DOE/NV/03624--0276

# National and International Assistance in the Technical Assessment of Nuclear and other Radiological Materials out of Regulatory Control

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**Abstract**

Considerable resources are dedicated worldwide to detect illicit materials of all types amid the concern of their potential use in criminal acts or acts of terrorism. Of particular concern are illicit nuclear and radiological materials as they have potential to cause serious harm to the general public if not maintained under regulatory control. As such, the international community has developed recommendations and guidance for States and their Competent Authorities to establish, implement, maintain, and strengthen their nuclear security regimes. The International Atomic Energy Agency (IAEA) provides recommendations for the security of nuclear and other radioactive material out of regulatory control through the publication *Nuclear Security Recommendations on Nuclear and Other Radioactive Material out of Regulatory Control, Nuclear Security Series No.15*. Based on this guidance and national/international practical experience and best practices, the international community has made considerable advances in the detection, interdiction, and adjudication of nuclear and other radiological materials out of regulatory control. The United States Department of Energy, National Nuclear Security Administration (DOE/NNSA), Office of Nuclear Incident Policy and Cooperation has national/international experience to share on providing emergency responders and front line officers assistance in the technical assessment of interdicted nuclear and other radioactive Materials Out of Regulatory Control (MORC).

## Introduction

Best practices for the detection of illicit nuclear and other radioactive materials at international ports of entry to include border checkpoints, shipping ports, and airports; involve the use of high sensitivity radiation portal monitors to scan cargo shipments. Radiation portal monitors are designed to passively detect the faint gamma ray and neutron radiation emissions from nuclear and other radioactive materials. Using these systems, thousands of detections occur annually around the world – all of which need to be investigated to determine the cause of the alarm. The majority of these investigations result in a determination that the alarms are innocent, being caused by common legitimate commercial and industrial materials which contain very low activity levels of Naturally Occurring Radioactive Materials (NORM). When the radiation level on a portal monitor exceeds the detection threshold, an alarm will sound and alert the front line officer operating the portal to initiate procedures and protocols to investigate the cause of the alarm. Most alarms are resolved through a security investigation which typically involves a driver/shipper interview, manifest review, and identification of the radioisotope in secondary inspection. If the incident cannot be resolved using established procedures and protocols, the best practice is to engage the State's Competent Authority to conduct a technical assessment of the information collected to determine if the cargo shipment is legitimate or a potential threat. A State's Competent Authority can also request international assistance in the technical assessment of the incident to include advice and consultation, data analysis and interpretation, and assistance with source recovery operations.

**International Technical Assistance**

The ability to reach back to subject matter experts with experience in the analysis and interpretation of radiation data and receive timely advice is critical in resolving nuclear security events. The U.S. DOE/NNSA maintains the Radiological Triage Program, which is a 24/7 reach back capability for radiation detector operators. The program provides access to radiation experts to aid in the assessment and interpretation of radiological data. The Triage program has a cadre of on-call scientists and engineers from the national laboratories with extensive experience in radiation measurements and data analysis and interpretation. The experts analyze the information from the interview, manifest, radiation portal monitor, and radioisotope identification measurement and provide an initial verbal assessment via a telephone call within one hour. The radiation portal monitor data for gamma rays and neutrons and the gamma ray energy spectrum from radioisotope identification instruments contain a wealth of information about the radiation source when analyzed using specialized analysis tools. The assessment includes the nature of the radioactive material, including identifying potential threats, and provides detailed radioisotope identification, radioactivity quantity estimates, intervening shielding materials, and radiation health and safety guidance. For special nuclear materials, the analysis includes the relative abundances of the isotopes (i.e. Pu-238, Pu-239, Pu-240, etc.) which are used to determine the enrichment of the material. The experts also provide advice and guidance on source recovery operations and material packaging.

Radiological spectral data can be very complex to analyze and interpret. Specialized gamma ray spectroscopy software tools have been developed in research laboratories around the world to analyze gamma ray spectra. As shown in Figure 1, the gamma spectrum can exhibit a relatively simple signature, such as the well-defined two gamma ray photopeaks at 1173 and 1332 keV from Co-60 (top spectrum). The spectrum is relatively simple to analyze as the photopeaks are clearly separated with minimal interference from the natural background radiation. Other radioactive materials, such as Ra-226 (bottom spectrum) exhibit more complex signatures involving a large number of gamma ray photopeaks which are spread over a wide energy range. Pu-239 also has a very complex spectral signature with a large number of gamma rays spread over a wide energy range. Even with the best high resolution detectors, such as High Purity Germanium (HPGe), some adjacent gamma ray photopeaks are not resolved and require peak shape-fitting algorithms to analyze.

