Fabrication and analysis of radiation dose for elastic lead polyester composites as a glass coating

A F Septiano*, H Sutanto1 and Susilo2
1 Physics Department, Diponegoro University, Semarang, Indonesia, 50275
2 Physics Department, Universitas Negeri Semarang, Semarang, Indonesia, 50229

*Corresponding author: alvinfachrully.2016@fisika.fsm.undip.ac.id

Abstract. Radiation affecting the human body can cause harm to workers from the lightest to the most fatal. As a result of these interactions, cells can undergo structural changes. Therefore a radiation shield is needed for radiation protection purposes. In this research, a polyester composite sample was made with a variation of lead doping concentration and illumination strength test using a flux meter to determine the permeability of the sample to light, as well as an X-ray radiation absorption test of the sample as desired by the lead polyester being able to be an alternative from the constituent materials of lead glass as a radiation shield that has the advantage of a high level of elasticity so as to minimize the risk of damage (break). Obtained the best mixture composition of 30% Lead Acetate and 70% Lead Polyester, with a radiation exposure test of 35 μSv the results of the radiation absorbing dose on the thickness of the 15mm lead resin layer and Transparency test with an inhibitory value of light of 394 Lux from an initial light source of 700 lux and the rest of the light that is able to penetrate a sample of 306 Lux

1. Introduction
Radiation on the human body can cause harm to workers from the mildest to fatal. As a result of the interaction of the cells may undergo structural changes. Therefore, it required radiation shielding for radiation protection purposes. To avoid unwanted dangers of this kind of radiation, a variety of protective materials used to weaken or even completely absorb radiation [1]. The building structure in plant installations such as buildings and reactor radiation plays an important role in the safety of operations because they help protect the environment from certain external and internal events. Internal events, including procedural accident or malfunction devices [2]. In this study conducted by making samples of composite polyester were added to the lead with a variation of doping concentration of lead and done, test transparency using a flux meter to determine the penetrating power of the sample to light, as well as to test the absorption of the radiation dose X-rays to the sample as in desired that the polyester lead able to replace the role of lead glass as a radiation shield which has the advantage of a high degree of elasticity so as to minimize the risk of damage (broken).

2. Theory
X-rays are electromagnetic waves that have wavelengths of between 10-9 up to 10-8 m, which is much shorter than visible light, so the energy is greater of its energy (E in Joules) can be determined by using the equation.
Effectiveness against radiation protective materials depends on the type and energy of radiation, is based on the use of certain transcendental characteristics of these elements, such as a higher density and greater energy than the radiation energy absorption edge [1]. Glass windows are transparent, hard, brittle and purely for glass elements. In addition, the glass is also classified as a good material for transmitting visible light. For that reason, the glass can be a noble substitute for concrete as a gamma-ray shielding material [3].

The implementation of lead as a radiation shield not only as coating walls and roofs but also on the glass doping is often known as lead glass (lead glass). The lead glass is used in a variety of nuclear installations is still fragile, and the price is still very expensive. Polyester acid is able to bind Pb-free and easy mixture in the environment. Polyester acid formed in the mold has a smooth side, elastic, and transparent [4].

Lead glass is used as catcher X-ray images need to be specified. Among them should be able to absorb the X-rays but is able to transmit light. Relations radiation absorption can be expressed:

\[ I = I_0 e^{-\mu x} \]

In recent years, the viewpoint has been formed, that layered materials and composites have properties very effective protection from the effects of radiation. These materials allow a reduction in the dose several times on aircraft equipment elements with the same mass-dimensional characteristics [5].

3. Method

The method used in this study is the experimental method. The tools used in this study were 1 Unit Mobile X-ray by brand/type Mednif / SF-100BY, which comprise X-ray tube, high voltage generator and its control panel, SurveyMETER radiation, measuring cups, spatulas, scales, bunsen and a set of powerful illumination experiment consisting of incandescent lamps, and lux meter.

Chronology of the research started from finding the best mix of compositions by making the initial sample with lead acetate and resin ratio of 30:70, 40:60, and 50:50. The sample exposed in X-ray radiation by a expose factor is 80 cm, 16 mA, 0.25's, and 70 kV, respectively. After the composition can be done best in the thickness variation of 0 mm, 3 mm, 6 mm, 9 mm, 12 mm, and 15 mm, the samples were analyzed to radiation dose absorbed measurements using survey meter, and illumination intensity was an examination by lux meter.

4. Results and Discussion

4.1 Preparation of Sample

In this study, the object of study is a mixture of polyester resin and lead acetate that is printed on the surface of transparent glass. In the process of mixing the ingredients needed heating samples using a bunsen so that the mixture has a temperature of 60 °C to eliminate bubbles during the printing process and the drying process using a room temperature so that the drying process can be observed.

