GUIDANCE FOR GROSS RADIOACTIVITY SCREENING OF "UNKNOWN" SAMPLES FOR NON-RADIOLOGICAL LABORATORIES

Integrated Consortium of Laboratory Networks
Radiation Laboratory Workgroup

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ABBREVIATIONS AND ACRONYMS

AHRF	All Hazards Receipt Facility
BSC	biological safety cabinet
CFR	Code of Federal Regulations
cpm	counts per minute
d	day(s)
DHS	U.S. Department of Homeland Security
DOT	U.S. Department of Transportation
GM	Geiger-Müller
GP	gas-proportional
h	hour(s)
IATA	International Air Transport Association
µ	micro (10^{-6})
m	mili (10^{-3})
min	minute(s)
NaI(Tl)	thallium-drifted sodium iodide
PPE	personal protective equipment
R	roentgen
s	second(s)
USEPA	U.S. Environmental Protection Agency
y	year(s)
ZnS	zinc sulfide

1. INTRODUCTION

In the response to an incident involving suspicious, uncharacterized material, a series of screening measures may need to be taken to characterize the general nature of a potential hazard before specific analytical practices can be undertaken. Gross physical, chemical, biological, and radiological properties may be determined during this initial screening process, the results of which may be used to guide further analyses or to classify the sample material for additional handling precautions or rejection by the laboratory.

In many cases, radiological screening data and other pertinent information regarding the incident may be available from first responders, sample management teams, or an All-Hazards Receipt Facility (AHRF[1]). In cases where radiological screening data are not available, or is otherwise inadequate or unreliable for any reason, individual laboratories should perform radiological screening of samples to enable appropriate decision-making with respect to the potential radiological hazards.

Established and licensed radioanalytical laboratories will have extensive protocols in place for the receipt, screening, and handling of radiological material. Non-radiological laboratories, however, can develop the capability and expertise to perform gross radiological screening of the incoming samples in order to ensure the protection of the laboratory staff and to prevent the radiological contamination of the laboratory facility.

This guide discusses the radiological screening of sample material in a non-radiological laboratory. While this guide is specifically applicable to state and federal public health laboratories and equivalent organizations, it may also be useful to commercial non-radiological laboratories. It is presumed that laboratories using this guide have established capabilities to screen uncharacterized shipping containers, sample containers, and sample materials for dangerous chemical and biological agents. The screening described in this document may be performed either in sequence with, or concurrent to, other physical, chemical, and biological screening analyses. This guide does not specifically address non-radiological (i.e., physical, chemical, or biological) screening processes.

With respect to radiological sample screening, individual laboratories should pre-determine **decision levels (or action levels)** that guide the acceptance or rejection of a sample, as well as the handling, storage, and waste management protocols used by the laboratory. This guide provides examples of such decision levels for illustrative purposes only. Each laboratory must establish decision levels based on the specific physical and operational capabilities of the laboratory, as well as applicable state and federal regulatory requirements.

2. SCOPE AND APPLICATION

2.1 This guide provides instruction for screening samples for elevated levels of alpha, beta, and gamma radiation at the time of arrival at the laboratory. The information generated should be used to determine which sample handling protocols available to the laboratory personnel are applicable to the sample shipment.

2.2 This document is not intended to be prescriptive, but to provide examples that may guide the development of laboratory-specific screening protocols.

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[1] See All Hazards Receipt Facility Screening Protocol, DHS/S&T-PUB-08-0001 EPA/600/R-08/105, USEPA, DHS, September 2009 and associated documents. Available at: http://www.epa.gov/nhsrc/.

2.3 The screening techniques described in this document may be employed

- when AHRF screening data are not available,
- when field screening results are unavailable, inadequate, unreliable, incomplete, or questionable, and
- under any other appropriate circumstances where the use of additional radiological screening information is indicated.

2.4 The approach described in this guide is intended to be an integral part of a larger sample screening protocol, in which the laboratory performs other necessary screening for physical, chemical, and/or biological hazards, as appropriate for the laboratory and the incident response. This guide does not address screening techniques for non-radiological hazards.

2.5 This guide assumes that appropriate packaging, shipping, receipt, and permit requirements for chemically, physically, and biologically hazardous materials have been implemented by qualified sample management and shipping personnel. Nonetheless, the receiving laboratory should take appropriate precautionary measures to protect the laboratory and personnel from such potential hazards, which may be encountered during the initial handling of the shipping containers.

2.6 This guide assumes that the laboratory has adequate health and safety and laboratory personnel training programs in place to ensure the safe handling of physically, chemically, and biologically hazardous materials, and that effective safe-handling protocols are consistently applied to incoming samples of unknown composition. When handling samples with unknown characteristics, the laboratory should employ:

- Adequate Personal Protective Equipment (PPE), including lab coat or coveralls, gloves, and safety glasses.
- Properly configured, working chemical fume hoods or biological safety cabinets (BSCs) that filter exhaust air prior to discharge.[2]
- Operational practices that restrict the access of untrained or unqualified workers to areas in which samples of unknown composition are being processed.

2.7 It is recommended that, in addition to the training and precautionary measures discussed above, the laboratory should incorporate appropriate training in basic radiation safety, including the safe handling of radioactive materials.

2.8 It is understood that the laboratory may have alternate protocols for handling uncharacterized sample materials and that, in some cases, samples may be routed to a biohazard laboratory first, or at some intermediate point in this guide. The laboratory should consider and coordinate responses to the various potential hazards in their development of comprehensive screening protocols.

2.9 This guide is only intended to produce gross screening results using readily available hand-held radiation survey equipment to aid in the decision whether or not to accept and/or process a potentially radioactive sample.

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[2] Initial screens should be performed in a BSC as specified in *Association of Public Health Laboratories Model Practice: Algorithm and Guidelines for Responding to an Incident Involving a Suspicious Non-Clinical Sample*, section 9.0.1.

2.9.1 It is NOT the intent of this guide to accurately quantify the radioactivity in the sample. Such measurements should be performed by a qualified radioanalytical laboratory.

2.9.2 The results of the survey may only be reliable to within approximately two orders of magnitude or more, depending on the sample characteristics and the measurement technique.

2.10 This guide does not address the screening of shipping containers to determine compliance with U.S. Department of Transportation (DOT) or International Air Transport Association (IATA) regulations for shipping radioactive materials packages.[3]

3. SUMMARY

3.1 Upon receipt in the laboratory, after ensuring that established laboratory protocols have been followed for the receipt of chemically, physically, and biologically hazardous shipments:

- Unopened shipping containers are surveyed for gamma radiation.
- Unopened sample containers are surveyed for gamma radiation.
- Unopened sample containers are qualitatively screened for high-energy beta radiation.

At this point, other laboratory precautions for non-radiological hazards are implemented prior to proceeding. This may include appropriate sub-sampling techniques and screening procedures.

- In the appropriate containment, each sample container is opened and a small amount of bulk material is removed and transferred to a swipe. The swipe is counted for beta and alpha radiation.

3.2 At each step of the survey, results are recorded and compared to established limits. If those limits are exceeded, a pre-defined response is initiated. Example limits are provided, however each laboratory should evaluate their working environment and establish limits that are appropriate to their specific situation.[4]

4. SAFETY

This guide does not attempt to prescribe laboratory safety protocols. The laboratory's health and safety program should evaluate and specify safety protocols that are specific to the facility and the work being performed. At a minimum, however, the screening procedures, including the radiation surveys, should be carried out in a working laboratory fume hood or BSC, with appropriate PPE.

[3] See 49 CFR 172 or IATA 10.4 for shipping regulations.

[4] An example of factors for the laboratory to consider when establishing screening limits is provided in Appendix A: *Considerations for Establishing Acceptance Limits on Radiation and Radioactivity Screening Measurements*.

5. RADIATION DETECTION INSTRUMENTATION

Radiation detection equipment is available with a broad range of detection capabilities. The more common types of survey instrumentation are briefly discussed below. It is important to understand that no single instrument should be expected to meet the needs of the laboratory to detect every radiation type that might be encountered at sensitivity levels needed to effectively address the protection of laboratory personnel and facilities in all situations.

