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# COMPARISON OF THE EFFECTIVENESS OF RADIATION SHIELD WALL BETWEEN LEAD-LAYERS AND PLASTERING BRICK-LAYERS

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**Abstract**

The rate of exposure to X-ray radiation on the radiation shielding wall at the Laboratory 3 of Radiology Study Program Purwokerto Diploma Three Program has been analyzed, to find out the difference in the effectiveness of the radiation shielding wall between a 10 cm thick Lead (2 mm) coated partition and a 28 cm thick stucco brick wall. Measurements were made using a radiation source, namely a mobile unit X-ray machine with a Fluke survey meter radiation measuring instrument. Measurement of the rate of exposure to X-ray radiation is carried out by adjusting the distance of the radiation source with the radiation shield wall from 100 cm, 150 cm and 200 cm and taken from 5 measurement points that represent the radiation shield wall. The measurement results show that measurement point C produces the highest radiation exposure rate and measurement point A produces the lowest radiation exposure rate for Do and D. There is a radiation exposure rate of more than 1 μSv/Hr after passing through a 10 cm thick Lead-coated partition wall (2 mm) at a distance of 100 cm to 150 cm. Radiation shielding walls of walls covered with stucco bricks with a thickness of 28 cm were more effective than partitions covered with lead (2 mm) with a thickness of 10 cm. It is necessary to pay attention to aspects of radiation protection, the use of a mobile unit X-ray machine in placing the X-ray tube in the direction of the X-ray tube and, the radiation source distance of at least 2 meters from the lead-coated partition radiation wall.

**Keywords:** *radiation shield; lead; brick*

## 1. Introduction

Radiation is energy in the form of waves or moving subatomic particles. Radiation can generally be divided into two types: electromagnetic radiation and particle radiation. Electromagnetic radiation consists of non-ionizing (radio waves, microwave, infrared, visible light, ultraviolet) and ionizing (X and gamma rays). The particle radiation consists of: alpha, beta and neutron radiation. Radiation is generally defined as ionizing radiation (Akhadi, 200). Radiation source is a material or substance that can emit ionizing radiation. While ionizing radiation is electromagnetic radiation or particles capable of producing ions along the path in the material (eg α-ray, β-ray, γ-rays, X-ray, and neutron). An ionizing radiation generator is a radiation source in the form of an X-ray or particle accelerator that produces a beam of radiation. The use of X-rays in various types and activities, such as in the fields of medicine, research and training has increased rapidly but safety procedures must be observed. Neglect of radiation source control safety procedures can result in unplanned radiation exposure that can be fatal. One of the radiation sources used in the

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health sector is X-ray aircraft. X-ray machines are widely used in the medical field for diagnostic and therapeutic purposes. X-rays have a potential radiation hazard and have a detrimental effect on humans, so their use must pay attention to aspects of radiation protection.

One of the most dangerous and beneficial properties of X-rays is that they can penetrate materials and experience attenuation (weakening) by the materials they pass through, so that the intensity of radiation after passing through the material will be smaller than the initial intensity. Meanwhile, electromagnetic radiation can only be reduced in intensity if the radiation barrier is thickened. The attenuation of X-rays into a material depends on the atomic number, the density of the material, the thickness of the material, and the hardness of the material. When expressed in an equation:

$$I = Io \cdot e^{-\mu . x}$$
$$\mu = \frac{1}{x} Ln \frac{Io}{I}$$

I = radiation intensity after cutting through the radiation-shielding material
Io = radiation intensity before it cuts through the radiation-shielding material
μ = linear absorption coefficient of a material
x = thickness of the radiation shielding material

Based on the Regulation of the Head of BAPETEN Number 8 of 2011 concerning Radiation Safety in the Use of Diagnostic and Interventional Radiology X-Rays, hospitals that provide radiographic examinations using X-rays must take into account the room plan which includes the size, material, and wall thickness of the room (Bapeten, 2011).

Radiation protection programs are carried out to protect officers, the general public, and patients so that radiation can be considered safe to use. The radiation source room is made of radiation retaining walls made of Pb (Plumbum) and concrete because these materials can weaken the intensity of radiation (Hart & Dugdale, 2013). The safe examination room has walls made of stucco bricks with a thickness of 25 cm and a density of 2.2 g/cm3. The thickness of the concrete used is 20 cm or the equivalent of 2 mm lead (Pb). The doors and ventilation of the X-ray examination room are coated with lead (Pb) 2 mm thick, with each Pb connection overlapping so that the radiation level around the X-ray examination room does not exceed the Dose Limit Value (NBD) of 1 mSv/year (Bapeten, 2014).

