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## Silicone rubber with lead-acid composite as alternative radiation filter in digital radiography (DR)

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**Abstract.** Digital Radiography (DR) uses poly-energy x-rays beams, where low-energy x-rays are easily absorbed by the tissues and do not contribute to the image, therefore the low energy x-rays should be removed from the beam. The use of the radiation filter is an effective method for minimizing low-energy. The purpose of the research was to produce an alternative radiation filter for protecting organs and minimizing the dose received by patients while maintaining the quality of the image in DR examination. In this study, the radiation filters were made from Silicone Rubber–Lead Acid (SR-Pb), with the dimension of 17 x 17 x 0.6 cm<sup>3</sup>. The Pb percentage in the SR-Pb was varied from 0 to 5 wt%. To find out the feasibility of SR-Pb as a radiation filter, the dose reduction was measured using a solid-state detector (the Piranha detector, RTI Electronics, Sweden). For image quality assessment, images of the foot phantom were visually analyzed. The contrast-to-noise ratio (CNR) and signal-to-noise-ratio (SNR) values of the CDR TOR phantom with and without an SR-Pb radiation filter were measured. By the addition of Pb wt%, the foot image is still in the readable range. Analysis from the TOR CDR phantom, provided that there is no significant different between CNR and SNR value with and without SR-Pb radiation filter. The addition of Pb wt% slightly reduced the CNR and increased the SNR. SR-Pb 5 wt% decreased dose down to about 50%. This study has successfully developed the SR-Pb as an alternative radiation filter for the protection in DR examination, especially for indications that do not require an excellent low-contrast image, for example in the bone examination.

### 1. Introduction

X-rays provide great beneficial to the medical field [1, 2]. One of the benefits is that it could be used as a non-destructive diagnostic [3, 4]. However, X-rays are also very dangerous if its use is not carefully controlled [1]. They are able to cause stochastic effects, such as the hereditary effect and cancer, or non-stochastic, such as erythema, decreasing number of blood cells, cataracts, and epilation [5-7]. Therefore, in the diagnostic field, the radiation exposure must follow the ALARA (as low as can be reasonably achievable) principle, i.e. aiming for the lowest dose while maintaining the image quality to establish the diagnosis.

The X-rays in the diagnostic field have polychromatic energy. Low-energy X-rays are easily absorbed by the tissues (i.e. it leads to increasing dose) and do not contribute to the image, therefore the



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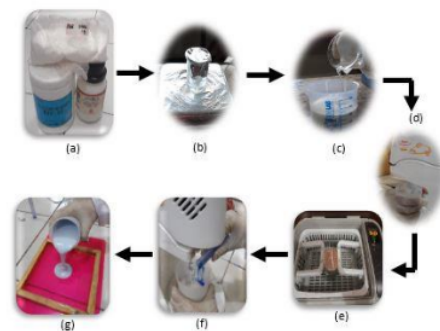
low energy X-rays should be minimized. The use of the radiation filter is an effective method for minimizing the low-energy X-rays [8]. The commonly used radiation filters are aluminum (Al) for low energy exposure and copper (Cu) for high energy exposure, although these filters cannot fully absorb the low energy radiation [9]. The ability of a material to absorb radiation is characterized by its atomic number (Z); if the atomic number increases then the ability to absorb radiation increases [10]. The Al has Z of 13 and the Cu has Z of 29. Hence to increase the ability of radiation filtration, material with a higher atomic number is needed.

The previous study by Jaya and Sutanto (2018) [11] proposed the SR as a radiation filter. They reported the SR filter with a dimension of  $17 \times 17 \times 1 \text{ cm}^3$  absorbs radiation up to 59.9% at a tube voltage of 52 kVp. Silicone rubber (SR) is a material that has biocompatible properties that make it safe for use in medical applications. The SR, which is part of the polydimethylsiloxane (PDMS) that make it flexible properties, has physical and chemical stability and its density relatively similar to human body tissue [12]. Previous study reported that the SR filter does not significantly decrease image quality [11]. In addition, its availability in Indonesia is abundant, therefore it reasonable to consider it as an alternative filter. An addition of other material with high Z to the SR may increase dose reduction. Lead (Pb) that has Z of 82 [1, 13] might be added to the SR for further dose reduction. SR is also included in the types of synthetic polymers, when it is combined with materials that have a high atomic number, such as Pb, it can increase the flexibility of the Pb [14-16]. Therefore the present research proposes an alternative filter radiation using SR-Pb to increase the dose reduction maintaining the image quality to establish the diagnosis.

