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# The Measurement of Environmental Radiation Exposure Around the Linac Radiotherapy Bunker

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**ABSTRACT**

*Radiotherapy is cancer therapy using radiation. One of the tools used for radiotherapy is the Linac. Using Linac also can have a detrimental effect on radiation workers, patients, and the public. The reaction can cause activation around the room to become radioactive. Therefore, radiation protection is needed. This research aimed to measure environmental radiation exposure as a radiation protection effort around the Linac bunker. This research uses a quantitative method by collecting data directly on the area around the Linac bunker, with a distance of ± 30 cm from the bunker wall, using the STEP OD-02 Detector. The average Linac operation is 2000 hours/year, while the safe dose limit used is 1/2 x Dose Limit from Nuclear Power Monitoring Agency. Based on measurements of environmental radiation exposure, there are eight areas classified as safe and four other regions experiencing radiation leakage, including Doors with a radiation exposure difference of 0.078 Sv/hour; West Field (0.074 Sv/hour); TPS Room (0.302 Sv/hour); and Meeting Rooms (0.199 Sv/hour), but still within the safe limit of radiation dose. The environmental radiation exposure around the Linac Radiotherapy bunker is safe.*



## Introduction

Radiotherapy is cancer therapy using radiation [1]. According to the International Agency for Research on Cancer (IARC), 50% of cancer patients require radiotherapy [2]. The radiation used in the radiotherapy method is electromagnetic wave radiation (x-rays and gamma rays), and particle radiation (electrons, protons, and neutrons). One of the tools used for radiotherapy is the Linac (Linear Accelerator), which uses high-frequency electromagnetic waves to accelerate charged particles such as high-energy electrons through a linear tube [3].

Linac is designed to accelerate the movement of electrons linearly to produce a beam of photons and electrons. Photon beams have 6 MV and 10 MV energies, and electron beams have

4 MeV, 6 MeV, 9 MeV, 12 MeV, 15 MeV, and 18 MeV. Photon beams expose cancers in body tissues such as breast cancer, cervical cancer, and nasopharyngeal cancer. In contrast, electron beams are usually used to expose cases of skin cancer [4].

In addition to providing benefits to the medical world, the use of ionizing radiation also can have a detrimental effect on radiation workers, patients, and the public. The reaction can cause activation around the room to become radioactive. This reaction is dangerous for the body during the therapy process because it can cause secondary cancer risks [5]. Therefore, radiation protection is needed. Radiation protection aims to prevent clinically deterministic effects of radiation by keeping radiation workers and the public exposed to certain threshold doses [6]. Based on the standards of the International Atomic Energy Agency (IAEA) Number 31 of 2016, every case of cancer using a therapeutic machine must be verified first [7]. It is also stated in the Regulation of the Head of the Nuclear Power Monitoring Agency Number 3 of 2013 concerning radiation safety [8].

Radiation dose acceptance by radiation workers, patients, and the public is always as low as possible so that the predetermined Dose Limit Value is not exceeded [9]. The dose limit value for radiation workers must not exceed 20 mSv per year on average for five consecutive years and 50 mSv in 1 certain year, while the dose limit value for the public must not exceed one mSv in 1 year [10]. Based on this description, it is necessary to measure environmental radiation exposure to protect radiation.

## Experimental Method

Data collection was carried out by measuring and direct research at the Radiotherapy Unit of Lavalette Hospital, Malang. This research uses a quantitative method by collecting data directly on the area around the Linac room, with a distance of ± 30 cm from the bunker wall, using the STEP OD-02 Detector.

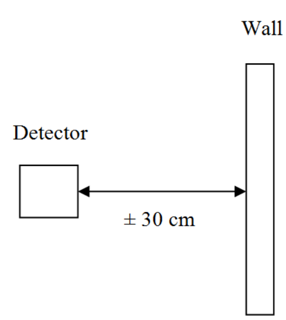


**Figure 1.** Detector Position

First, the background radiation is measured with a calibration factor of 1.08. Data analysis is done by comparing measured dose rate and background dose rate. If the measured dose rate is smaller than the background dose rate, then the value is assumed to be the same as the background dose rate. Suppose the measured dose rate is greater than the background dose rate. In that case, there is a difference that indicates a radiation leak from Linac, which will later be analyzed to determine whether the radiation is still within safe limits or not.

The effectiveness of the radiology room is measured to ensure that no radiation leakage is received outside the room, either by radiation workers or by the public [11]. The safe dose limit used at Lavalette Hospital, Malang, is $\frac{1}{2}$ $x$ half dose limit value from BAPETEN (Nuclear Power Monitoring Agency).

