Determination of Radiation Dose Rate in Radiology Installations Using Raysafe X2 Surveymeter

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Abstract *- Based on the study of radiation dose rates in the Radiology Installation of Pariaman Regional Hospital using a Raysafe surveymeter, it can be reported that the radiation dose rate in the CT-Scan room is measured at (0.30-1.27) μSv/hour. In the conventional X-ray room, the radiation dose rate is found to be between (0.2-0.5) μSv/hour, while in the mammography room, the dose rate ranges from (0.00-0.40) μSv/hour. These findings indicate that the highest radiation exposure occurs in the CT-Scan room, which aligns with the higher complexity and intensity of the imaging procedures performed there. The relatively low dose rates in the conventional X-ray and mammography rooms suggest effective radiation shielding and adherence to safety protocols. Continuous monitoring of radiation levels is essential to ensure they remain within safe limits for both patients and medical staff. Furthermore, this data can be instrumental in optimizing exposure parameters, helping to minimize unnecessary radiation exposure while maintaining diagnostic quality. Implementing regular training for staff on radiation safety practices is also critical, as it enhances awareness and adherence to established protocols. Overall, these measures contribute to a safer radiology environment for all involved.*

Keywords*: CT-Scan; dose rate; mammograpy; raysafe X2; X-ray*

INTRODUCTION

The radiation dose rate is an important parameter in ensuring safety and protection, specifically in medical environments such as radiology installations (Baudin et al., 2021; Fardela et al., 2021; Hidayatullah, 2017; Hricak et al., 2011; Paolicchi et al., 2016; Putri et al., 2023). Radiodiagnostics is a procedure that aims to detect damage or abnormalities in organs as well as cancer using low-energy X-ray devices, producing anatomical images as a result. There are several types of x-ray devices used in the diagnostic field namely Computed Tomograpy (CT-Scan), Mammography, conventional X-rays and Panoramic (Behling, 2016). Moreover, the equipment and techniques used in radiology practice need to be closely monitored to ensure the radiation dose received by patients and workers does not exceed the established safe limits (Amis et al., 2007; Chinangwa et al., 2017; Fardela et al., 2020; IAEA, 2002; Johary et al., 2023). The International Commission on Radiological Protection (ICRP) establishes three main principles in radiation protection: justification, optimization, and limitation. Justification refers to any activity involving radiation must have a clear benefit or value. Optimization means that any use of radiation should be kept as low as necessary. Limitation aims to ensure that radiation exposure does not exceed the dose limits set by the relevant authorities. There is also the need to implement a series of steps to protect people from the dangers of radiation exposure, both stochastic and deterministic. This can be achieved by measuring the level of exposure in the radiology room (Dja'afar et al., 2022). Furthermore, for every activity related to the use of ionizing radiation, protection needs to be optimized by ensuring the number of people exposed as well as the possibility and magnitude of exposure are kept as low as reasonably achievable

(ALARA) (Bolognese-Milsztajn et al., 2004; Rahman et al., 2020). This optimization is the key to achieving the goal of radiation protection which focuses on preventing deterministic effects and reducing the possibility of stochastic effects (Abuelhia & Alghamdi, 2020; Kiragga et al., 2018; Mitelman et al., 2007; Zira et al., 2020). Radiation exposure in a medical context is intended to provide direct benefit to the exposed individual but some community members and radiation workers can be subjected to higher doses than recommended due to ineffective shielding mechanisms (Alemayehu et al., 2023; BAPETEN, 2013; Brown & Jones, 2013; Fardela et al., 2023; Mohammad & Najam, 2019).

The use of X-ray machines in diagnostic and interventional radiology requires a permit showing the user meets radiation safety requirements, as regulated in the Regulation of the Nuclear Energy Regulatory Agency Number 4 of 2020 (Kepala Badan Pengawas Tenaga Nuklir Republik Indonesia, 2020).