While different laboratories will have different numbers and types of instrumentation based on the type of samples being received and the required sensitivity of the screening measurements, it is expected that each laboratory will have, at a minimum, hand-held survey instruments capable of detecting alpha, beta, and gamma radiation. In some cases, a laboratory might choose to employ basic, gross screening instrumentation such as a Geiger-Müller (GM) detector, which may not be able to distinguish between the various types of radiation, and which might have high uncertainties associated with the screening results. In other cases, the laboratory might opt for more sensitive, dedicated hand-held or fixed instrumentation designed to discriminate between the types of radiation with lower uncertainty in the measurement results. Individual laboratories must decide which instrumentation to use in their screening practices, based on the quality of data needed from the screening process. In addition, the laboratory's decision levels and sample handling protocols should be consistent with the quality of data obtainable from that instrumentation. **In all cases, the instrument user should be adequately trained and familiar with the various features and limitations of any survey instrumentation.**

The following brief comments regarding types of detectors and their various capabilities might be considered in the laboratory's selection.

5.1 Minimum Radiation Screening Instrumentation

At a minimum, it is recommended that each laboratory have at least the following two types of hand-held survey instruments:

5.1.1 A thin window GM detector, preferably in a "pancake" configuration.

GM detectors may detect any ionizing radiation depending on the configuration of the detector. In most cases, there is no discrimination between alpha, beta, and gamma radiation beyond that which can be obtained by observing changes in instrument response to progressive shielding of the detector. GM detectors come in a wide variety of sizes and configurations to suit a broad range of applications. For example:

- Thin window GM probes, including end-window and pancake probes, measure beta and gamma, as well as alpha radiation. Various shields or "attenuators" may be provided to discriminate between the different types of radiation.
- Shielded GM tubes (commonly called "hot dog" probes) are configured to respond to gamma radiation with the side shield closed or beta and gamma radiation, and to a lesser extent to alpha radiation, with the side shield opened.

GM survey instruments are particularly useful for direct measurements of potentially contaminated surfaces, containers, and sample material, where sub-sampling and laboratory analysis is undesirable or impractical.

GM "pancake" detectors used for screening and contamination surveys should have moderate to high sensitivity (i.e., greater than approximately 3,000 cpm/mR/h for Cs-137, approximately 15% counting efficiency for Pu-239 alpha activity), and a reasonably low background count rate (< 60 cpm).

5.1.2 A thallium-drifted sodium iodide [NaI(Tl)] gamma radiation exposure rate meter.

Most gamma radiation exposure rate meters respond only to gamma radiation, although some advanced instruments have additional features for beta measurements as well. Basic gamma exposure rate meters measure gamma exposure in Roentgens (R). Many instruments have dual-readout displays for gamma exposure and for gamma activity. Basic gamma exposure rate instruments may have an energy-dependent response, in which higher energy gamma rays are not measured with the same efficiency as lower energy gamma rays. Some advanced instruments are "energy compensating" to avoid this potential bias. As discussed above, the instrument user should be adequately trained and familiar with the various features and limitations of any survey instrumentation.

Gamma radiation exposure rate meters with sufficient sensitivity will enable the detection of elevated gamma activity in a sample, without having to unpack or open the sample container.

Gamma radiation exposure rate meters used for screening and contamination surveys should be sufficiently sensitive to provide a measurable instrument response at less than 10 μR/h.

Note that ionization chamber detectors, although used in a similar manner as NaI(Tl) exposure rate meters, are usually designed to measure higher levels of gamma radiation. They are typically configured to provide integrated dose-rate measurements and are not particularly suitable to the screening measurements described in this procedure.

5.2 Enhanced Radiation Screening Instrumentation:

Laboratories wishing to enhance their capabilities, or those requiring more accurate determinations of contamination and sample activity, may consider additional hand-held survey and fixed laboratory instrumentation that provides greater sensitivity and discrimination between the various types of ionizing radiation.

5.2.1 Plastic scintillator detectors are readily available, are responsive to specific types of radiation (e.g., alpha, beta, gamma), and generally have good sensitivity, making them well-suited to the type of screening measurements described in this guide.

- A zinc sulfide (ZnS) alpha detector is a scintillator detector that is generally more sensitive for measuring alpha radiation since it does not respond to beta or gamma radiation and has much lower background count rates.
- ZnS alpha detectors may be combined with beta-gamma scintillating plastic to create a dual phosphor detector that can perform simultaneous measurements for alpha-beta-gamma radiation.

5.2.2 Gas proportional (GP) counters measure alpha and beta radiation with more specificity, and generally with greater sensitivity, than GM detectors. Most GP detectors can be configured to discriminate between alpha and beta radiation. GP detectors are generally heavily shielded to minimize background count rates, and typically require a continuous flow of compressed gas. Most GP detectors suitable for contamination and sample screening measurements are therefore fixed laboratory instruments, though some portable hand-held models are available. GP detectors are especially useful for when sub-sampling of the sample material is feasible, and when the lab requires greater precision or lower limits of detection than may otherwise be achieved with the screening instrumentation described above.

5.3 Instrumentation Used In This Guide

While each laboratory will select instrumentation and craft screening procedures that are specific to their particular operational requirements, this guide describes the use of a gamma radiation exposure rate meter for hand-held gamma surveys, a GM pancake probe for hand-held alpha+beta surveys, and a fixed bench-top dual phosphor alpha/beta detector for individual alpha and beta measurements. Laboratories with other radiation detection equipment may need to make minor procedural modifications to accommodate their equipment.

To ensure proper operation and use of radiation screening instrumentation:

- Laboratory staff should be trained in the proper use of the instrumentation and the basic interpretation of the results.
- Instrumentation should be properly calibrated, preferably with the radionuclide of interest to the incident, if known.
- The instrument calibration and any required maintenance should be performed at the frequency prescribed by the laboratory's Quality Plan or by the instrument manufacturer.
- Instrument performance should be verified daily prior to use, preferably by the laboratory personnel who will be using the instrument. This should include checks for battery, instrument operability (cables, connections, etc.), and a radioactive source check.

6. EQUIPMENT AND SUPPLIES

The mention of trade names or specific applications in this procedure does not imply endorsement by the Federal agencies comprising the Integrated Consortium of Laboratory Networks.

6.1 Gamma radiation exposure rate meter; NaI(Tl) with sufficient sensitivity to provide a measurable instrument response at less than 10 μR/h.

6.2 Geiger-Müller pancake-type probe; thin window, GM pancake-type probe, with nominal gamma sensitivity greater than approximately 3,000 cpm/mR/h for Cs-137, nominal alpha counting efficiency of approximately 15% for Pu-239, nominal beta counting efficiency of approximately 20% for Sr/Y-90, and a nominal background less than 60 cpm, (with appropriate rate-meter, as recommended by instrument manufacturer).

6.3 Alpha/beta sample counter, dual phosphor (ZnS/plastic scintillator); capable of accepting up to 5.1 cm diameter samples, with nominal alpha counting efficiency of approximately 30% for Pu-239, nominal beta counting efficiency of approximately 25% for Sr/Y-90, and alpha background less than 10 cpm.

Note that dual-phosphor alpha/beta sample counters have the advantage of greater sensitivity, lower uncertainty, and the ability to discriminate between alpha and beta radiation, as compared to the GM pancake probe described in 6.2. It is noted, however, that a GM pancake probe may be used in lieu of an alpha/beta sample counter if the latter is not available, although the sensitivity of the alpha measurements will be significantly lower due to the high background count rate of the instrument.

6.4 Tongue depressors.

6.5 Disposable transfer pipettes, graduated, preferably in 0.25 mL increments.

6.6 Swipes, appropriately sized to fit the detector.

6.7 Small aluminum foil squares to be used as alpha shielding of appropriate size to shield the entrance window of the GM pancake probe.

7. PROCEDURE

Prior to the initiation of the screening process, the samples are presumed to have arrived at the laboratory by courier or common carrier, without adequate or reliable radiological screening information. The hazard risk from the samples has not been determined. The shipping container is accepted by the laboratory and the process is initiated in the sample receiving area, inside a fume hood or BSC, prior to opening the shipping container.

An initial gamma survey of the unopened shipping container will identify high activities of gamma- and x-ray activity, if present in samples. This will be followed by an alpha/beta contamination survey of the shipping container. The following procedural steps are illustrated in the flow chart in Appendix D.

