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**Original Research Paper**

# Safety analysis of X-ray radiation exposure in installation

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## Abstract
Radiology is important in early detection and risk assessment through real-time imaging. However, radiation safety in radiology installations remains a major concern in protecting patients, medical personnel, and the public from ionizing radiation exposure to avoid exceeding the Dose Limit Value (NBD). This study aims to analyse the results of X-ray radiation exposure and evaluate the radiation safety procedures implemented to reduce the risk of radiation exposure in the Radiology Installation of Panti Nugroho Sleman Hospital. The method used in this research is qualitative with an experimental approach conducted at Radiology Installation of Panti Nugroho Hospital Sleman in August 2024 - January 2025. Data collection was carried out at 10 measurement points where each point was measured three times then the measurement results were calculated using the formula and then compared with BAPETEN Regulation No. 5 of 2016. The results obtained are the value of radiation exposure measurements for 10 points of measurement area on conventional aircraft, namely 0 µSv / hour, 0 µSv / hour, 0.03 µSv / hour, 0 µSv / hour, 0.33 µSv / hour, 0.03 µSv / hour, 0 µSv / hour, 0.13 µSv / hour, 0.03 µSv / hour, and 0 µSv / hour. As well as radiation exposure measurement values for 10 points of measurement area in the panoramic plane, namely 0 µSv/hour, 0 µSv/hour, 0 µSv/hour, 0 µSv/hour, 0.03 µSv/hour, 0 µSv/hour, 0 µSv/hour, 0 µSv/hour, 0 µSv/hour, 0 µSv/hour. In addition, standard operating procedures such as room management, equipment maintenance, provision of aprons, implementation of radiation exposure testing, use of TLD (Thermoluminescence Dosimeter), and health checks have been implemented in a structured manner in order to prevent and protect the safety of all parties and the environment. It is expected that this research can be useful for health aspects for radiation workers such as being able to identify ways to reduce radiation exposure in order to avoid stochastic effects, gene mutations, and so on by developing more effective safety protocols to reduce X-ray radiation exposure for radiology workers and the public.

**Keywords:** dose limit value; public; radiation exposure; radiation worker; risk

## 1. Introduction

Radiologists play an important role in preparedness efforts by providing real-time imaging, supporting early detection and risk assessment. Optimising X-rays can reduce the negative impact of general and conventional X-ray aircraft through proper techniques for optimal radiographic results. Examination rooms must meet radiation protection criteria and be sized according to applicable regulations. For X-ray equipment, the walls of the room must be designed in such a way as to ensure safety for patients, staff and the wider community (Rosyida, 2016). Radiation protection is an effort to ensure that the dose of ionizing radiation that hits humans and surrounding living things does not exceed the predetermined limit value (Martin et al., 2018).

Radiation safety protects humans and the environment from the hazards of ionizing radiation through radiation protection efforts. Radiation protection is defined as measures taken to protect humans and the environment from the effects of exposure to ionizing radiation (Government Regulation No.45 of 2023). High radiation exposure can cause acute radiation syndrome and cell damage, including genetic mutations and cell death. X-rays can also damage body tissues, especially blood-forming organs and glands (Wang et al., 2018). Efforts to prevent losses due to radiation exposure are to apply three

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principles of radiation protection, namely the length of radiation exposure (time), distance from the radiation source (distance), and the use of radiation shielding (shielding). To reduce radiation exposure for medical personnel, it is necessary to pay attention to the safe distance between medical personnel and the radiation source is enlarged, the examination time is shortened, and the shield used is adjusted to the thickness and density of the material (Septina et al., 2022).

