



IAEA

International Atomic Energy Agency

LESSON 5: SURFACE CONTAMINATION MEASUREMENT

Outline

Introduction

Calibration and Testing

Technique

Direct Monitoring

Indirect Monitoring

Practical Measurement

Instruments

Specific emissions and interpretation

INTRODUCTION

Definitions and Types

Contamination:

Presence of radioactive substances in a volume or on a surface where they are unwanted and undesired (air, water, internally in the body, etc.)

Transferable, non-fixed or loose contamination: surface contamination that can be easily removed

Non-transferable or fixed contamination: surface contamination that cannot be easily removed

What causes surface contamination?

Spill/leak of radioactive material

Deposition of airborne radioactive substances on surfaces

Contact of a contaminated object (e.g. hand, shoes, clothes) with the surface

Need for Surface Contamination Monitoring

Occupational exposures may result from loose contamination:



Transfer of surface contamination to the atmosphere leading to internal exposure through inhalation or ingestion

External exposure to whole body, eyes or extremities if contamination is significant

Measurement of loose contamination is very important

Fixed surface contamination may cause:



Potential for future loose contamination

External exposure if contamination is significant.

Purpose

- Verification that levels of contamination are well within the permissible levels.
 - 0.4 Bq/cm² for alpha emitters and 4 Bq/cm² for beta/gamma emitters (IAEA guidelines*).
- Classification of controlled and supervised areas
- Provision of assistance with methods to determine and prevent the spread of contamination.
- To detect breach in containments and departures of good working practices.
- To provide relevant inputs to decide on individual monitoring or dose assessment

**Regulations for the. Safe Transport of. Radioactive Material, IAEA, TS-R-1*

TECHNIQUE

Methods of Contamination Monitoring

Direct method

- detecting contamination directly using instruments
- used to detect both transferable (fixed) and non-transferable (loose).

Indirect method

- Using dry or wet wipes
- Detecting contamination on wipes using instruments
- Used to detect transferable (loose) contamination and by calculation the total contamination.

Direct Method

- ❑ Measurements normally performed on a ratemeter basis
 - Surveyor scans the instrument over area of interest
 - Identifies contaminated areas and averages the indication
 - Use of audio output is useful



- ❑ Scaler readings increasingly being used to detect lower levels and make measurements more auditable and repeatable
 - Place instrument and average or integrate over a short time, e.g. 10 seconds, at various locations.

Direct Method

Points to consider:

1. Nature and location of the contamination
2. The average area to be covered
3. The detector to surface distance during measurements
4. The speed of monitoring.



Direct Method-Nature and Location

Presence of water/grease/
dirt/paint/polish on the surface
(*consider self absorption*)

Radio nuclides (Type and energy of
radiations)

Homogeneity of potential
contamination

Other radiation sources in the vicinity.
▪ There may be a need to remove
sources or shield an area before the
contamination monitoring is started.

**Nature and Location of
Contamination**



Area of measurement:

- The sensitive area of the detector defines the minimum averaging area.
- For surfaces such as floor, wall etc, contamination should be averaged over an area of 1000 cm² or less
 - *Regulation may dictate the averaging area.*

Direct Method-Detector to Surface Distance

Detector to surface distance

Alpha and low energy beta emitters will only be detected if the probe to surface distance is not greater than a few millimetres due to short range of these particles.

Never allow the probe to touch the surface as this might contaminate the probe.
(e-g : *Use a spacer*)

Direct Method- Speed of Monitoring

The speed of monitoring

The speed at which a probe can be moved over a surface to ensure reliable assessment of contamination levels, needs to be carefully assessed prior to any survey.

Generally one detector dimension per second is recommended from practical experience.

Monitoring speed depends on the required detection level.

Example of Calculation of Surface Contamination-Direct Method

- Example: Counting efficiency= 5%, Meter window area = 50 cm², Counts=75 cpm, Background counts= 20 cpm

Formula
$\text{Bq/cm}^{-2} = \frac{\text{CPM} - \text{CPM}_{(\text{background})}}{60} \times \frac{100}{\text{counting efficiency}}$ $\text{Area counted (cm}^2\text{)}$
Example
$\text{Bq/cm}^{-2} = \frac{75-20}{60} \times \frac{100}{5} = 3.67 \times 10^{-1}$ 50 cm^2

- ❑ Wipe method is used for estimation of non-fixed or transferable (loose) contamination
- ❑ Either dry or wet wipe method is employed
 - Dry wipes identify the potential airborne hazard and PPE
 - Collection efficiency could be improved by wetting the swipe materials in water or alcohol
 - *Never count a wet wipe for alpha*
- ❑ Wiped samples may be analysed using a contamination monitor in the workplace or may be analysed in a laboratory.

Indirect Method-Wipe Area

Typical wipes used the area in the range of 100 cm² (for quantification) to larger (for identification)

↙ The wipe area may be determined by regulation

↙ Otherwise the *qualified* expert should define the area

For localized contamination use small area wipes to prevent contamination spread.

Sub-divide large areas into smaller areas and wipe each one.

For objects wipe each one or identifiable parts.

In practice may use a combination of both methods.

Wipe Materials

Many types of swipe materials are used including paper, styrofoam, cotton swabs, cloth patches, and glass fibre filters.

Large area wipes usually use cloth.

Adhesive tape can be used to collect particulates for monitoring/analysis.