Extensive research has been conducted on radiation dose rates. For example (Rochmayanti et al., 2018) focused on the profile of occupational radiation exposure and the effectiveness of the shielding mechanism in the radiology department of Semarang City to optimize the protection system. The results showed that 4 out of 5 radiology institutions recorded radiation exposure on survey meter and only 1 hospital showed no leakage. Moreover, (Lee et al., 2004) determined the level of awareness of radiation dose and possible risks associated with the use of CT-Scan among patients, emergency physicians, and radiologists. The research found that all patients and most emergency physicians, as well as radiologists, could not accurately estimate the dose for a single CT-Scan compared to the single chest radiograph. Another research by (Savage et al., 2013) reported that eye exposure was reduced by 99% for Zgrav with enhanced face protection compared to LAS (Lead-Apron-Shield). The overall reduction in eye and head exposure for the entire research was 94%.

Raysafe surveymeter is part of the tools often used to measure the radiation dose rate. It is a portable instrument specifically designed to measure ionizing radiation with high accuracy. The tool is often used for area monitoring in radiology installations to ensure the work environment remains safe based on radiation safety standards. (Hariyanto & Sidik, 2019; Irsal et al., 2020).

Pariaman Regional General Hospital has complete and modern radiology facilities, consisting of conventional radiography, CT-Scan, dental panoramic, mammography, and USG examination rooms. Therefore, the radiation dose rate in the radiology installation of the hospital was determined using the Raysafe X2 surveymeter as presented in Figure 1.

Figure 1. *Surveymeter* rasysafe X2

The focus was on 3 rooms, including the mammography, CT-Scan, and conventional X-ray. The aim was to ensure compliance with applicable regulations and preventive measures required to protect medical personnel and patients from the dangers of radiation. The dose rate in each room was analyzed based on BAPETEN Regulation No. 4 of 2013.

RESEARCH METHODS

This research was conducted at Pariaman Regional General Hospital using a raysafe surveymeter. Figure 2 shows the stages of research that will be carried out to determine the radiation dose rate in the radiology installation of Pariaman Regional General Hospital.

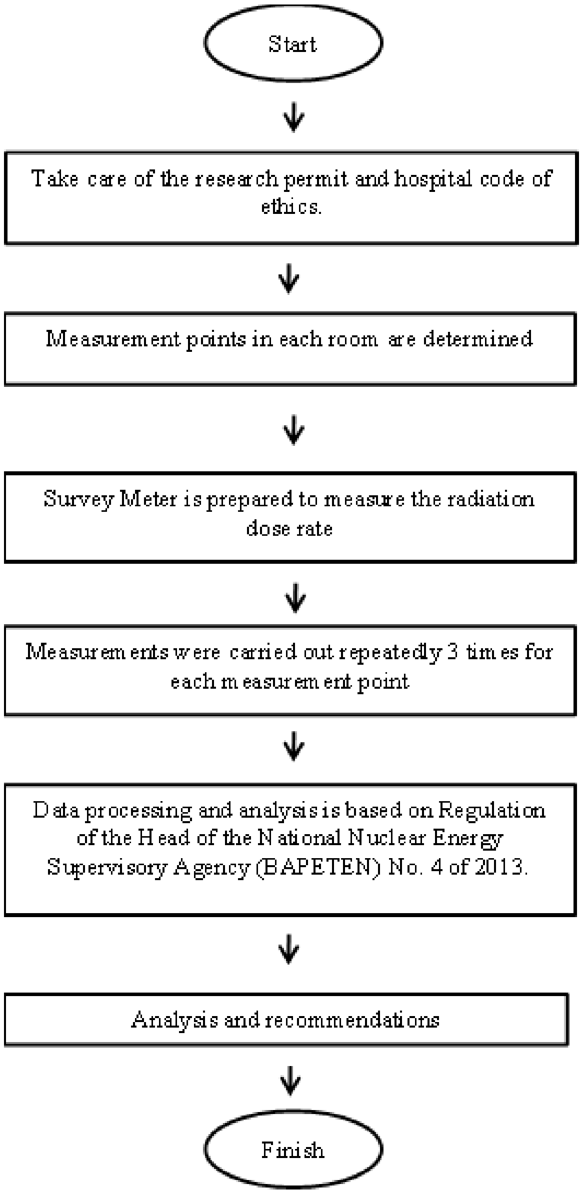

Figure 2. Research Stages

Measurement of radiation dose rate begins with determining the radiation dose measurement points in three radiology rooms, namely: CT-Scan, mammography and conventional X-ray. Each room will be measured at six different measurement points (Figure 3) and each measurement point is irradiated three times. The background dose and ambient dose are measured in each room. The background dose rate and measured dose rate are then used to determine the true dose rate value using Equation 1.

