

Determination of Radiation Dose Rate and Dose Analysis of Radiation Workers in Radiology Installation at Pariaman Hospital

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ABSTRACT–Diagnostic radiology is the most significant contributor to irradiation in the general population. Unnecessary irradiation of workers, patients, and the public during radiological procedures should be significantly reduced without affecting the medical diagnostic value. This study was conducted to analyze and evaluate the radiation dose rate, radiation protection facilities and radiation worker dose of Radiology Installation of Pariaman Regional Hospital. The method of determining the radiation dose rate at the Radiology Instalansi of Pariaman Hospital uses a PDR 303 gamma surveymeter and the rooms to be measured are CT-Scan rooms, conventional X-rays and mammography. Collecting data on radiation protection facilities, then it will be analyzed based on Nuclear Energy Regulatory Agency Regulation No. 4 of 2020 and radiation worker dose data in 2023 will be analyzed based on Nuclear Energy Regulatory Agency Regulation No. 4 of 2013. The results of the study showed that the radiation dose rate around the CT-Scan room was found to be (0.24-1.61) $\mu\text{Sv}/\text{hour}$, the conventional X-ray room with irradiation using the minimum exposure factor obtained a radiation dose rate around the room ranging from (0.013-0.33) $\mu\text{Sv}/\text{hour}$ and with the maximum exposure factor obtained a dose rate around the room of (0.33-1.08) $\mu\text{Sv}/\text{hour}$ and the mammography room obtained a radiation dose rate of (0.03-0.40) $\mu\text{Sv}/\text{hour}$. The radiology room facilities used by Pariaman Hospital are in accordance with the standards set by Nuclear Energy Regulatory Agency Regulation No. 4 of 2020. And the dose rate received by radiation workers at Pariaman Hospital is below the Dose Limit Value set by Nuclear Energy Regulatory Agency Regulation No. 4 of 2013. Based on the results of this study, it is found that there are several measurement points in the CT-Scan and conventional X-ray rooms that exceed the community dose limit value.

Keywords: CT – Scan; Dose rate; Mammography; Radiology; X-ray.

INTRODUCTION

The application of ionizing radiation in the medical field has been utilized in Diagnostic and Interventional Radiology to date. Diagnostic radiology is the most significant contributor to irradiation in the general population (Baudin et al., 2021;

Fardela et al., 2021; Hricak et al., 2011; Paolicchi et al., 2016). Unnecessary irradiation of workers, patients, and the public during radiological procedures should be significantly reduced without affecting the medical diagnostic value. This point can be achieved by using well-designed X-ray

equipment installed, operated, and maintained and by implementing standard procedures that have been determined (Al-Abdulsalam & Brindhaban, 2014; Chinangwa et al., 2017; Fardela et al., 2020; IAEA, 2002; Kiragga et al., 2018; Zira et al., 2020). According to the standard procedure set by the Nuclear Energy Regulatory Agency, the dose limit value for radiation workers should not exceed 20 mSv in one year, and the public should not exceed 1 mSv in one year (BAPETEN, 2013). Regular dose monitoring is emphasized to reduce radiation exposure for patients and workers, as this helps ensure proper protection, adequate lead shields, and sufficient information about radiation protection (Fardela, 2016, 2023; Maharjan, 2017; Ünal et al., 2018).

Accidental radiation exposure to patients, radiation workers, and the general public can cause deterministic and stochastic effects, even at low doses (Adliene et al., 2020; Alkhorayef et al., 2020; Dahal & Budoff, 2019; Wilson-Stewart et al., 2018). Although radiation exposure in a medical context is intended to provide direct benefits to the exposed individual, some members of the public and radiation workers may be exposed to higher doses than recommended because the available shielding is ineffective (Alemayehu et al., 2023; Brown & Jones, 2013; Fardela et al., 2023; Lee et al., 2004; Mohammad & Najam, 2019). The license holders must meet radiation safety requirements in the use of X-ray machines in diagnostic and interventional radiology, which are regulated in the Regulation of the Nuclear Energy Regulatory Agency Number 4 of 2020 (Nuclear Energy Regulatory Agency, 2020).