7.1 Survey the shipping container for gamma radiation using the gamma radiation exposure rate meter.

Note: Prior to each use, verify instrument performance using the laboratory's protocol for survey meter performance checks. The process should check battery, cables and connections, and include a check of instrument response with a radioactive check source. The background check is performed as described in 7.1.1–7.1.2.

7.1.1 Turn the gamma radiation exposure rate survey meter on. Turn the audio on, if available. Ensure that the instrument is set to the "slow" response rate and located several meters away from potential sources of radiation exposure.

Note: Survey meters may be equipped with a switch to select either a "fast" or a "slow" response. "Slow" response settings show the time-weighted average over a pre-determined response time. The response time may vary from a few seconds to nearly one minute, depending on the manufacturer and model. The user should be familiar with the response time of the instrument. All survey measurements, in which the probe or instrument is stationary, are taken with the instrument set to the "slow" response rate and should be made over a period of time that is at least as long as the instrument response time. Fixed contamination surveys, in which the probe is moved along a surface, are taken with the instrument set to the "fast" response rate. This is a critical distinction and should be followed carefully.

7.1.2 Wait for the required instrument response time described in 7.1.1 and record the instrument background reading and compare to previously established background measurements.

Significant changes in the instrument background response may require investigation into the instrument performance or laboratory environmental conditions.

7.1.3 Place the survey meter on a clean surface inside the fume hood or BSC.

7.1.4 Survey the center of all sides, including the top and bottom, of the shipping container by holding the survey meter approximately 1 cm from the surface near the center of the face being surveyed.

7.1.5 Wait the required instrument response time described in 7.1.1 and record the gross instrument reading.

7.1.6 Determine the appropriate action from the example chart below.

Note that the values shown here and elsewhere in the procedure are only examples, provided to illustrate limits that might be appropriate for ensuring worker protection in some typical laboratory situations. These limits may not address laboratory contamination concerns that might be of significant importance in some laboratories. Each laboratory should develop its own action limits and corresponding responses, in accordance with the laboratory's health and safety program, quality assurance program, state and federal regulations, and association of public health laboratories (APHL[5]) guidance documents, as applicable.

[5] http://www.aphl.org.

Gross Exposure Rate @ 1 cm	Lab Response
≤ 500 µR/h	Proceed to step 7.2
> 500 µR/h	STOP – Notify H&S Manager

7.2 Perform an alpha/beta survey on the container using the GM pancake probe. This survey will provide the sum of the fixed + removable activity contamination.

7.2.1 Turn the GM pancake probe survey meter on and ensure that the instrument is set to the "fast" response rate.

7.2.2 With the probe at least one meter from potential sources of radiation, record the instrument background reading and compare to previously established background measurements.

7.2.3 Survey the bottom, top, handles, and other surfaces of the container likely to be contaminated by holding the probe face approximately 1 cm from surface and moving over the surface at approximately 2-4 cm/sec.

7.2.4 Record the highest gross instrument reading obtained in the previous step.

7.2.5 Determine the appropriate action from the chart below.

GM Pancake Probe Gross Count Rate	Lab Response
≤ 3x background	Proceed to step 7.4
> 3x background	Proceed to step 7.3

For example, a GM pancake probe background count rate of 60 cpm would result in a decision level of 180 gross cpm. In this guide, no "background subtraction" is performed and all decision levels are expressed in terms of the gross instrument response.

7.3 Perform an alpha/beta removable contamination survey on the container using swipes and the dual phosphor alpha/beta detector.[6]

7.3.1 Using moderate pressure and an S-motion, swipe a 100 cm^2 area of the container, with emphasis on the bottom, top, handles, and other surfaces of the container likely to be contaminated. Use multiple swipes for large containers.

7.3.2 Affix the swipes to a planchet and count on the dual phosphor alpha/beta detector for one minute each.

7.3.3 STOP. Report the results of the fixed and removable contamination surveys to the H&S Manager. Do not proceed until notified to do so.

Note: Materials that accumulate static charge, such as plastic coolers, may attract radon progeny (i.e., ^{214}Pb and ^{214}Bi, ^{214}Po) to their surfaces. Although there are no significant health or safety concerns from the radon progeny, elevated screening results may be observed on surface swipe samples. Short-lived radon progeny can be differentiated from the longer-lived radioactivity of

[6] If a dual phosphor alpha/beta detector, or similar instrument, is not available, the swipes may be counted using a GM pancake probe, using the guidance described in section 7.10.3.

concern by recounting the swipe sample over time. The observed radioactivity of swipes with radon progeny will drop significantly, in some cases to approximately 1/20 or less of the initial activity over the first three hours after collection. Additional details regarding the measurement and decay of short-lived radon progeny is provided in Appendix D.

7.4 The shipping container should be opened in a hood or BSC per APHL Guidelines (see footnote 2 above). The laboratory protocol for removing individual samples from the shipping container is followed, including inspection of samples, condition upon receipt, and chain of custody review. Upon completion of these tasks individual sample containers are surveyed, before opening.

7.5 After opening the shipping container, survey each individual sample container for gamma radiation, using the gamma radiation exposure rate meter as follows:

7.5.1 Turn the gamma radiation exposure rate meter on, ensure that the instrument is set to the "slow" response rate, and located several meters away from potential sources of radiation exposure.

7.5.2 Wait the required instrument response time described in 7.1.1 and record the instrument background count rate and compare to previously established background measurements.

7.5.3 Place the survey meter on a clean surface inside the fume hood or BSC.

7.5.4 Place the sample container in the fume hood or BSC, approximately 1 cm from the gamma radiation exposure rate meter.

7.5.5 Wait the required instrument response time described in 7.1.1 and record the gross instrument reading.

7.5.6 Determine the appropriate action from the chart below.

Gross Exposure Rate @ 1 cm	**Lab Response**
≤ 500 µR/h	Proceed to step 7.6
> 500 µR/h	STOP. Notify Health and Safety Manager

7.6 Perform an alpha/beta survey on the sample container using the GM pancake probe.

7.6.1 Turn the GM pancake probe survey meter on; ensure that the instrument is set to the "fast" response rate.

7.6.2 With the probe at least one meter from potential sources of radiation, record the instrument background reading.

7.6.3 Survey the sides, lid and other surfaces of the sample container likely to be contaminated by holding the probe face approximately 1 cm from surface and moving over the surface at approximately 2-4 cm/sec.

7.6.4 Record the highest gross instrument reading obtained in the previous step.

7.6.5 Determine the appropriate action from the chart below.

GM Pancake Probe Gross Count Rate	Lab Response
≤ 3x background	Proceed to step 7.8
> 3x background	Proceed to step 7.7

7.7 Perform an alpha/beta removable contamination survey on the container using swipes and the dual phosphor alpha/beta instrument.[7]

7.7.1 Using moderate pressure and an S-motion, swipe a 100 cm^2 area of the container, with emphasis on the sides, lid, and other surfaces of the container likely to be contaminated.

7.7.2 Affix the swipes to a planchet and count on the dual phosphor alpha/beta detector for **ten minutes** each.

7.7.3 Determine the appropriate action from the chart below.

Activity Type	Gross Alpha CPM	Lab Response
Alpha	≤ 3x Background	Release samples to laboratory for scheduled analyses
	> 3x Background	STOP. Notify Health and Safety Manager
Beta	≤ 3x Background	Release samples to laboratory for scheduled analyses
	> 3x Background	STOP. Notify Health and Safety Manager

In steps 7.6 and 7.7, elevated surveys of the sample container measured directly, with corresponding removable contamination swipe surveys below the laboratory decision level, may indicate one of two things:

- *Fixed contamination on the exterior of the sample container; or*
- *Elevated higher-energy beta activity in the sample, which may be detected through thinner sample containers such as plastic bags or thin-walled plastic bottles.*

In these cases, step 7.6 may be repeated using a clean sheet of paper to shield the face of the GM pancake probe. If the reading falls to background levels, the outside of the sample container shows fixed alpha contamination. If the high reading persists, the bulleted items above still apply.

WARNING

Do not proceed with further radiological screening or open the sample container until the established laboratory protocol for screening chemical, physical, and biological hazards has been completed and approved by the appropriate laboratory personnel.

