Te Kāwanatanga o Aotearoa
New Zealand Government

MANATŪ HAUORA
MINISTRY OF HEALTH

Guidance for Radiation Monitoring and Instrument Selection

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Introduction

Selecting an appropriate radiation monitoring instrument is crucial for overall radiation protection and compliance with legislation. To make the selection, you need a thorough understanding of the regulatory requirements for the sources your facility is using and the activities it is undertaking. This information sheet is designed to help you with the general selection of instruments and provide guidance on conducting the main types of radiation surveys.

Each type of instrument has its own characteristics. Instruments differ in the purposes they serve and each has its own advantages and disadvantages for a given situation and the types of radiation being measured.

All radiation monitoring instruments must meet several requirements to comply with the **radiation safety requirements**. Instruments must have an appropriate response to radiation overload scenarios and be subject to regular calibration and in-service checks.

Every instrument must be able to withstand an overload scenario, where the internal electronics cannot determine dose or count rate above a certain level and are able to recover when returned to a low dose field. This is an issue particularly with old instruments. The instrument must have an appropriate response to overload—for example, an audible alarm or a visual indication, such as a flashing screen or lamp.

Some instruments offer additional features such as integrated dose accumulation, which measures the radiation dose accumulated over time. This is particularly useful for assessing workplace radiation levels and ensuring that a user does not receive an excessive dose. A dose rate alarm or vibrate function is also useful to give an early warning of enhanced radiation levels.

Each instrument may target a single type of radiation and application or may have multiple functions or add-ons to allow it to target multiple radiation types. The choice of the meter should be well informed and carefully made.

Meters must be regularly calibrated and maintained. Perform calibration at least every two years to ensure the instrument responds accurately and properly, although we recommend following the manufacturer's guidance on the specific period for each type of instrument. It is also good practice to perform six-monthly in-service checks of the response, battery level and overall condition, to ensure that the meter remains ready to be deployed.

For more specific advice on setting up or developing a workplace monitoring programme and on selecting the most suitable instruments for it, we strongly recommend that holders of a source licence consult a **qualified expert**.

Radiation monitoring guide

Carry out pre-survey checks

As part of your pre-survey checks:

- ensure the meter is within calibration and that it applies to the survey being performed
- check the meter, probe and cables for damage
- check the condition of the battery
- verify background radiation level, including by checking for potential surface contamination
- verify the meter responds correctly to a check source
- check the smooth operation and backlight of digital meters
- for an analogue meter, check the needle moves freely
- verify the audio output function
- check the condition of the detector window
- verify alarms are set at appropriate levels.

Types of survey

The three main types of surveys are: benchmark, routine and non-routine. Before starting any survey, develop a plan for performing it. During the survey, check a range of conditions in order to ensure both that the survey is thorough and that the person performing the survey is safe.

Benchmark survey

The aim of this initial survey is to establish radiation levels against which subsequent surveys are performed. Your findings will establish any areas of interest such as high radiation fields, which can be the focus of future surveys, as well as identifying any personal protective equipment required.

Routine survey

Routine surveys are completed regularly in survey area(s) with known levels . Mark the areas of interest identified in the benchmark survey as survey points or regions and measure levels in those areas during routine surveys.

These surveys are usually completed quarterly, six-monthly or annually. In writing a report, express the levels found and compare them with earlier measurements.

Non-routine survey

Typically you conduct a non-routine survey when unusual circumstances have changed the radiological conditions of the survey area, or to perform a radiological assessment of areas that are not normally assessed due to the radiological conditions. Emergency scenarios also fall into this category, so it is especially important to make plans to keep personnel safe.

For non-routine surveys, it is important to set safe levels for operators to work to, as these surveys may involve accessing areas with higher radiation and/or contamination levels. For this reason, take greater care concerning the exposure of operators.

General monitoring techniques

- Switch on instruments for two to three minutes (or longer for ion chambers) before use. Check that background levels are stable and under 0.2 uSv/h or under 1 count per second.
- Acclimatise instruments to ambient conditions, away from any radiation fields.
- Consider using a separate probe and base unit for confined spaces. You can sacrifice surface volume for getting a result.
- Position instruments correctly and hold them steady during readings. Look at the manufacturer's user guide for further details.
- Ensure the display is visible, or that audible signals can be heard.