Research on radiation dose rates has been widely conducted. Radiation dose measurements can be done using the Unfors-Xi Survey meter. Data from radiation dose measurements were used to evaluate the extent to which radiation shielding effectively protects (Andriani & Jamil, 2023). The analysis of the distribution of radiation doses in the Multi-Slice 64 CT-Scan area at the Sanglah

Central General Hospital, Denpasar, has been conducted as a reference (Abuelhia & Alghamdi, 2020). As a result, the dose rate measurements and distribution analysis results obtained values for areas C, E, and D, namely 142.32 $\mu\text{Sv/h}$, 111.36 $\mu\text{Sv/h}$, and 40.68 $\mu\text{Sv/h}$. The three areas exceeded the established Dose Limit Value (DLV) of 20 $\mu\text{Sv/h}$, while the others had values below the dose limit. The latest research that (Harwin et al., 2023) discusses the radiation dose rate was also done by monitoring the radiation dose rate using a fluke survey in the CT-Scan room of the DR. Drs. M. Hatta Bukittinggi Brain Hospital. The measurement findings showed that the radiation dose level around the CT-Scan room varied between 0 and 0.367 $\mu\text{Sv/h}$.

Pariaman Regional General Hospital is a regional general hospital in Pariaman City, West Sumatra. This hospital has radiology facilities with conventional radiography, CT-Scan, dental panoramic, mammography, and ultrasound. The radiation dose rate in the radiology installation at Pariaman Hospital was determined using a PDR 303 gamma survey meter in this study. The rooms to be measured consist of 3 rooms, namely the mammography room (Figure 1.a), CT-Scan (Figure 1.b), and conventional X-ray (Figure 1.c).

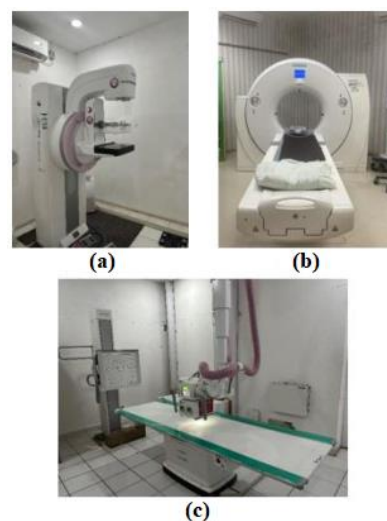


Figure 1 (a) Mammography, (b) CT-Scan and (c) Conventional X-ray

Dose rate measurements were carried out to improve radiation protection by minimizing the adverse effects caused by ionizing radiation and to ensure whether or not there is radiation

leakage in the radiology room. Evaluation of radiation protection facilities is carried out based on Nuclear Energy Regulatory Agency Regulation No. 4 of 2020 and the application of three principles of radiation protection: time, distance, and use of shielding. In addition, the dose rate received by radiation workers will also be evaluated to determine the estimated dose received by radiation workers at Pariaman Hospital. This study was conducted to ensure that the radiology of Pariaman Hospital has good radiation protection, thus indicating there is no exposure to radiation outside the room when radiation sources are used so that the radiation dose received by workers or the general public does not exceed the Dose Limit Value.

METHODOLOGY

The study was conducted at the Pariaman Regional General Hospital using a PDR 303 survey meter. Surveymeter PDR 303 is a gamma radiation dose measuring instrument designed for the measurement of environmental radiation dose levels. The PDR 303 surveymeter uses silicon semiconductor detectors. Silicon-based detectors are used in charged particle and X-ray detectors. This tool has a measurement range between 0.1 $\mu\text{Sv}/\text{hour}$ to 1 Sv/hour . Figure 2 shows the research stages that will be carried out to determine the dose rate at the radiology installation of the Pariaman Regional General Hospital.