Solvents include methanol or distilled water (the swipe must be dry before counting).

Steps in Wipe Procedure

- Prepare labeled vials or envelopes as appropriate
 - Small boxes with separations, plastic bags or envelopes can be used
 - Prevent cross contamination between wipes
- Wearing gloves, use filter paper/cotton swab to take several samples from different areas.
 - Rough surfaces should generally not to be wipe tested
- Wipe should be rubbed with uniform pressure over the area of interest.
 - Use tongs if high levels of activity or dose rate
- Place samples in separate vial or envelope
- Note the location of the sample as appropriate.

- ❑ Analysis method depends on contamination level
 - For high activity, perform direct monitoring using an instrument for an adequate time and record the result
 - For lower activities and low energy beta or gamma emitters, count in a laboratory counter or shielded counter in a low dose rate area
 - Handle the wipes with tweezers
 - Wipes are typically counted for one minute, depending on the sensitivity required
 - Ensure background and a blank wipe are counted
 - If wipe requires further analysis, do not use liquid scintillation counting
 - Retain wipe for radiochemical analysis if required.

Recording of Surface Contamination Results

It is not only good practice but also a legal requirement that contamination monitoring results are recorded. This contains:

Manufacturer, model and serial number of the contamination meter used

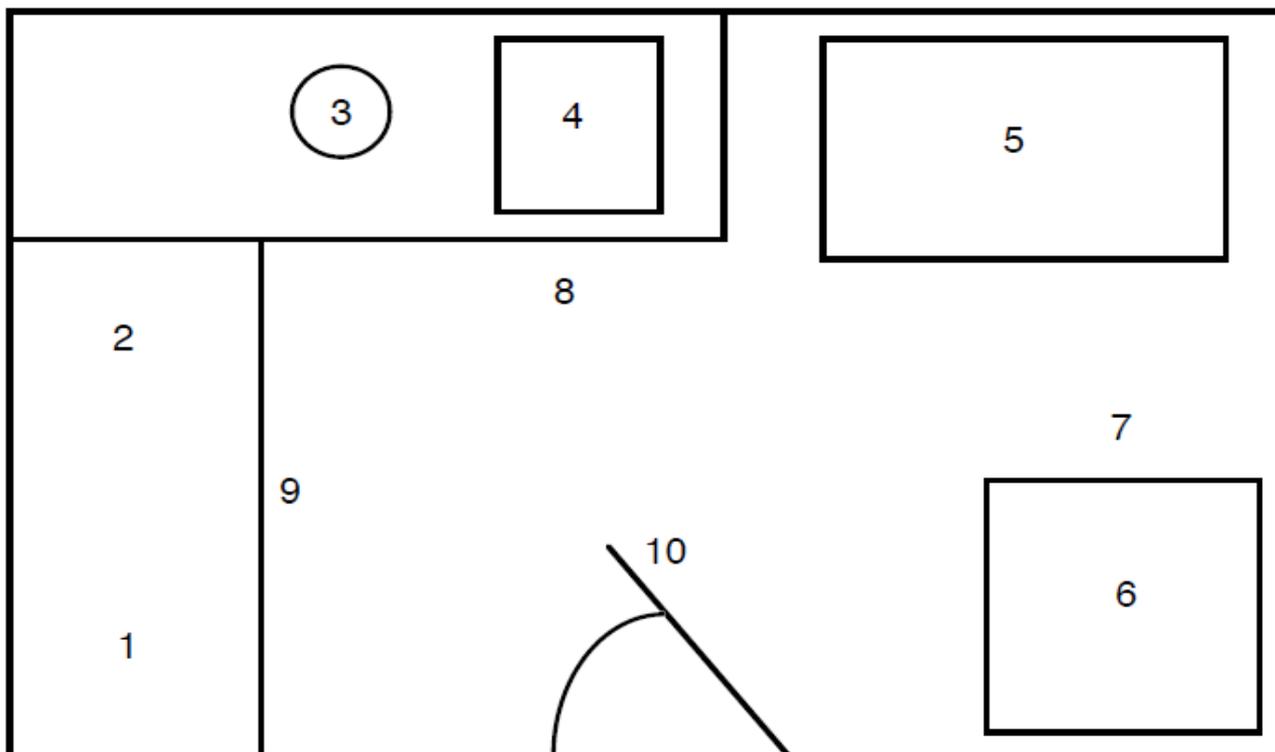
Background measurement

A basic description of each location monitored

Monitoring readings in Bq/cm^2 or cps / cpm
(depending the local rules and regulator request).

Recording of Contamination Monitoring –Area Wise

Record of Contamination Monitoring



1,2,-Lab bench top, 3-Centrifuge, 4-sink, 5-workfloor,6-Refrigerator shelves,
7-Floor Refrigerator,8-Floor Sink,9-Floor bench,10-Inside door handle

Factors that influence Wipe Efficiency

- ❑ The wipe efficiency or pick up factor is the percentage of contamination picked up by a single swipe of the surface. It is affected by
 - type of wipe used.
 - pressure applied by the person when making the wipe.
 - contamination distribution.
 - porosity, chemical composition, texture and cleanliness of the surface.
- ❑ Traditionally a pick up factor value of 10% is used.
- ❑ Self absorption by the wipe (usually: 25 % for alpha and 5% for beta).