## Result and Discussion

Linac operation on working days and hours at Lavalette Hospital, Malang is an average of 2000 hours/year, so the dose limit calculation is:

**Table 1**. Dose Limits in Radiotherapy Unit.

| Category | Dose Limit Value |
|---|---|
| **Radiation Workers** | $20\ mSv/_{year} = {}^{20000\ \mu Sv}/_{2000hours} = {}^{10\ \mu Sv}/_{hour}$ |
| | $\frac{1}{2}\ x\ Dose\ Limit = \frac{1}{2}\ x\ 10 = 5\ {}^{\mu Sv}/_{hour}$ |
| **Public** | $1\ mSv/_{year} = {}^{1000\ \mu Sv}/_{2000hours} = {}^{0,5\ \mu Sv}/_{hour}$ |
| | $\frac{1}{2}\ x\ Dose\ Limit = \frac{1}{2}\ x\ 0,5 = 0,25\ {}^{\mu Sv}/_{hour}$ |

Table 2 shows the radiation exposure values in the control and supervision areas. A Control Area is a work area that requires special protective measures and safety provisions to control normal exposures during normal working conditions and prevent or limit potential exposure levels. This area can only be accessed by radiation workers and visitors who Radiation Protection Officers accompany. At the same time, the Supervision Area is an area that requires a review of Occupational Exposure and does not require protective measures or special safety provisions. This area is accessible to the public [12].

**Table 2**. The Measurement of Environmental Radiation Exposure Around the Linac Bunker.

| Function | Description | Gantry Angle Direction | Background (μSv/hour) | CF x BG (μSv/ hour) | CF x MD (μSv/ hour) |
|---|---|---|---|---|---|
| Operator Room | Control Area | 0 | 0.618 | 0.667 | 0.324 |
| Door | Control Area | 0 | 0.618 | 0.667 | 0.745 |
| South Field | Supervision Area | 90 | 0.900 | 0.972 | 0.730 |
| South Field | Supervision Area | 135 | 0.900 | 0.972 | 0.721 |
| North Field | Supervision Area | -90 | 0.786 | 0.849 | 0.737 |
| North Field | Supervision Area | -135 | 0.786 | 0.849 | 0.804 |
| West Field | Supervision Area | 180 | 0.740 | 0.799 | 0.873 |
| TPS Room | Control Area | 180 | 0.320 | 0.346 | 0.648 |
| Meeting Room | Control Area | 180 | 0.320 | 0.346 | 0.545 |
| Roof | Control Area | 180 | 0.980 | 1.058 | 0.663 |
| Panel Room | Control Area | 180 | 0.600 | 0.648 | 0.609 |
| Chiller Room | Control Area | 180 | 0.600 | 0.648 | 0.534 |

Note : CF = Calibration Factor; BG = Background; MD = Measured Dose

Based on Table 2, there are four areas where radiation exposure leaks, including a Door with a radiation exposure difference of 0.078 Sv/hour; West Field (0.074 Sv/hour); TPS Room (0.302 Sv/hour); and Meeting Room (0.199 Sv/hour). Because the dose limit set by Lavalette

Hospital, Malang is 5 Sv/hour for radiation workers; and 0.25 Sv/hour for the public, radiation exposure in the four areas experiencing radiation leakage is still within the safe limit. However, it is necessary to pay attention to radiation workers' time limitations, particularly when within that radius. The accumulated radiation exposure absorbed in the body is highly dependent on the length of time the radiation worker is in the radiation field [13].

If they receive an excessive dose, radiation workers must study the factors causing the overdose, corrective action, and preventive action. The survey of overdosage includes a study of the workload and frequency, work history, condition of facilities and infrastructure, radiation exposure in the work area, and radiation worker discipline in applying the principles of radiation protection. Corrective actions include improving facilities and infrastructure, improving a radiation protection system, counseling actions, and health checks and follow-up. Preventive measures include improving safety culture, checking and maintaining facilities, implementing a dose management system, and limiting dose acceptance in the remaining period [14].

Primary radiation shielding is beneficial in blocking radiation beams from the therapy room, and secondary radiation shielding needs to be designed to be able to protect a person outside the accelerator room from radiation leakage, radiation scattering from patients, radiation scattering from walls, and secondary radiation produced at the accelerator head or scattering whole room [15].

## Conclusion

The exposure to environmental radiation around the Linac Radiotherapy bunker at Lavalette Hospital, Malang, is included in the safe category.

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