[7] If a dual phosphor alpha/beta detector, or similar instrument, is not available, the swipes may be counted using a GM pancake probe, using the guidance described in section7.11.

7.8 Optional — Direct Screening Of Sample Material

At this point, the sample container has been shown not to be significantly contaminated with radioactive material, and the sample itself has been shown not to emit significant gamma radiation. Further radiological screening of the sample material itself will require that the container be opened and a small amount of material sub-sampled for radiological measurement.

In the following optional steps, 7.8 through 7.12, the sample container is opened and a small amount of sample material is transferred to a swipe, to be counted using a dual-phosphor alpha/beta counter (or equivalent instrumentation).

Counting techniques for particulate air filters will depend on the size of the filter. Thin, flat air filters that are appropriately sized for the detector system being used (i.e., 5 – 10 cm diameter) are the focus of this guide. Larger or unusually shaped air filters may present additional challenges and may require direct measurement with a GM pancake probe, as described in section 7.2 for a moving scan of larger filters or section 7.10 for a static scan of smaller filters, with sample-specific guidance from the laboratory Health and Safety Manager.

Note: air samples often concentrate naturally occurring radon (^{222}Rn) and thoron (^{220}Rn) progeny. Although they are not a significant health or safety concern, they may produce elevated results until the radioactivity has decayed away. While radon progeny decay in several hours time, the thoron decay product ^{212}Pb, has a half-life of 10.6 hours and may lead to elevated results for three days after sampling ceases. If a minimum three-day waiting period before screening can be reasonably accommodated, the laboratory may use the same decision levels that apply to swipe samples. If the laboratory chooses to screen newly collected particulate air samples, there are special considerations and modified decision levels that should be considered. These are discussed briefly in Appendix D.

If screening delays and elevated decision levels are a significant concern, interference from thoron and radon progeny can also be addressed in real-time with commercially available radon compensating instrumentation.

Under certain circumstances, and with approval from the laboratory director, the following steps may be considered optional on the assumption that subsequent handling of the sample, up to and including ultimate disposition, will include routine protective measures for chemical, physical, and biological hazards that may be considered adequate protection for the alpha and beta radiation that would be identified in the following steps.

If additional information regarding the gross alpha and/or beta activity in the sample is required, proceed to steps 7.8 through 7.12.

WARNING

Thus far, the sample container has provided protection from all alpha and some beta activity and has contained potential laboratory contamination from the sample. An estimate of the total alpha and beta activity requires that the sample be opened. This must be performed in a working fume hood or biological safety cabinet.

7.9 For Solid Samples

For solid samples, a tongue depressor will be used to transfer a small amount of sample material to a swipe.

7.9.1 Open the sample container.

7.9.2 Immerse the tip of a clean tongue depressor approximately 3–4 cm into the sample.[8] Avoid creating airborne dust in the fume hood or BSC, but the sample may be gently stirred, if there is obvious inhomogeneity and a "representative" sub-sample is needed.

7.9.3 Remove the tongue depressor from the sample container. For finely divided material, such as soil or dust, the residual contamination on the tongue depressor will be sufficient material. Otherwise, a small amount of material (approximately 10 mg) may need to be deliberately removed with the tongue depressor.

7.9.4 Wipe the tongue depressor with a swipe, taking care to transfer as much of the material as possible to the swipe, as evenly on the swipe as possible.

7.9.5 Inside the fume hood or BSC, lay the swipe flat on a clean, disposable surface such as plastic backed absorbent paper.

7.9.6 Proceed to step 7.12.

7.10 For Liquid Samples

7.10.1 Place a new swipe on a clean, flat, disposable surface in the fume hood or BSC.

7.10.2 Open the sample container.

7.10.3 Using a disposable transfer pipette, remove approximately 0.25 mL of the sample.

7.10.4 Carefully transfer the sample, drop-wise, to the swipe. Start at the center and move outward, leaving approximately 5 mm between each drop.

7.10.5 Allow the swipe to air-dry for several minutes. Alternately, a heat lamp may be used to speed the process.

7.10.6 Proceed to step 7.12.

[8] This assumes that the testing to be performed will not be compromised by using a wooden tongue depressor. If that is not the case, a stainless steel spatula or other device may be used to transfer a very small amount of sample material to the swipe.

7.11 For Counting Particulate Air Filters and Swipes With a GM Pancake Probe

This section is applicable for counting swipes and particulate air filters, when an alpha/beta sample counter is not available or when it is preferable to count the sample without removing it from the BSC or chemical fume hood. This section is also applicable for counting large or unusually shaped air filters that are not appropriately sized for an alpha/beta sample counter.

7.11.1 Do not attempt to remove material from the filter or swipe or to sub-sample the material.

7.11.2 Open the sample container and lay the swipe or filter flat, leaving it in the original container, if possible.

7.11.3 Counting particulate air filters and swipes with a GM pancake probe:

7.11.3.1 Turn the GM survey meter on and ensure that the instrument is set to the "slow" response rate.

7.11.3.2 With the probe at least one meter from potential sources of radiation, record the instrument background reading and compare to previously established background measurements.

7.11.3.3 With the swipe or filter laying flat in the fume hood or BSC, and using a clean, gloved hand, pick up the GM pancake probe.

7.11.3.4 With the GM pancake probe window facing the swipe or filter, and held approximately 1 cm from the swipe or filter, count the sample for at least the required instrument response time described in 7.1.1 and record the gross count rate. This will be the "alpha + beta" gross reading.

7.11.3.5 Place an aluminum foil square over the face of the detector to block alpha radiation and repeat the measurement. Record the result as the "beta" reading.

7.11.3.6 Calculate the gross "alpha" result as the difference of the "alpha + beta" and the "beta" readings (i.e., [alpha] = [alpha + beta] - [beta]). Record the result.

7.11.3.7 Record the gross alpha and beta instrument readings.

7.11.4 Proceed to step 7.13.

7.12 Counting Particulate Air Filters and Swipes in an Alpha/Beta Sample Counter

This section is applicable for counting appropriately sized (i.e., 5 – 10 cm diameter) particulate air filters and swipes in an alpha/beta sample counter.

7.12.1 Position the swipe in a planchet with the potentially contaminated surface facing upward. Count for **ten minutes** on the alpha/beta sample counter and record the gross alpha and beta results.

7.12.2 Proceed to 7.13.

7.13 Determine the appropriate action for swipe samples and for appropriately aged (≥3 days after collection) particulate air filters from the chart below.

Note: For newly collected particulate air filters, which have not been allowed to decay for at least 3 days prior to counting, refer to Appendix D for additional discussion and modified decision levels.

Activity Type	Gross Alpha CPM	Lab Response
Alpha	≤ 3x Background	Release samples to laboratory for scheduled analyses
	> 3x Background	STOP – Notify Health and Safety Manager
Beta	≤ 3x Background	Release samples to laboratory for scheduled analyses
	> 3x Background	STOP – Notify Health and Safety Manager

8. WASTE MANAGEMENT

The evaluation, segregation, and disposal of residual sample material and laboratory waste is beyond the scope of this guide and should be carefully addressed in the laboratory's Waste Management Plan, or other appropriate document. Samples that exceed the laboratory's pre-determined decision levels (action levels) should be appropriately labeled and segregated to aid in the waste management process.

9. QA/QC

9.1 All radiation detection instruments, including hand-held survey meters, should be calibrated at least annually.

9.2 All radiation detection instruments should have acceptable day-of-use performance checks.

9.3 An example checklist for ensuring that instrument performance meets day-of-use acceptance criteria is provided in Appendix B: *EXAMPLE INSTRUMENT PERFORMANCE CHECKLIST.*

10. FORMS

An example form for recording survey results is provided in Appendix C: *EXAMPLE SURVEY RESULTS FORMS.*

APPENDIX A: CONSIDERATIONS FOR ESTABLISHING ACCEPTANCE LIMITS ON RADIATION AND RADIOACTIVITY SCREENING MEASUREMENTS

The screening limits provided as examples in this guide are not intended to be used in any specific laboratory or situation. Each laboratory should develop their own acceptance criteria and protocols for responding when the criteria are exceeded for each of the radiation and radioactivity screening measurements discussed in this guide. The acceptance criteria and response should reflect the capabilities and the limitations of the specific working environment.