Instrument reading techniques

Two techniques for obtaining readings are eye averaging and time integration.

For **time** integration, measurements are usually more precise, especially with digital instruments.

- To take this approach, accumulate a dose over a known time and use this to calculate a dose or count rate.
- Integrating techniques include automatic and manual integration.
- Integration time depends on radiation field, instrument response and required precision.

Eye averaging involves manually determining the average of fluctuating readings.

- You can use systematic and intuitive methods for eye averaging.

Measuring dose rate

- Different techniques are involved for X-ray, gamma (γ), beta (β) and neutron radiation.
- Perform pre-survey instrument checks.
- Monitor the area carefully and set the instrument to the appropriate range.
- Record measurement results and carry out post-survey instrument checks.

Measuring surface contamination

- Differentiate between fixed and loose contamination. Loose contamination presents an internal hazard and should be removed.
- Various methods for contamination monitoring are available: direct probe, dry wipes, damp wipes or a combination of these.
- Some factors affecting measurement are surface absorbency, presence of substances on the surface, and radiation type.

- Audio indications usually react faster than displayed count rate, and are a better indication of 'hot spots'.
- Record all relevant measurements and be aware of action levels.
- Carry out post-survey checks and monitor yourself when leaving the contamination area.

Indirectly measuring surface contamination (wipe testing)

- Wipe tests can be dry or wet.
- Wipe filter paper over a contaminated area and then assess the area for radioactivity.
- Uncertainties in wipe testing are high, especially in assessing the 'pick-up' factor.
- A common practice is to assume a pick-up factor of 10%.

Summary of instrument selection based on types of radiation and use

Radiation type	Use cases	Detector types
X-ray, gamma (γ)	• General area monitoring • X-ray compliance testing, including CT and panoramic X-ray units • Scatter/leakage monitoring	Ionisation chamber Proportional counter Steel-walled Geiger Müller (GM) tube Solid state detectors Thin end-window GM tube End-window GM tube Plastic scintillator NaI-based scintillators
Beta (β) contamination	• Unsealed radioactive materials, eg, nuclear medicine departments, nuclear medicine veterinary clinics	Beta scintillation detectors Thin-windowed gas refillable Proportional counter Titanium-windowed, Xenon-filled, sealed proportional counter Thin-walled GM tube
Alpha (α) contamination	• Unsealed radioactive materials, eg, nuclear medicine departments, nuclear medicine veterinary clinics	Zinc sulphide scintillator Dual phosphor scintillation probe Thin-windowed gas refillable Proportional counter
Neutron	• Well logging • Nuclear density meters • High-energy linear accelerators (≥ 10 MV)	Boron trifluoride (BF_3) proportional counter with spherical moderator helium-3 (^3He) proportional counter with spherical moderator BF_3 proportional counter with cylindrical moderator Europium doped lithium iodide (LiI(Eu)) scintillator with spherical moderator Lightweight wide-energy neutron scintillator

Gamma (γ) and X-ray meters

Meter type	Strengths	Weaknesses
Ionisation chamber	Good response to X-ray, γ, acceptable β response. Range from 2 uSv/hr to 10 mSv/hr, but response outside this range varies by meter	Unstable under 2 uSv/hr, susceptible to pressure, humidity changes. Requires maintenance, especially around use of desiccants
Proportional counter	Good X-ray, γ energy response down to 30 keV. Good response for high-energy β. Capable of measuring pulsed fields. Good size to sensitivity relationship	Can use highly polarised fields. Expensive, susceptible to high voltage variations
Steel-walled GM (energy compensated)	Stable for small volume, in comparison with ionisation chambers. Consistent voltage across meter, thus stable. Cheap	No measurement of β or α. X-ray, γ response falls rapidly below 50 keV. Not suitable for pulsed fields
Thin end-window GM (energy compensated)	Acceptable X-ray, γ response from 10 keV to 1.25 MeV	
End-window GM	Response to X-ray, γ from 5 keV upwards, and β and α radiation. Acceptable response	Vulnerable to damage, typically not repairable. Poor response to X-ray, γ
Plastic scintillator	Good energy response for X-ray, γ down to 20 keV. High sensitivity for volume. Good dynamic range with varied voltage	Large (scintillator and photomultiplier (PM) tube). Expensive
NaI-based scintillator	Very high sensitivity. RM identification possible	Very expensive. Limited dynamic range