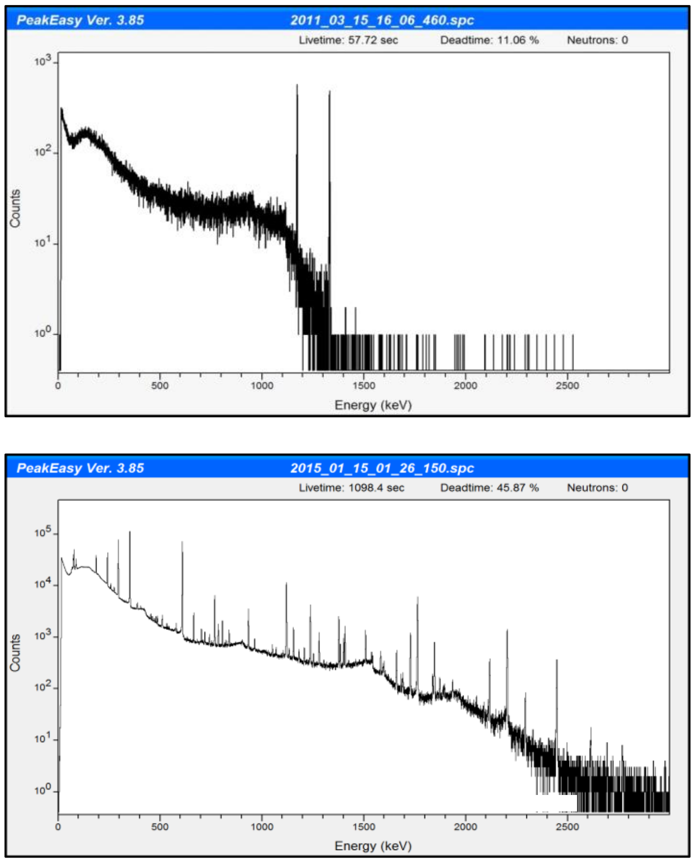


Figure 1. Example gamma ray spectra of radioisotopes with a relatively simple signature, Co-60 (top spectrum), and a very complex signature, Ra-226 (bottom spectrum).

**National or International Assistance in the Technical Assessment**

The following section provides several examples where national or international assistance in the technical assessment of nuclear and other radiological materials out of regulatory control can aid in resolving nuclear security events. One of the most common concerns at international ports of entry is illicit radioactive materials in cargo entering a country. Extensive technical assistance by U.S., European Union, the IAEA have provided partner nations with an extensive network of radiation portal monitors strategically positioned to detect and interdict radioactive material out of regulatory control. When a cargo container triggers a radiation alarm and is interdicted, the best practice protocol is to detain the container in a secure secondary inspection area and conduct additional interviews, manifest reviews, and radiation measurements in order to revolve the incident.

The technical nature of the secondary inspection process involves trained inspectors conducting radiation measurements with specialized detection instruments. Many of these inspectors have been trained through technical assistance programs provided by the U.S., IAEA, and European Union. The first step for technical assistance is typically through the countries Competent Authority or other national authority. The Competent Authority can provide scientific advisors to assist with guidance on safety, measurement techniques, equipment operation, and data analysis. If requested, they can also deploy a Mobile Emergency Support Team (MEST) with experts and specialized response equipment to aid in resolving the incident. International assistance can also be requested by the Competent Authority if the issue cannot be resolved or just to get a second opinion from other experts.

Several factors are of concern with a detained cargo container which may require technical assistance. First, from a radiation dose perspective, is it safe for the inspectors to be near the container? The dose rate can be measured using a dose rate meter. According to protocols, the inspectors will scan the container and locate the radiation hotspot, at which point they will measure the dose rate at the surface of the container. Standard protocols will provide guidance on safe dose rates permissible to continue the investigation. If the dose rates exceed the standard protocol guidance, expert assistance should be requested. One reason for this is that inspectors are typically not trained to assess the health risk associated with acute radiation exposure. The Competent Authority can provide a health physicist to make an assessment and provide recommendations and/or experts to aid in resolution of the incident.

Second, what is the identification of the radioactive material – NORM, medical, industrial or nuclear? The type of radioactive material will determine the next step in the assessment process. NORM materials are routinely detected and are typically low level radiation sources and pose no health risks. However, certain thorium ores, for example, can trigger significant alarm levels which may cause concern. These can typically be resolved using high resolution spectral measurements and a review of the shipping documents and manifest. Technical assistance, however, is most likely warranted as thorium has a complex spectral signature containing a large number of gamma rays from its decay chain progeny. Expert analysis by a gamma ray spectroscopist can aid in adjudicating the alarm by conducting a detailed analysis of the HPGe spectrum.