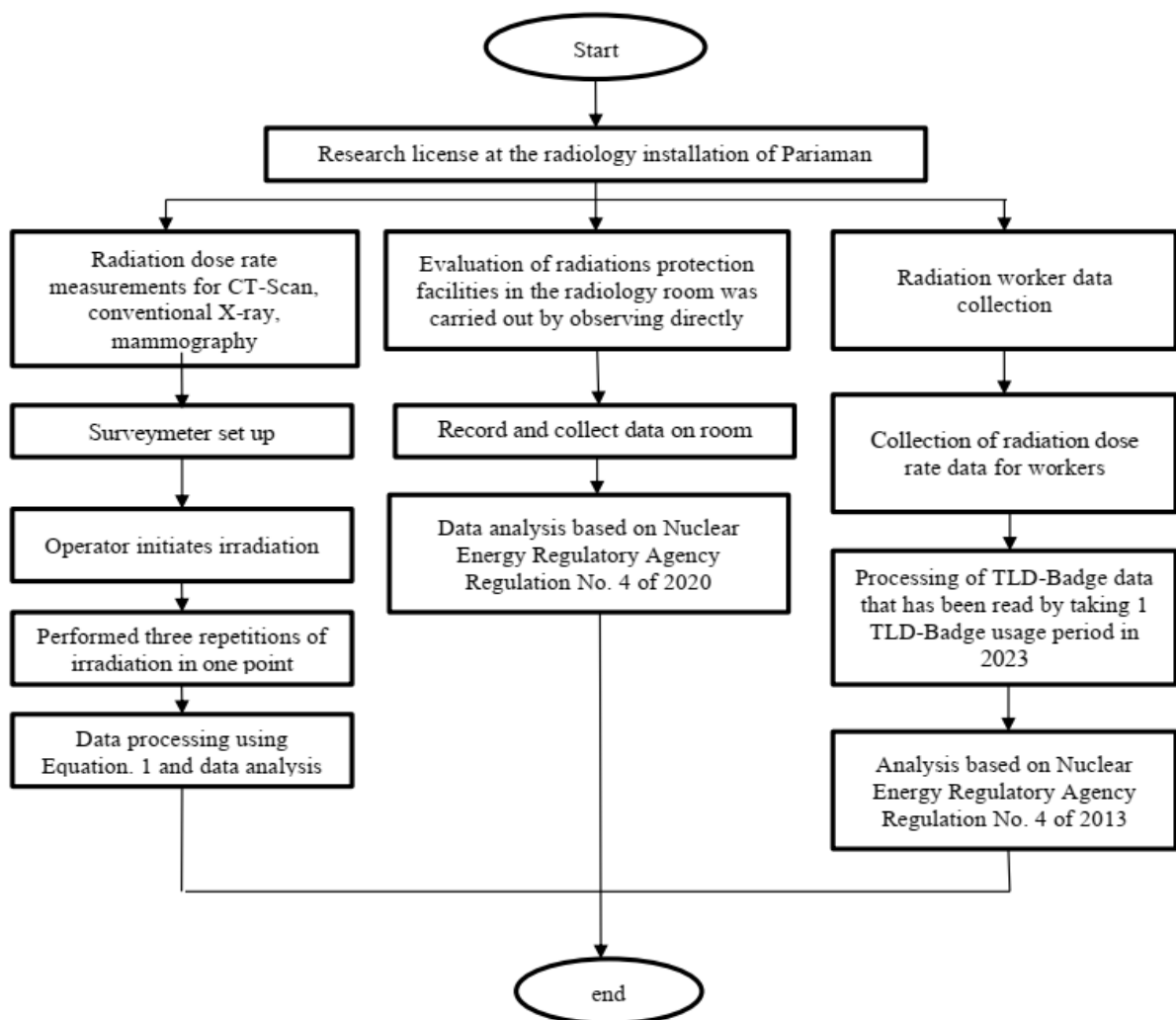


Figure 2 Research Stages

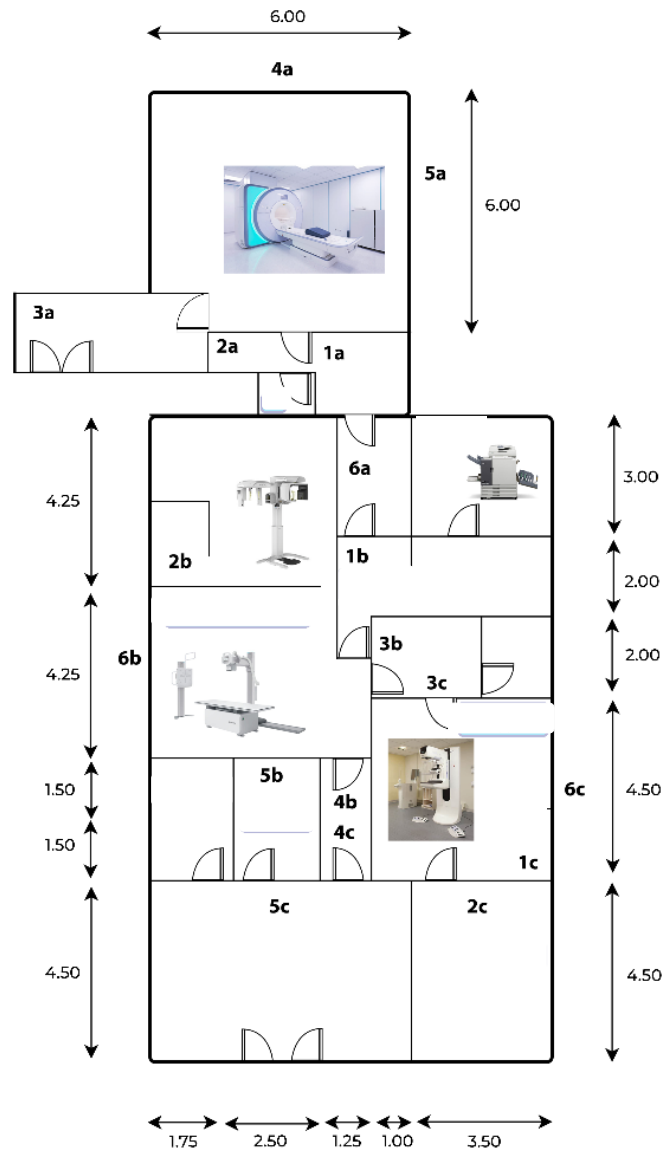


Figure 3 Measurement points

The measurement of radiation dose rate begins with determining the radiation dose measurement point in three radiology rooms, namely CT-Scan, conventional X-ray, and mammography. Each room is measured at six different measurement points using a survey meter. Measurement points in each room can be seen in the Figure 3.

The background dose and the dose around the room are measured in each room. The measurement was carried out with three repetitions. The background and measured dose rates were then used to determine the actual dose rate value using Equation 1 ($\dot{D}_s$ is true dose rate ($\mu\text{Sv}/\text{hour}$), $\dot{D}_U$ is radiation dose ($\mu\text{Sv}/\text{hour}$), $\dot{D}_{Bg}$ is background radiation dose ($\mu\text{Sv}/\text{hour}$) and F_k is calibration factor).

$$\dot{D}_s = \dot{D}_U - \dot{D}_{Bg} \times F_k \quad (1)$$

Furthermore, the evaluation of radiation protection facilities was reviewed by observing directly in the four radiology rooms. After the review, the completeness of the existing protection is recorded and analyzed based on Nuclear Energy Regulatory Agency Regulation No. 4 of 2020. Finally, processing the dose data on radiation workers in 2023 which has been measured by TLD-badge. The data obtained will then be analyzed based on Nuclear Energy Regulatory Agency Regulation No. 4 of 2013.

RESULTS AND DISCUSSION

Radiation dose rate measurements in the mammography room were carried out at

six different measurement points. As shown in Table 1, shows that measurement point 3c produces the highest radiation dose rate of $(0.40 \pm 0.08) \mu\text{Sv/hour}$. Point 3c is a toilet. The lowest radiation dose rate is found at point 5c which is $(0.03 \pm 0.05) \mu\text{Sv/hour}$. Point 5c is a patient waiting room.