The following items, at a minimum, should be considered in the laboratory's development of acceptance criteria and exceedence responses:

- Applicable state and federal regulations, including;
    - radioactive materials licensing requirements,
    - limitations on the receipt and handling of unlicensed (e.g. "general license") radioactive materials,
    - limitations on employee exposure to ionizing radiation,
    - limitations on the disposal of potentially radioactive materials,
- The physical layout of the laboratory, including the laboratory's ability to segregate acceptable material from that which is not considered acceptable,
- The laboratory's safety practices, since these facilitate the protection of the employees from the effects of ionizing radiation,
- The laboratory's ability to segregate, export, and/or dispose of sample and waste material that may be contaminated with radioactive materials,
- The level of expertise of the workers performing the radiation screening measurements and the supervisory and management staff who are consulted in the event of a sample that exceeds the acceptance criteria.

1

XYZ Laboratory

SURVEY INSTRUMENT PERFROMANCE CHECK - COMPLETE EACH DAY PRIOR TO USE

Date and Time: _____

Performed By: _____

Instrument IDs:	Model 19, SN 12345	Model 44, SN 45678	Model 3030, SN 98765
Check all that apply:			
Instrument calibration is < 1 yr. old			
Instrument Battery Check is "Good"			N/A
Check Source ID:	123-1	5234-82	7752-01
Daily Check Source Acceptance Range:	5,000 - 5,500 uR/h	10,000 - 12,500 cpm	1,100-1,350 α cpm, 1,800-1,950 β cpm
Daily Check Source Result:			
Daily Background Acceptance Range:	<20 uR/h	10-40 cpm	<1 α cpm, <2.5 β cpm
Daily Background Result:			
Comments:			

Approved By: _____

Date: _____

XYZ Laboratory - EXAMPLE ONLY **SHIPPING CONTAINER SURVEY**

RADIATION SCREENING SURVEY REPORT

Shipper: _____ Client: _____

CoC ID: _____ Project: _____

Delivery Date & Time: _____ Cooler ID: _____

Radionuclide(s): _____ ☐ (check if unknown)

Other Info: _____

FOR EACH INSTRUMENT USED, INITIAL PERFORMANCE CHECKS AND BACKGROUND MEASUREMENTS HAVE BEEN COMPLETED, AND ARE RECORDED ON THE APPROPRIATE WORKSHEET.

INSTRUMENT 1: _____ INSTRUMENT 2: _____ INSTRUMENT 3: _____

BACKGROUND: _____ BACKGROUND _____ BACKGROUND _____

MEASURED BY: _____ MEASURED BY: _____ MEASURED BY: _____

Exposure Rate @ ~1 cm from shipping container surface

Instrument # _____ Gross Reading: _____ µR/h

Action Level = 500 µR/h

If Action Level is exceeded, report to H&S Officer.

Fixed + removable α/β @ ~1 cm from shipping container surface

Instrument # _____ Gross Reading: _____ cpm

Action Level = 3x Background

If Action Level is exceeded, perform swipe survey.

Removable α/β swipe survey of shipping container (if necessary) ALPHA | BETA

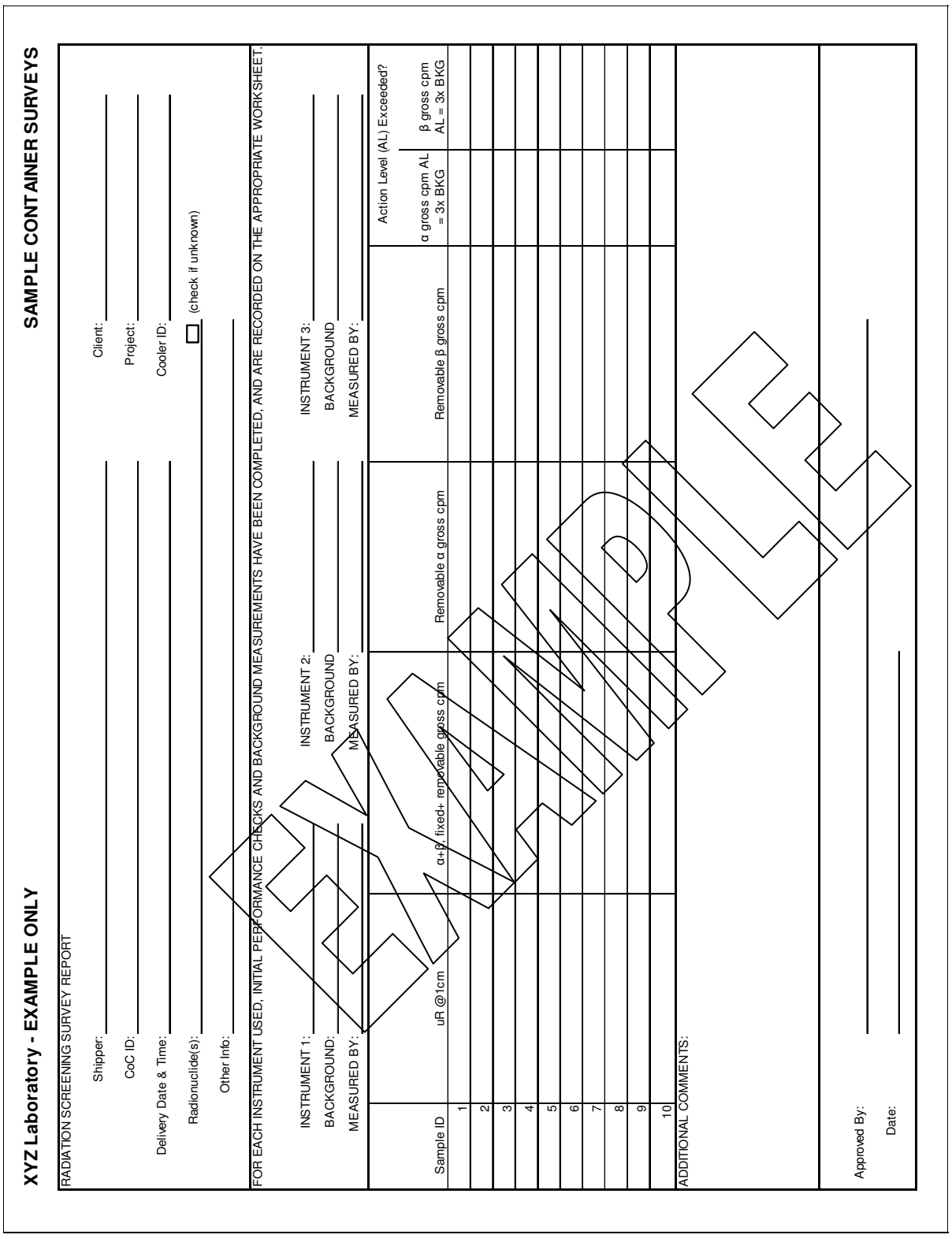
Instrument # _____ Gross Reading: _____ cpm

STOP - DO NOT PROCEED UNTIL H&S MANAGER PROVIDES INSTRUCTION.

ADDITIONAL COMMENTS:

Approved By: _____

Date: _____



XYZ Laboratory - EXAMPLE ONLY

SAMPLE CONTAINER SURVEYS

RADIATION SCREENING SURVEY REPORT

Shipper: _____ Client: _____

CoC ID: _____ Project: _____

Delivery Date & Time: _____ Cooler ID: _____

Radionuclide(s): _____ ☐ (check if unknown)

Other Info: _____

FOR EACH INSTRUMENT USED, INITIAL PERFORMANCE CHECKS AND BACKGROUND MEASUREMENTS HAVE BEEN COMPLETED, AND ARE RECORDED ON THE APPROPRIATE WORKSHEET.

