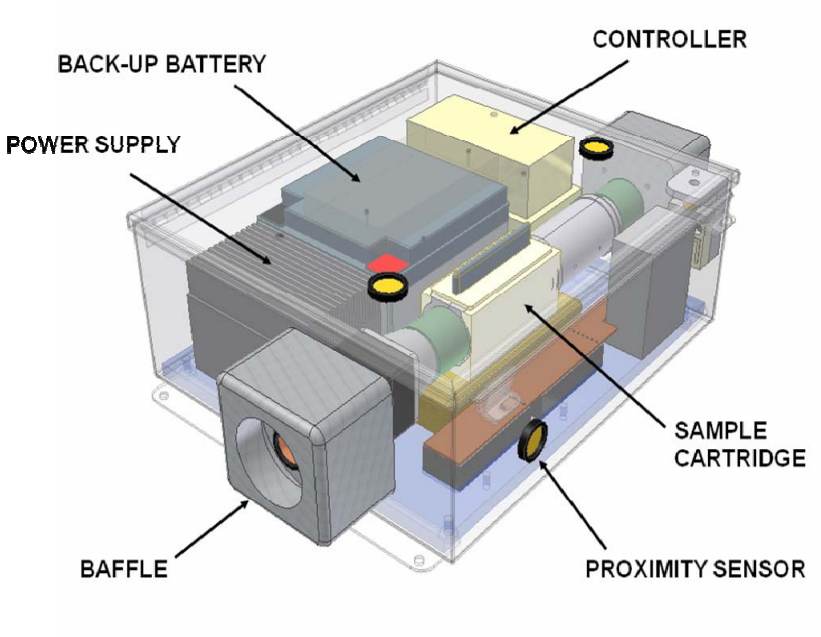

Figure 4: Schematic of a standard ACE unit with additions for tamper resistant and tamper indicating capabilities.

Future Work

Following the work described above, the prototype TRI-ACE unit will be fabricated and laboratory tested. Laboratory testing of the electrical components and robustness will be conducted at SRNL. Testing against possible upset conditions, using the UF_6 Test Loop, will be conducted at ORNL. Several TRI-ACE units will then be fabricated for US and international field trials at bulk handling facilities. Final efforts will then focus on socializing the TRI-ACE concept and significance to the IAEA and determining design specification modifications for a second generation TRI-ACE

References

1. IAEA Department of Safeguards, “Research and Development Programme for Nuclear Verification 2010-2011,” 98-105.