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Re-use of waste components of accumulators (accu) as x-ray radiation protection

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Abstract. Radiation protection is the means for protecting radiation workers and the general public from the harmful effects of radioactive substances and / or other radiation sources. The principle of radiation protection is to reduce the radiation intensity, one of which can be done by using a radiation absorbing materials. Lead is a material that effectively absorbs radiation due to its high atomic number and density. A research has been conducted by using lead components of waste accumulators dopped with yukalac C108B. Samples were made with variations in lead concentrations of 10%, 20%, 30%, and 40% and with variations in thickness of 0.5 cm; 1 cm; 1.5 cm; 2 cm; 2.5 cm, 3 cm. Tests were carried out by exposing samples to X-ray and measure its absorbtion dose rate using a surveymeter. The increase in lead concentration and thickness causes an increase in the X-ray absorption dose rate. In addition, it also shows an increase in logarithm of light intensity that enters the film against the intensity of light transmitted through the film as the alternative to optical density, and a decrease in X-Ray Transmittance which is the X-ray-to-sample transmission value. The results obtained show, the attenuation coefficient value with variation in lead concentration and average thickness were 0.11328048 cm⁻¹ ; 0.15691327 cm⁻¹ ; 0.1831095 cm⁻¹ ; and 0.21584088 cm⁻¹ . The lead components from waste accumulators can be used as an alternative for the manufacture of radiation absorbing materials with consideration of its ability to absorbs radiation.

1. Introduction

Radiation protection is an attempt to reduce the received dose of radiation. Radiation protection aims to protect radiation workers and the general public from the dangers of using radioactive substances and / or other radiation sources [1]. The principle of radiation protection is to reduce the intensity of radiation with matter, namely by converting radiation energy into heat energy so that radiation exposure is reduced [2]. Radiation protection efforts must be carried out according to the ALARA (As Low As Reasonably Achievable) principle, namely that the radiation dose received is strived to be as minimal as possible in order to minimize the radiation exposure received by the radiation worker.

The government has issued Government Regulation number 33 of 2007 concerning Safety of Ionizing Radiation and Security of radioactive sources, Decree of the Head of Bapeten number 01 / Ka-Bapeten / V-99 concerning Health against ionizing radiation called radiation safety, which contains a dose limit value, namely radiation workers < 50 mSv / year and the general public <5 mSv / year [2]. Based on the International Commission on Radiological Protection (ICRP), the effective dose limit for radiation workers is 20 mSv / year and for the public 1 mSv / year.



The interaction of radiation with matter differs according to the type of radiation and radiation energy, so the thickness of the radiation barrier used is also different. In general, radiation will decrease as the thickness of the radiation-bearing material increases [3]. X-ray radiation with a certain intensity when it penetrates the material, the radiation intensity will decrease exponentially in proportion to the thickness of the barrier [4].

Many materials can be used as radiation protection materials. Almost all radiology rooms in Indonesia use lead as a radiation protection material. The use of Lead is very large in its ability to protect the radiation generated by X-ray aircraft. Lead is considered as one of the best radiation retaining materials to date [5]. Nowadays lead metal has many benefits in life. One of the benefits of lead is as the main component in making batteries. This research was conducted to test the lead plate of used motorcycle batteries as radiation protection material against X-rays

The process of forming x-rays begins when the cathode in the tube, which is a coil of wire, is used as a filament, which when heated will form electrons. The electrons are accelerated towards the metal anode target which has a high atomic number and melting point. The flow of electrons flows from the cathode to the anode due to the potential difference between the cathode and the anode [6,7]. As a result of the collision between the electrons and the anode metal, x-rays are produced. X-rays scattered out of the tube will be captured by a light-sensitive film. The amount of x-ray energy can be determined by the equation [6].

$$E = \frac{hc}{\lambda}$$

The tube voltage (kV) in the X-ray generator is one factor that can be controlled to reduce scattered radiation and reduce the dose used in radiodiagnostics [8]. Increasing the tube voltage value decreases the wavelength value. An increase in the voltage value of the X-ray generator tube used must be balanced with a decrease in the current value of the X-ray generator tube and the time of irradiation in order to obtain sufficient radiation intensity [9].

1.1. Attenuation Coefficient

The attenuation coefficient (μ) is defined as the ability of a material to absorb an incident radiation. If there is radiation coming to an object, the value of the radiation intensity that enters the material and the value of the radiation intensity that comes out of the material will be different [10], this is due to the attenuate properties of the material [5].

The attenuation mechanism into a material depends on the atomic number, density of the material, thickness of the material, hardness of the material or it can be expressed using the Beer-Lambert law [4].