## 2. Material and methods

### 2.1. Synthesis of samples

The SR-Pb consisted of SR-RTV52 (Indrasari Chemical Store, Semarang, Indonesia) and Pb in the form of Lead (II) Acetate Trihydrate ( $\text{Pb}(\text{CH}_3\text{COO})_2 \cdot 3\text{H}_2\text{O}$ ) (GM Chemical Store, Jakarta, Indonesia). A PEG 4000 (CV. Kit Equipment, Semarang, Indonesia) was used to bind Pb to avoid agglomeration in the SR. Figure 1 is a schematic diagram of the synthesis procedure for the sample.



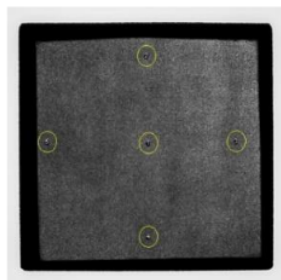
**Figure 1.** The SR-Pb radiation filter synthesis procedure (a) considering PEG-Pb-SR, (b) Stirring PEG-Pb, (c) Pouring PEG-Pb to SR, (d) Mixing PEG-Pb-SR, (e) Sonification, (f) Pouring catalyst to SR-Pb-PEG, (g) Pouring mixer material into the mold.

The synthesis of the sample was started by dissolving PEG 20 gr into 10 ml of aquades in a hot plate stirrer at a temperature of  $60^\circ\text{C}$  and round 3 scales for 1 hour, then the Pb powder was added with variations in percentage (1 wt%, 2 wt%, 3 wt%, 4 wt%, and 5 wt%) at the same temperature, round and duration. Furthermore, PEG-Pb was mixed with the SR as much as 185.14 grams using a mixer for 30

minutes then a sonification using an ultrasonic bath for 30 minutes to accelerate homogenization was carried out. It was then mixed with catalyst bluesil 3.5 ml for 6 minutes to accelerate drying. The results of the synthesis were then poured into a mold that has been smeared with silicone oil and left to dry completely.

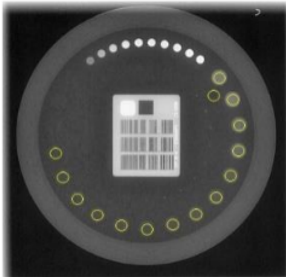
### 2.2. Image quality determination

The image quality assessment was carried out at the Health Polytechnic Semarang, Indonesia. The first test was homogeneity test of the SR-Pb filter and it was carried out by taking 1 Region of Interest (ROI) at the center and 4 ROIs at the edges, at 12, 3, 6, and 9 o'clock, with each having area of 570 mm<sup>2</sup>. Subsequently, an average pixel value for each ROI to determine a homogeneity was calculated using ImageJ software. ROIs placement can be seen in figure 2.



**Figure 2.** Techniques for determining the homogeneity test. One ROI was located at the central of SR-Pb filter image and four ROIs were located at the edges of the SR-Pb filter image.

Image quality analysis was carried out on the images of the foot and CDR TOR phantoms. The CDR TOR has 17 circles of 11 mm diameter used to measure the contrast of an image. Image analysis on foot phantom was carried out at 48 kVp and 8 mAs by comparing images with and without radiation filter. The contrast-to-noise ratio (CNR) and signal-to-noise ratio (SNR) values was measured on the CDR TOR phantom. To obtain the CNR and SNR values, the ROIs in the 17 circles in CDR TOR phantom were drawn. However, after addition of a SR-Pb filter, the visible circles at the CDR TOR become 14 circles, as it was shown in figure 3.