Based on Bapeten Number 4 (2020) regarding Radiation Safety in the Use of X-ray Aircraft for Diagnostic Radiology and Interventional Radiology, routine or periodic radiation monitoring is very important to ensure that the Dose Limit Value received by radiation workers remains within safe limits and is not exceeded. The effective dose limit for radiation workers is set at 20 mSv per year, with an average calculation over a period of 5 (five years). Meanwhile, the effective dose limit for the general public is 1 mSv per year (Bapeten No.5 Year 2016). Therefore, in the operation of X-rays in radiology installations, it is very important to monitor radiation exposure using a survey meter, conduct dose monitoring, and prepare radiation protection equipment (Putri, 2018).

Some previous studies have discussed radiation safety in radiology installations, such as those conducted by Napitupulu et al. (2023), who analysed the implementation of radiation safety based on Perka BAPETEN No. 4 of 2020 at Tanjungpinang City Hospital. However, this study only assessed management and procedural aspects without directly measuring radiation exposure. Meanwhile, research by Yuliamdani et al. (2020) at Makassar City Hospital has measured radiation exposure using a survey, but only on conventional X-ray aircraft, without considering radiation interactions from panoramic aircraft in one room.

Until now, research related to simultaneous measurement of radiation exposure on conventional and panoramic X-ray aircraft in one room is still limited. This is a gap for researchers considering that the interaction of the two types of X-ray aircraft in one room can potentially increase the level of radiation exposure received by workers and patients. In addition, previous studies have not specifically evaluated how the distribution of scattering radiation from these two aircraft, so the potential cumulative exposure has not been optimally measured.

Thus, this study aims to conduct a safety analysis of X-ray radiation exposure in radiology installations that have conventional and panoramic X-ray aircraft in one room. This study is expected to provide more comprehensive data on the level of radiation exposure that occurs and provide more specific recommendations in efforts to mitigate the risk of radiation exposure for workers and the surrounding environment.

## 2. Research Methods

This study used a mixed method with an experimental approach to assess the safety analysis of X-ray radiation exposure in the Radiology Installation of Panti Nugroho Sleman Hospital. This research was conducted from August 2024 to January 2025. This study involved one informant, the radiation protection officer who also served as the head of the hospital's hospital room head. The informant was selected based on his expertise and responsibility in managing radiation safety in the radiology installation. Data collection techniques were conducted through in-depth interviews to obtain information on radiation safety procedures, direct observation of radiation protection practices in conventional radiology rooms, and direct measurements to assess the area's radiation exposure level. Tools and materials for data collection include documentation tools in stationery and mobile phones, measuring instruments in surveymeters, conventional X-ray planes, panoramic planes, cranium phantoms, and aprons. This study used 10 measurement points carried out thrice at each point. The measurement points can be seen in Figure 1 below:

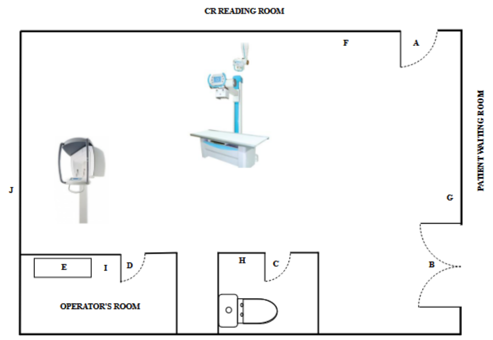


**Figure 1.** Plan of Radiology Installation Examination Room of Panti Nugroho Sleman Hospital

Description:

1. Point A (Employee Entrance)
2. Point B (Patient Entrance)
3. Point C (Bathroom Door)
4. Point D (Operator Door)
5. Point E (Operator Glass)
6. Point F (Employee Entrance Wall)
7. Point G (Front Wall of Patient Entrance)
8. Point H (Bathroom Wall)
9. Point I (Operator Room Wall)
10. Point J (Warehouse Room Wall)

