# Measurement of the background radiation level using the pressurized ion chamber-based survey meter

CENTER FOR MEDICAL AND RADIATION PHYSICS

**Aim:**

- Determination of Minimum Detectable Dose Rate (MDDR) for a Pressurized Ionization Chamber (PIC) based radiation survey meter.
- To check the energy response of the survey meter.
- To validate the calibration of the PIC survey meter.
- To measure ambient background gamma dose rate using a pressurized ion chamber survey meter and to analyze variability over time/locations.

**Apparatus Required:**

- Pressurized Ionization survey meter
- Check Sources

**Theory:**

A pressurized ionization chamber (PIC) survey meter is a radiation detection instrument used to measure radiation levels at different locations. It operates on the principle of gas ionization. The detector consists of a chamber filled with gas (usually an inert gas) at high pressure. When gamma radiation enters the chamber, it interacts with gas molecules, producing ion pairs (positive ions and electrons). An electric field applied across the chamber collects these charges, producing a small current. This current is directly proportional to the radiation dose rate, which is displayed by the instrument in units such as μSv/h or mR/h.

**Minimum Detectable Dose Rate (MDDR)** is the lowest radiation dose rate that a PIC survey meter can reliably distinguish from background radiation. It indicates the minimum detectable radiation level with a specified confidence level. Since background radiation fluctuates statistically, a measured value must exceed these fluctuations to confirm the presence of radiation.

The MDDR is determined from repeated background measurements using the relation:

$$\text{MDDR} = k\sigma$$

where:

- $\sigma$ = standard deviation of the background dose-rate measurements
- k = confidence factor corresponding to the desired confidence level

The standard deviation $\sigma$ represents the spread or fluctuation in background radiation readings and is calculated from repeated measurements as:

where: $\sigma = \sqrt{\frac{\sum_{i=1}^{n} (X_i - \underline{X})^2}{n-1}}$

- $X_i$ = individual background reading
- $\underline{X}$ = average background reading
- n = number of measurements

The confidence factor "k" defines the probability that the detected signal is real and not due to random background fluctuations. Commonly used values are:

- (k ~ 2) for 95% confidence

- (k ~ 3) for 99% confidence

Thus, if the measured dose rate exceeds the background level by at least (kσ), the radiation is considered detectable with the selected confidence level.

The **energy response** of a PIC survey meter describes how its sensitivity changes with different radiation energies. A PIC is designed to provide a nearly energy-independent response over a wide photon energy range. High-pressure gas is used inside a sealed chamber that increases ionization efficiency and reduces statistical fluctuations. Due to their stable, relatively flat energy response, pressurized ion chambers are widely used in environmental gamma monitoring, background radiation surveys, and emergency radiation assessment, where accurate measurements over broad energy ranges are required.

**Calibration of Radiation Instruments**: Calibration is the process of establishing the relationship between the readings of a radiation-measuring instrument and the true value of the quantity being measured under known, controlled conditions. The primary objective of calibration is to ensure that the instrument is functioning properly and can be used for monitoring. Calibration also helps determine the deviation of the measured quantity from its actual value, and, if needed, the calibration factor can be adjusted to achieve the desired overall measurement accuracy. Calibration validation is the process of verifying that an already-calibrated instrument continues to perform within specified tolerance limits when tested under known radiation conditions. While calibration establishes the correction factor, validation confirms that the instrument remains accurate over time.

All radiation survey and measuring instruments should be calibrated periodically to ensure they provide accurate readings, and this is also a regulatory requirement. A convincing method to calibrate these instruments is to place them in a radiation field of a known dose rate (produced by radioactive elements) and compare their response with the dose rate. Different calibration factors are used for β and $\gamma$ radiations. The known dose rate can be calculated from the exposure rate constant of the given radionuclide (Calculation shown below).

**Measurement of ambient background gamma dose rate using a pressurized ion chamber:** Ambient background gamma radiation is naturally present in the environment. It originates from naturally occurring radioactive materials in soil, rocks, and building materials, as well as from cosmic rays and radioactive gases such as radon and its decay products. A Pressurized Ion Chamber (PIC) is a highly sensitive radiation survey instrument used to accurately measure low levels of environmental gamma radiation. Background gamma dose rates may vary with location and time due to differences in geological composition, altitude, building materials, weather conditions, and radon concentration. By taking measurements at different locations or over different time intervals, the variability of ambient background radiation can be studied and analyzed statistically. Thus, the pressurized ion chamber serves as a reliable instrument for measuring ambient background gamma dose rates and assessing spatial and temporal variations in environmental radiation levels.