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

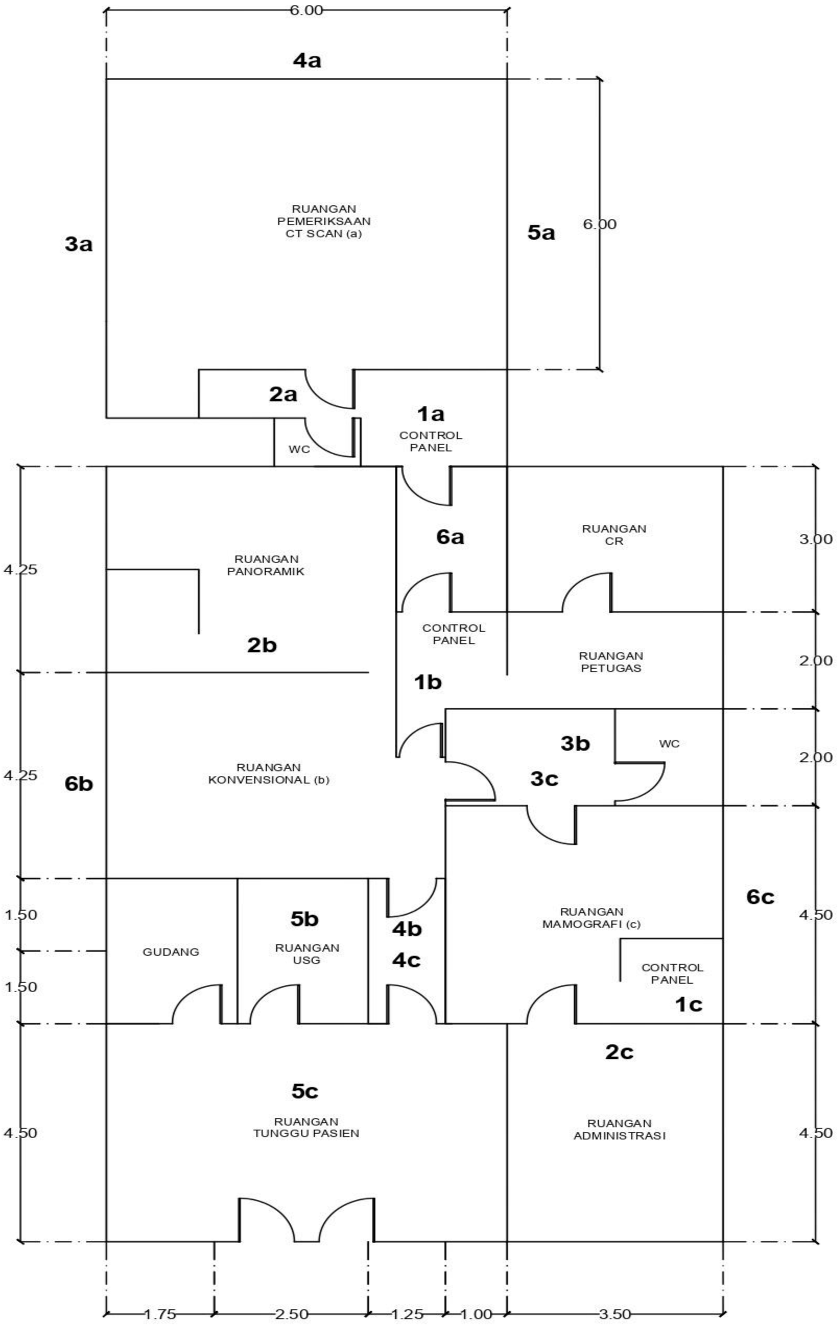

Figure 3. Measurement points in each room

The results were compared with the requirements stated in BAPETEN Regulation No. 4 of 2013 to ensure the rate around the rooms is safe for radiation workers, patients, and members of the community. Moreover, the exposure of the workers was also evaluated based on the assumption of 3 working hours in a day.