Table 1. Radiation dose rate in the Mammography room

Measurement points	The value of radiation dose rate ($\mu\text{Sv/hour}$)
Control room (1c)	0.27 ± 0.05
Administration room(2c)	0.17 ± 0.05
Toilet (3c)	0.40 ± 0.08
Patient corridor (4c)	0.17 ± 0.09
Patient waiting room (5c)	0.03 ± 0.05
Pharmacy room (6c)	0.17 ± 0.09

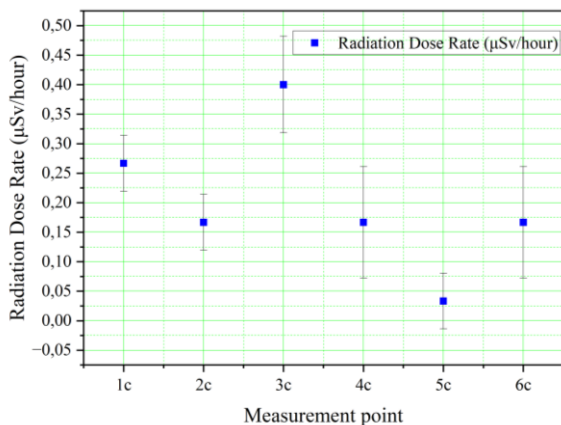


Figure 4 Distribution of radiation dose rate in the Mammography room

These results are still below the dose limit value determined by Nuclear Energy Regulatory Agency Regulation No. 4 of 2013. Based on the length of time radiation workers work in a day, the conversion of the dose limit value determined by Nuclear Energy Regulatory Agency Regulation No. 4 of 2013 for workers is $10 \mu\text{Sv/hour}$ and for the general public is $0.5 \mu\text{Sv/hour}$. This is because the radiation shield used is in accordance with applicable standards and the radiation source produces small radiation.

Radiation dose rate measurements in the CT-Scan room were carried out at 6 (six)

different measurement points shown in Table 2.

Table 2. Radiation dose rate in the CT-Scan

Measurement points	The value of radiation dose rate ($\mu\text{Sv/hour}$)
Control room (1a)	0.35 ± 0.05
Attendant door (2a)	1.61 ± 0.14
Patient waiting room (3a)	1.02 ± 0.05
Parking (4a)	0.61 ± 0.08
Doctor's office (5a)	0.34 ± 0.07
Officer corridor (6a)	0.24 ± 0.03

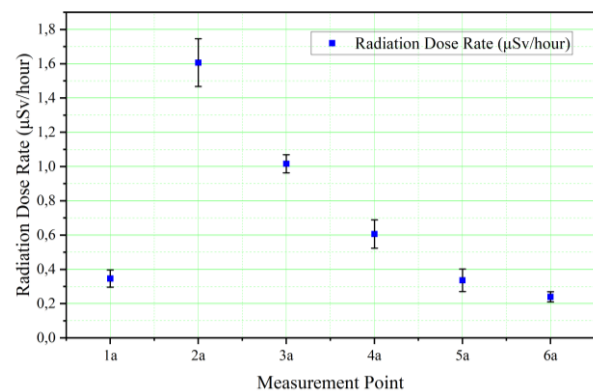


Figure 5 Radiation dose rate distribution in the CT-Scan room

In Figure 5, it can be seen that measurement point 2a produces the highest radiation dose rate of $(1.61 \pm 0.14) \mu\text{Sv / hour}$ where point 2a is the CT-Scan control room officer's door. The high dose rate at that point is thought to be caused by the gap in the officer's door. The lowest radiation dose rate is found at point 6a which is $(0.24 \pm 0.03) \mu\text{Sv/hour}$ where point 6a is an officer corridor, this is because the distance to the measurement point is far from the radiation source and good radiation shielding so that not much radiation is scattered out. The radiation shielding used is a 4 mm layer of Pb and 28 cm thick concrete.

From this radiation dose value, it is known that there are two measurement points, namely in the parking lot and patient waiting room, there is a radiation dose that exceeds the radiation dose limit for the

community, this is thought to be due to radiation leakage caused by doors or wall structures so that the radiation spread around the room is large.

Radiation dose rate measurements in conventional X-ray rooms were carried out at six different points with maximum and minimum exposure factors. As shown in Table 3 obtained measurement point 2b produces the highest radiation dose rate of $(0.33 \pm 0.01) \mu\text{Sv/hour}$, point 2b is a panoramic room. This conventional X-ray room is adjacent to the panoramic room, but when the conventional X-ray plane is turned on, the panoramic plane is off. The high dose rate at this point is thought to be caused by the gap in the door between the conventional X-ray room and the panoramic room. Measurement point 6b produced the lowest radiation dose rate of $(0.13 \pm 0.02) \mu\text{Sv/hour}$ where point 6b is a corridor. The radiation shielding used at point 6b is in accordance with applicable standards, namely 28 cm thick concrete coated with 4 mm thick Pb.