With an exposure factor on a conventional X-ray plane of 70 kV, 16 mAs, and FFD of 100 cm, and an exposure factor on a panoramic plane of 71 kV, 12 mAs, and 13.2 s. The measurement results were then calculated using the formula:

$$D_{actual} = D_{average} - \text{Background Exposure}$$

Then compared with Bapeten No. 5 (2016) Regulation which states that the Dose Limit Value for radiation officers is set at 20 mSv/year while for the public it is 1 mSv/year. Conversion of Dose Accumulation Unit (µSv) according to Mubarok & Hervin (2022) in 1 year there are 50 weeks, where 1 week there are 5 working days. Working time in 1 day is 8 hours (this assumption is very overestimate because X-rays are not lit continuously, but used as an assumption to improve safety). So with this assumption, the safe dose rate for the radiation worker area is 5 µSv / hour and for the general public area is 0.25 µSv / hour, which if assumed the dose is the same every hour, it can be converted into a radiation worker dose of 2.28 µSv / hour in 1 year. While the Dose Limit Value set for the community is 1 mSv / year, which if assumed the dose is the same every hour, then the converted dose for the community is 0.11 µSv / hour. By the principle of radiation protection, the results show that radiation shields or protectors used to reduce radiation exposure are needed to absorb radiation so that the receipt of radiation doses by the body can be reduced (Rahmat et al., 2022). Data analysis is presented in tables and narratives, then conclusions can be drawn. This research has received ethical approval from the Research Ethics Committee of the Faculty of Medicine, Public Health, and Nursing, Gadjah Mada University with No. KE/FK/0942/EC/2024.

## 3. Results and Discussion

### 3.1. Measurement of X-ray Radiation Exposure in Radiology Installation of Panti Nugroho Hospital Sleman

According to Government Regulation No. 24 of 2020, the size of the room adjusts to the needs or size of the equipment, where for the X-ray room without fluoroscopy the minimum room size with power equipment up to 125 kV is 4 m (p) × 3 m (l) × 2.8 m (t) and the power equipment room> 125 kV is 6.5 m (p) × 3 m (l) × 2.8 m (t) with a wall thickness of 25 cm of red brick or concrete with a thickness of 20 cm or equivalent to 2 mm Pb According to Rahma et al. (2024) for a conventional room in the Radiology Installation of Salatiga Regional Hospital which measures 7 m2 (p) × 4.5 m (l) × 3.5 m (t) but the wall material and wall thickness do not match the indicators of radiology room requirements.

This is because the wall material used is light bricks with a thickness of 20 cm so the wall material is less than the standard. In addition, there is Pb that sags because the wall collides with the patient's brankart. So based on the results of observations and measurements made by researchers, the results of X-ray radiation exposure in the conventional and panoramic fields at 10 points of the measurement area at the Radiology Installation of Panti Nugroho Sleman Hospital are safe for radiation workers and the public because the size of the room is wider and is by the rules of Government Regulation No. 24 of 2020. The room size has a size of 5 m (p) × 4 m (l), 4 m (t) and has a wall thickness using bricks which is 18.5 cm and coated with 2 mm lead. It is also known that the patient peephole glass is 1.5 cm thick with Pb glass, the patient door is 5 cm thick with wood and Pb, the operator door is 4 cm thick with wood and Pb, the patient bathroom door is 4 cm thick with wood and Pb, and the employee entrance door is 4 cm thick with wood and Pb.

Research by Rahmat et al. (2022) has analyzed the scattering radiation distribution on a conventional X-ray aircraft with measurement points at the operator's door, main door, and several room walls. However, the study did not include bathroom walls and bathroom doors, which in this study were identified as potential areas of exposure to scattering radiation. In addition, it only focused on one type of X-ray aircraft. At the same time, this study considers the interaction of exposure from conventional and panoramic aircraft in one room, which provides a new perspective in radiation risk mitigation. Meanwhile, Irsal et al's (2020) study at the COVID-19 Emergency Hospital Wisma Atlet Jakarta has measured radiation exposure in control and supervision areas, including the entrance and walls of the room. However, the study was conducted in the context of an emergency radiology installation with a mobile X-ray aircraft, which is different from the conditions of the permanent radiology room studied in this study. So it has not explored how cumulative exposure from two X-ray aircraft in one room can affect the distribution of scattering radiation, which is the main focus in this study.