**Figure 3.** Techniques for determining ROI<sub>in</sub> and ROI<sub>out</sub> for SNR and CNR.

### 2.3. Percentage of x-rays transmission

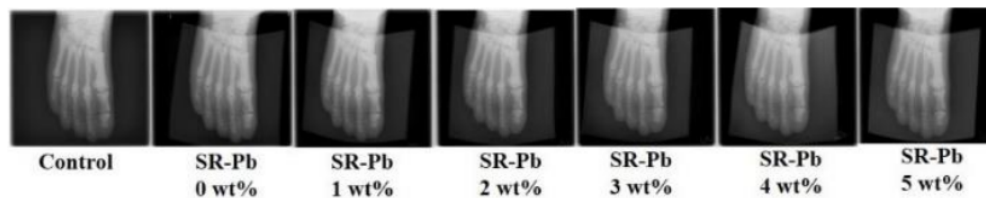
In this study, determining the percentage of X-rays transmissions in samples was carried out using mobile radiography systems (Polymobile Plus, Siemens) as a source of X-rays and piranha detectors (Sweden, Piranha-657) at the Training Center of Diponegoro University. The samples were scanned by tube voltage variations of 48, 60, 70, and 81 kVps, with a constant tube current of 10 mAs and a constant

of radiation source-detector distance of 100 cm. the sample was located between X-rays source and the detector. The results can be directly seen in the operator's room using Ocean Software.

### 3. Result and discussion

#### 3.1. Image analysis on the foot phantom

The image of the foot phantom with an expose factor of 48 kVp and 8 mAs can be seen in figure 4. It shows that if the more Pb wt% is added, then the pixel value in the filtered area increases. This is because more radiation is absorbed by the Pb. The Pb has a high atomic number, i.e., the ability to absorb radiation is high. However, the image produced is still in the readable range, because the details of the organs are still quite clear. With visual observation, there is no significant difference when compared to the image without radiation filter.



**Figure 4.** Image of the foot phantom without a filter as control and images of the foot phantom with the SR-Pb filter with various Pb percentage.

#### 3.2. Image analysis on CDR TOR phantom

There are two main parameters used in this study for determining image quality, which is in contrast-to-noise ratio (CNR) and signal-to-noise ratio (SNR) [17]. In the CDR TOR phantom, there are 17 circles of 11 mm diameter used to measure the contrast of an image. However, after exposed and applying the SR-Pb filter, only 14 circles can be seen in the CDR TOR phantom (figure 3). The reduced number of circle in the CDR TOR phantom indicates that the contrast in the resulting image decreases as the percentage of Pb in the filter increases. This phenomenon can be seen from the CNR value of the image, as shown in figure 5.

The addition of Pb to the radiation filter affects the CNR value of the CDR TOR image. An increase of Pb in the filter, the CNR value in the image decreases. This is because, by increasing the percentage of Pb, the low energy radiation absorption increases and it leads to an increase in the average radiation energy. Therefore, objects with low-density differences can no longer be distinguished.

The effect of signal, noise and SNR value on Pb percentage addition can be seen in figure 6. The addition of Pb obviously increases the SNR value in the image and same with CNR value that there is no significant different between SNR with and without SR-Pb filter. In a radiographic image, the greater the SNR value, the better the image will be found because it is easier to distinguish between signals and noise [18]. This can happen because, when Pb percentage is added, the radiation intensity coming to the detector decreases, and it leads to increase the pixel value (it should be noted that in this system, the maximum pixel value is achieved for no radiation come to that pixel, and the minimum pixel value is for maximum radiation come to it). At the same time, there will be an increase in noise, but the increase in pixel value is higher than that of noise; therefore the SNR value increases with the addition of Pb percentage.