Radiation shielding for X-ray installations consists of two types, namely the primary radiation shield contained in the X-ray tube case and the secondary radiation shield which is the design of the irradiation room in a hospital or laboratory. The instrument for measuring radiation intensity in the form of exposure or radiation dose is the gamma meter survey. This tool is used to measure external radiation such as gamma rays, X-rays and neutrons, alpha radiation and beta radiation (Schlapper, 1984).

Radiation protection is a very important aspect in controlling these adverse effects. Therefore, each radiology agency must pay attention to radiation protection, especially protection for the X-ray radiation source room, the use of X-ray aircraft must have an operational permit from BAPETEN which in applying for an operational permit must meet the requirements, one of which is the design of radiation barriers on the walls of the aircraft room. X-ray. On the walls of the X-ray aircraft room, radiation exposure measurements are carried out and the measurement results must be safe for workers and the environment around the X-ray examination room (Bapeten, 2020). According to the national standard of BAPETEN Regulation No. 15 of 2014, the maximum value of leakage radiation on the radiation shield is 1 mGy/hour with an FFD distance of 100 cm.

Radiation shielding is needed to absorb radiation so that it can reduce the intensity of the radiation emitted and reduce the radiation dose received by the human body. If radiation enters the radiation shielding material, then some of the radiation will be absorbed by the material. The greater the effectiveness of the radiation shield of a room, the better the radiation shield of the room at absorbing radiation.

In addition to hospitals, the use of X-rays is also used as a practical learning tool for students in educational institutions, one of which is the Purwokerto Radiology Study Program, Diploma Three Program at the Health Polytechnic of the Ministry of Health, Semarang as an effort to achieve practical competence in carrying out

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radiographic examination procedures in the laboratory. X-ray radiation is not only useful but can also be detrimental to students and practical instructors if the facilities and infrastructure used in the laboratory are not in accordance with established regulatory standards. Purwokerto Radiology Study Program Diploma Three has a laboratory building that has a radiographic examination room with 2 (two) types of radiation retaining walls, namely walls with a layer of bricks with a plaster layer of 28 cm and a partition wall with a layer of lead (2 mm) with a thickness of 10 cm. Given the differences in the use of materials as radiation retaining wall layers in laboratory 3, it is necessary to test the effectiveness of the radiation retaining wall materials. Then the results of measuring the rate of radiation exposure are referred to the regulation of the nuclear power supervisory agency number 4 of 2013.

## 2. Method

This type of research is descriptive quantitative research with a survey approach. The equipment used is the Fluke Surveymeter which is used to measure the rate of exposure to X-ray radiation generated by the X-ray radiation source, namely the Mobile X-ray X-ray machine. Phantom abdomen as a human substitute object and distance measuring instrument / meter. The steps for data collection were initiated by determining 5 measurement points on each radiation retaining wall (each 50 cm apart), determining the distance between the central point of the X-ray beam parallel to the measurement point, namely 1 meter, 1.5 meters and 2 meters. Do the exposure with an exposure factor of 80 KV and 25 mAs with each measurement point 3 times exposure and then the results are averaged. The effectiveness of the radiation retaining wall can be determined by measuring the rate of exposure to X-ray radiation before the X-ray beam hits the radiation shielding wall (Do) and after it passes through the radiation shielding wall (D). The percentage effectiveness of the radiation shielding wall using:

$$Effectiveness = \frac{Do-D}{Do} x100\%$$

Do = Measurement of radiation exposure rate before radiation shield wall
D = Measurement of radiation exposure rate after radiation shielding wall

After the data is obtained, then the data is presented in the form of tables and then analyzed descriptively.

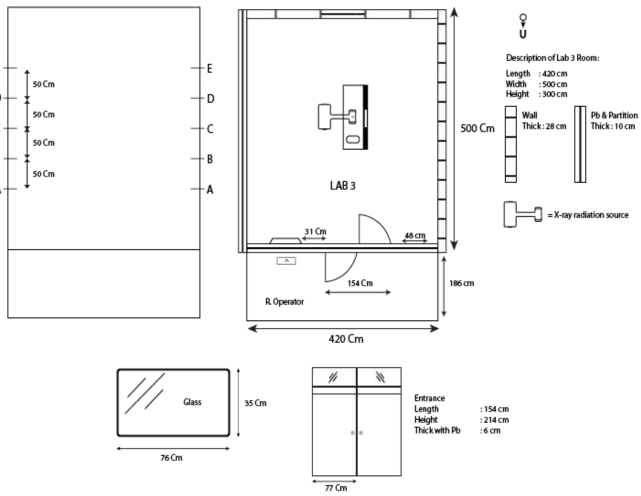


*Figure 1.* *Laboratory radiography examination room plan Purwokerto Radiology Study Program*