Furthermore, research by Yuliamdani et al (2020) has measured radiation exposure in the radiology room of Makassar City Hospital with measurement points in the operator area and operator glass. This study has similarities with the research conducted. However, its scope is more limited to the distance and time factors to the exposure dose, without considering the radiation distribution at various room points. In this study, measurements were taken at 10 strategic points, including areas that have not been widely studied before such as bathroom walls and walls in front of employee doors, which can potentially become pathways for the spread of scattering radiation.

Radiation exposure measurement in Radiology Installation of Panti Nugroho Sleman Hospital uses 10 measurement points divided into control and supervision areas. The control area in this measurement includes employee entrance, patient entrance, bathroom door, operator door, and operator glass. The supervision area in this measurement includes the wall in front of the employee door, the wall in front of the patient door, the bathroom wall, the operator room wall, and the warehouse wall.

### 3.1.1. Measurement of Radiation Exposure on Conventional Aircraft

The results of radiation exposure measurements on conventional aircraft in the Radiology Installation of Panti Nugroho Sleman Hospital can be seen in Table 1 as follows:

**Table 1.** Calculation Results of Radiation Exposure Measurement on Conventional Aircraft in Radiology Installation of Panti Nugroho Hospital Sleman

| No. | Measurement Area | $D_{actual}$ | Bapeten | Material | Ket. |
|---|---|---|---|---|---|
| 1 | Employee Entrance | 0 | 2,28 | Wood+Pb | Safe |
| 2 | Patient Entrance | 0 | 2,28 | Wood+Pb | Safe |
| 3 | Bathroom Door | 0,03 | 2,28 | Wood+Pb | Safe |
| 4 | Operator Door | 0 | 2,28 | Wood+Pb | Safe |

| No. | Measurement Area | $D_{actual}$ | Bapeten | Material | Ket. |
|---|---|---|---|---|---|
| 5 | Operator Glass | 0,33 | 2,28 | Pb glass | Safe |
| 6 | Employee Door Front Wall | 0,03 | 2,28 | Brick + Pb | Safe |
| 7 | Patient Door Front Wall | 0 | 2,28 | Brick + Pb | Safe |
| 8 | Bathroom Wall | 0,13 | 2,28 | Brick + Pb | Safe |
| 9 | Operator Room Wall | 0,03 | 2,28 | Brick + Pb | Safe |
| 10 | Warehouse Wall | 0 | 2,28 | Brick + Pb | Safe |

In the measurement results of conventional aircraft in the Radiology Installation of Panti Nugroho Sleman Hospital, it is known that radiation is still detected after passing through the radiation shield. The highest measured radiation exposure value is found at measuring point E (operator glass) with a measurement result of 0.33 µSv/hour. The second highest radiation exposure value is found at measuring point H (bathroom wall) which is 0.13 µSv/hour. The third highest radiation exposure value is found at measuring points C (bathroom door), F (wall in front of the employee door) and I (operator room wall) which amounted to 0.03 µSv/hour. When viewed from the measured area, the community area is found at measuring point B (patient entrance) and point G (wall in front of the patient's door). In both areas, the dose exposure result obtained in conventional aircraft measurements is 0 µSv/hour.

According to Putri (2018), the most significant radiation leakage was first identified at location A (lead glass in the operator area) with a rate of 29.5 µSv/hour. The reason is that the thickness of the shield contained in the glass in the operator area is too minimal, which is only 1.5 mm of lead, so it cannot block the scattered radiation properly. As a result, location A is considered unsafe for both personnel and the public. The second highest radiation leakage was measured at measuring point 1, at the patient entrance at a distance of 5 meters from the radiation source, with a rate of 0.35 µSv/hour. The cause is a double-leaf door with a door handle fastened with screws, so there is still a gap that allows radiation leakage.