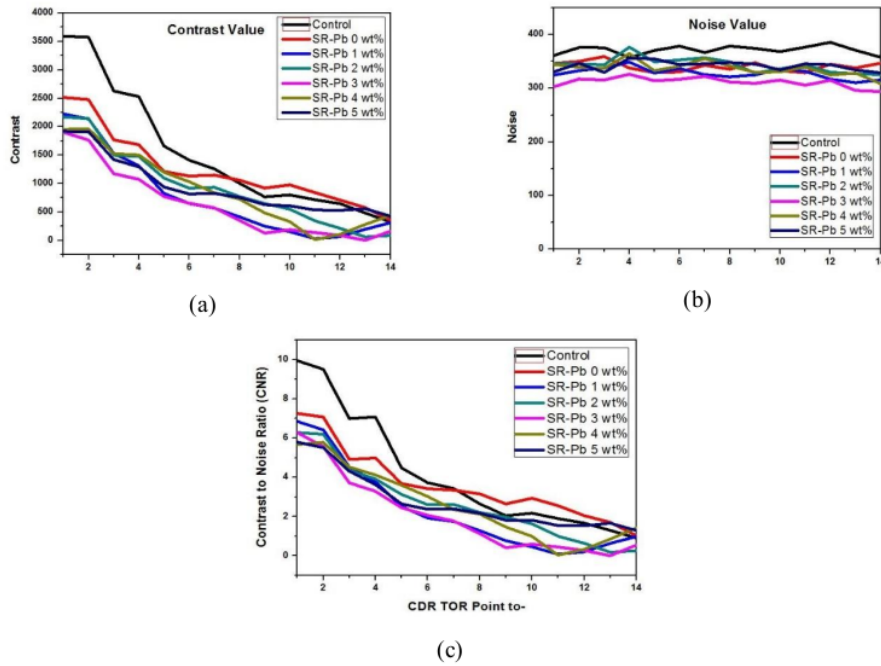


Figure 5. Effect of SR-Pb filter variation on (a) contrast, (b) noise and (c) CNR values.

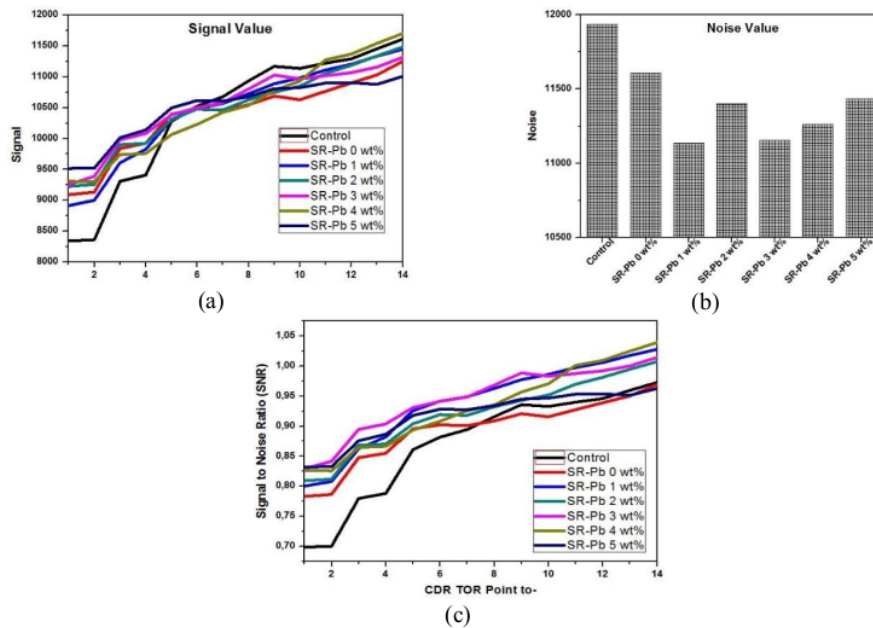


Figure 6. Effect of SR-Pb filter variation on (a) the signal, (b) noise, and (c) SNR values.

### 3.3. Dose reduction

The impact of the SR-Pb filter on the doses can be seen in figure 7. The increasing in tube voltage affects the doses received by the patient. The higher tube voltage used, the greater the dose will be received by the patient. However, the dose could be minimized by using SR-Pb radiation filters because the amount of radiation absorbed by the SR-Pb filter will make a percentage of X-ray transmission to decrease. The dose reduction using the SR-Pb radiation filter up to 50% for all tube voltage variation.

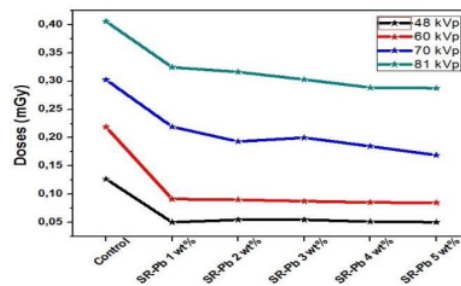


Figure 7. Effect of tube voltage and SR-Pb filter composition on the dose.

## 4. Conclusion

We have successfully develop SR-Pb with various Pb percentages. The SR-Pb composite can be used as an alternative radiation filter. The maximum SR-Pb radiation filter composition is achieved through the addition of 5 wt% Pb because it can reduce a half of the patient's dose and produce an image in the readable range to make a diagnosis with no significant different between control and SR-Pb radiation filter in terms of CNR and SNR values, even though the CNR value decreases.