Table 3. Radiation dose rate in a conventional X-ray room with minimum exposure factor

Measurement point	The value of radiation dose rate ($\mu\text{Sv/hour}$)
Control room (1b)	0.27 ± 0.02
Panoramic room (2b)	0.33 ± 0.01
Toilet (3b)	0.22 ± 0.04
Patient corridor (4b)	0.17 ± 0.02
Ultrasound room (5b)	0.15 ± 0.03
Public corridor (6b)	0.13 ± 0.01

Table 4 shows that measurement point 2b produces the highest radiation dose rate of $(1.08 \pm 0.031) \mu\text{Sv/hour}$, point 2b is a panoramic room. The high dose rate at that point is thought to be caused by the gap in the door connecting the panoramic room and the distance to the radiation source is quite close. The lowest dose rate value is found at point 4b which is $(0.33 \pm 0.04) \mu\text{Sv/hour}$, point 4b is a patient hallway. This is because the shield used is in accordance with applicable standards so that it can absorb all scattering radiation from ongoing irradiation.

Table 4. Radiation dose rate in a conventional X-ray room with maximum exposure factor

Measurement point	The value of radiation dose rate ($\mu\text{Sv/hour}$)
Control room (1b)	0.48 ± 0.13
Panoramic room (2b)	1.08 ± 0.31
Toilet (3b)	0.82 ± 0.08
Patient corridor (4b)	0.33 ± 0.04
Ultrasound room (5b)	0.37 ± 0.01
Public corridor (6b)	0.59 ± 0.60

Radiation dose measurements under irradiation conditions with the maximum exposure factor, showed that points 2b, 3b, and 6b exceeded the radiation dose threshold permitted for the general public. This is believed to be due to radiation leakage around the rooms, potentially related to the high intensity of radiation exposure generated, as well as deficiencies in the connecting door structure of the rooms. To address this issue, a thorough evaluation of the design and materials of the room doors is essential to ensure that the escaping radiation is minimized and does not exceed the established dose limits.

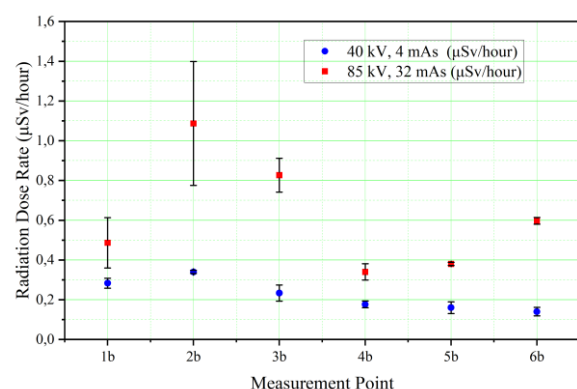


Figure 6 Radiation dose rate distribution in the conventional X-ray room

Irradiation with a minimum exposure factor obtained radiation doses that are below the radiation dose limit value for radiation workers or the public. This low radiation dose proves that if the exposure factor used is small, the radiation that comes out is also small so that there is no radiation leakage around the room.

Based on the radiation worker's working time, the conversion of the dose limit value determined by the Nuclear Energy Regulatory Agency Regulation No. 4 of 2013 is 10 $\mu\text{Sv/h}$, while for the general public, it is 0.5 $\mu\text{Sv/h}$. From the result, it was known that the dose rate in the mammography room was below the specified dose limit value; in the CT-Scan room was found at several points where the radiation dose rate measurement exceeded the specified radiation dose limit value, this was due to the gap in the officer's door that was able to pass a large amount of radiation. For the radiation dose rate in the conventional X-ray room, the considerable radiation dose rate value was significant, with an exposure factor value with a tube voltage of 80 kV and a time current of 32 mAs. The radiation dose obtained with this maximum exposure factor has several measuring points that exceed the radiation dose limit value for the general public. This can be expected due to leakage in the surveillance area which can occur if there are deficiencies in the shielding design, such

as gaps or cracks in the walls or joints or doors that are not tight. In addition, the radiation dose rate was measured with a minimum exposure factor, namely with a tube voltage of 40 kV and a time current of 4 mAs. This dose was below the specified dose limit value this data proved that the greater the voltage, the greater the radiation produced.