Wipe Testing Advantages



Prolonged measurement in laboratory can provide a lower detection limit than direct method.



It is possible to make a spectrometry to identify the radionuclides.

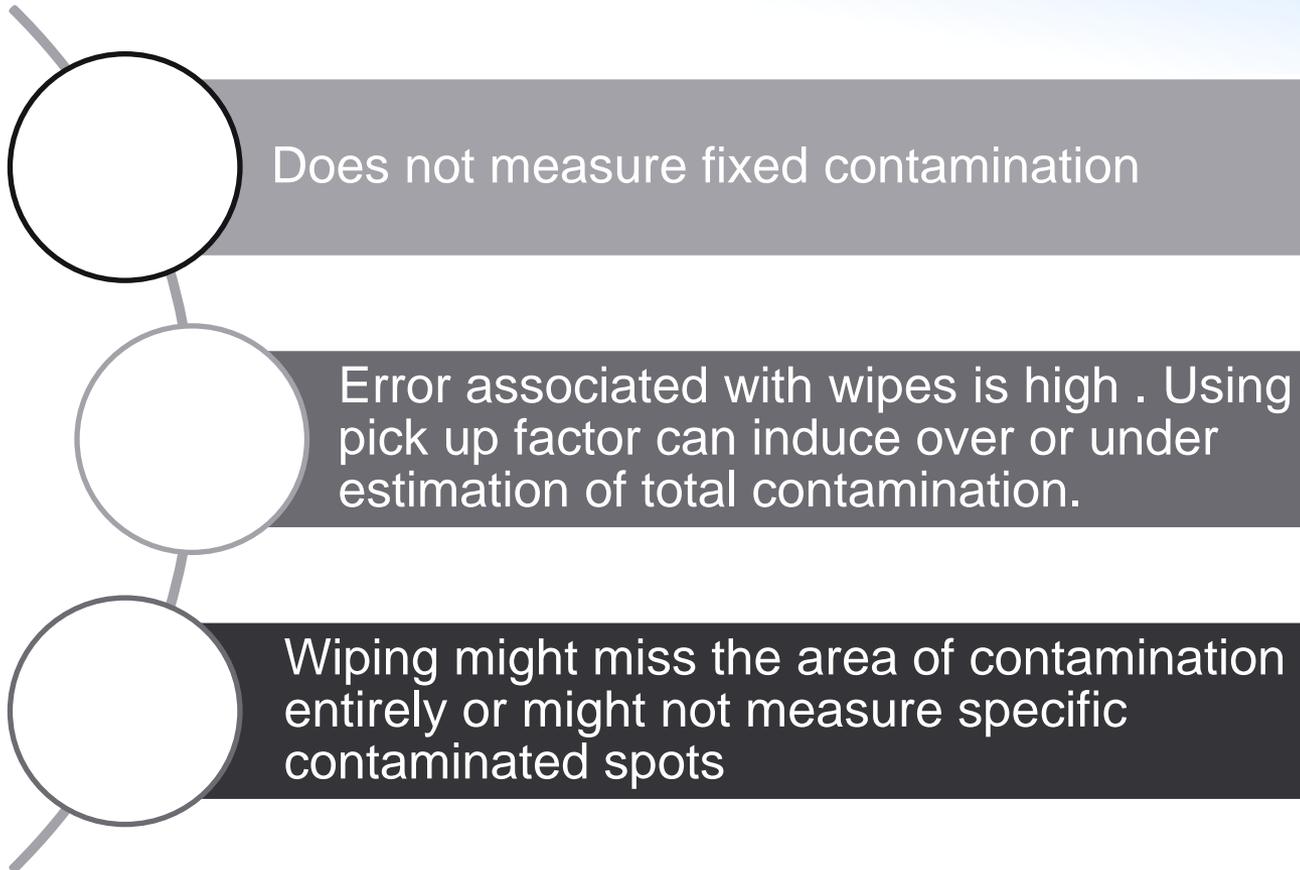


Can be used in high background areas or where physical geometry and accessibility is a constraint.



For some low energy beta emitting radionuclides (Tritium for example), this is the only way you can for routine measurement of surface contamination.

Wipe Testing - Disadvantages



The qualified expert should always interpret the results and identify if further monitoring is required

INSTRUMENTS

Choosing the Equipment

- ❑ Selection of monitor according to the type and the energy of radiation
 - A full list of nuclides which could be encountered must be made and the decay schemes studied

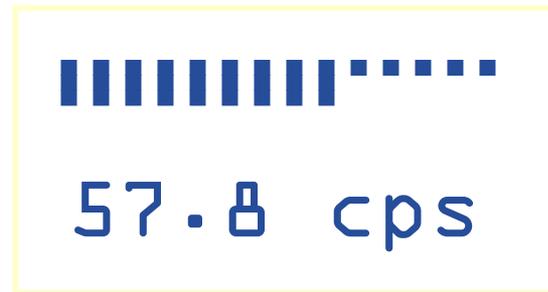
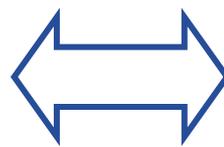
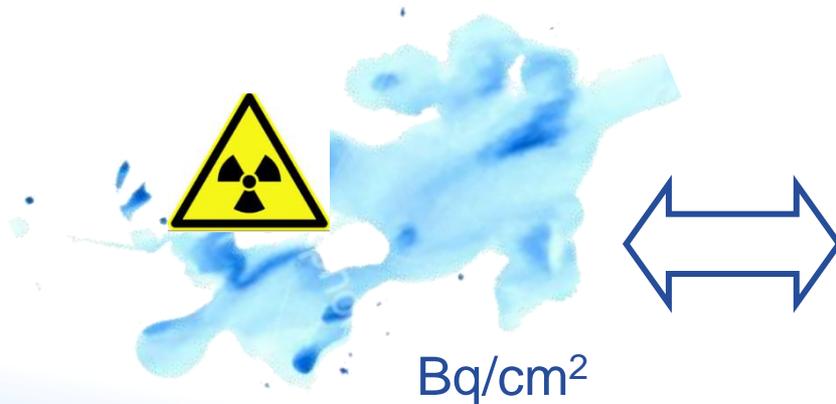
- ❑ The calibration of the monitor will also require knowing the radiation type and energy to determine efficiency

