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ANALYSIS OF RADIATION BARRIER DESIGN IN PEAT SOIL USING NCRP METHOD NO.147 AT MURJANI REGIONAL HOSPITAL

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ABSTRACT

The use of X-ray aircraft can hurt workers and the community, so they must pay attention to radiation protection aspects such as the design of radiation retaining walls which function to absorb and attenuate the resulting radiation exposure. This research was conducted to analyze the value of radiation exposure from radiology buildings on peat soil using the NCRP method No. 147. In this analysis, the rate of radiation exposure was measured using a Gamma Surveymeter, and the Pb thickness was calculated using the fitting and algebraic methods recommended by NCRP No. 147. Measurement and calculation of Pb are divided into 2 areas, namely controlled areas (Point B, Point C, and Point F) and uncontrolled areas (Point A, Point D, Point E, Point G, and Point H). The results of measurements and calculations from these eight protection points obtained radiation exposure rates in controlled areas at Point B (0.09 µSv/hour), Point C (0.04 µSv/hour), and Point F (0.03 (µSv/hour), and the results of calculating Pb thickness at Point B (0.07 mm), Point C (0.03 mm), and Point F (0.18 mm). Meanwhile, the rate of radiation exposure in uncontrolled areas at Point A (0.480 µSv /hour), Point D (0.068 µSv/hour), Point E (0.075 µSv/hour), Point G (0.41 µSv/hour), and Point H (0.45 µSv/hour), and the results of Pb thickness calculations at Point A (0.46 mm), Point D (0.08 mm), Point E (0.071 mm), Point G (0.038 mm), and Point H (0.005 mm). Based on these results, the radiation exposure rate value in controlled areas is still within safe limits, and in uncontrolled areas, the rate of radiation exposure that occurs is above the threshold of the dose-limiting value set by NCRP No. 147.

Keywords: *radiation, barrier design, peat soil*

INTRODUCTION

One of the important things that must be considered before building a building is the type of land it will occupy. The type of soil will influence whether a building is strong or not. The type of soil that requires special treatment for building foundations is peat soil. Peat soil is soil that contains very high levels of organic matter. This soil is usually also referred to as organic soil. The use of peat soil for radiation barrier buildings must be very careful. This is because the water content of peat soil is very high (Harnawan et al., 2021; Maryani & Juairiyah, 2018). So it requires a special structure for the building to be erected. If the building structure is used incorrectly, it will result in construction failure and cracks in the building structure (Nurdin, 2011). Therefore, appropriate methods are needed for constructing radiation barriers (Rahayu Basuki, 2021).

One method of stabilizing peat soil is by mixing peat soil with solid material. The solid materials used are usually sand and cement (Nugraheni & Pangaribuan, 2008). You can also use building soil as a backfill on top of the peat soil (Lesmana, 2022). If the water content in the soil is too high, preloading is carried out on the soil. This preloading system is by inserting material into the ground (Hafiz Alfarisyi et al., 2020). The input material is formed into columns one meter thick which are then pounded with heavy equipment. The distance between columns is eight meters. Before preloading, decomposition acceleration must be carried out by spreading anti-microbial liquid or powder. This is intended to reduce the water content in the soil (Nugraheni & Pangaribuan, 2008).

METHOD

The second method uses NCRP No. 147 where the radiation barrier wall functions to absorb radiation so that the radiation intensity received by workers and the public does not exceed the NBD. The ability to absorb radiation is influenced by the thickness of the Pb layer used as a radiation barrier. Therefore, measurements are needed to determine the suitability of the thickness of the Pb layer used in the general radiography room during construction and current conditions along with the increasing number of examinations (Elisa Fitriani & Gatot Murti Wibowo, 2018). To determine the thickness of the Pb layer contained in a general radiography room, you can use the calculation method published by the NCRP (National Council on Radiation Protection) (Fakhrurreza & Astari, 2019).