Based on the results of the author's observations when associated with the research of Putri (2018) at point E (operator glass) in the operator's room, a dose value of 0.33 µSv/h was obtained. This dose value if for the community then the dose obtained exceeds the safe limit. The thickness of the peekaboo glass in the operator's room containing Pb of 1.5 mm is known to be a contributing factor to the high dose value obtained, so it cannot reduce the scattering radiation optimally. On the front wall of the operator's room above the glass for viewing patients, there is an 18 cm hole that was originally used for an exhouse fan. In the conventional radiology examination room there is a patient bathroom that has a door with a size of P: 1.84 m and L: 9.7 cm with wood material and 2 mm thick Pb. It is also known that point H (bathroom wall) has a Pb thickness of 2 mm made of brick and Pb. However, from the results of measurements that have been made, the results of radiation doses are not safe for the community. The results of the researcher's observations show that there is a gap of 1.5 cm on the bathroom door which causes radiation scattering to be still able to cross the area.

In the study of Yıldız et al (2022) This study analyzed precautions against X-ray radiation exposure in a hospital in Gaziantep by measuring exposure in various diagnostic units, such as mammography, CT scans, and fixed X-rays, using a Fluke 451 Ion Chamber Radiation Survey Meter. The results showed that the highest exposure (410 µSv) occurred in the examination room, while the lowest value (0.01 µSv) was detected behind the lead screen. This study emphasizes the importance of limiting the frequency of exposure for medical personnel and using personal protective equipment (PPE) to reduce the risk of long-term radiation dose accumulation. It only focuses on radiation prevention measures without taking measurements at various points of the radiology room, so it has not explored how the distribution of radiation exposure in the room.

In the research of Sugiarti et al. (2023), this study measured X-ray radiation exposure in thorax examinations at the Radiology Installation of Wajak Husada Hospital to assess the level of safety for workers and the community. Measurements were taken at several strategic points in the room, such as the front wall, side walls, wooden doors, and Pb glass, using a calibrated surveymeter of 107 µSv/hour. The results showed that the highest exposure occurred in the control panel room (0.19 µSv/hour or 0.88 mSv/year), but was still below the safe limit set by BAPETEN. No significant radiation leakage was found, so the radiology installation environment is declared safe for operation. This study was limited to measuring exposure from thoracic examinations, without considering specific exposure factors and the type of X-ray aircraft used. In addition, this study also did not use a phantom as a test object, which in this study was used to ascertain the radiation dose distribution more accurately.

Abubakar et al (2017) evaluated the indoor ionizing radiation profile in the Radiology Department of FMC Asaba, Nigeria, by measuring exposure at 22 points with high radiation levels using the Radiation Alert Inspector Survey Meter. The results showed that the average post-exposure exposure ranged from 0.09 - 0.20 µSv/hour (0.60-2.01 mSv/year), with the highest point in the X-ray diagnostic room (2.01 ± 4.11 mSv/year) and the lowest point in the staff room (0.60 ± 0.3 mSv/year). Although all results were within safe limits according to ICRP and UNSCEAR standards, this study emphasizes the importance of regular monitoring to maintain the safety of workers and patients in the long term. This study focused on a general evaluation of indoor radiation exposure levels, without considering variations in exposure factors, types of test objects, and dose distribution based on measurement points as was done in this study.

While this study focuses on the Safety Analysis of X-ray Radiation Exposure in the Radiology Installation on a conventional aircraft using a Medonica brand DR X-ray aircraft at an exposure factor of 80 kV and 8 mAs. Radiation exposure measurements were carried out with a Raysafe X2 Survey surveymeter and using a phantom cranium as a patient replacement object to simulate real conditions when exposure is carried out. Tests were conducted at 10 measurement points with each point measured three times, and the distance between the radiation source and the object (SID) was set at 100 cm with the vertical beam direction perpendicular to the object.