- ❑ In practice, it is common to require a range of contamination monitoring equipment

Conversion Factor Approach

The approach used here is as follows:

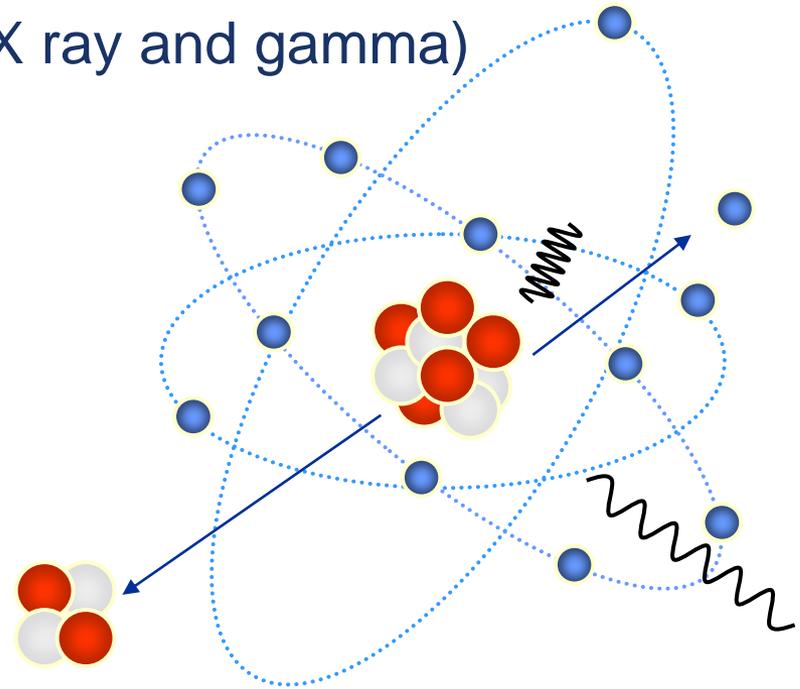
- As the equipment usually does not display the radiation protection quantity to be measured a conversion from **cps** to **Bq/cm²** is necessary



Conversion from cps to Bq/cm²

Conversion from cps to Bq/cm² – i.e: Detection efficiency, area are to be taken into account:

- Type of radiation (alpha / beta / X ray and gamma)
- Energy of radiation
- Window size
- Background



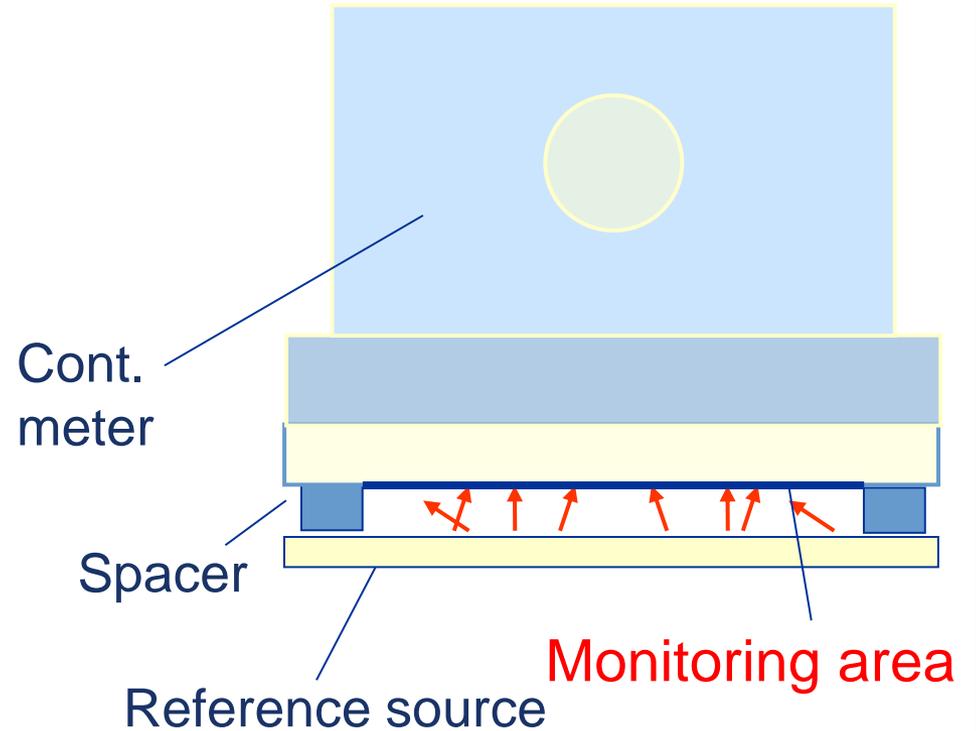
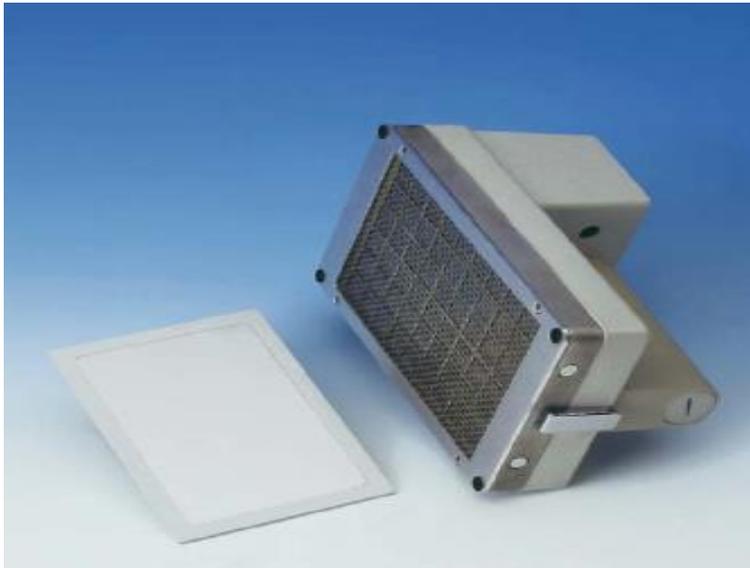
Therefore, determination of a conversion factor for a contamination monitor;