INSTRUMENT 1: _____ INSTRUMENT 2: _____ INSTRUMENT 3: _____

BACKGROUND: _____ BACKGROUND _____ BACKGROUND _____

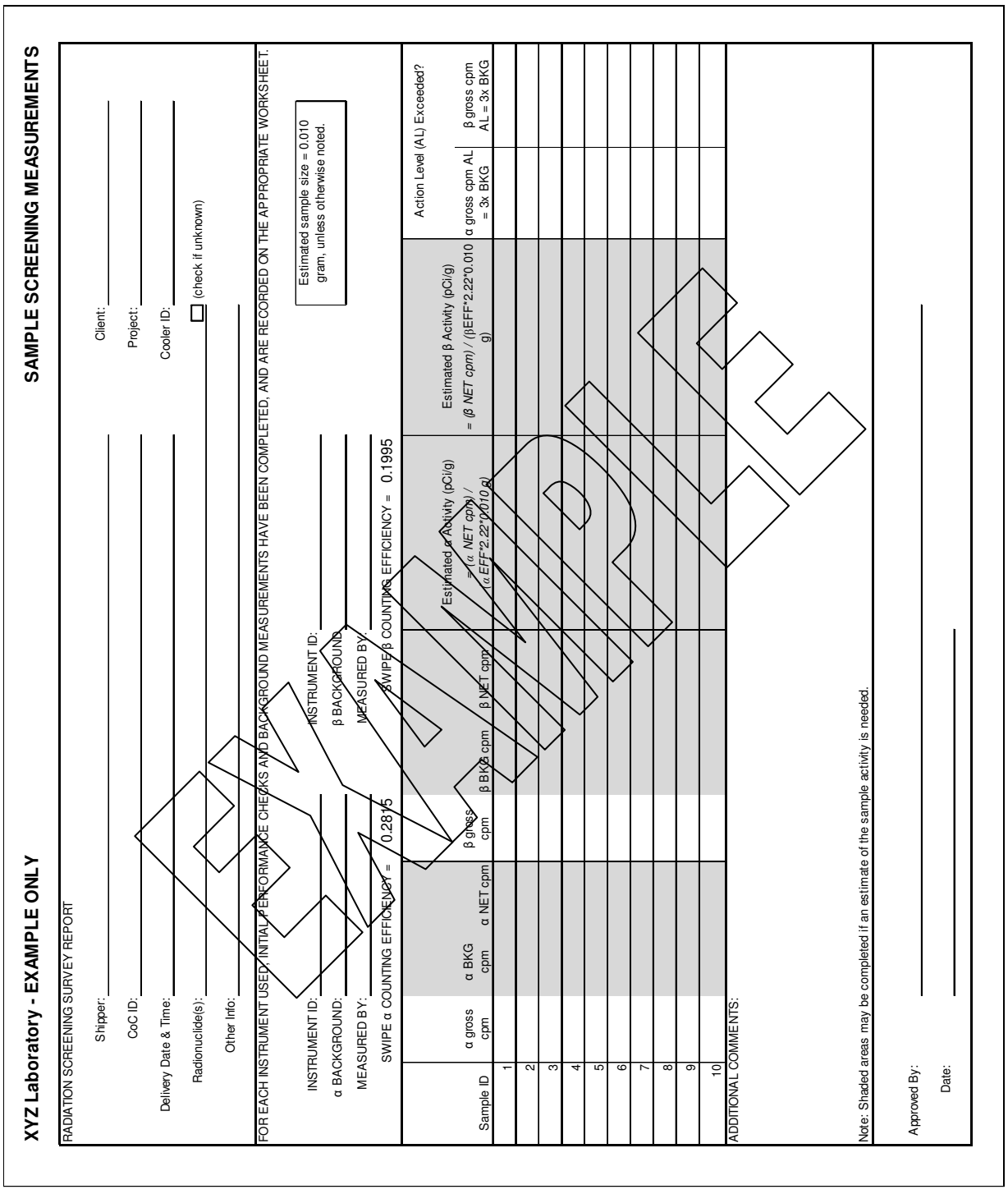
MEASURED BY: _____ MEASURED BY: _____ MEASURED BY: _____

Sample ID	uR @1cm	α+β, fixed+ removable gross cpm	Removable α gross cpm	Removable β gross cpm	Action Level (AL) Exceeded?	
					α gross cpm AL = 3x BKG	β gross cpm AL = 3x BKG
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						

ADDITIONAL COMMENTS:

Approved By: _____

Date: _____



XYZ Laboratory - EXAMPLE ONLY

SAMPLE SCREENING MEASUREMENTS

RADIATION SCREENING SURVEY REPORT

Shipper: _____ Client: _____

CoC ID: _____ Project: _____

Delivery Date & Time: _____ Cooler ID: _____

Radionuclide(s): _____ ☐ (check if unknown)

Other Info: _____

FOR EACH INSTRUMENT USED, INITIAL PERFORMANCE CHECKS AND BACKGROUND MEASUREMENTS HAVE BEEN COMPLETED, AND ARE RECORDED ON THE APPROPRIATE WORKSHEET.

Estimated sample size = 0.010 gram, unless otherwise noted.

INSTRUMENT ID: _____ INSTRUMENT ID: _____

α BACKGROUND: _____ β BACKGROUND: _____

MEASURED BY: _____ MEASURED BY: _____

SWIPE α COUNTING EFFICIENCY = 0.2875 SWIPE β COUNTING EFFICIENCY = 0.1995

Sample ID	α gross cpm	α BKG cpm	α NET cpm	β gross cpm	β BKG cpm	β NET cpm	Estimated α Activity (pCi/g) = *(α NET cpm) / (α EFF*2.22*0.010 g)*	Estimated β Activity (pCi/g) = *(β NET cpm) / (βEFF*2.22*0.010 g)*	Action Level (AL) Exceeded? α gross cpm AL = 3x BKG	Action Level (AL) Exceeded? β gross cpm AL = 3x BKG
1										
2										
3										
4										
5										
6										
7										
8										
9										
10										

ADDITIONAL COMMENTS:

Note: Shaded areas may be completed if an estimate of the sample activity is needed.

Approved By: _____

Date: _____

Early in an incident before all agents have been identified, laboratories handling samples for non-radiological agents may wish to screen samples for the possible presence of radiological agents as part of the determination of whether they can safely handle the samples. Air particulate filters present a unique challenge since naturally-occurring members of the uranium and thorium decay-chains may interfere with screening measurements. The radioactive decay-products of radon-222 and radon-220 are of specific concern because they cause transitory high activity when air filters are counted promptly after collection.

Wherever feasible, the use of commercially available radon-compensating detection systems is recommended for screening particulate air filters shortly after collection. When radon-compensating detection systems are not available, it may be necessary to implement an alternate protocol for screening samples that can determine how much radiological contaminant may be present in spite of interfering radon decay products.

This appendix presents a screening protocol using a dual-phosphor alpha-beta counter to estimate whether significant levels of longer-lived radioactivity may be present in samples containing interfering levels of radon progeny.

INTRODUCTION

Radon-222 is a gaseous product of the naturally occurring U-238 decay chain. Radon-222 is emanated from the soil and, while airborne, decays via the serial decay chain shown in Figure D1.

The collection of particulate air filters will trap airborne radon decay products, which are measured as alpha and beta activity. A state of “transient equilibrium” establishes between Pb-214 and its progeny within the first hour after sample collection. After this first hour, Pb-214 and progeny decay, with the 27 minute half-life characteristic of Pb-214 as shown in Figure D2.

Four hours after sample collection about 99% of the Rn-222 progeny will have decayed and will no longer interfere with counting of air filters.

Radon-220 is a slightly longer-lived decay product of the naturally-occurring thorium-232 decay chain. The thorium decay chain and the decay properties of Pb-212 are shown in figures D3 and D4. The considerations here are similar to those for Rn-222 except that “transient equilibrium” is achieved after approximately six hours beyond the end of sampling. After this point, future activity levels of the Rn-220 progeny may be predicted based on the half-life of Pb-212. Due to its longer half-life, several days are needed before Pb-212 and its decay products have decayed to about 1% of their initial activity.