## 3. Result and Discussion

*The results of the measurement of the rate of exposure to X-ray radiation on a radiation retaining wall of partition material with a layer of lead (2 mm) 10 cm thick.*

Table 1. shows that the measurement of the rate of exposure to X-ray radiation is carried out 2 (two) times, namely before the radiation barrier (Do) inside the laboratory 3 and after passing the radiation barrier (D) outside the laboratory 3. Then it is carried out calculation of the radiation barrier effectiveness of lead-coated partition materials. From the results of the measurement of the radiation exposure rate, the closer the X-ray radiation source is to the measurement point, the greater the X-ray radiation exposure rate measurement results. On the other hand, the farther the X-ray radiation source is from the measurement point, the smaller the X-ray radiation exposure rate will be.

**Table 1.** Results of measuring the rate of exposure to X-ray radiation on a radiation retaining wall made of lead-coated partitions (2 mm) with a thickness of 10 cm

| Measuring point | Radiation source distance to radiation retaining wall of lead coated partition material with a thickness of 10 cm | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 100 cm | | | 150 cm | | | 200 cm | | |
| | Do | D | Effectiveness (%) | Do | D | Effectiveness (%) | Do | D | Effectiveness (%) |
| A | 1600 | 3 | 99.81 | 1514 | 2 | 99.87 | 1314 | 0 | 100 |
| B | 4900 | 4 | 99.91 | 4800 | 2 | 99.95 | 4600 | 0 | 100 |
| C | 7800 | 6 | 99.84 | 7600 | 3 | 99.96 | 7510 | 1 | 99.99 |
| D | 5400 | 4 | 99.92 | 5100 | 2 | 99.96 | 4910 | 0 | 100 |
| E | 3726 | 2 | 99.95 | 3420 | 1 | 99.97 | 3310 | 0 | 100 |

At a distance of 100 cm is the closest distance to produce the highest radiation exposure rate value, namely at the measurement point C of 7800 μSv/hour before the radiation barrier (Do) and 6 μSv/hour the radiation exposure rate after passing the radiation barrier (D). then the effectiveness as a radiation retaining wall is 99.84%. While the lowest radiation exposure rate value is shown at the measurement point A with the radiation exposure rate value of 1600 μSv/hour before radiation barrier (Do) and 3 μSv/hour radiation exposure rate after passing radiation barrier (D). then the effectiveness as a radiation retaining wall is 99.81%.

At a distance of 150 cm, the measurement point C produces the highest radiation exposure rate value, which is 7600 μSv/hour before radiation barrier (Do) and 3 μSv/hour radiation exposure rate after passing radiation barrier (D). then the effectiveness as a radiation retaining wall is 99.96%. Meanwhile, the lowest radiation exposure rate value is shown at the measurement point A with the radiation exposure rate value being 1514 μSv/hour before radiation barrier (Do) and 2 μSv/hour radiation exposure rate after passing radiation barrier (D). then the effectiveness as a radiation retaining wall is 99.87%.

At a distance of 200 cm, the measurement point C produces the highest radiation exposure rate, which is 7510 μSv/hour before radiation barrier (Do) and 1 μSv/H radiation exposure rate after passing radiation barrier (D). then the effectiveness as a radiation retaining wall is 99.99%. Meanwhile, the lowest radiation exposure rate value is shown at the measurement point A with the radiation exposure rate value being 1314 μSv/hour before the radiation barrier (Do) and 0 μSv/H the radiation exposure rate after passing the radiation barrier (D). then the effectiveness as a radiation retaining wall is 100%.

*The results of measuring the rate of exposure to X-ray radiation on a radiation retaining wall from a wall with a layer of stucco bricks with a thickness of 28 cm.*

Table 2. shows that the measurement of the rate of exposure to X-ray radiation is carried out 2 (two) times, namely before the radiation barrier (Do) inside the laboratory 3 and after passing the radiation barrier (D) outside the laboratory 3. Then it is carried out Calculation of the radiation barrier effectiveness of a wall covered with stucco bricks. From the results of the measurement of the radiation exposure rate, the closer the X-ray radiation source is to the measurement point, the greater the X-ray radiation exposure rate measurement results. On the other hand, the farther the X-ray radiation source is from the measurement point, the smaller the X-ray radiation exposure rate will be.

At a distance of 100 cm is the closest distance to produce the highest radiation exposure rate value, namely at the measurement point C, which is 8311 μSv/hour before the radiation barrier (Do) and 0 μSv/hour the radiation exposure rate after passing the radiation barrier (D). then the effectiveness as a radiation retaining wall is 100%. While the lowest radiation exposure rate value is indicated at the measurement point A with the radiation exposure rate value of 2310 μSv/Hour before the radiation barrier (Do) and 0 μSv/Hour radiation exposure rate after passing the radiation barrier (D). then the effectiveness as a radiation retaining wall is 100%.