- Needs to be made with a with reference sources of different radiation types and qualities compatible with those that will be measured with the equipment

$$\text{Conversion factor}_{(\text{Nuclide})} = \frac{\text{Bq/cm}^2}{\text{cps}}$$

Determining Conversion Factors in Practice

□ How does it work in practice?



Determining Conversion Factors in Practice

- ❖ Measure the response to the source in cps
- ❖ Reference source will ideally be a large source with units of Bq/cm^2 so express conversion factor directly.
- ❖ If it is in other units, then estimate conversion to Bq/cm^2
 - Bq (divide by monitoring area)
 - $\text{s}^{-1}/\text{cm}^2$ (multiply by two assuming is an ideal source)
 - s^{-1} (multiply by two and divide by monitoring area)
- ❖ Express conversion factor in $\text{Bq}/\text{cm}^2 / \text{cps}$

Example for response calculation

- Calculate the response of a pancake probe where the probe response to a contamination source is 100 cps to a 1kBq source (probe area is 15 cm²)
 - Source strength = 1000 Bq
 - Dividing by monitoring area =
1000Bq/15cm² or 66 Bq/cm²
 - Conversion factor = 100 cps per 66 Bq/cm²
 - or 1.5 cps/Bq/cm²

Calculation based on loose Surface Contamination

- **Surface contamination = $(N - N_b) / (E \times 60 \times A \times F)$ (Bq/cm²), where:**
- **N** = is the total count rate in counts per minute (cpm) measured directly or on the wipe.
- **N_b** = is the count rate of the blank (in cpm)
- **E** = instrument efficiency for specific isotope (e.g. for 26% efficiency, E = 0.26)
- **60** = sec/min
- **A** = area wiped in cm² (not to exceed 100 cm²) or area of detector (direct measurement)
- **F** = is the pick-up factor for the wipe. (e.g. a value of F = 0.1; i.e., 10%).

Frequency of checking the Conversion Factors

How often shall I check my equipment?

- ❑ Standards, Tecdoc or national standards specify the calibration intervals
 - Usually every 1-2 years, the test is performed using various reference sources of the radionuclide source of interest (e.g. planchets or planar sources) with a traceable surface emission rates of different activities at the same distance as contamination measurement. For counting equipment, use the same size source and counting geometry as the smear
 - The detector's efficiency should be determined as recommended in the appropriate ISO standard.

- ❑ To ensure reliability and to verify stability of the equipment, a check source should be used prior to every day of measurement (function testing)

CALIBRATION AND TESTING

Example

The calibration time interval should be defined in the quality management system documentation

The results of calibration should be normally noted on the data sheet of the equipment or documented in another way

A daily check source need not be a traceable standard – typically just looking for a response.

- To maintain the good quality of the reference source and prevent the source from being damaged, it is recommended that the traceable source is not used for functional testing of the instruments.

Probes should not be routinely exchanged between rate meters and the equipment should always be tested as a full assembly

Function Testing – Surface Contamination Equipment

Check the physical integrity of the detector, especially the window, cable and probe

For proportional counters, check gas pressure or re-fill the chamber

Check the calibration validity

Check the battery

Check the expected background reading

Check the alarm, if appropriate

Place the detector on a low activity alpha or beta check source with the source usually in the center of the window. Check whether the reading is within the expected range – for a scintillation probe, check against light to detect leaks

PRACTICAL MEASUREMENT

Before starting a measurement:

1. Ensure to select the correct equipment (radiation type, energy and surface activity range)

2. Perform a functional test

3. Use the audio signal. Set the alarm signals at a known surface contamination level. Be careful in noisy workplaces.

Surface Contamination Measurement(2)

Before starting a measurement:

Follow the procedure for the specific type for the measurement (more to follow later)



When an unusually high or low measurement result is indicated, act immediately on the information



Allow an appropriate time for the equipment reading to stabilize.