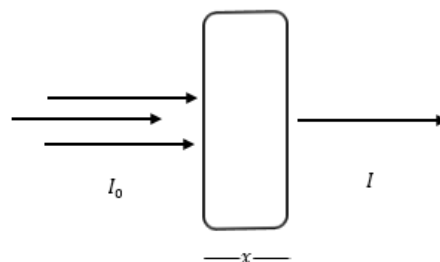


Figure 1. X-Ray absorption Mechanism

The number of primary photons that escape the material will decrease exponentially [11].

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

2. Methods

This study used lead (pb) from a used motorcycle battery and Yukalac C 108 B resin as a doping material. Lead polyester plate made using 10x10 cm mica mold with various thicknesses; 5, 10, 15, 20,

25, 30 mm. Then for each thickness value, a lead polyester plate was also made with various concentrations of lead; 10%, 20%, 30%, and 40%.

The test was carried out by exposing the sample to X-rays using a Mednif SF-100BY X-ray plane and a digital radiography system in the Medical Physics Laboratory of the State University of Semarang. The sample was exposed to X-rays twice. In the first exposure, the dose rate was measured using a survey meter with the exposure factor; tube voltage 70kV; electric current 32 mA; and exposure time 0.2 s. To find out the radiation dose rate with an analog survey, a recording must be done because the analogue survey meter will return to point 0 after the radiation is lost. Whereas in the second exposure, where the results of the radiographic image are used in the gray level analysis using MATLAB software, it is carried out with the exposure factor; tube voltage 70 kV; electric current 16mA; and exposure time 0.2 s.

3. Results and Discussion

In this research, used lead motorbike battery which is considered to have lead content in its components. This is evidenced by the SEM-EDX test which shows that the battery components contain lead with a presentation of more than 90%. Furthermore, the lead is used as a filler for the manufacture of polyester plates which are dipped in resin. The manufacture of lead polyester plates is done by varying the concentration of lead doping on the polyester.

Furthermore, X-ray exposure was carried out on the sample to determine the X-ray absorption dose rate. To find out the radiation dose rate with an analog survey, a recording should be done, because the analog survey will return to point 0 after the radiation is lost.

The test results on lead polyester plate as a radiation protection material by measuring the absorption dose of radiation show that the absorption dose of radiation will increase with increasing thickness of the lead polyester plate. In addition, the radiation absorption dose rate will increase exponentially with the increase in the concentration of lead doping on the polyester plate as an absorbent material.

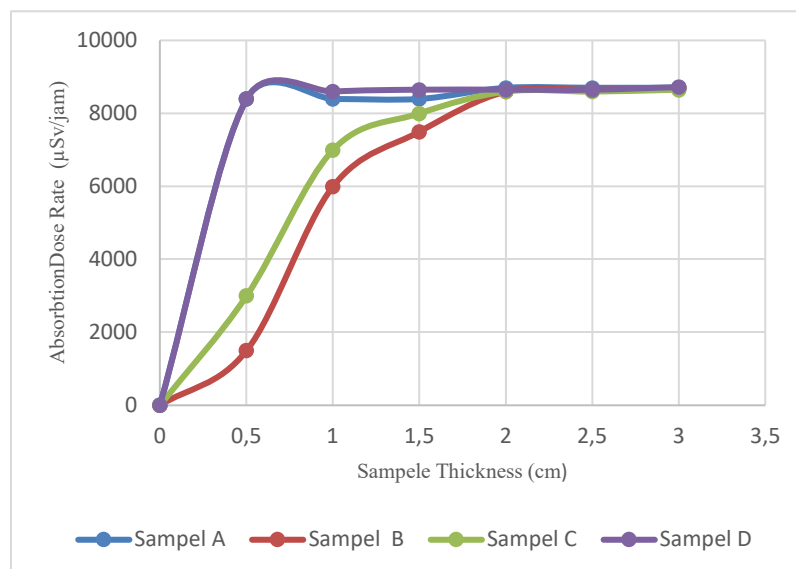


Figure 2. Comparison chart of the absorption dose rate to the thickness of the lead polyester plate

Factors that affect the quality of the radiograph include exposure factors consisting of tube voltage (kV), tube current (mA), and exposure time (s). Setting the right exposure factor can produce optimal radiographic contrast, which is able to show clear differences in the degree of blackness between organs with different densities [7]. With the exposure factor used in the study, namely 70kV tube voltage; electric current of 16 mA; and the exposure time of 0.2 s resulted in an image which was not much different with the naked eye, but after analysis was carried out using MATLAB software to determine

the gray level of the radiograph image. After analyzing with MATLAB software, the gray level of each step can be seen the difference.

Figure 3 shows that the more lead concentration was dopped on polyester and the thicker the polyester plate, the greater the value of the optical density. According to [12] the greater the optical density, the greater the image contrast, so it can be concluded that the image with a high gray level of the sample has a high optical density.