Spectral analysis which yields an industrial source such as Am-241, Cs-137, or Co-60 is a good indicator of possible MORC. There radioactive materials have been found in scrap metal cargo bound for recycling as a result of old industrial gauges being improperly discarded as waste. The sources, once removed from the gauge, are typically small, < 0.5 cm width and length and double encapsulated in stainless steel. These point sources will provide a radiation pattern which is highly localized at one point in the container. Dose rate or count rate measurements at the container surface and at 1 meter, on all sides where detectable, can be used to locate the source in the container. Using the $1/r^2$ method, one can estimate the position of the source in the container as noted in Figure 2. This information can be very useful to the technical assistance experts for future source recovery operations.

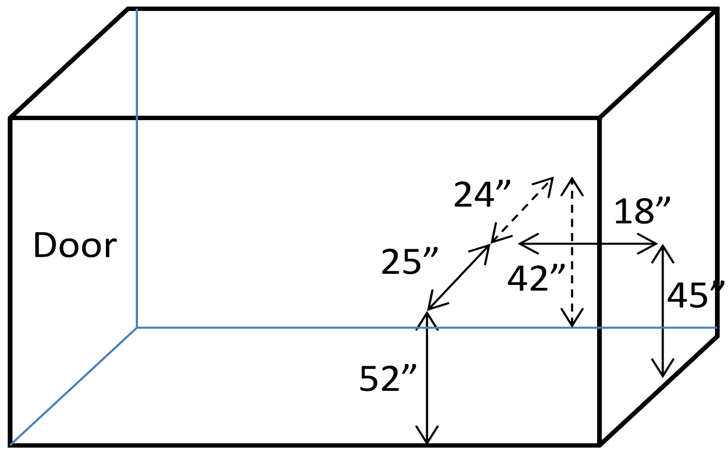


Figure 2. Example of using the $1/r^2$ method on all sides of a container where a source is detectable to locate the position of the source.

Not all Cs-137 and Co-60 radioactive materials identified via gamma ray spectroscopy are point sources. Cargo has been encountered where the dose rate or count rate is not localized to a single point, but found to be distributed throughout spatial areas of the container. An example of such a radiation pattern is shown in Figure 3. The triangular-shaped pattern at the rear of the container is an example of a non-point source spatial radiation pattern detected in a cargo container. The cargo was metal products contaminated with a low activity level of Co-60. When a Co-60 source is discarded improperly, it can end up comingled with scrap metal destined for a smelter. The Co-60 is then melted in blast furnaces with non-radioactive scrap metal resulting in contaminated raw metal stock. The contaminated metal stock is then turned into finished commercial products such as gauges, containers, and re-enforcing bar. The triangular shape shown originated from a stack of boxes containing Co-60 contaminated metal products. Cs-137 has also been found in contaminated wood products from the Chernobyl, Ukraine area and on the exterior of car parts from the Fukushima, Japan area, both of which exhibit distributed spatial radiation patterns.

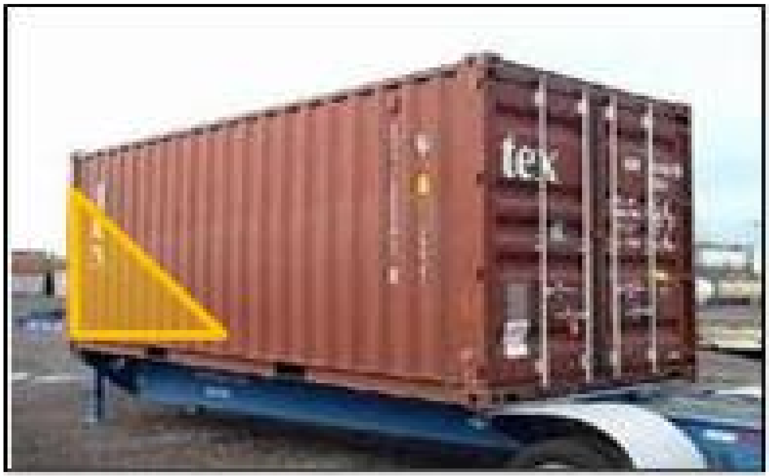


Figure 3. Example of a spatial radiation pattern that is indicative of a distributed source. For comparison, a point source would be localized to a single point on the container.