At a distance of 150 cm, measurement point C produces the highest radiation exposure rate value, namely 8111 μSv/hour before the radiation barrier (Do) and 0 μSv/H radiation exposure rate after passing radiation barrier (D). then the effectiveness as a radiation retaining wall is 100%. While the lowest radiation exposure rate value is indicated at the measurement point A with the radiation exposure rate value of 2009 μSv/Hour before radiation barrier (Do) and 0 μSv/Hour radiation exposure rate after passing radiation barrier (D). then the effectiveness as a radiation retaining wall is 100%.

**Table 2.** The results of measuring the rate of exposure to X-ray radiation on a radiation retaining wall from a wall with a layer of stucco bricks with a thickness of 28 cm

| Measuring point | The distance of the radiation source to the radiation-retaining wall from the wall with stucco bricks with a thickness of 28 cm | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 100 cm | | | 150 cm | | | 200 cm | | |
| | Do | D | Effectiveness (%) | Do | D | Effectiveness (%) | Do | D | Effectiveness (%) |
| A | 2310 | 0 | 100 | 2009 | 0 | 100 | 1810 | 0 | 100 |
| B | 5610 | 0 | 100 | 5309 | 0 | 100 | 5100 | 0 | 100 |
| C | 8311 | 0 | 100 | 8111 | 0 | 100 | 8000 | 0 | 100 |
| D | 5910 | 0 | 100 | 5611 | 0 | 100 | 5400 | 0 | 100 |
| E | 4210 | 0 | 100 | 3911 | 0 | 100 | 3800 | 0 | 100 |

At a distance of 200 cm, the measurement point C produces the highest radiation exposure rate, which is 8000 μSv/hour before radiation barrier (Do) and 0 μSv/H radiation exposure rate after passing radiation barrier (D). then the effectiveness as a radiation retaining wall is 100%. Meanwhile, the lowest radiation exposure rate value is shown at the measurement point A with the radiation exposure rate value being 1810 μSv/hour before radiation barrier (Do) and 0 μSv/hour radiation exposure rate after passing radiation barrier (D). then the effectiveness as a radiation retaining wall is 100%.

Experimentally, it was found that the overall rate of exposure to X-ray radiation before hitting the radiation retaining wall (Do) of a wall covered with stucco bricks with a thickness of 28 cm was greater than that of a 10 cm thick lead-coated Do partition (2 mm). This happens because the radiation-resistant material with a greater thickness of the material, the higher density of the material will be able to withstand and reflect more X-ray radiation intensity. Likewise, when the radiation exposure rate passes through the radiation barrier, it will give a very low or even non-existent value, so the effectiveness of the radiation barrier from the wall material covered with stucco bricks with a thickness of 28 cm is better/optimal compared to a 10 cm thick lead-coated partition. With the use of a radiation retaining wall made of a 10 cm thick lead-coated partition, there is still a leakage rate of X-ray radiation exposure of more than 1 μSv/hour at a distance of 100 cm and 150 cm, while at a distance of 200 cm it is relatively safe. If referenced from Bapeten Perka No. 8 of 2011 that the measurement results of X-ray radiation exposure rate are declared safe if they do not exceed the Limit Dose Value (NBD) which is 1 mSv/year for the general public and 20 mSv/year for radiation workers.

## 4. Conclusion and Suggestion

Based on the research that has been done, it can be concluded that there is a difference in the effectiveness of the use of radiation retaining walls between wall materials covered with stucco bricks with a thickness of 28 cm and partitions covered with lead (2 mm) with a thickness of 10 cm. By varying the distance between the radiation source and the measurement point 3 times, namely 100 cm, 150 cm and 200 cm, it shows that the results of the measurement of the radiation exposure rate are influenced by the distance of the X-ray radiation source to the measurement point where the closer will give the results of the measurement of the exposure rate. X-ray radiation is getting bigger. On the other hand, the farther the X-ray radiation source is from the measurement point, the smaller the X-ray radiation exposure rate will be. At measurement point C produces the highest radiation exposure rate and measurement point A produces the lowest radiation exposure rate for Do and D. Radiation retaining walls of walls covered with stucco bricks with a thickness of 28 cm are more effective than partitions covered with lead (2 mm) with a thickness of 10 cm. It should be noted that when using an X-ray machine, the positioning of the X-ray tube and the distance of the radiation source must be at least 2 meters from the lead-coated partition radiation retaining wall.

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