Synthesis and characterization of resin lead acetate composites and ability test of X-ray protection

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Abstract. Radiation is widely used in various fields, especially in the health sector, but radiation can cause dangers. Including genetic mutations, therefore we need a system to protect from these dangers. One of the radiation protection systems is to use lead glass. In this research, an alternative substitute for lead glass is offered where a composite resin has been made with the addition of lead acetate variations. Several tests have been carried out including the absorption of x-ray radiation reaching 100% obtained at a sample thickness of 13mm with a ratio of 50% resin and 50% lead acetate. In SEM testing, it was obtained dense morphological results and EDX testing showed a balance of constituent compounds between Carbon (C), Oxygen (O) and Lead (Pb) in this sample.

1. Introduction
The interaction of radiation in humans can cause changes in cell structure, this can cause harm to workers or patients from the mildest to the most fatal, because this requires a radiation shielding system to avoid unwanted dangers and make the most of radiation. Various protective materials are used to attenuate or completely absorb radiation [1].

Building structures in radiation generating installations such as buildings and reactors are very important for the safety of operations, because they help protect the environment from certain external and internal events. Internal events include procedural accidents or equipment malfunction [2].

In this study, the synthesis and characterization of composite samples added with lead with various concentrations of lead doping were carried out and then tested the morphological composition of the samples using Scanning Electron Microscopy and Energy Dispersive X-Ray Spectroscopy (SEM EDX).

X-rays are electromagnetic waves that have a wavelength between 10-9 to 10-8 m which is much shorter than visible light, so the energy is greater [3]. The protective effectiveness of the material against radiation is highly dependent on the type and energy of the radiation, this usage is based on certain transcendent characteristics of these elements, such as higher density and greater energy of the radiation energy absorption edge [1]. Glass is usually transparent, hard, brittle and pure to the elements of glass. Apart from that, glass is also classified as a good material for visible light transmission. For that reason, glass can be a noble substitute for concrete as a gamma-ray protection agent [4].

Pethe use of lead as a radiation barrier not only as a coating for walls and roofs but also in doping on glass which is often known as lead glass. As for lead glass used in various nuclear installations, it is fragile and is still very expensive. Polyester acids are able to bind free and complex Pb metals in the environment. The polyester acid that is formed in the mold has a smooth, elastic and clear side [5].
Lead glass used as X-ray protection requires certain specifications. Among them must be able to absorb X-ray radiation but be able to transmit light as well. The radiation intensity absorption relationship can be stated:

$$I = I_0 e^{-\mu x}$$

In recent years the point of view has been established that mixtures of multilayered and composite materials have very effective protective properties from the effects of radiation. These materials allow multiple dosage reductions in the resulting mixture of material elements with the same mass dimensional characteristics [6].

SEM EDX is an electron microscope that uses a focused beam of electrons that react with the sample to produce topological images and relative composition [7].

2. Methods

The method used in this research is the experimental method. The tool used in this research is 1 Mobile X-ray unit with the brand / type Mednif / SF-100BY, which consists of X-ray tube facilities, high voltage generators along with control panels, radiation survey meter, measuring cups, spatulas, scales, Bunsen, and a suite of SEM EDX Brand Phenom Pro X tests.

The flow of this research began with the search for the best mixture composition by making an initial sample with a lead acetate and resin ratio of 10;90, 30;70, and 50;50. Then the thickness variations are made of 1 mm, 3 mm, 5 mm, 7 mm, 9 mm, 11 mm, 13 mm, and 15 mm. Then the sample is scraped to get optimal precision, which of the abrasive process results in a powder that is used as a SEM EDX test sample. Then measuring the absorption dose of radiation using a survey meter with exposure to X-ray radiation with an exposure factor of 100 cm, 32 mA, 0.2 s, 80 kV.

3. Results and Discussion

In this study, the object used was a mixture of yukalac 108 polyester resin and lead acetate which was printed on plastic media in a tube shape. In the process of mixing the sample material, heating is needed using a Bunsen so that the mixture has a temperature of 60°C to remove bubbles during the printing process and the drying process uses room temperature so that the drying process can be observed.

Radiation exposure testing uses an X-ray radiation source with an established exposure factor of 100 cm, 32 mA, 0.2 s, 80 kV. The exposure factor was measured using a survey meter with the resulting radiation value of 750 µSv / h. By knowing the initial radiation value is used as a reference to determine the dose absorbed by the sample by reducing the initial dose minus the final dose or the dose that is able to pass through the sample.

Radiation exposure testing has been carried out with variations in the composition of the mixture and the thickness of the sample with the results in Tables 1, 2 and 3.

| Table 1. Mixed composition variation 90 ; 10. |
|-------------------------|-------------------------|-------------------------|-------------------------|
| No | Thickness (mm) | Initial Dose (µSv / h) | Remaining Dose (µSv / h) | Absorbed Dose (µSv / h) |
|---|---------------|-----------------|-----------------|-----------------|
| 1 | 1 | 750 | 750 | 0 |
| 2 | 3 | 700 | 50 |
| 3 | 5 | 700 | 50 |
| 4 | 7 | 650 | 100 |
| 5 | 9 | 650 | 100 |
| 6 | 11 | 600 | 150 |
| 7 | 13 | 600 | 150 |
| 8 | 15 | 550 | 200 |
From the data above, it can be explained that the more lead content in the sample affects the absorption of radiation. It can be seen from the data above that the best composition in the ratio of 50% Resin: 50% Lead Acetate at a thickness of 13mm no longer has a residual dose which means up to 100% absorption. Whereas at composition 70 : 30 and 90 ; 10 even with the maximum thickness the author still gets the remaining dosage data.