Based on the measurement results obtained, the radiation dose rate value is greater than the research of (Cahyati et al., 2017; Wahyudi & Milvita, 2018). Research that has a measurement point that has a radiation dose rate value exceeding the radiation dose limit is the research of (Ratini et al., 2019) which is equal to (40.64-142.32) $\mu\text{Sv/hour}$. This must be reviewed regarding the radiation protection used by the hospital under study (Hiswara et al., 2016, 2020; Putri et al., 2023; Sawyerr et al., 2020; Telleria & Proehl, 2013). In addition, it is also necessary to pay attention to the optimality of the use of the door so that there is no gap in the door.

Table 5 Evaluation of room radiation protection facilities based on the Nuclear Energy Regulatory Agency Regulation No. 4 of of 2020

No.	Radiation protection facility	Regulation from the Nuclear Energy Regulatory Agency No. 4 of of 2020	Room		
			CT-Scan	Conventional X-ray	Mammography
1.	Pb glass	Radiation workers can clearly observe the patient from the control room through the Pb glass	√	√	√
2.	Access door	The room door must always be tightly closed during irradiation	√	√	√
3.	Warning signs for radiation	Signs must be posted at the entrance to the control area	√	√	x
4.	Hazard lamp	The lights are placed at the entrance to the radiology room	√	√	√
		The lights must be turned on during irradiation	√	√	x
5.	Cooling system	The radiology room has an adequate cooling system	√	√	√

Note:

√ : meets the standard of the Nuclear Energy Regulatory Agency No. 4 of of 2020

x : does not meet the standard of the Nuclear Energy Regulatory Agency No. 4 of of 2020

Because at the measurement point with the highest dose rate value, most of them are on the door. The parking lot and public corridors should also be evaluated to find out why radiation leakage can occur. Checks should be made by examining the structural parts of the walls or windows to detect gaps, cracks or damage to the radiation shielding material. After all the problems have been evaluated, the hospital is expected to quickly make repairs or add protective layers such as lead if there is a shortage in the thickness of the protection.

After direct observation, the evaluation of radiation protection facilities in the CT-Scan room, conventional X-rays and mammography was recorded using the radiation protection evaluation form that had been prepared. The regulated radiation protection facilities can be seen in Table 5.

Table 5 shows that three rooms in radiology installation has met the requirements set out in the Nuclear Energy Regulatory Agency No. 4 of 2020. However, several things still need to be considered for meeting the requirements. Pariaman Regional General Hospital uses Pb glass with a thickness of 4 mm in the CT-Scan and conventional X-ray control rooms, and the mammography control room uses Pb glass with a thickness of 2 mm.

The CT-Scan, conventional X-ray, and mammography rooms have different access doors for worker and patient radiation. The access door for the CT-Scan room is 5-6 cm thick and coated with 4 cm of Pb, while the conventional X-ray and mammography room doors have a Pb layer of 2 mm. No radiation hazard sign exists on the conventional X-ray and mammography room doors.

However, a radiation hazard sign is installed on the patient waiting room's wall, representing the radiation hazard in the two rooms. The radiation hazard sign for the CT-Scan room is installed on the door and attached to the side wall of the room door. The CT-Scan, conventional X-ray, and mammography rooms

have radiation hazard warning lights according to existing regulations, where a warning light is installed on the X-ray room door and must be on when irradiation occurs. In addition, the CT-Scan, conventional X-ray, and mammography rooms are equipped with a cooling system so that the radiation source device does not get too hot and prevents room humidity that causes interference with the X-ray machine.