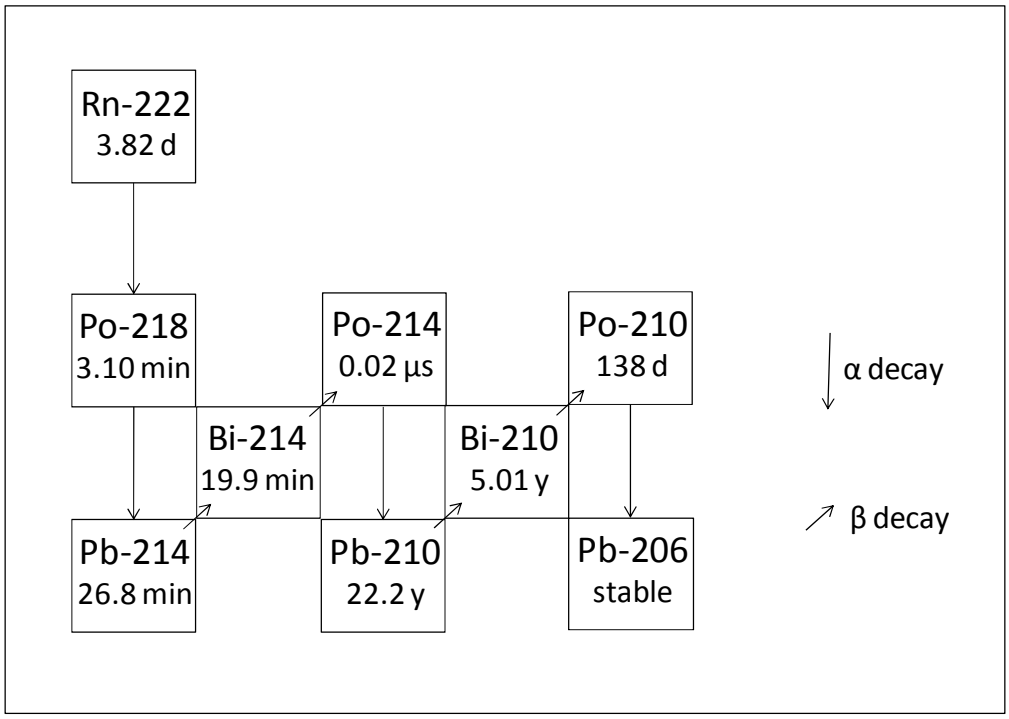


Figure D1 – The uranium decay chain, Rn-222 to Pb-210.[9]

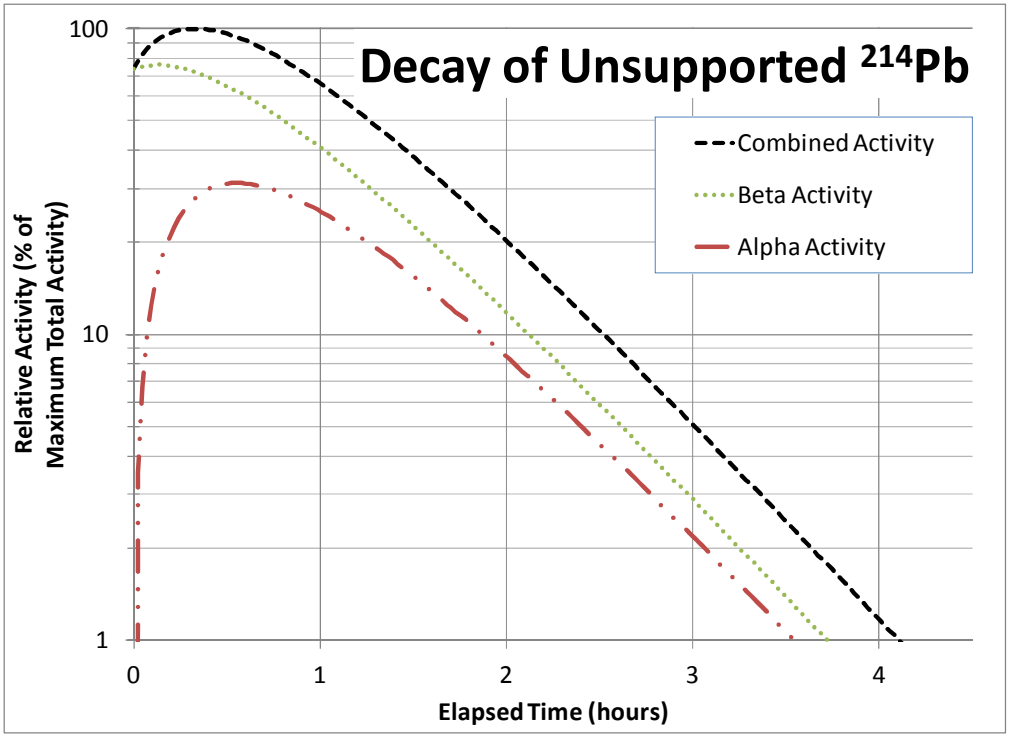


Figure D2 – The decay of Pb-214 after collection.

[9] Source: Draft Toxicological Profile for Radon, U.S. Dept. of Health and Human Services, ATSDR, 9/08.

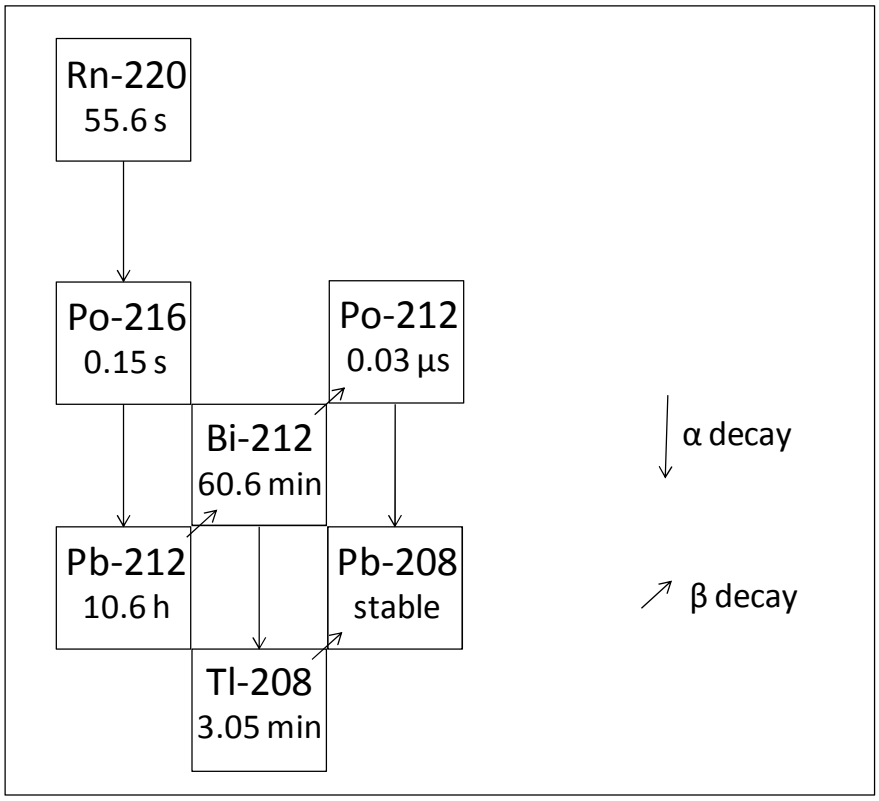


Figure D3 – The thorium decay chain, Rn-220 to Pb-208.[10]