These unusual radiation patterns may seem confusing to a portal monitor inspector in the secondary inspection process. As such, technical assistance from a Competent Authority can provide guidance on the potential nature of the contents and potential threats. A detailed dose rate or count rate survey at low, medium, and high points on the container surface conducted at 1 meter intervals around the container will reveal the pattern. It should be noted that the level of Cs-137 and Co-60 contamination in these bulk materials identified is typically very low (parts per million levels), and as a result typically does not present at health risk while inside the container. The contaminated cargo, however, is now considered radioactive, hazardous material and will require technical assistance from the Competent Authority and/or international assistance for proper recovery and disposal operations.

If the radioisotope is found to be nuclear such as U-235 or Pu-239, Competent Authority assistance should be requested immediately as this may be smuggled nuclear material with malicious intent for criminal acts or acts of terrorism. U-235 is very difficult to detect as it is not very radioactive (i.e. low specific activity). In addition, the density of U-235 metal is very high which results in considerable self-attenuation of the emitted gamma rays. Pu-239 metal also has a high density resulting in considerable self-attenuation of the emitted gamma rays. However, Pu isotopes also emit neutrons, which can be difficult to shield and can be detected by radiation portal monitors. Neutron sources are rarely detected from cargo containers, but when it is detected, the concern level is elevated and the container directed to secondary inspection. The gamma ray spectrum acquired using a HPGe detector in secondary inspection should be sent to the Competent Authority for analysis. Nuclear materials have complex gamma ray signatures and international expert assistance is available through the U.S. DOE Triage program and the IAEA.

Third, is there any loose contamination from a breached radiation source? Cargo which contains a breached source resulting in loose contamination is a difficult problem to solve and is going to require technical assistance by Competent Authority or international experts trained in source recovery operations. Testing for contamination should not be attempted by inspectors as they typically do not have the proper training, personal protective equipment (PPE), or survey meters to conduct the test. If the cargo in the container is suspected to be contaminated, the container should be cordoned off to limit access, marked with signs, and technical assistance requested from the Competent Authority. Competent Authority experts can survey the outside of the container by checking areas that may contain contamination such as the door edges and handles as shown in Figure 4. These are likely places to find contamination without opening the container.

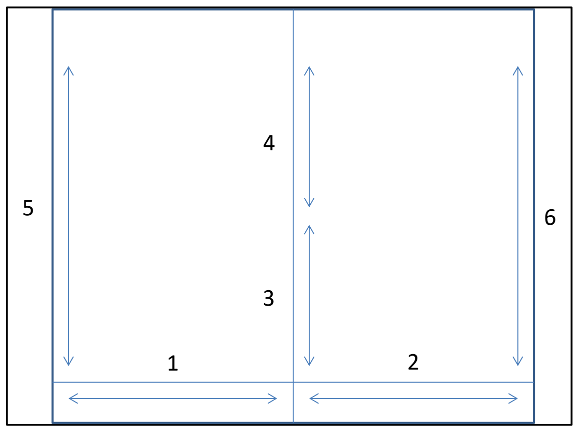


Figure 4. Example of the swipe pattern to check the door area of a cargo container for external contamination prior to opening the container.

The survey technique is to wear rubber gloves and use a series of paper swipe on the handles and door edges to pick up any loose contamination. The swipes are then moved away from the container and counted using a beta/gamma and/or alpha probe, depending on the radioisotope identified by the gamma ray spectrum. If no contamination is detected, then the next step is to develop a detailed source recovery plan with PPE guidance and formulate a deliberate process to open the container for the recovery operations. International assistance can be requested through the Competent Authority to the U.S. and IAEA for source recovery assistance by technical experts.

## Summary

Radioactive materials are routinely detected by radiation portal monitors at international ports of entry such as border checkpoints, shipping ports, and airports around the world. The majority of the detections are assessed and resolved by the portal operators using established protocols to be legitimate shipments and attributed to commercial and industrial materials containing naturally occurring radioactive materials. However, when the site assessment protocols cannot resolve the situation, the best practice is access to a technical reach back capability with experts from the State's Competent Authority or other qualified authority. The experts can review the data and provide timely assessments of potential threats or illicit radioactive materials. The U.S. DOE/NNSA Radiological Triage reach back capability can be accessed 24/7 via the IAEA Incident and Emergency Centre at +43-1-26-32-000, the DOE/NNSA Watch Office at +1-202-586-8100, or the U.S. Department of State Operations Center at +1-202-647-1512.