Thus, this study's novelty lies in using a Medonica brand DR X-ray aircraft with a specific exposure factor, using a cranium phantom as a patient simulation, and more systematic measurements at 10 measurement points with three tests at each point. This allows for a more accurate analysis of radiation distribution around the examination room and provides more comprehensive data in assessing radiation exposure safety for workers and the surrounding environment. These findings are expected to be an important reference in the optimization of radiation safety procedures in radiology facilities using conventional X-ray aircraft.

### 3.1.2. Radiation Exposure Measurement on Panoramic Aircraft

The results of radiation exposure measurements in the Panoramic field at the Radiology Installation of Panti Nugroho Sleman Hospital can be seen in Table 3 as follows:

**Table 2.** Calculation Results of Radiation Exposure Measurement on Panoramic Field in Radiology Installation of Panti Nugroho Hospital Sleman

| No. | Measurement Area | $D_{actual}$ | Bapeten | Material | Ket. |
|---|---|---|---|---|---|
| 1 | Employee Entrance | 0 | 2,28 | Wood+Pb | Safe |
| 2 | Patient Entrance | 0 | 2,28 | Wood+Pb | Safe |
| 3 | Bathroom Door | 0 | 2,28 | Wood+Pb | Safe |
| 4 | Operator Door | 0 | 2,28 | Wood+Pb | Safe |
| 5 | Operator Glass | 0,03 | 2,28 | Pb glass | Safe |

| No. | Measurement Area | $D_{actual}$ | Bapeten | Material | Ket. |
|---|---|---|---|---|---|
| 6 | Employee Door Front Wall | 0 | 2,28 | Brick + Pb | Safe |
| 7 | Patient Door Front Wall | 0 | 2,28 | Brick + Pb | Safe |
| 8 | Bathroom Wall | 0 | 2,28 | Brick + Pb | Safe |
| 9 | Operator Room Wall | 0 | 2,28 | Brick + Pb | Safe |
| 10 | Warehouse Wall | 0 | 2,28 | Brick + Pb | Safe |

In the measurement of panoramic field in Radiology Installation of Panti Nugroho Sleman Hospital in 10 areas, the result of radiation measurement after hitting the radiation shield is the highest radiation exposure value measured at measurement point E (operator glass) which is 0.03 µSv/h. The radiation exposure value at points A,B,C,D,F,G,H,I,J is 0 µSv/h.

The measurement results on the panoramic plane according to Ilmi & Rochmayanti (2018) Measurements were made at several points, namely at point A behind the partition between the panoramic room and the CT-Scan operator room with a value of 0.001 mSv / hour, point B behind the panoramic examination room door with a value of 0.019 mSv / hour, point C behind the porthole of the panoramic examination room with a value of 0.019 mSv / hour, point D behind the wall of the panoramic room behind the panoramic plane with a value of 0.013 mSv / hour, and point E behind the wall of the panoramic room to the right of the panoramic plane with a value of 0 mSv / hour. Based on the measurement results, all points are declared to be below the NBD limit. Point A showed a lower value than points B, C, and D due to the plywood material used and spots on the wood joints. Point B obtained the highest score due to the hinges not functioning properly, resulting in the door not closing tightly and causing a wide gap. Point C also received a high score due to the location of the radiation source close to the measurement location, allowing the peekaboo glass to expand. Point D has a lower value than points B and C, although the wall meets the standard, because it is located closest to the radiation source and the measured value is quite large. Furthermore, point E has the lowest value because the wall is still in good condition, so there is no radiation exposure behind the wall.