RESULTS AND DISCUSSION

Results

Measurement of radiation dose rate in the mammography room was carried out at six different measurement points. Table. 1 shows that measurement point 3c produces the highest radiation dose rate of (0.40±0.08) μSv/hour. Point 3c is a toilet. The lowest radiation dose rate is found at point 5c which is (0±0) μSv/hour. Point 5c is a patient waiting room.

Figure 4 shows the distribution of radiation dose rate data in the mammography room, on the graph it can be seen that the standard deviation of the measurement is not too large because the average value of the measured radiation dose rate is relatively constant.

Table 1. Radiation dose rate in the Mammography room

Measurement points	The value of radiation dose rate (μSv/h)
Control Room	0,27±0,05
Administration Room	0,17±0,05
Toilet	0,40±0,08
Patient Corridor	0,17±0,09
Patient Waiting Room	0,00±0,00
Pharmacy Room	0,13±0,05

The radiation dose rate obtained in the mammography room is below the radiation dose limit value determined by BAPETEN Regulation No. 4 of 2013.

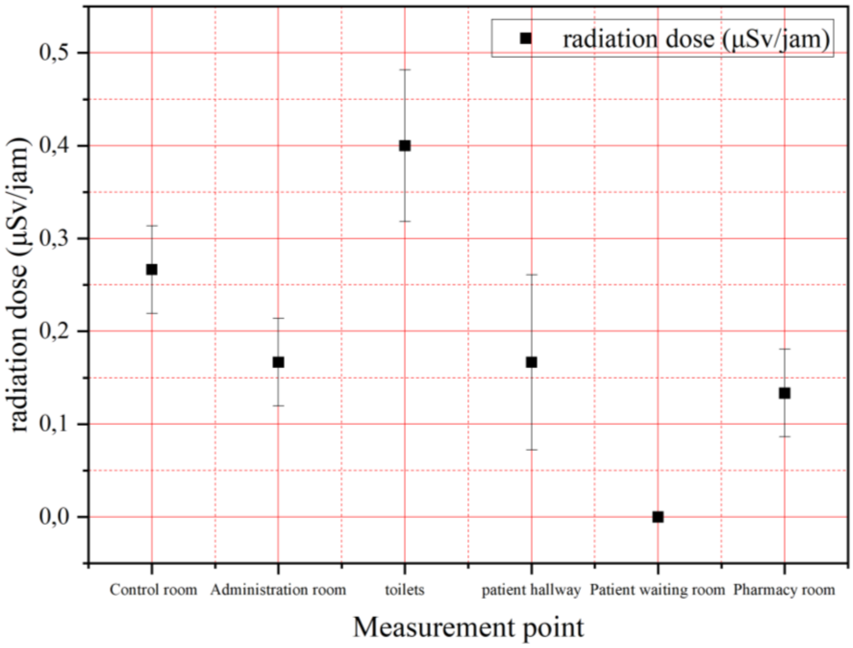

Figure 4. Distribution of radiation dose rate in the Mammography room

The results of radiation dose rate measurements in the CT-Scan room can be seen in Table 2.

Table 2. Radiation dose rate in the CT-Scan room

Measurement points	The value of radiation dose rate (μSv/h)
Control room	0,53±0,12
Attendant door	1,27±0,17
Patient waiting room	0,70 ±0,17
Parking	0,47±0,16
Doctor's office	0,30±0,05
Officer corridor	0,47±0,09

According to Figure 5, Point 2 a which is the door of the CT-Scan control room has the highest radiation dose rate of 1.27 ± 0.17 µSv/hour while Point 6a, the corridor of the office has the lowest with 0.30 ± 0.08 µSv/hour. The high value recorded was estimated to be due to the gap in the door of the CT-Scan office which allowed the spread of the radiation out of the room. Even though the dose rate is below the limit required, the radiation protection used in the CT-Scan room needs to be evaluated. This is due to the fear that the radiation around the room can eventually exceed the limit for radiation workers, patients, and the public.

