



SAFE DISTANCE AGAINST RADIATION EXPOSURE TO PORTABLE X-RAY PLANES WITHOUT SHIELDING FOR RADIATION WORKERS AND THE COMMUNITY

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ABSTRACT

According to data from BAPETEN 2.0, nearly 1,890 X-ray machines were recorded across Indonesia in 2019 [3]. A portable X-ray machine is a small-scale X-ray device designed for easy transport, allowing it to be moved from one location to another [1]. The absence of radiation protection in the form of physical shielding requires medical personnel to maximize other radiation protection principles, particularly distance [6]. The purpose of this study is to determine the radiation exposure at distances of 4 meters, 5 meters, and 6 meters when using a portable X-ray machine for both medical personnel and the public. This research is a controlled experimental study, conducted in the auditorium of the Siti Bariyah Building at Universitas 'Aisyiyah Yogyakarta. The results of the radiation exposure measurements at four points across the 4, 5, and 6-meter distances indicated that the exposure fell within the safe category for medical personnel and the public. In accordance with Government Regulation No. 45 of 2023, exposure must not exceed 5.71 μSv for both medical personnel and the general public. The author suggests further research in smaller-room settings, such as the intensive care unit (ICU). This would help simulate emergency situations where portable X-ray machines are used at the patient's bedside instead of transferring patients to distant facilities.

Keywords: Radiation Exposure; Distance, Portable X-ray; Medical Personnel

Introduction

Radiology is a branch of medical science concerned with the use of all modalities involving radiation for diagnostic purposes. Diagnostic radiology is a radiological technique used to diagnose diseases or morphological abnormalities within a patient's body using X-ray machines [10].

According to data from BAPETEN 2.0, nearly 1,890 X-ray machines were recorded across Indonesia in 2019 [3]. There are several types of radiographic X-ray machines: fixed (stationary), mobile, and portable. A portable X-ray machine is a small-scale X-ray device equipped with a protective case (suitcase), allowing it to be

easily transported from one location to another [10].

According to Omori et al. [5], portable X-ray machines are used to provide medical diagnostic services in hard-to-reach locations or emergency situations such as natural disasters. They assist in detecting injuries, infections, and lung problems, enabling rapid assessment and patient care without the need to transport patients to distant medical facilities.

The utilization of ionizing radiation offers significant benefits in medical diagnostics but also poses risks to patients, the general public, and medical personnel. Radiation exposure at sufficiently high doses causes a condition known as Acute Radiation Syndrome. High-dose radiation exposure can lead to death from cerebral edema within 48 hours. Low-dose exposure can cause gastrointestinal damage, and long-term low-dose exposure requires vigilance as it may lead to neoplastic risks. The effects of radiation vary per individual based on their sensitivity and the duration of exposure [2].

Pursuant to Government Regulation No. 45 [7], radiation protection refers to measures taken to reduce the negative impacts caused by radiation exposure. The goal is to minimize negative impacts as much as possible and prevent deterministic effects. The principles of radiation protection are divided into three categories: justification, dose limitation, and optimization. Optimization must be based on the ALARA (As Low As Reasonably Achievable) principle, which advocates that radiation exposure should be kept as low as possible while still providing optimal image quality.

According to Mubarak [8], dose constraints are used to analyze safe levels of accumulated doses. The constraint used is 1/2 of the Dose Limit (NBD); thus, the dose constraint for radiation workers is 10 mSv/year, and for the general public, it is 0.5

mSv/year. The conversion for accumulated dose (μSv) is as follows: assuming 2,500 chest examinations per year (10 per day), the safe accumulated dose per examination is 4 μSv for radiation workers and 0.2 μSv for the general public.

Implementation of the ALARA principle involves three factors: distance, time, and shielding. Reducing exposure for medical personnel involves maintaining a safe distance from the X-ray tube; specifically, doubling the initial distance significantly reduces exposure (Irsal et al., 2020). Time involves shortening the duration of the examination to minimize the dose received, while shielding—based on the Half Value Layer (HVL)—shows that X-ray intensity decreases as the thickness and density of the shielding material increase [9].

Based on researcher observations in hospitals, it was found that during *Cito* (emergency) thorax examinations in the ICU, radiation workers often do not provide shielding to other patients who are not being examined. Conversely, [6] state that radiation protection reviews should monitor scattered radiation relative to shielding to ensure safety. Their research suggests that when the tube is in a vertical position, the X-ray source should be at a distance of 2 meters with the operator positioned behind shielding.

The absence of radiation protection in the form of physical shielding requires medical personnel to maximize other protection principles, primarily the principle of distance [6].

Methods

This study is a controlled experimental study. The research was conducted at the Auditorium of the Siti Bariyah Building, Universitas 'Aisyiyah Yogyakarta, in July 2024. The research subjects included a portable X-ray machine, a thorax phantom, and a survey meter, while the research

object focused on the safe distance from portable X-ray radiation exposure.

Results and Discussion

Radiation exposure measurements were conducted at the Auditorium of the Siti Bariyah Building, Universitas 'Aisyiyah Yogyakarta. The study utilized a Fujifilm FDR Xair portable X-ray machine with exposure factors set at 90 kV and 2.5 mAs. Radiation exposure was measured using a Fluke Biomedical 451P Ion Chamber survey meter, which was re-calibrated on September 6, 2024, with an instrument calibration factor of 1.1 μSv . A thorax phantom was used as a patient substitute during the exposures.