**Procedure 1 (MDDR Measurement):**

- Switch on the Radiation survey meter and keep it on for 1-2 mins.
- Keep the survey meter away from any radiation sources.
- Measure the dose rate at 2-minute intervals and repeat this for 10 measurements.
- Tabulate the data to determine the MDDR using the theoretical formula.

**Table 1: For MDDR Measurement**

| Sl.No | Background Dose Rate (μR/h) | Average Dose Rate (μR/h) | Standard Deviation ($\sigma$) | MDDR=kσ k=3 (μR/h) |
|---|---|---|---|---|
| 1 | 12 | 14.8 | 2.93636 | 8.8090 |
| 2 | 10 | | | |
| 3 | 13 | | | |
| 4 | 15 | | | |
| 5 | 16 | | | |
| 6 | 13 | | | |
| 7 | 15 | | | |
| 8 | 20 | | | |
| 9 | 16 | | | |
| 10 | 18 | | | |

**Procedure 2 (Energy Response Testing):**

- Calculate the True Dose rate for $Ba^{133}$ at a distance of 20cm.
- Measure the background radiation level without any source nearby. Take at least 5 readings.
- Place a $Ba^{133}$ check source 20cm from the survey meter and take 4 readings, each with a 1min gap.
- Take $Cs^{137}$, $Na^{22}$, and $Co^{60}$ sources and adjust the source-to-detector distance so that the expected dose rate is equal to that obtained with the $Ba^{133}$ source at 20 cm. Subsequently, repeat the measurement procedure for each radionuclide at the determined distance.
- Tabulate the data; the response should be constant for different energy sources. And find out the standard deviation.

**Table 2: For Energy Response Measurement**

**Average Background for Pressurized ion chamber = 11**(μR/h)

| Sr. No. | Source | Energy (MeV) | Current Activity (KBq) | Distance (cm) | Dose (μR/h) | | | | M=Average-BKG | Standard Deviation |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | **1** | **2** | **3** | **4** | | |
| 2 | $Ba^{133}$ | 0.356 | 85.08 | 20 | 31 | 28 | 30 | 29 | 18.5 | 0.92 |
| 3 | $Cs^{137}$ | 0.662 | 101.1 | 25.6 | 28 | 30 | 28 | 28 | 17.5 | |
| 4 | $Na^{22}$ | 1.275 | 89.07 | 29.6 | 27 | 30 | 29 | 27 | 17.25 | |
| 5 | $Co^{60}$ | 1.25 | 37.41 | 48 | 26 | 28 | 28 | 27 | 16.25 | |