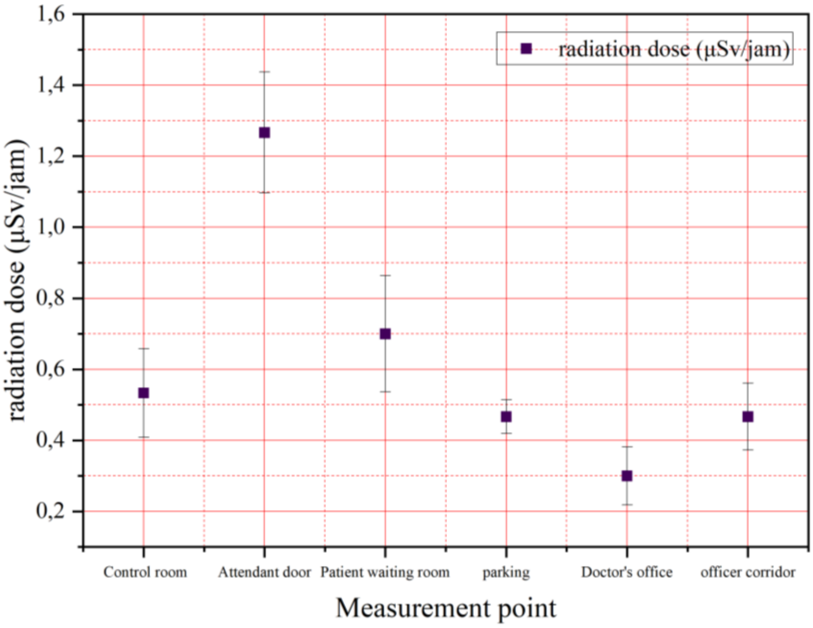

Figure 5. Radiation dose rate distribution in the CT-Scan room

Radiation dose rate measurements in the conventional X-ray room were performed at six different points (Table 3).

Table 3. Radiation dose rate in a conventional X-ray room

Measurement point	The value of radiation dose rate (µSv/h))
Control Room	0,31±0,00
Panoramic Room	0,48±0,12
Toilet	0,17±0,05
Patient Corridor	0,17±0,05
Ultrasound Room	0,27±0,05
Public Corridor	0,41±0,00

As seen in Figure 6, measurement point 2b produced the highest radiation dose rate of (0.48±0.12) µSv/hour, point 2b is the 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 points 3b and 4b produced the lowest radiation dose rate of (0.17 ± 0.05) µSv/hour where points 3b and 4b are the patient's toilet and hallway. The radiation shields used at points 3b and 4b are in accordance with the applicable standards, namely 28 cm thick concrete coated with 4 mm Pb.