Measurements were taken at four specific points: Point A (Anode), Point B (Right of the radiation source), Point C (Cathode), and Point D (Left of the radiation source). These were performed at distances of 4, 5, and 6 meters, with three repetitions for each measurement point. The Focus-to-Film Distance (FFD) was set at 150 cm, with the beam directed vertically and perpendicular to the object.

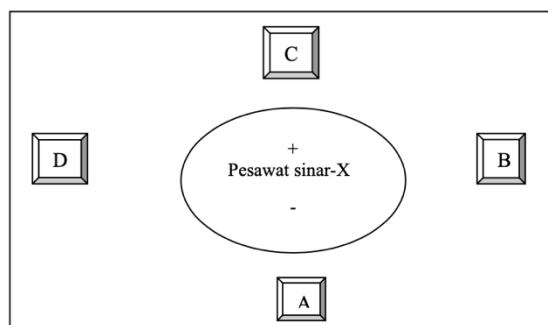


Figure 1. Denah Pengukuran

The formula used to measure scattered radiation using a survey meter is:

$$D_{\text{Actual}} = D_{\text{Measured}} \times \text{Calibration Factor}$$

Table 1. Radioation Exposure Measurement Result A (Anode)

Distance	Measurement Number (μSv)			Mean (μSv)
	1	2	3	
4 m	0,08	0,04	0,10	0,0733
5 m	0,03	0,04	0,06	0,0433
6 m	0,02	0,02	0,02	0,02

Table 2. Radiation Exposure Measurement Results B (Right of the radiation source)

Distance	Measurement Number (μSv)			Mean (μSv)
	1	2	3	
4 m	0,07	0,06	0,09	0,0733
5 m	0,05	0,07	0,06	0,06
6 m	0,03	0,04	0,06	0,0433

Table 3. Radiation Exposure Measurement Results C (Cathode)

Distance	Measurement Number (μSv)			Mean (μSv)
	1	2	3	
4 m	0,08	0,08	0,09	0,0833
5 m	0,05	0,07	0,07	0,0633
6 m	0,02	0,04	0,03	0,03

Table 4. Radiation Exposure Measurement Results D (Left of the radiation source)

Distance	Measurement Number (μSv)			Mean (μSv)
	1	2	3	
4 m	0,08	0,05	0,06	0,0633
5 m	0,02	0,04	0,04	0,0333
6 m	0,02	0,02	0,01	0,01667

The radiation exposure measurement results at points A, B, C, and D are detailed as follows. At Point A, the recorded radiation exposure was 0.733 μSv at a distance of 4 meters, which decreased to 0.0433 μSv at 5

meters, and reached its lowest value of 0.02 μSv at 6 meters. Similarly, measurements at Point B showed an exposure of 0.733 μSv at 4 meters, 0.06 μSv at 5 meters, and 0.0433 μSv at 6 meters. For Point C, the radiation exposure was measured at 0.0833 μSv at a distance of 4 meters, followed by 0.0633 μSv at 5 meters, and 0.03 μSv at 6 meters. Lastly, Point D yielded exposure levels of 0.0633 μSv at 4 meters, 0.0333 μSv at 5 meters, and 0.01667 μSv at a distance of 6 meters.

Based on these results, a radiation exposure curve was generated by multiplying the raw data from each measurement point by a calibration factor of 1.1. This calculation provides the following standardized values:

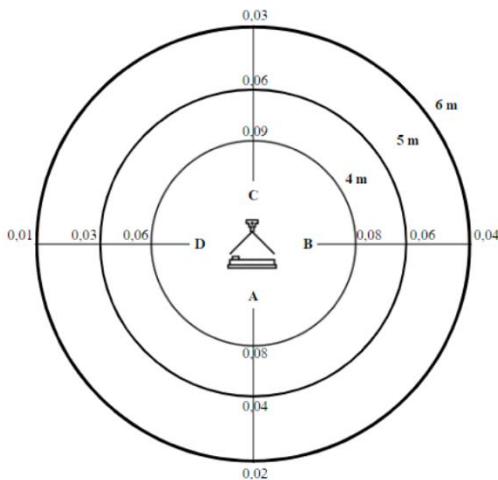


Figure 2. Actual Radiation Distribution Curve

According to Mubarok (2022), the safe accumulated radiation exposure dose for a single examination—assuming 2,500 chest X-rays are performed annually—is established at 4 μSv for radiation workers and 0.2 μSv for the general public. Based on these criteria, the results obtained from all measurement points indicate safe exposure levels that do not exceed the specified limits.

Radiation exposure from portable X-ray machines is significantly influenced

by distance, which is one of the fundamental principles of radiation protection. This is supported by previous research by Irsal et al. (2022), which states that the distribution of scattered radiation is affected by the direction, position, and distance from the radiation source, emphasizing the necessity of radiation protection. Furthermore, Rahmat et al. (2022) suggest that for safe exposure when the X-ray tube is in a vertical position, the source-to-operator distance should be maintained at 2 meters, with the personnel positioned behind a protective shield.

Conclusion

Based on the results of the radiation exposure measurements conducted at the Auditorium of the Siti Bariyah Building, Universitas 'Aisyiyah Yogyakarta, at four measurement points (A, B, C, and D) across distances of 4, 5, and 6 meters, it is indicated that the radiation exposure levels are categorized as safe

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