| Table 2. Mixed composition variations 70 ; 30. |
|------------------------------------------------|
| **No** | **Thickness (mm)** | **Initial Dose (µSv / h)** | **Remaining Dose (µSv / h)** | **Absorbed Dose (µSv / h)** |
|--------|---------------------|-----------------------------|-------------------------------|-----------------------------|
| 1      | 1                   | 750                         | 600                           | 150                         |
| 2      | 3                   | 550                         | 500                           | 200                         |
| 3      | 5                   | 500                         | 450                           | 250                         |
| 4      | 7                   | 450                         | 400                           | 300                         |
| 5      | 9                   | 400                         | 350                           | 350                         |
| 6      | 11                  | 350                         | 300                           | 400                         |
| 7      | 13                  | 300                         | 250                           | 450                         |
| 8      | 15                  | 250                         | 200                           | 500                         |

| Table 3. Mixed composition variation 50 ; 50. |
|------------------------------------------------|
| **No** | **Thickness (mm)** | **Initial Dose (µSv / h)** | **Remaining Dose (µSv / h)** | **Absorbed Dose (µSv / h)** |
|--------|---------------------|-----------------------------|-------------------------------|-----------------------------|
| 1      | 1                   | 750                         | 300                           | 450                         |
| 2      | 3                   | 550                         | 250                           | 500                         |
| 3      | 5                   | 500                         | 200                           | 550                         |
| 4      | 7                   | 450                         | 150                           | 600                         |
| 5      | 9                   | 400                         | 100                           | 650                         |
| 6      | 11                  | 350                         | 50                            | 700                         |
| 7      | 13                  | 300                         | 0                             | 750                         |
| 8      | 15                  | 250                         | 0                             | 750                         |

To find out the reasons why the sample can absorb X-ray radiation, the authors conducted a SEM EDX test to determine the composition and morphology of the mixture between resin and lead acetate. Tests were carried out with variations in the composition of 90 ; 10, 70 ; 30, 50 ; 50 with powdered sample preparation and coating with argon gas and producing shown in Table 4.

From the data in Table 4 the EDX test can show the results of the mixture with a composition of 90 ; 10 Carbon (C) content obtained a concentration of 87.09%, the content of Lead (Pb) can be a concentration of 2.39%, while the content of Oxygen (O) amounting to 10.59%.

For the mixture with a composition of 70 ; 30 carbon content, the concentration is 57.39%, the lead content is 20.51%, while the oxygen content is 22.11%. And the results of the mixture with a composition of 50; 50 carbon content obtained a concentration of 40.62%, the content of Lead (Pb) obtained a concentration of 31.61%, while the oxygen content of 27.77%. Meanwhile, pure resin has a carbon content of 85.26% and oxygen content of 14.47%.

From this data and correlated with the radiation absorption dose test data which is at the composition 90 ; 10 and 70 ; 30 although it has a maximum thickness in this study but still leaves a radiation dose, it can be concluded that this composition has the ability to absorb radiation that is not good enough, caused by the lead content which is not sufficient to withstand the radiation dose that passes through it as stated.
in the research presented by Tishkevich that lead is very suitable for reducing the effects of gamma rays and X-rays because of its high atomic number [6].

Table 4. EDX test results table.

| Resin; PB Acetate | Atomic Conc (%) | Element |
|-------------------|-----------------|---------|
| 90 ; 10           | 87.09           | C       |
|                   | 10.52           | O.      |
|                   | 2.39            | Pb      |
| 70 ; 30           | 57.39           | C       |
|                   | 22.11           | O.      |
|                   | 20.51           | Pb      |
| 50 ; 50           | 40.62           | C       |
|                   | 27.77           | O.      |
|                   | 31.61           | Pb      |
| 100 ; 0           | 85.26           | C       |
|                   | 14.47           | O.      |
|                   | 0               | Pb      |

This is supported by Figure 1 SEM test image results at composition 90 ; 10 has a sufficiently large degree of distance between particles so that X-ray radiation can pass through it, while for Figure 2 SEM test results at composition 70 ; 30 have a better density level than the previous composition marked by the results of better absorption of the radiation dose than the previous composition even though it still has a residual dose.

Figure 1. Morphology 90 ; 10

Figure 2. Morphology 70 ; 30

For the composition of 50 ; 50, it can be stated that this is the best composition that the authors get in Table 3 with a thickness of 13 mm, there is no residual dosage which can be stated that the absorption of radiation is 100%, as for Figure 4 and Figure 1 this composition has a balanced content. From Figure 3, it can be seen that the density between particles is very good so that X-ray radiation can be absorbed maximally.
4. Conclusion
The use of lead acetate doped polyester resin can be used as an alternative material from lead glass which has a function as a radiation protection material, details on the composition of 50% lead acetate and 50% resin with a thickness of 13 mm obtained a radiation absorption value of 750 $\mu$Sv / h from the initial radiation dose was 750 $\mu$Sv / h, which was stated as the percentage of absorption of the radiation dose reaching 100%.

In the SEM EDX test, it was stated that the composition of 50% Resin and 50% Lead Acetate was the best composition because it had a balanced content between carbon, oxygen and lead. As for the results of SEM in this composition looks very good density between particles so that X-ray radiation can be absorbed optimally.

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