Surface Contamination Measurement(3)

Performing the measurement (cont'd)

Keep the thin window away from sharp objects to avoid irreparable damage to the detector.

Turn the equipment off when not in use

If the equipment has a separate probe, do not hold the probe by the cable.

SPECIFIC CONSIDERATIONS FOR ALPHA EMITTERS

General Aspects: Alpha Surface Contamination Measurements

❑ Alpha emitters have higher inhalation dose coefficients (radio-toxicity) compared to beta and photon emitters

This leads to a lower maximum acceptable surface contamination level, usually 10 times lower than beta contamination (and not more than 0.4 Bq/cm^2)

Any alpha detected is significant.

General Aspects: Alpha Surface Contamination Measurements

- Measurements are difficult due to the very short range of alpha radiation in air and by absorption on the surface itself
 - This makes the alphas very susceptible to attenuation in layers of grease or dust on the surface and also demands that any probe is held not more than **a few mm** from the surface
- In practice, direct alpha monitoring is only possible on smooth, clean, non-porous, relatively flat surfaces
 - This means many objects cannot in effect be monitored
- Monitoring speed for alpha is typically slow
- Generally, it is advisable to use equipment with the largest practical window size
 - Increasing window area can increase speed of monitoring

Equipment for Alpha Measurements (1)

Two types of detectors are commonly employed:

Large area at least 100 cm² for clearance.

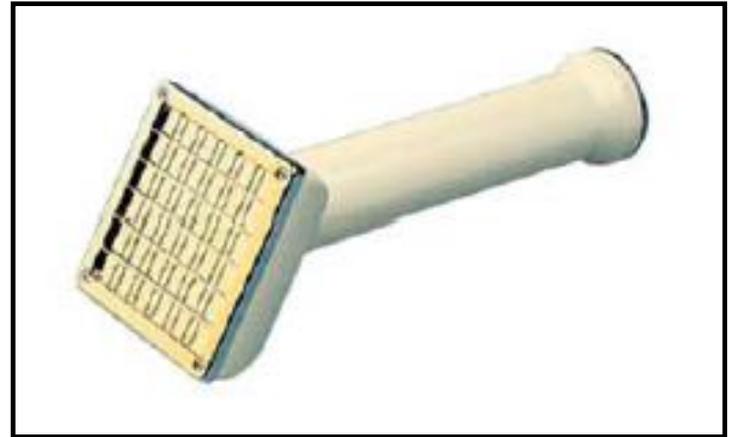
Zinc sulphide scintillation detector, either as a pure alpha detector or deposited on a plastic scintillator plate as a dual alpha and beta detector

Thin windowed refillable proportional counter

Equipment for Alpha Measurements (2)



Scintillation detector for alpha



Scintillation detector for alpha

Equipment for Alpha Measurements (3)



Butane gas proportional chamber for alphas.

Equipment for Alpha Measurements (4)



Pancake halogen quenched
GM tube. Window = 12 cm²

Efficiency = 15 % for ²³⁹Pu

Procedure for Alpha Surface Contamination Measurements (1)

Scanning in rate mode,

- The rate of movement for low level measurements should normally be a few centimeters per second with a 100 cm² probe
- The surface scanning should be made using the audio output. When the contaminated area has been found, then the instrument should be held still and the reading should be used to estimate the surface contamination.

Static integrated mode: put the probe over the surface for a fixed time, and record the result.

Two methods can be used

Procedure for Alpha Surface Contamination Measurements (2)

Be careful to maintain a constant distance of a few mm between the detector window and the surface to be measured



To maintain the constant distance, it may be helpful to stick a disposable plastic or rubber spacer on the detector frame (not on the window). The spacer may be placed directly on the surface and replaced when necessary if contaminated

Procedure for Alpha Surface Contamination Measurements (3)

The equipment used for alpha surface contamination measurements shows a very low gamma background rate, usually around 0.1 cps for a 100 cm² probe

If you touch the contaminated surface, you may contaminate the window or probe, and low levels of window contamination will produce a high background rate

Procedure for Alpha Surface Contamination Measurements (4)

A disadvantage of large area detectors, other than the weight and size, is if the activity is in the form of discrete hot spot which would be averaged over the area of the detector and the spot could be high.

Floor monitors can use many detectors, therefore increasing sensitivity.

The large window will also not allow the exact location of a small spot of contamination.

If necessary, a detector with a smaller window can be used to detect the spot with higher sensitivity.