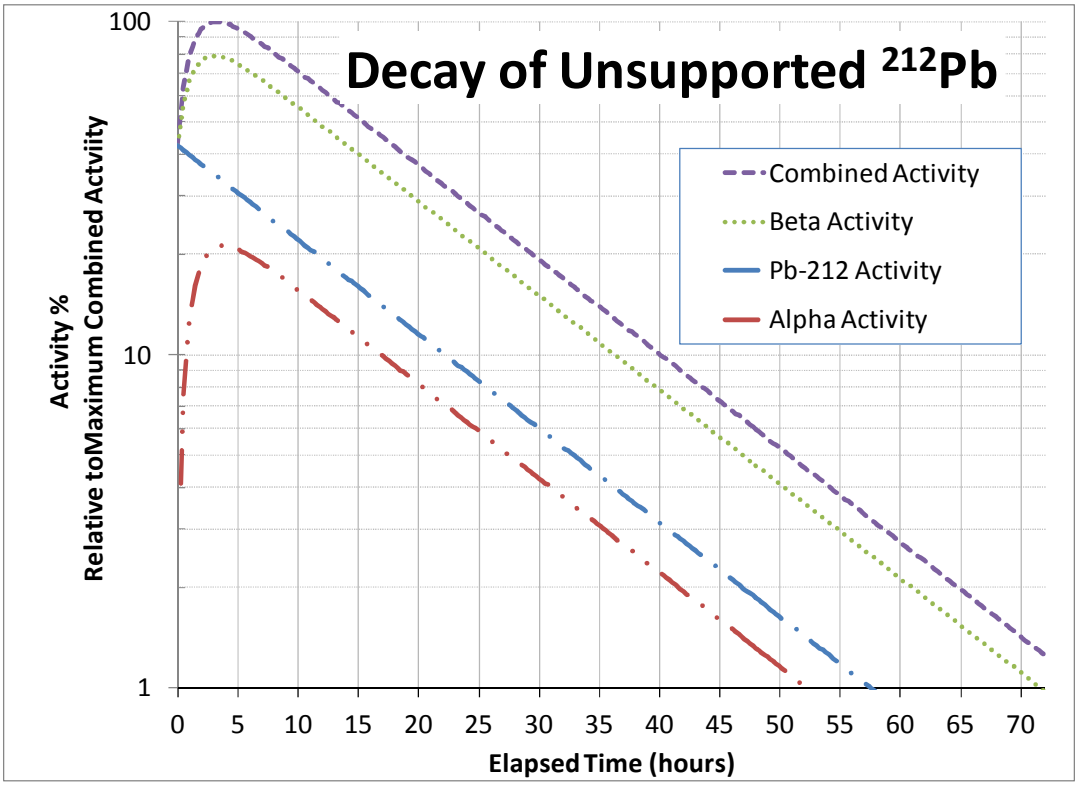


Figure D4 – The decay of Pb-212 after collection.

It is not necessary to wait several days to determine whether a radiological agent may be present at elevated levels in the sample. Activity in excess of the Rn-220 decay products corresponds to longer-lived radionuclides that are possibly indicative of the presence of a radiological agent in the sample.

The constituents of a newly collected particulate air filter, which are not related to the decay of radon and radon progeny may be calculated as follows:

$$R_c = R_n - R_B - \left[\frac{(R_n - R_i) \times e^{-0.06515 \times t`}}{1 - e^{-0.06515 \times t}} \right]$$

Where:

R_c	=	An estimate of the count rate of contaminant in the sample (cpm)
R_i	=	Count rate of the initial measurement of the sample (cpm) taken at least 4 hours after collection
R_n	=	Count rate of the test (second) measurement of the sample (cpm)
R_B	=	Count rate of the background measurement (cpm)
e	=	2.718 (the base of the natural logarithms)
0.06515	=	Decay constant lambda for Pb-212 (assumes a half-life of 10.64 hours)
t	=	Time elapsed between the initial and test (second) measurement (hours)

The application of this equation is simplified in tabular form in the procedure below. This approach assumes that the laboratory has established the level of radioactivity it can handle based on the particular engineering and administrative controls in place at the laboratory, and any regulatory restrictions on the possession of radioactive materials.

Air samples may be counted at any time after receipt and the results compared to established limits. If the results are less than established limits, the air filter may be released for analysis. The following approach may be used when screening results indicate that there is possibly activity in excess of the established limits.

Based on the introductory information shown above, the procedure for analyzing newly collected particulate air filters begins with a count of the sample at least six hours after collection. By this time Rn-222 progeny will have decayed away and transient equilibrium will effectively have been established between Rn-220 progeny. The sample is counted a second time waiting at least three hours between the counts. The results of the two sample counts are processed, as described below, and an estimate of the non-radon sample activity is determined.

PROCEDURE

1. For the purpose of the procedure in this appendix, the initial sample measurement must be performed at least six hours after the completion of sample collection.

    1.1. If a preliminary sample measurement was performed before six hours have elapsed, and that result is below the existing acceptance criteria, the sample may be accepted and no further action described in this appendix is necessary.

    1.2. If a preliminary sample measurement was performed before six hours have elapsed, and that result is above the existing acceptance criteria, the sample should be held for six hours after the end of sampling and the initial measurement should be repeated.

1.3. If six hours have elapsed and no initial measurement has been performed, the initial sample analysis should be performed at that time.

2. Record the gross count rate of the sample measurement, performed at least six hours after the end of sample collection.

   2.1. If the sample measurement is below the existing acceptance criteria, the sample may be accepted and no further action described in this appendix is necessary.

   2.2. If the sample measurement is above the existing acceptance criteria, the sample should be held for at least an additional three hours, then recounted.

   Note: The power of the screen increases proportionally to the time between two counts.

3. Record the gross count rate of the second sample measurement.

   3.1. If the second sample measurement is below the existing acceptance criteria, the sample may be accepted and no further action described in this appendix is necessary.

   3.2. If the second sample measurement is above the existing acceptance criteria, proceed to the next step.

4. Calculate the ratio of the first gross count rate to the second gross count rate as follows:

   $$Y = R_i/R_n$$

   where:

   Y = The count rate ratio

   R_i = The gross count rate from the first count

   R_n = The gross count rate from the second count

5. From Table D1 below, based on the count rate ratio and the elapsed time between counts, select the applicable factor δ (delta). For count rate ratios and elapsed times not specifically shown, the values may be interpolated. Alternately, the next larger δ-value may be selected as a conservative estimate.

Delta Factors: Gross Count Rate for Source Term (non-Rn) = Second Count Rate * Delta													
	Elapsed Time between Counts (hrs)												
Ratio of Ct1/Ct2	3	4	5	6	7	8	10	12	16	20	24	36	48
1.0	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2
1.3	0.0	0.4	0.6	0.7	0.8	0.8	0.9	1.0	1.1	1.1	1.1	1.2	1.2
1.4		0.0	0.3	0.5	0.6	0.7	0.8	0.9	1.0	1.1	1.1	1.2	1.2
1.5			0.0	0.3	0.4	0.5	0.7	0.8	1.0	1.0	1.1	1.2	1.2
1.6				0.0	0.2	0.4	0.6	0.7	0.9	1.0	1.1	1.1	1.2
1.7					0.0	0.2	0.5	0.6	0.8	0.9	1.0	1.1	1.2
1.8						0.0	0.3	0.5	0.8	0.9	1.0	1.1	1.2
1.9							0.2	0.4	0.7	0.9	1.0	1.1	1.2
2.1							0.0	0.3	0.6	0.8	0.9	1.1	1.2
2.3								0.2	0.5	0.7	0.9	1.1	1.1
2.4								0.0	0.4	0.7	0.8	1.1	1.1
2.8									0.2	0.5	0.7	1.0	1.1
3.0									0.1	0.5	0.7	1.0	1.1
4.0										0.1	0.4	0.9	1.1
5.0											0.1	0.8	1.0
6.0												0.7	1.0
8.0												0.5	0.9
10.0												0.3	0.8

Source Term Half-Life is < 10.6 hrs.

Table D1 – Delta Factors

6. Estimate the gross count rate of the non-radon constituents of the air filter as follows:

$$R_c = R_n \times \delta$$

Note: In Table D1 above, certain simplifying assumptions have been made in the development of δ factors:

- *Any observable decrease in the measured sample activity is attributable solely to the decay of thoron progeny.*
- *For results that would be of concern to the laboratory, the instrument background count rate is not a significant contribution to a measurement that exceeds the decision level.*
- *There is inherent uncertainty in the measurement process, which cannot be precisely accounted for without specific information about the laboratory's counting system. The values in Table D1 assume an overall 20% uncertainty in the determination of net source term activity not related to thoron progeny.*

If these assumptions are not valid, or if there are other over-riding conditions that should be considered, the laboratory should develop δ values that are consistent with those current conditions, based on the formula presented in the introduction at the beginning of this appendix.

7. Determine the appropriate action from the chart below.

Activity Type	Gross Alpha CPM	Lab Response
Alpha	≤ 3x Background	Release samples to laboratory for scheduled analyses
	> 3x Background	STOP. Notify Health and Safety Manager
Beta	≤ 3x Background	Release samples to laboratory for scheduled analyses
	> 3x Background	STOP. Notify Health and Safety Manager