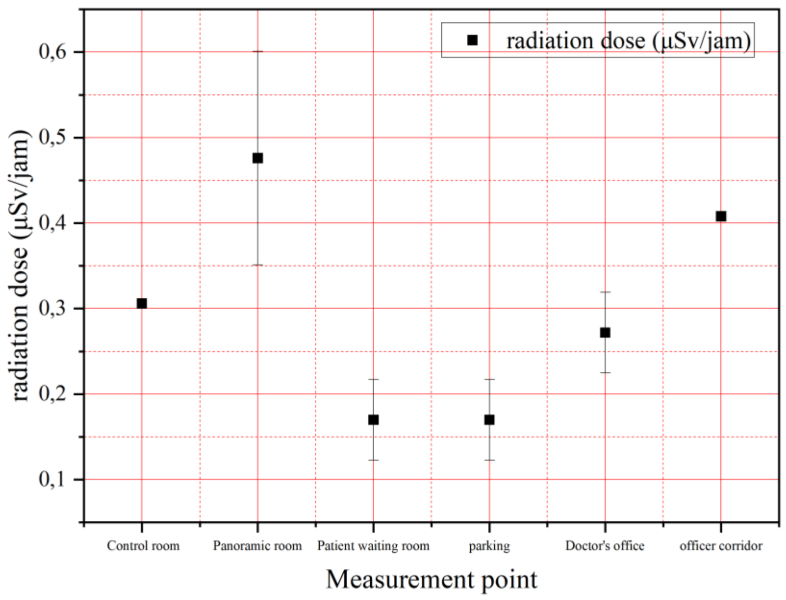

Figure 6. Radiation dose rate distribution in the conventional X-ray room

Based on BAPETEN Regulation No. 4 of 2013, the exposure of radiation workers is not expected to exceed 20 mSv in 1 year and the limit for the general community is 1 mSv in the same period. The results showed that the dose rate in the mammography, conventional X-ray, and CT-Scan rooms was below the specified dose limit value.

The rate recorded in each of the radiology rooms could be used by medical physicists to estimate the average radiation dose received by radiation workers for 1 year based on the assumption of 3 hours of exposure in a day. The results obtained in this research are presented in the following Table 4.

Table 4. Radiation worker's radiation dose for one year

No.	Room	Radiation dose rate (µSv/h)	Estimated radiation dose received by radiation workers (mSv/year)
1.	Mammography	0,27	0,20
2.		0,17	0,13
3.		0,40	0,30
4.		0,17	0,13
5.		0,00	0,00
6.		0,13	0,10
7.	CT-Scan	0,53	0,40
8.		1,27	0,95
9.		0,70	0,53
10.		0,47	0,35
11.		0,30	0,23
12.		0,47	0,35
13.	X-rays conventional	0,31	0,23
14.		0,48	0,36
15.		0,17	0,13
16.		0,17	0,13
17.		0,27	0,20
18.		0,41	0,31

The accumulated working time for 1 day was estimated to be 3 hours while the radiation dose received by radiation workers for 1 year was 0.00-0.95 mSv/year. This showed that the workers received a small radiation and the value was significantly lower than the limit value determined by BAPETEN Regulation No. 4 of 2013. Moreover, the value on the TLD badge worn by the workers when irradiating was almost similar to the calculated radiation dose value.

Discussion

Figure 4 shows a graph of the radiation dose rate in various rooms around the mammography room. When the mammography radiology equipment is activated, the highest radiation dose rate is found in the toilet room. This is thought to be due to the gap in the door connecting the toilet with the mammography room. The spread of radiation around the mammography room can be minimized by the use of radiation shielding in accordance with BAPETEN standards (Kepala Badan Pengawas Tenaga Nuklir Republik Indonesia, 2020). Appropriate shielding materials are needed to reduce radiation dose, i.e. materials that are able to absorb radiation energy or reduce radiation intensity. The linear absorption coefficient of radiation shielding varies depending on the type of shielding material and the energy of the radiation source. In addition, the selection of shielding materials should consider the appropriate thickness and type of material for more effective protection. Examples of commonly used shielding materials are lead, concrete, and composite materials that have high absorption properties (Dhanesar, S. K., Rojas, C. E., & Wolff, 2017; Yusoff, N. M., Salleh, N. M., & Hamid, 2020). Periodic testing of shielding effectiveness is also important to ensure that radiation doses remain within safe limits. With the optimal application of shielding, the risk of radiation exposure for medical personnel and people around the room can be significantly reduced.

Figure 5 shows the radiation dose rate graph around the CT-Scan room. Based on the measurements at six points, it is revealed that the radiation dose rate measured when the CT-Scan device is operated is still below the predetermined dose threshold. Although the radiation dose value around the door of the radiation officer's room tends to be higher, this figure is still within safe limits in accordance with the Dose Limit Value (NBD) intended for radiation officers. This larger dose is likely due to the relatively close distance of the door to the CT-Scan device, so that the surveymeter captures more radiation. Basic principles of radiation safety from external sources of ionizing radiation emphasize that distance is the main factor affecting the level of radiation exposure. The closer a person is to a radiation source, the higher the exposure received, and vice versa (International Commission on Radiological Protection, 2019; Nash, C., & Nair, 2020).