The radiation exposure dose limit value will be one of the factors for calculating radiation barriers and will be a reference for the possibility of radiation leaks which could pose a danger to workers and the public. Controlled areas are areas that directly contain X-ray equipment and are occupied by radiation workers with a radiation exposure limit value of 0.1 mGy/week (NCRPReportNo.147, 2004) and uncontrolled areas are areas around the equipment that are usually occupied by anyone with an exposure limit value. the radiation received was 0.02 mGy/week (NCRP Report No.147, 2004). This protective design aims to protect workers and the public in controlled and uncontrolled areas so that the radiation exposure dose received is still safe.

To minimize the possible risks arising from exposure to X-ray radiation, a Dose Limit Value (NBD) is applied to control the dose of radiation exposure received by workers and the public. By the Regulation of the Head of the Nuclear Energy Supervisory Agency (BAPETEN) No. 8 of 2011 concerning radiation safety in the use of radio diagnostic and interventional X-ray aircraft, the annual NBD for radiation workers is 20 mSv/year and for the public, it is 1 mSv/year (BAPETEN, 2020). Dose constraint values for building design purposes in hospitals in radiology installations.

Radiation Retaining Wall

Radiation barrier walls are the use of radiation barrier materials that function to attenuate the resulting radiation exposure. The ability to absorb radiation is influenced by the thickness of the Pb layer used as a radiation barrier. For the use of general X-ray radiography facilities, the calculation of the thickness of Pb as a radiation barrier material is carried out using the algebraic calculation method and fitting method which has been published in NCRP No. 147 for primary radiation barrier walls and secondary radiation barrier walls.

Primary Radiation Barrier Wall

lgebraic method $x_{barrier} = \frac{1}{\alpha\gamma} ln \left[\frac{\left(\frac{NTUK_p^1}{Pd_p^2}\right)^\gamma + \frac{\beta}{\alpha}}{1+\frac{\beta}{\alpha}} \right] - x_{pre}$

Fitting method

$$B_p(x_{barrier} + x_{pre}) = \left(\frac{P}{T}\right) \frac{d_p^2}{K_p^1 UN}$$

Where P is the radiation barrier design weekly dose limit, T is the occupancy factor, d_p is the distance from the primary radiation source to the location of maximally exposed individuals outside the primary barrier, K_p^1 is the primary air kerma, U is the utilization factor and N is the amount of workload/week, and the parameters α, β, and γ are the type of light transmission used.

Secondary Radiation Barrier Wall

Algebraic Method

$$x_{barrier} = \frac{1}{\alpha\gamma} ln \left[\frac{\left(\frac{NTK_{sec}^1}{Pd_{sec}^2}\right)^\gamma + \frac{\beta}{\alpha}}{1+\frac{\beta}{\alpha}} \right]$$

Fitting Method

$$B_{sec}(x_{barrier}) = \left(\frac{P}{T}\right) \frac{d_{sec}^2}{K_{sec}^1 N}$$

Where d_sec is the distance from the secondary radiation source to the individual's maximally exposed location outside the secondary barrier, and K_sec^1 is the secondary air kerma.

Research Methods

The research was conducted in the general radiography room of the radiology installation at one of the Palangka Raya city hospitals. The tools used are X-ray aircraft, Gamma Surveymeter, Phantom, and Meter. Data collection began with observations of the design of the general radiography examination room which included wall size, room size, doors, space around the examination room, number of patient examinations, occupancy factors, and occupancy factors (Sutjipto, 2000).

Next, the rate of radiation exposure is measured which is divided into eight protection points covering Point A (patient waiting room), Point B (operator's room), Point C (examination room 1), Point D (officer's room), Point E (officer's corridor) , Point F (patient door), Point G (toilet) and Point H (changing room) which can be seen in Figure 2.