Procedure for Alpha Surface Contamination Measurements (5)

Interpretation of the measurement result is dependent on the type of surface

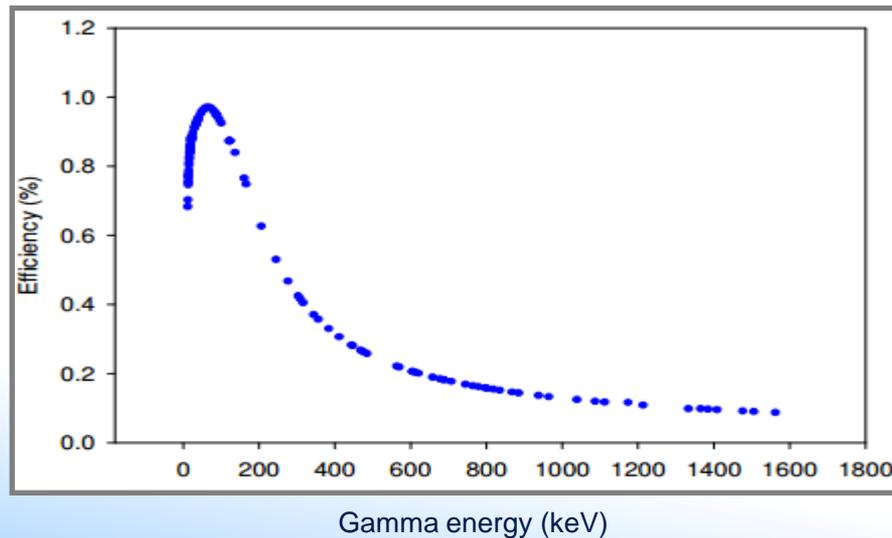
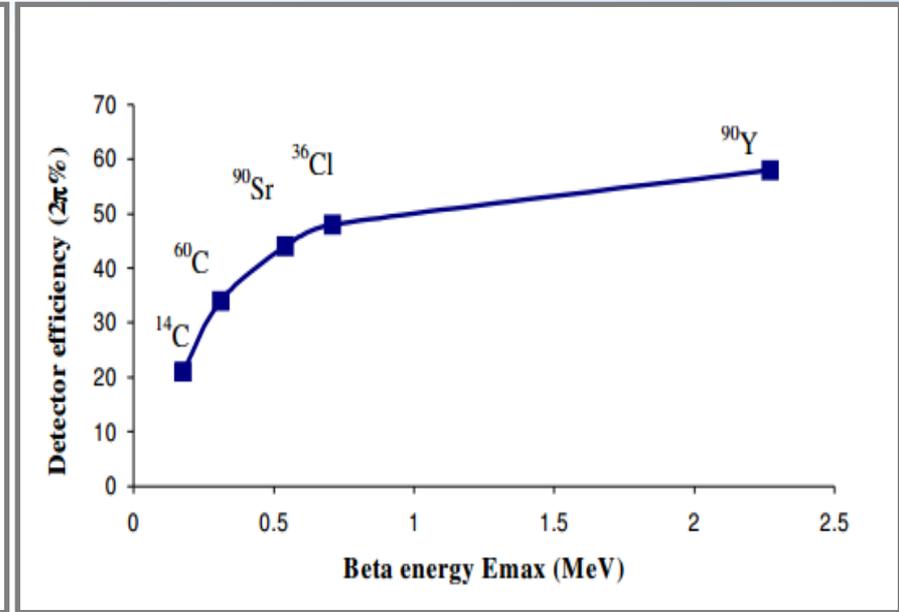
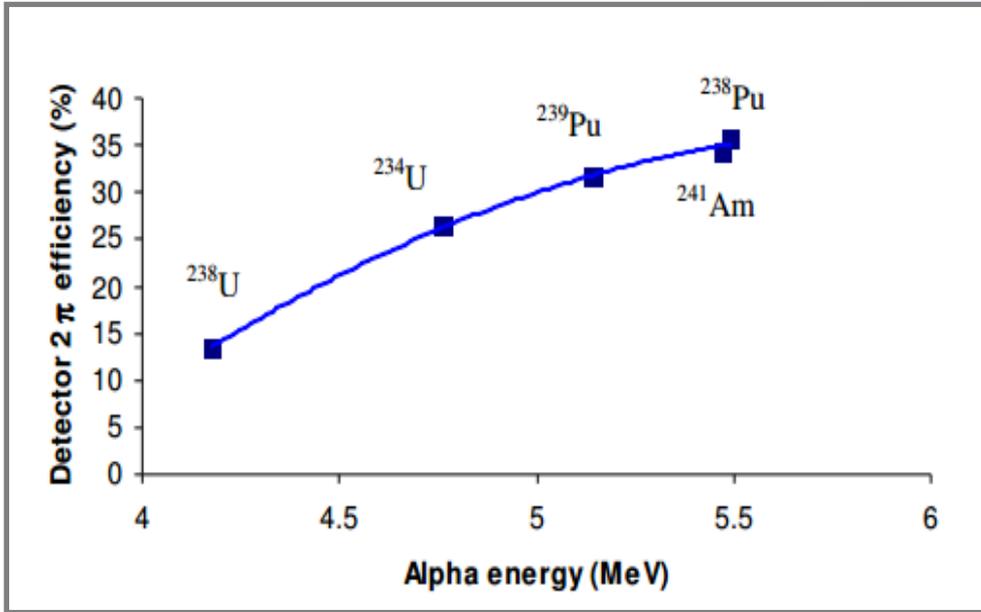
Smooth surfaces, such as stainless steel, will have a high efficiency whilst surfaces such as unpainted wood, will have a poor efficiency or may hide contamination.

A layer only 2 mg/cm^2 thick will fully absorb the alpha particles and prevent monitoring (for water, oil and grease, this corresponds to a thickness of 20 micrometre)

It is important to note the condition of surfaces monitored if there may be any concern over the efficiency of detection and this should be considered during interpretation.