According to Ancila & Hidayanto (2016), this study measured radiation doses in the dental panoramic radiology installation of Dr. Kariadi Hospital using a Babyline surveymeter in the operator's room, waiting room, and employee corridor to assess the effectiveness of radiation shielding. The results showed that the dose in the operator's room (5.83 µSv/h) was still within safe limits, while the waiting room had a dose close to the set limit (2.4 µSv/h). The effectiveness of the radiation shielding in the operator's room was high (82.29%), but the room door shielding was low (12.24%), allowing radiation leakage. Therefore, improvements to radiation protection are needed, especially in the waiting room to reduce unnecessary exposure. Research by Sutejo & Daryati (2016) measured the radiation exposure rate on the panoramic room shield at Klaten Islamic Hospital using a Babyline surveymeter, with measurements before and after exposure at several points in the room. The results showed that the background radiation exposure rate ranged from 0.14 - 0.175 µGy/hour, exceeding the UNSCEAR standard for that location. After exposure, all measurement points were still within safe limits according to NCRP No. 147, with the highest value at point G (0.000735 mGy/h) located in the shield gap. Although within normal limits, radiation exposure at the shield gap allows for exposure to workers' feet, so improvements to the radiation shield design are needed to increase protection.

Research by Suliman and Abdelgadir (2018) measured radiation doses in patients undergoing intraoral and panoramic radiographs in Sudanese hospitals, comparing digital (DR) and conventional film (SF) systems. Results showed that the incident kerma air dose (IAK) in intraoral radiographs was lower in digital systems (1.45 mGy) than film (4.45 mGy). In comparison, the kerma area product (PKA) dose in panoramic radiographs was higher in adults (103.4 mGy.cm$^2$) than children (70.4 mGy.cm$^2$). The study also found that the lack of a quality assurance program and the use of circular collimators increased unnecessary radiation exposure, so radiation protection optimization is needed to improve patient safety.

Whereas in this study using the Raysafe X2 Survey surveymeter with a phantom cranium as a patient substitute, and taking measurements at 10 points repeated 3 times to improve data accuracy. The exposure settings used were 71 kV, 12 mA, and 13.2 seconds, making it more specific in simulating the dose received by the patient. Meanwhile, research (Ancila & Hidayanto, 2016) used a Babyline surveymeter without a phantom, focusing on dose measurements in the operator room, waiting room, and employee corridor to assess the effectiveness of radiation shielding. Research (Sutejo & Daryati, 2016) also used the Babyline surveymeter to measure radiation exposure rates at several points in the panoramic room at Klaten Islamic Hospital, but did not use a phantom and was more oriented towards evaluating radiation protection than patient dose. Different from the two journals, Suliman & Abdelgadir's (2018) study used a Piranha Multimeter and ionization chamber, with head and neck phantoms to measure patient dose in panoramic and intraoral radiographs. The journal also compared the use of digital (DR) and conventional film (SF) systems in relation to the dose received by the patient. Thus, this study has the advantage of dose measurement accuracy using a modern surveymeter and the use of a cranium phantom, which is closer to the approach in Suliman and Abdelgadir (2018) than other journals.

### 3.2. Expected Radiation Safety Procedures to Reduce the Risk of X-ray Radiation Exposure in Radiology Installation of Panti Nugroho Hospital Sleman

Radiation Protection in Radiology Installation of Panti Nugroho Sleman Hospital, it is known that radiation safety procedures applied in the installation include radiation exposure testing using survey meters that are carried out periodically every year, usually through a calibration process carried out by the relevant officers. In addition, equipment function testing and operational license renewal processes are also carried out at five-year intervals, by applicable rules and regulations, to ensure that all devices and procedures meet established radiation safety standards. According to research by Yıldız et al (2022), X-ray radiation exposure measurements were made using the Fluke 451 Ion Chamber Radiation Survey Meter at various locations within the hospital. This measurement aims to determine the level of radiation exposure in medical personnel and their work areas.