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## References

- [1] Bagheri K, Razavi S M, Ahmadi S J, Kosari M, and Abolghasemi H 2017. Thermal Resistance, Tensile Properties, and Gamma Radiation Shielding Performance of Unsaturated Polyester/Nanoclay/PbO Composites *Radiation Physics and Chemistry* **146** 5-10
- [2] El-mallawany R, Sayyed M I, Dong M G, and Rammah Y S 2018 Simulation of Radiation Shielding Properties of Glasses Contain PbO *Radiation Physics and Chemistry* **151** 239-252
- [3] Gong P, Ni M, Chai H, Chen F, and Tang X 2018 Preparation and Characteristics of a Flexible Neutron and Gamma-Ray Shielding and Radiation Resistant Material Reinforced by Benzophenone *Radiation Physics and Chemistry* **50** 470-477
- [4] Hashemi S A, Mousavi S M, Faghihi R, Arjmand M, Sina S, and Amani A M 2018. Lead Oxide-Decorated Graphene Oxide / Epoxy Composite Towards X-ray Radiation Shielding *Radiation Physics and Chemistry* **146** 77-85
- [5] Seeram E 2009 Computed Tomography: Physical Principle Clinical Applications in Radiotherapy and Radioprotection *Radiation Protection Dosimetry* **162** 167-170
- [6] Ongole R, and BN P 2013 *Textbook of Oral Medicine, Oral Diagnosis and Oral Radiology*. India: ELSEVIER
- [7] Morin R L 2018 Complex Nature of Radiation Risk in Medical Imaging *Florida: American College of Radiology*
- [8] Bam L C, Miller J A, Becker M, and Basson I J 2019 X-ray Computed Tomography: Practical Evaluation of Beam Hardening in Iron Ore Samples *Minerals Engineering* **131** 2016-215



- [9] Ekpo E U, Hoban A C, and McEntee M F 2014 Optimisation of Direct Digital Chest Radiography Using Cu Filtration *Radiography* **20** 346-350
- [10] La L B T, Leong Y K, Leatherday C, Au P I, Hayward K, and Zhang L C 2016 X-ray Protection, Surface Chemistry, and Rheology of Ball-Milled Submicron Gd<sub>2</sub>O<sub>3</sub> Aquades Suspension *Colloids and Surfaces A: Physicochem and Engineering Aspects* **501** 75-82
- [11] Jaya G W and Sutanto H 2018 Fabrication and Characterization of Bolus Material using Polydimethyl-Siloxan. *Material Research Express* **5** 1-7
- [12] Kaliyathan, Vayyaprontavida A, Mathew A, Rane A V, Kanny K, and Thomas S 2018 *Natural Rubber and Silicon Rubber-Based Biomaterial* Elsevier, Ltd: New York, USA
- [13] Erdem M, Baykara O, Dogru M, and Kuluozturk F 2010 A Novel Shielding Material Prepared From Solid Waste Containing Lead for Gamma Ray Radiation *Physics and Chemistry* **79** 917-922
- [14] Spunei M, Malaescu I, Mihai M, and Marin C N 2014 Absorbing Materials With Applications in Radiotherapy and Radioprotection *Radiation Protection Dosimetry* **162** 167-170
- [15] Mahmoud M E, El-Khatib A M, Badawi M S, Rashed A R, El-Sharkawy R M, and Thabet A A 2017 Fabrication, Characterization and Gamma Rays Shielding Properties of Nano and Micro Lead Oxide Dispersed High-Density Polyethylene Composites *Radiation Physics and Chemistry* **145** 160-173
- [16] Irdawati Y, Sutanto H, Anam C, Fujibuchi T, and Dougherty G 2019 Development of a Novel Artifact-Free Eye Shield Based on Silicone Rubber-Lead Composition in the CT Examination on the Head *Journal of Radiological Protection* **39** 991-1005
- [17] Nazemi E, Rokrok B, Movafeghi A, Dastjerdi M H C, and Dinca M 2019 Obtaining Optimum Exposure Condition for Digital X-Ray Radiography of Fresh Nuclear Fuel Rods *Nuclear Instruments and Methods in Physics Research* **923** 88-96
- [18] Louk A C and Suparta G B 2014 Pengukuran Kualitas Sistem Pencitraan Radiografi Digital Sinar-X *Journal of MIPA* **24** 149-166

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