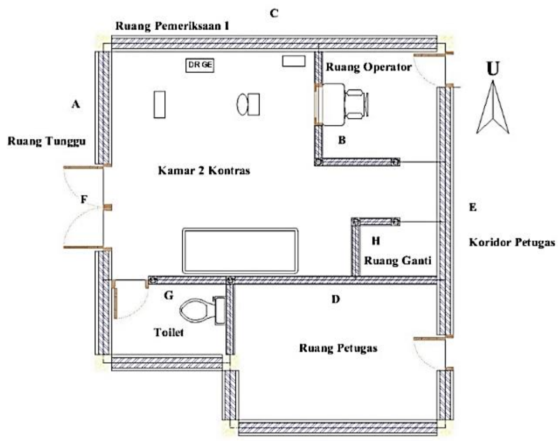

Figure 2. General Radiography Room Plan

Measurement of the rate of radiation exposure was carried out with the primary and secondary radiation range to the residential point as far as 0.3 meters outside the shield (wall) (Daniel et al., 2021). Exposure rate measurements were carried out before exposure and during exposure with repetitions five times. Next, the Pb thickness calculation was carried out on the primary and secondary radiation retaining walls using fitting and algebraic methods based on NCRP No.147. Through this data, data processing and analysis of the results of radiation exposure rates and Pb thickness are carried out based on the dose-limiting values set by NCRP No. 147 and PERKA BAPETEN.

RESULTS AND DISCUSSION

The general radiography room is in the radiology installation and has a fairly strategic location because it is close to the ER (Emergency Department) and ICU (Intensive Care Unit) which makes patient access easier. The size of the general yeastography room is structurally by the provisions (BAPETEN, 2011) shown in Table 1.

Table 1 General Radiography Room Observation Results (BAPETEN, 2011).

No	Room Specifications	Size Observation Results	Remarks
1	Room Length	595 cm	Suitable
2	Room Width	484 cm	Suitable
3	Room height	300 cm	Suitable
6	Wall Thickness	25 cm	Suitable
7	Installed Pb thickness	0,2 cm	Suitable

The general radiography space and its surroundings are divided into two occupancy areas, namely controlled areas at Point B, Point C, and Point F, and uncontrolled areas at Point A, Point D, Point E, Point G, and Point H. Each point in the controlled area and uncontrolled areas have walls 20 cm thick with red brick material plastered and coated with Pb with a thickness of 2 mm. Then the rate of radiation exposure was measured and the calculated Pb thickness was calculated on the radiation retaining walls in controlled and uncontrolled areas (Poedjo Rahardjo & Henky, 2011).

Rate of Radiation Exposure and Pb Thickness in Controlled Areas

Table 2. Results of measuring radiation exposure rates in controlled areas

Measuring Point	Distance from Source (m)	Exposure Rate to Background Radiation ($\mu Sv/jam$)	Radiation Exposure Rate ($\mu Sv/jam$)	Calculated Pb Thickness (mm)
Point B	3,6		0,09	0,059
Point C	3	0,071	0,04	0,034
Point F	2,3		0,03	0,15

Based on the radiation exposure rate measurements in Table 2, the background radiation exposure rate value in the general radiography room in the controlled area is 0.071 (μSv/hour) and there is no radiation leakage because the background radiation value that occurs is still below the leakage limit value that has been determined. set to <1 (μSv/hour).

The radiation exposure rate values at Point B, Point C, and Point F are still below the threshold values set by NCRP No. 147 in controlled areas of 0.2 mSv/week or 0.095 (μSv/hour). Meanwhile, based on PERKA BAPETEN No. 8 of 2011, the exposure rate value in the general radiography room is still within safe limits for workers (BAPETEN, 2011).

The radiation exposure rate value obtained is influenced by several factors such as distance and radiation retaining walls. From the measurements carried out, the highest exposure rate value occurred at Point F at 0.055 (μSv/hour) and the lowest radiation exposure rate value was at Point C at 0.042 (μSv/hour). This is because the distance between Point F and the X-ray source is closer, whereas at Point C there are two layers of Pb, namely from inside the general radiography room and from inside examination room 1 so that the radiation exposure rate obtained is lower.

Based on Table 2, the Pb thickness value at Point B is 0.07 mm with a distance of scattered radiation from the point on the patient to inhabited areas of 3.6 m. The thickness of Pb at Point C is 0.034 mm with a distance of scattered radiation from the point on the patient to the inhabited area of 6 m and the thickness of Pb at Point F is 0.18 mm with a distance of scattered radiation from the point on the patient to the inhabited area of 2.3 m. From these results it is known that the largest Pb thickness value in the controlled area is at point F (0.15 mm Pb) and the lowest Pb thickness value is at Point B (0.059 mm Pb). This can happen because Point B has a greater distance from the X-ray source to the protection point than Point F. The Pb thickness value obtained is the minimum Pb thickness that a radiation retaining wall must-have for a workload of 105 patients/week at the hospital.