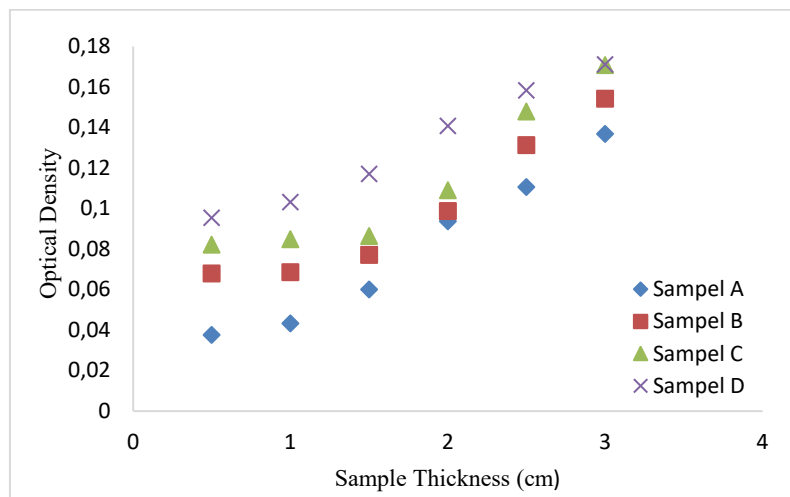


Figure 3. Graph of $\log \frac{GL_0}{GL}$ relationship to the thickness of lead polyester plate with variations in material composition

The measurement of the X-ray transmittance value ($\ln \frac{I}{I_0}$) using Gray Level (GL) can be done as in determining the $\ln \frac{I}{I_0}$ value with the intensity of X-rays I and I_0 , so that the $\ln \frac{I}{I_0}$ value can be measured using GL [13] and the results are obtained in Figure 4.

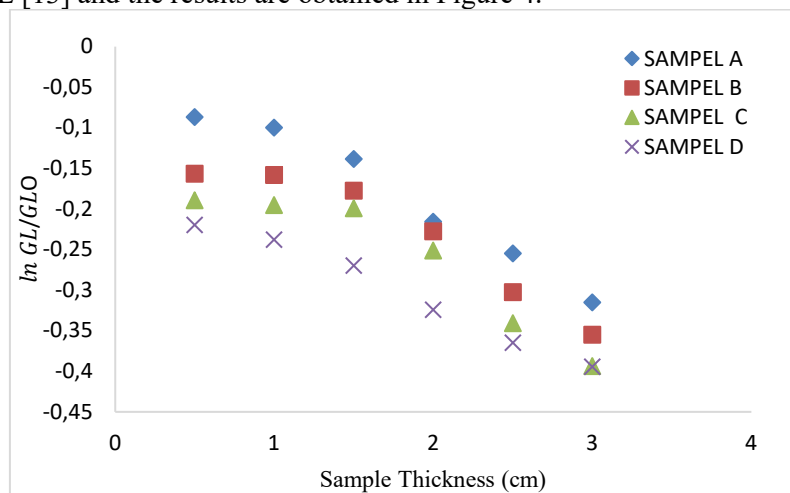


Figure 4. Graph of $\ln \frac{GL}{GL_0}$ relationship to the thickness of the lead polyester plate with variations in the composition of the material

The amount of absorption by the material depends on the x-ray wavelength, the object arrangement, the thickness, and the density of the material [14]. The results from Figure 4. illustrate that the more

lead content in the sample, the less the transmittance value is, indicating that the arrangement of the density of particles in the object will affect the absorption of X-rays.

In addition to the composition of the density of the particles in the object, the absorption of X-rays also depends on the atomic number of the element being irradiated by X-rays. The greater the atomic number of the material, the greater the absorption [3]. So the greater the atomic number of an element, the better the element will absorb the x-rays that hit it.

Based on measurements using the gray level, it shows that the more lead concentration in polyester, the greater the attenuation coefficient value. This is evidenced in samples with a concentration of 40% lead and 60% resin having an average attenuation coefficient of $0.21584088 \text{ cm}^{-1}$, samples with a concentration of 30% lead and 70% resin $0.1831095 \text{ cm}^{-1}$, samples with a lead concentration of 20% and resin 80% $0.15691327 \text{ cm}^{-1}$, and samples with a concentration of 10% lead and 90% resin $0.11328048 \text{ cm}^{-1}$.

4. Conclusion

Lead used from motorcycle batteries can be used as an alternative material for making personal protective equipment from radiation by considering its ability to absorb radiation. The radiation absorption dose rate is proportional to the thickness of the polyester plate. This is evidenced by the decrease in the value of X-Ray transmittance, which is the transmittance ability of the sample to X-rays. In the variation of lead concentration, the more lead was dopped on the lead polyester plate, the higher the absorption dose rate. Optical density, also proportional to the thickness and concentration of lead.

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