Beta (β) contamination meters

Meter type	Strengths	Weaknesses
Beta scintillation detectors	Can cover a wide range of energies. Inefficient response to X-ray, γ, which minimises background. Easily replaceable window. Lightweight. Easy operation	Susceptible to magnetic fields. Highly variable operating potential. Uniformity of larger detectors can be poor. No α discrimination, unless a dual phosphor scintillation probe
Thin-windowed gas refillable proportional counters	Very good detection efficiency. Available in large sizes. Very good β detection efficiency, operates down to 0.156 MeV. Easily repaired window. Consistent operating potential. Good α rejection	Requires regular refreshing with counting gas. Not suitable for intermittent use. Operates at high potentials, 1.5 to 2 kV
Titanium-windowed, Xenon-filled, sealed proportional counters	Useful for β and low-energy X-ray, γ. Relatively tough windows. Lightweight. No refilling required for normal use. Consistent operating potential	Window difficult to replace. Repair costs high. Higher background than all other types for same unit area

Meter type	Strengths	Weaknesses
Thin-walled GM detectors	More robust windows than thin-windowed versions. Larger useful area than thin-windowed versions. Very simple set-up procedure. Consistent operating voltage and radiation characteristics. Low cost. Lightweight	Relatively high minimum useful energy. Unrepairable

Alpha (α) contamination meters

Meter type	Strengths	Weaknesses
Zinc sulphide scintillation detectors	Good α detection efficiency. Wide range of sizes available. Reasonable β, X-ray, γ rejection, at low dose rates. Lightweight, separate probes common. Low intrinsic background. Easy set-up	Sensitive to magnetic fields. Uniformity with larger detectors can be poor, low response in detector corners. Highly variable operating potential, 700 to 1,200 V.
Dual phosphor scintillation probe (zinc sulphide on plastic scintillator)	Good α detection efficiency for standard α pulses. Useful for mixed α and medium-high energy β. Lightweight. Easily repaired window	More complicated set-up. Sensitive to magnetic fields. Highly variable operating voltage
Thin-windowed gas refillable proportional counters	Very good detection efficiency, near 100% for α above 0.5 MeV. Available in very large sizes if needed. Good detection efficiency of β above 0.156 MeV. Easily repaired window. Consistent operating potential. Not affected by magnetic fields	Requires regular gas refilling. Not suitable for intermittent use. Operation at very high voltages, 1.5 to 2 keV, may cause issues in high humidity

Neutron survey meters

Meter type	Strengths	Weaknesses
BF_3 proportional counter with spherical moderator	Good γ rejection, near isotropic response	Poor sensitivity, typically 0.2 to 0.7 s^{-1} mSv^{-1} h for 241Am-Be. BF_3 is poisonous
^3He proportional counter with spherical moderator	Near isotropic response	Poor sensitivity, typically 0.2 to 0.7 s^{-1} mSv^{-1} h for 241Am-Be. ^3He is expensive
BF_3 proportional counter with cylindrical moderator	Good γ rejection	Poor sensitivity, typically 0.2 to 0.7 s^{-1} mSv^{-1} h for 241Am-Be. Non-isotropic response. BF_3 is poisonous
LiI(Eu) scintillator with spherical moderator	Near isotropic response	Poor sensitivity, typically 0.2 s^{-1} mSv^{-1} h. Energy response is inferior to cylindrical moderator. Poor γ rejection. Variable operating voltage
Lightweight wide energy neutron scintillator	High sensitivity, lightweight	Limited γ rejection

Bibliography

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