In addition to maintaining distance, the use of protective shields in areas with high exposure potential, such as around doors, is also important to protect radiation officers. Periodic evaluation of radiation shielding and room layout is necessary to ensure that radiation exposure remains within safe limits (IAEA, 2014). More advanced surveymeter technology can also help to measure and monitor radiation dose more accurately so that preventive measures can be taken more quickly.

Figure 6 shows a graph of radiation dose rates in various rooms around a conventional X-ray room. The radiation dose rate measured from conventional X-ray equipment is relatively small, as the measurements are made using an exposure factor commonly used for patients with normal body weight. The exposure factor in conventional X-rays can be adjusted according to the condition of the patient who will undergo the examination (Buch, K., & Wenzel, 2017; Kumar, A., & Bansal, 2020; Seeram, 2018). For example, patients with a smaller body weight will receive a lower exposure factor than patients with a larger body weight or obesity. The greater the patient's weight, the higher the radiation dose used. However, in this measurement, the dose used was appropriate for a patient with a normal body weight, so the resulting radiation dose rate was below the threshold set for radiation workers and the general public.

In addition, this low radiation dose rate may also be due to the presence of radiation shielding in the room that has met safety standards according to BAPETEN regulations. Nonetheless, there were higher radiation dose values in the mammography room adjacent to the conventional X-ray room. This is likely due to the fact that the door between the two rooms could not be closed properly, leading to radiation leakage. Regular monitoring of the condition of the shields and doors is necessary to ensure an optimal level of safety (Mettler, F. A., & Guiberteau, 2012).

The results of radiation dose measurements in various rooms of an X-ray aircraft can be used to estimate the radiation exposure received by radiation workers. Radiation workers tend to have high levels of radiation exposure because they are often around radiological areas. Table 4 presents the radiation doses received by radiation workers over a year, assuming that each worker is exposed to radiation for three hours each day. The calculation results show that the radiation dose received by radiation workers is below the maximum limit set by the Head of BAPETEN Regulation No. 4 of 2013, which states that radiation workers should not receive radiation doses of more than 20 mSv in one year (BAPETEN, 2013).

From the results of this radiation dose, it can be concluded that radiation workers at Pariaman Regional Hospital have applied the basic principles of radiation safety. One of these principles is exposure time management, where the radiation dose received by a person is directly proportional to the duration of time they are around the radiation source (Baker, J. J., & Terenzio, 2021; Zhou, Z., Xie, X., & Liu, 2018). In other words, the longer a person is near a radiation source, the higher the radiation dose that will be received. Therefore, by reducing the exposure time around the radiation source, the radiation dose received can also be minimised. Enforcement of this principle is essential to protect the health of radiation workers and ensure that they stay within the safe limits of radiation exposure. (Guan, Y., Wu, Y., & Liu, 2019; International Commission on Radiological Protection, 2012; Mettler, F. A., & Guiberteau, 2018).

CONCLUSION

Based on the study of radiation dose rates in the Radiology Installation of Pariaman Regional Hospital using a Raysafe surveymeter, it can be reported that the radiation dose rate in the CT-Scan room is (0.30-1.27) μSv/hour. In the conventional X-ray room, the radiation dose rate is between (0.2-0.5) μSv/hour. Furthermore, in the mammography room, the dose rate is (0.00-0.40) μSv/hour. These findings indicate that the highest radiation exposure occurs in the CT-Scan room, which aligns with the higher complexity and intensity of the imaging procedures performed there. The relatively low dose rates in the conventional X-ray and mammography rooms suggest effective radiation shielding and safety protocols in place. Continuous monitoring of radiation levels is essential to ensure that they remain within safe limits for both patients and medical staff. Additionally, the data can be utilized to optimize exposure parameters and enhance the overall safety measures in the radiology department.

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