Rate of Radiation Exposure and Pb Thickness in Uncontrolled Areas

Table 3 Results of Measurement of Radiation Exposure Rates in Uncontrolled Areas

Measuring Point	Distance from Source (m)	Exposure Rate to Background Radiation ($\mu Sv/jam$)	Radiation Exposure Rate ($\mu Sv/jam$)	Calculated Pb Thickness (mm)
Point A	3,3	0,071	0,480	0,46
Point D	3		0,068	0,034
Point E	6		0,075	0,071
Point G	3,7		0,418	0,038
Point H	4,8		0,453	0,005

Based on the radiation exposure rate measurements in Table 3, the value of the background radiation exposure rate in the general radiography room in uncontrolled areas is 0.071 (μSv/hour) and there is no radiation leakage because the background radiation value that occurs is still below the leakage value limit that has been determined. set to <1 (μSv/hour).

The radiation exposure rate values in uncontrolled areas at Point A, Point D, Point E, Point G, and Point H are above the threshold values set by NCRP No. 147, namely 0.01 mSv/week or 0.059 (μSv/hour). Meanwhile, based on PERKA BAPETEN No. 8 of 2011, the value of radiation exposure rates in general radiography rooms in uncontrolled areas is still within safe limits for the public (BAPETEN, 2011).

From the results of the resulting radiation exposure rate, the radiation retaining walls in the controlled area are not optimal in attenuating the radiation exposure that occurs because the value of the radiation exposure rate that occurs is above the threshold set by NCRP No.147. This can happen due to several things, such as point A for the patient waiting room only having one side of the radiation barrier wall from inside the examination room and the distance between point A and the bucky stand being quite close. Then at point D in the officer's room, there is only one side of the radiation barrier wall, whereas at point G the toilet door cannot be closed tightly, allowing radiation exposure to pass through the door gap so that the rate of radiation exposure that occurs is greater. Furthermore, in the changing room, the door is only closed with a curtain so that the radiation exposure that occurs in that room is greater.

Based on Table 3, the calculated value of Pb thickness for the uncontrolled area at Point A is 0.46 mm with a maximum distance of primary radiation from the X-ray tube to the exposed area of 3.3 m. The thickness of Pb at Point D is 0.071 mm with a distance of scattered radiation from the point on the patient to inhabited areas of 3 m. The thickness of Pb at Point E is 0.071 mm with a distance of scattered radiation from the point on the patient to inhabited areas of 6 m. The thickness of Pb at Point G is 0.038 with a distance of scattered radiation from the point on the patient to inhabited areas of 3.7 m, and the thickness of Pb at Point H is 0.005 mm with a distance of scattered radiation from the point on the patient to inhabited areas of 4.8 m.

From these results it is known that the largest Pb thickness value in the uncontrolled area is at point A (0.46 mm Pb) and the lowest Pb thickness value is at Point H (0.005 mm Pb). This happens because Point A has a greater occupancy factor than Point H and the coverage distance at Point H is greater than at Point A. The Pb thickness value obtained is the minimum Pb thickness that a radiation retaining wall must-have for a total workload of 105 patients/week at the hospital.

CONCLUSION

Based on the results of research that has been carried out, the design of radiation retaining walls in the controlled area of the general radiography room is optimal and within safe limits for workers where the radiation exposure rate value is still within the safe limits of the NBD set by NCRP No. 147 and PERKA BAPETEN No. 8 2011. Meanwhile, the design of radiation retaining walls in uncontrolled areas is not yet optimal because the radiation exposure rate value is above the specified NBD. However, it is still within safe limits because individuals in the area have not been there for a long time. The Pb thickness values obtained in controlled and uncontrolled areas are appropriate and optimal based on the provisions of NCRP No. 147 and PERKA BAPETEN No. 8 of 2011.

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