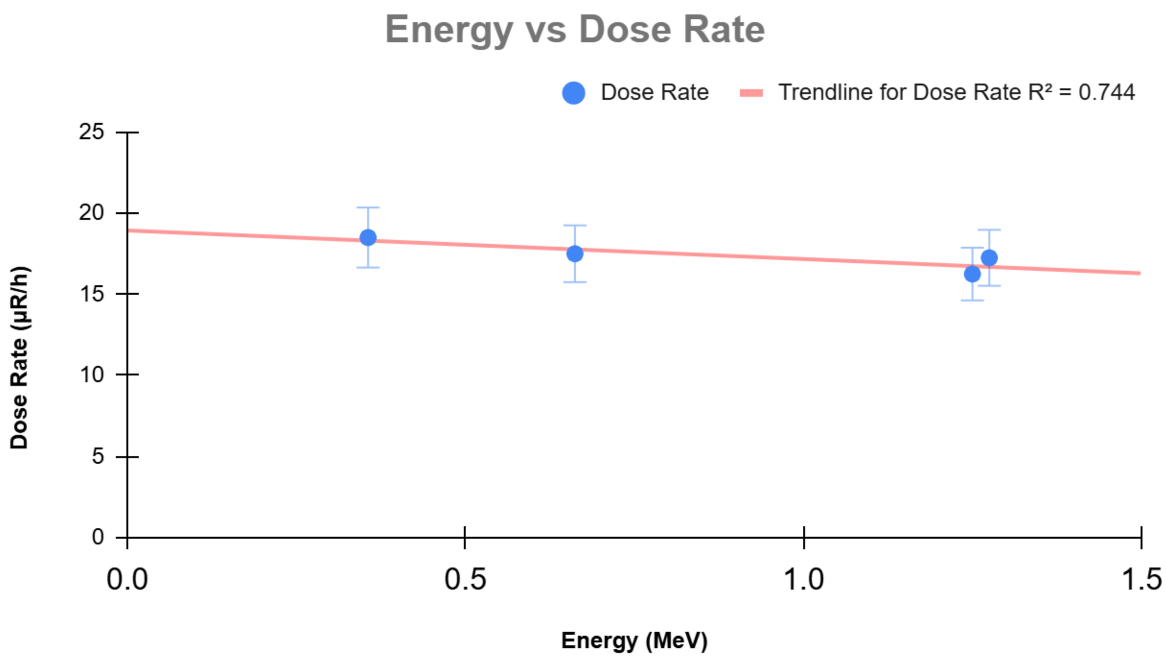


Figure 1: Graph showing Energy Vs Dose Rate

**Calculation:**

$True\ Dose\ Rate\ (R) = \frac{\gamma\, A}{d^2}$ (R/hr)

γ is the exposure rate constant of a specific radionuclide.

A is the Activity of Radionuclide in Ci at the of experiment.

d is the distance between the source and detector.

**Procedure 3 (Validate the Calibration of the Survey meter):**

- Calculate the Radiation exposure rate at the fixed distance theoretically from the exposure rate constant. This is the reference value (True value).
- Tabulate the readings shown by the Radiation Survey Meter. (As shown below)
- Calculate the percentage error in the dose rate.

**Table 3: For the Validation of Calibration**

<table>
<tr><td colspan="10" align="center">Response for Fluke</td></tr>
<tr><td>Source: Cs-137</td><td colspan="6">Activity: 3.7 MBq</td><td colspan="3">Distance: 50 cm</td></tr>
<tr><td colspan="10" align="center">Background Counts (B in μR/h) = $\frac{20+26+28+17+12}{5}$ = 20.6 μR/h = 0.0206 mR/h</td></tr>
<tr><td rowspan="2">Sr. No.</td><td rowspan="2">True Dose Rate (mR/h)</td><td colspan="6" align="center">Observed Dose Rate (mR/h)</td><td rowspan="2">Corrected Dose Rate (Xc)</td><td rowspan="2">Uncertainty (%)</td></tr>
<tr><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>Avg</td></tr>
<tr><td>1</td><td>0.119</td><td>0.148</td><td>0.136</td><td>0.133</td><td>0.147</td><td>0.140</td><td>0.141</td><td>0.120</td><td>0.84</td></tr>
</table>

**Procedure 4 (Ambient Dose Rate Measurement at Different Locations):**

- Switch on the survey meter and allow it to stabilize.
- Select several measurement locations, as mentioned in the table
- Hold the detector approximately 1 meter above ground level and ensure no radioactive source is present nearby.
- Measure for a fixed time period (e.g., 2 minutes) and record the displayed dose rate.
- Take at least 5 repeated readings at each location.
- Calculate the average dose rate for each location.

**Table 4: Ambient Dose Measurement**

| **Sr.No** | **Locations** | **Survey Meter Reading in** µR/h | | | | | **Average** µR/h | **STDV** |
|---|---|---|---|---|---|---|---|---|
| | | **1** | **2** | **3** | **4** | **5** | | |
| **1** | Medical Physics Lab | | | | | | | |
| **2** | Open Terrace | | | | | | | |
| **3** | Near Entrance Door | | | | | | | |
| **4** | Near Any concrete wall | | | | | | | |
| **5** | Inside Classroom | | | | | | | |

**Procedure 4 (Ambient Dose Rate Measurement Over Time Intervals):**

- Place the detector at the same location, position, and height.
- Record the dose rate at regular intervals: Every 3 hours
- Continue measurements for the desired duration and tabulate the data

**Table 4: Dose Rate Measurement Over Time**

| **Sr.No** | **Time** | **Survey Meter Reading in** µR/h | | | | | **Average** µR/h | **STDV** |
|---|---|---|---|---|---|---|---|---|
| | | **1** | **2** | **3** | **4** | **5** | | |
| 1 | 9:00 AM | | | | | | | |
| 2 | 12:00 PM | | | | | | | |
| 3 | 3:00 PM | | | | | | | |
| 4 | 6:00 PM | | | | | | | |

**Result:**

**Conclusion:**

**Precautions:**

- Ensure batteries are properly installed and replace weak or leaking batteries promptly.
- Keep away from contaminated materials.
- Avoid dropping, striking, or applying mechanical shock to the survey meter.
- Do not tamper with the pressurized ion chamber.

**References**


- Lloyd A. Currie, "Limits for Qualitative Detection and Quantitative Determination," *Analytical Chemistry*, 1968.
- International Atomic Energy Agency Radiation Measurement Publications.
- Radiation detection and measurements by G. F. Knoll