The radiation dose to worker radiation was obtained from TLD-Badge in 2023 obtained from secondary data (Table 6). The highest TLD-Badge reading in 2023 was obtained from the TLD-Badge used by physician, which was 0.146 mSv/year, and the lowest TLD-Badge reading was obtained from the TLD-Badge used by radiographers, which was 0.036 mSv/year. Based on observations during the study, it is known that radiation workers in the radiology room rarely use the TLD-Badge (Thermoluminescent Dosimeter) during work. This could potentially affect the optimal measurement of radiation dose, as the TLD-Badge is not used consistently during irradiation or while in the radiology room.

Table 6 Radiation dose rate for radiation workers for the period January-December 2023

No.	The initial of the workers	Average radiation dose received (mSv/year)	Dose Value (Nuclear Energy Regulatory Agency No. 4 of 2020)	Limit
1	WA	0.045	20 mSv/year	
2	FH	0.055		
3	MP	0.090		
4	AW	0.065		
5	YR	0.060		
6	AR	0.049		
7	OMR	0.081		
8	AS	0.036		
9	VBJ	0.060		
10	RT	0.068		
11	dr. IN	0.146		
12	SF	0.040		
13	IZ	0.058		

The highest radiation dose was recorded for the doctor's TLD-Badge, which is thought to be due to the doctor's consistency in wearing the TLD-Badge while in the radiology room. This consistency allows the TLD-Badge to record accumulated radiation exposure more representatively compared to other workers who rarely use the device.

Increased awareness and implementation of radiation safety protocols, including the mandatory routine use of the TLD-Badge, are needed to ensure accurate radiation dose measurement and protection of workers' health.

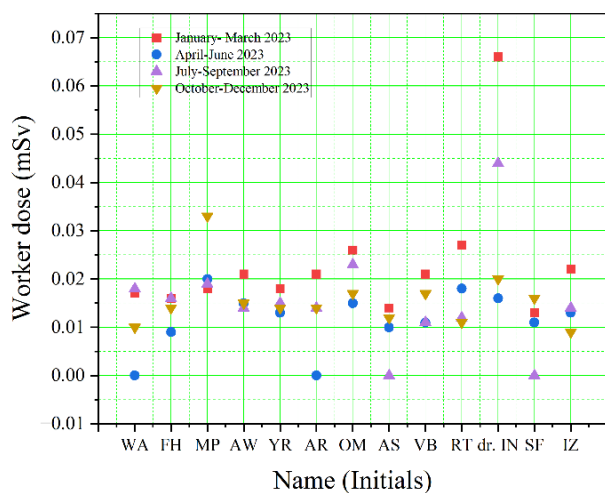


Figure 7 Dose distribution of radiation workers in 2023

The results of the TLD-Badge reading show that the dose rate received by radiation workers does not exceed the dose limit value set by the Nuclear Energy Regulatory Agency Regulation No. 4 of 2013. However, radiation workers must maintain safety while working so that the radiation dose is as low as possible.

In this study, it was found that the radiation dose rate value for low radiation workers from research conducted by (Harwin et al., 2023; Sahfira et al., 2024; Yashima & Chida, 2023). This is because the radiation protection applied by the hospital is in accordance with the standard. Dose of radiation workers is measured based on effective dose and equivalent dose (Demb et al., 2019; Shubayr et al., 2021).

CONCLUSION

Based on research on the radiation dose rate in the Radiology Installation of Pariaman Hospital using the PDR 303 gamma survey meter, it can be informed that the radiation dose rate at the CT-Scan room was (0.24-1.61) $\mu\text{Sv/h}$. In the conventional X-ray room with irradiation using an exposure factor of 32 kV and 4 mAs, the radiation dose rate was between (0.013-0.33) $\mu\text{Sv/h}$. Moreover, with an exposure factor of 85 kV and 32 mAs, the dose rate was (0.33-1.08) $\mu\text{Sv/h}$. Furthermore, in the mammography room, the dose rate was (0.03-0.40) $\mu\text{Sv/h}$.

The radiology room facilities used by Pariaman Hospital met the standard set by the Indonesian Nuclear Energy Regulatory Agency No.4 of 2020. However, several room facilities still need to meet the standards. The dose rate received by seventeen radiation workers at Pariaman Regional Hospital was below the Dose Limit Value set by the Nuclear Energy Regulatory Agency Regulation No. 4 of 2013.

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