Radiation safety procedures related to the use of aprons are strictly implemented in every examination to protect individuals from unwanted radiation exposure. The use of an apron is mandatory, especially for the patient's family who must wait or accompany the patient during the examination process involving radiation, to minimize the risk of secondary radiation exposure. In addition, the use of lead apron is also a major obligation for pregnant women who require ionizing radiation examinations, as a preventive measure to protect the fetus from the potential biological effects of radiation, so this safety aspect is expected to ensure maximum protection for all parties involved. According to a study by Yıldız et al (2022), radiology workers must use lead aprons and thyroid shields as the main protection against X-ray radiation exposure. In addition, the rules for using this personal protective equipment are strictly monitored to ensure the safety of medical personnel.

In the Radiology Installation of Panti Nugroho Sleman Hospital, all radiation officers are required to wear a TLD (Thermoluminescence Dosimeter) while on duty in the radiology room, then every three months the personal monitor film/TLD is submitted to the Health Facility Inspection Center (BPFK) for storage and evaluation. According to research (Seo & Yu, 2021), Thermoluminescence Dosimeter (TLD-100) is used to measure radiation dose in panoramic radiographic examinations. This TLD was calibrated using a radiation diagnostic device to improve dose measurement accuracy. According to the study of Yıldız et al. (2022), radiology personnel are required to use personal dosimeters that are checked periodically to ensure that the radiation exposure received does not exceed the limits set by occupational health and safety regulations.

The interview also explained about the use of two modalities in one radiology examination room. The PPR officer explained that the presence of two radiology equipment in one examination room is not a problem as long as they are not operated simultaneously, so that the potential for cross radiation exposure can be avoided. This is in line with the provisions stipulated in the regulations issued by the Nuclear Energy Regulatory Agency (BAPETEN) which prioritizes the principle of radiation safety to protect patients, staff, and the environment from the risk of unwanted exposure. Thus, this arrangement still supports operational efficiency without neglecting safety aspects according to applicable standards. To prevent the occurrence of long-term and short-term radiation effects, radiation officers in the Radiology Installation of Panti Nugroho Sleman Hospital undergo a medical examination which is carried out periodically once a year. Laboratory examinations include routine blood and chemical examinations as well as X-ray examinations if needed, then the results of these examinations are stored and archived in the Radiology Unit. According to research by Yıldız et al. (2022), medical personnel working in radiology units should undergo regular medical examinations every six months. This includes blood tests to monitor possible side effects due to radiation exposure.

Thus, this regulation still supports operational efficiency without neglecting safety aspects according to applicable standards. Radiation protection aims to reduce radiation intensity by utilizing radiation interaction with materials (Romarti et al., 2023). In this case, the thickness of the barrier or shield greatly affects the radiation exposure obtained, the thicker the barrier or radiation shield, the less the radiation exposure value obtained (Tunggadewi et al., 2021). So that the standard operating procedures (SOP) applied by the Radiology Installation of Panti Nugroho Sleman Hospital have fulfilled the provisions as stipulated in BAPETEN Regulation Number 4 of 2020 concerning Radiation Safety in the Use of X-ray Aircraft in Diagnostic and Interventional Radiology. The implementation of this SOP reflects compliance with regulations aimed at ensuring the safety of patients, labor, and the environment from potential radiation exposure hazards.

## 4. Conclusion

The radiation exposure dose value is in the safe category for radiation workers and the general public. The radiation exposure dose for workers does not exceed 2.28 μSv/hour, while for the general public the exposure dose is not more than 0.11 μSv/hour. In addition, the presence of two modalities in one examination room does not cause an excessive increase in radiation dose, provided that the two modalities are not operated simultaneously. This shows that the configuration of the examination room has met the radiation safety standards.

The radiation safety standard operating procedures (SOPs) implemented in the radiology installation are in accordance with the provisions regulated by BAPETEN. Implementing radiation protection for patients, workers, and the environment is carried out in a structured and careful manner, including room management, radiation exposure testing, equipment maintenance, dose control, and the use of radiation personal protective equipment. All of these steps are designed with accurate calculations to prevent radiation leakage, so as to maintain the safety of all parties involved and the environment around the installation.

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