SPECIFIC CONSIDERATIONS FOR BETA EMITTERS

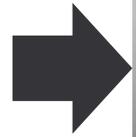
Plot of Efficiency vs Energy



Beta Surface Contamination Measurements (1)



Most beta surface contamination measuring equipment detects betas with E_{\max} above around 150 keV



Low energy beta radiation needs to be monitored at a few mm from the surface to detect the contamination



Below this energy, the range of the beta becomes small, not enough to cross a few mm air gap and penetrate the window of a practical detector



Counting equipment can be used to detect lower energy betas, e.g. Fe-55, Ni-63, H-3 (liquid scintillation or proportional counters – see lesson 7)



Windowless gas flow proportional instruments are also available on the market, although these are difficult to use in practice.

Beta Surface Contamination Measurements (2)

□ For higher energy beta radiation (e.g. Sr-90, P-32) the probe can be held up to 1cm from the surface being monitored with little impact on count rate

□ The beta surface contamination measuring equipment will show a significant background count from artificial or natural gamma radiation.

- This is around 5 cps per 100 cm² or 1 cps per 20 cm² of probe window.

Beta Surface Contamination Measurements (3)

- ❑ The authorized level of beta contamination for non-radiologically controlled area is normally higher than for alpha contamination, typically 4 Bq/cm².
 - This level can usually only be detected in low gamma background levels
 - Higher contamination levels can be detected
 - Monitoring for these levels should be conducted in low background or wipes should be taken and counted in a low background area.

Equipment for Beta Measurements (1)

Many types of instrument can be used for direct beta contamination measurements:



Thin end window GM detectors

Thin glass or metal walled GM detectors ($E_{\max} > 0.5 \text{ MeV}$)

Gas refillable proportional counters (as for alpha)

Thin window xenon filled sealed proportional counters

Thin windowed scintillation detectors (as for alpha)

Equipment for Beta Measurements (2)



Pancake detector



Contamination monitor

Interpretation of the Measurement Results

1.

- Low energy beta measurement experience similar interpretation issues as alpha.

2.

- There is only a limited range of nuclides which will be available during calibration and type testing. It is often necessary to estimate the response for the actual nuclides encountered.



Use a conservative conversion factor if a mix of radionuclides

SPECIFIC CONSIDERATIONS FOR PHOTON EMITTERS

X Ray and Gamma Measurements(1)

Many nuclides produce low energy X rays, typically by a process of electron capture.

- ^{125}I emits two X-rays at 27 keV and 32 keV and a gamma at 35 keV

X ray emitting nuclides can also be found in contamination around reactors.

- The most prominent, low energy photon emitting nuclide in nuclear plants is ^{55}Fe , which emits X ray at 5.19 keV.

X Ray and Gamma Measurements(2)

- ❑ Most gamma emitters also emit beta radiation and, generally, it is the beta radiation which is easiest to detect on surface and is used in contamination measurements
 - Typical examples are ^{137}Cs and ^{60}Co

- ❑ Pure Gamma/X ray emitters will not be detected by beta probes, but can also be assessed using scaling factor based on the fingerprints if there is a mix of radionuclides

X Ray and Gamma Measurements(3)

There are two conflicting issues:

- For low energies, the detector window has to be relatively thin and have a low atomic number to ensure good transmission
- For high energies, the problem is to ensure that the relatively penetrating radiation is attenuated sufficiently by the detector. This demands a high mass per unit area, high atomic number detector

In practice this means that the same probe cannot be used for measuring both low and high energy gamma/X ray emissions.

Equipment for X Ray and Gamma Measurements (1)

There are two popular forms of detector:

- One is the xenon filled, titanium windowed, proportional counter, more useful for lower energies
- The other is the aluminum or beryllium windowed sodium iodide scintillation detector which is useful for a wider range of energies



Xenon filled proportional counter



NaI detector with window

Equipment for X Ray and Gamma Measurements (2)

- The sodium iodide scintillation detectors are usually less sensitive than the xenon filled proportional counters
- Since the probes are designed to detect gamma contamination, they are very sensitive to background radiation and may have a significant background count rate
- Most instruments employed for low energy photon measurements will respond to beta emitters. If in doubt, shield the betas with a filter
- Photomultiplier tubes are susceptible to magnetic fields, they are often supplied with mu-metal shields to overcome this issue.

Procedure for X Ray and Gamma Surface Contamination Measurements

A distance of a few cm from the surface is adequate for scanning for higher energies

Need to be closer to the surface for low energies

The audio output should be listened to locate the contamination. Then the operator should move the probe to maximize the count rate.

In high background areas, perform wipe test and measure the sample in a low background area.

Interpretation of the Measurement Results

1

- The main issue is calculation of the response to a particular nuclide due to complicated decay schemes.

2

- There is only a limited range of nuclides which will be available during calibration and type testing. It is often necessary to estimate the response for the actual nuclides encountered.
 - The rationale for the estimated response should be recorded

3

- Interpreting gamma contamination in the presence of a gamma background is a significant issue

- Alpha and Beta
 - Large area silicon diode connected to a scalar timer
 - Gas flow proportional counter
 - Plastic scintillator with ZnS layer
- Beta only
 - Thin end window pancake GM
 - Plastic scintillator
- Alpha only
 - ZnS(Ag) & PIPS
- X ray & Gamma
 - NaI(Tl) and HPGe