4.2 Radiation Exposure Test

From the research, we get the exposing factor are 80 cm, 16 mA, 0.25's, 70 kV. Exposing factors were measured using SurveyMETER with the value of radiation produced by 90μSv / h. By knowing the value of the initial radiation is used as a reference to determine the dose absorbed by the sample by subtracting the first dose or dose reduced final dose that is capable of passing through the sample.

Radiation exposure has been carried out as determining the value of the composition that will be used on the sample according to the Table 1.
Table 1. The composition of the mixture and Dose Radiation Absorption

| Composition | Thickness | Residual Dose (μSv / h) | Absorption Dose (μSv / h) |
|-------------|-----------|-------------------------|---------------------------|
| Lead Acetate : Resin | (μSv / h) | (μSv / h) |
| 30:70 | 3mm | 35-40 | 50-55 |
| 40:60 | | 30-20 | 60-70 |
| 50:50 | | 0 | 90 |

From the above data, the authors choose the composition of 30% and 70% Lead Acetate Polyester Resin by doing some variation of the layer thickness. The test data with a thickness variation of radiation exposure obtained from the mixture of sample thickness variations are shown in Table 2.

Table 2. The thickness of the sample and Dose Radiation Absorption

| Composition | Coating Thickness | Total Thickness | Residual Dose (μSv / h) | Absorption Dose (μSv / h) |
|-------------|------------------|----------------|-------------------------|---------------------------|
| Lead Acetate: Resin (mm) | | (mm) | (μSv / h) | (μSv / h) |
| 30:70 | 0 | 3 | 80 | 10 |
| 3 | 6 | 35 | 55 |
| 6 | 9 | 25 | 65 |
| 9 | 12 | 15 | 75 |
| 12 | 15 | 5 | 85 |
| 15 | 18 | 0 | 90 |

Figure 1. Against Radiation Absorption Test Sample Thickness
From the table 1 and 2 then figure 1 above shows if the thicker layer of polyester resin lead sample the higher the absorbed dose of radiation from a sample with known from the decreasing value of the residual radiation is able to pass through the sample.

4.3 Illumination Test (Transparency of the Light)
Lighting vigorous testing to get the value of transparency sample to light. If the value of the transparency of the sample to light can either be marked with a small light absorption value so that light is able to penetrate the sample and conversely the greater the light absorption value of the sample, the more difficult of light through the sample. The robust test data illumination with a light intensity of 700 Lux initial and variation of the thickness of the sample shown in Table 3.

| Coating Thickness | Total Thickness | Residual Intensity (Lux) | Absorption Intensity (Lux) |
|-------------------|-----------------|--------------------------|---------------------------|
| Lead Acetate: Resin (mm) | Glass + Mixed (mm) | 680 | 20 |
| 0 | 3 | 680 | 20 |
| 3 | 6 | 563 | 137 |
| 6 | 9 | 481 | 219 |
| 9 | 12 | 391 | 309 |
| 12 | 15 | 365 | 335 |

From these data, it can be stated that the thicker the sample, the greater the value intensity absorption of light so that the value of transparency and light shrink increasingly difficult to penetrate the sample.

5. Conclusion
The use of polyester resin material by doping lead acetate can be used as a glass coating material that has a function as a radiation protection material, the details on the composition of 30% and 70% Lead
Acetate Resin with a thickness of 3 mm obtained value of the absorption of radiation of 50-55 μSv/h of dose initial radiation by 90 μSv/h and leaving the dose by 35-40 μSv/h. The thicker the glass coating material, in this case, a mixture of polyester resin samples of lead, the greater the radiation absorption value of the sample with a coating thickness of 15 mm and 18 mm with a total thickness of the glass. Although thick still capable of coating material in translucent glass with light at the highest absorption value at a total thickness of 18 mm by 394 Lux and have a residual light intensity of 306 Lux.

References
[1] Shik, N A and Gholamzadeh L 2018 Appl. Radiat. Isot. 139 61-65
[2] Azreen N M, Rashid R S M and Haniza M 2018 Constr. Build. Mater. 172 370-377
[3] Sayyed, M I and Lakshminarayana G 2018 J. Non-Cryst. Solids 487 53-59
[4] El-Mallawany R, Sayyed M I, Dong, M G and Rammah Y S 2018 Radiat. Phys. Chem. 151 239-252.
[5] Tishkevich S S, Grabchikov S S, Lastovskii S B, S.V.Trukhanov S V, Vasin D S, Zubar T I, Kozlovskiy A L, Zdorovets M V, Sivakov V A, Muradyan T R and Trukhanov A V 2018 J. Alloys Compd. 771 238-245.