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*by Eko Hidayanto*

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## The Effect of silicone rubber-lead (SR-Pb) as an additional filter on radiation dose and image quality in computed radiography (CR)

F Zahroh<sup>1,2,3</sup>, C Anam<sup>1</sup>, H Sutanto<sup>1,2,3</sup>, Y Irdawati<sup>1,2,3</sup>, E Hidayanto<sup>1</sup>, Z Arifin<sup>1,2</sup>, and U Indrayanti<sup>4</sup>

<sup>1</sup>Department of Physics, Faculty of Sciences and Mathematics, Diponegoro University, Indonesia

<sup>2</sup>Medical Physics Research Center, Diponegoro University, Indonesia

<sup>3</sup>Smart Material Research Center (SMARC), Diponegoro University, Indonesia

<sup>4</sup>Departement of Radiology, Tugurejo Regional Public Hospital, Semarang, Indonesia

E-mail: herisutanto@live.undip.ac.id

**Abstract.** This study aims to determine the validity of the Silicone Rubber-Lead (SR-Pb) as an additional filter on the computed radiography (CR) using the tube voltage of 70 kVp and current-time of 6.3 mAs with a Pb percentage of 5 wt%. In addition, the thickness variations of the SR-Pb were 2, 4mm, 6mm, 8mm, and 10 mm, were compared to the Aluminum (Al) filter, of 0.5 mm, 1.0 mm and 1.5 mm. The effect of both SR-Pb and Al filters on radiation dose and image quality was studied. The radiation dose was measured using the Piranha detector, while the image quality was quantified using the signal to noise ratio (SNR) and the contrast to noise ratio (CNR) from images of the CDR TOR phantom. It was found that the dose decreased with an increase in the thickness of SR-Pb filter. At 77% and 53%, the thickness increased to 10 mm and 6 mm, respectively, which is equivalent to a 1.5 mm Al filter. The result showed that when CNR decreases, SNR increases with a rise in thickness values of SR-Pb filter. The decrease in CNR value at 6 mm SR-Pb filter was greater than 1.5 mm Al which is 45.3% and 11.04%, respectively. In addition, the use of SR-Pb filter led to an increase in SNR value by 45.9%, while the 1.5 mm Al filter increased SNR value of about 47.5%. In conclusion, the SR-Pb filter has the potential to be used as an alternative additional filter for the CR examination.

### 1. Introduction

X-ray is used in the computed radiography (CR) examination. Its beam is poly-energy therefore, it consists of very low to high energy levels which are dependent on the tube voltage set by medical personnel. The low energy X-ray is utilized on patients without adverse effects, However, its beam needs to be filtered to prevent the patient dose from being reduced [1, 2].

The use of filter has the ability to reduce image contrast and increase noise [3, 4]. Therefore, its usage needs to be optimized with the resulted image quality used to diagnose the patient with the lowest possible dose. Aluminium (Al) and copper (Cu) are the most commonly used additional filters [3, 4]. The use of Al and Cu filters influenced image quality which was indicated by a decrease in signal to noise



ratio peak ( $SNR_p$ ) and contrast to noise ratio peak ( $CNR_p$ ) [3]. Furthermore, Cu filter increased exposure time by 48% and SDNR for the same entrance surface dose (ESD) [4].

Currently, an alternative radiation filter based on silicon rubber-lead (SR-Pb) has been introduced [5]. An advantage of SR-Pb filter over Al or Cu filter is printed or cut according to a specific organ shape, to reduce the dose of organs not considered in diagnosis but included in the radiation beam. Irdawati [6] stated that the SR-Pb has the ability to reduce up to 50% radiation dose with little impact to image quality in CT, therefore it has the potential to be used as an organ shield [6]. Furthermore, the material consists of silicon rubber (SR) and lead (Pb), with the SR composed of polymer chains with strong oxygen bonds and high adhesion properties, thereby, producing high binding capacity when mixed with other materials [7, 8]. The SR sheet with a thickness of 0.6 mm used as a filter has X-ray attenuation that ranges from 29.7%-48.8% [9], while Pb has a high atomic number of 82, with high absorption radiation rate, therefore, it was used as gamma radiation shield [10]. A combination of SR and Pb with a certain percentage is used as an effective alternative filter. Till date, the impact of SR-Pb on dose and image quality of computed tomography (CR) and its comparison to the commonly used filter, however, the use of Al, has not been investigated. Therefore, this study aimed to determine the validity of the SR-Pb as an alternative additional filter on dose reduction and image quality in the CR and to compare its efficacy with the Al as a standard additional filter.

## 2. Method

### 2.1 SR-PB synthesis

To produce the SR-Pb, approximately 5wt% Pb was added to the SR, using SR RTV 52, Bluesil catalyst, Pb powder, aquades, and Polyethylene glycol (PEG) materials. The SR-Pb filter was synthesized using a simple sol-gel method (Fig.1) and printed with the dimension of 17x17 cm<sup>2</sup> using thickness variations of 2, 4, 6, 8, and 10 mm.

### 2.2 Radiation dose measurement

The SR-Pb were compared to Aluminum filters with thickness variations of 0,5 mm, 1.0 mm, and 1.5 mm. All filters were scanned using computed radiography unit (Fuji, Japan), which operated at 70 kVp, 6.3 mAs, source to image-receptor distance (SID) of 100, and 20x25 cm<sup>2</sup> field of view. Radiation dose was measured using the Piranha detector (RTI, US). Finally, the SR-PB filter was placed in the bottom of the collimator, with the Piranha on top of the imaging plate.

### 2.3 Image quality assessment

A TOR CDR phantom (Faxil, UK) consisted of high and low-contrast sensitivity test pattern, comprising 16 circular objects were used for image quality assessment (Fig 2(a)). The low-contrast pattern diameter was 11 mm, with x-ray value specification in the range of 0.954-0.039 at 70 kVp, with the image quality quantified using the CNR and SNR values. The experimental set up is depicted in Fig. 2(b), with the SNR and CNR values calculated using equations (1) and (2):

$$SNR = \frac{PV_V}{SV_B} \quad (1)$$

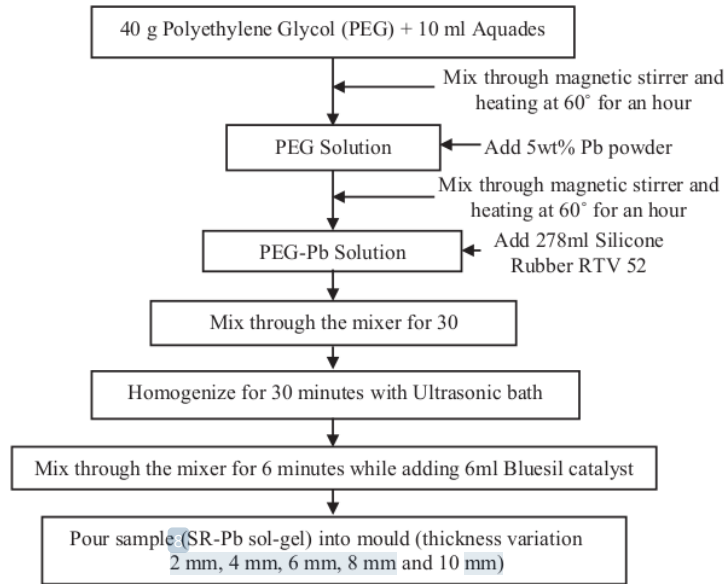


Figure 1. The steps of the SR-PB synthesis.

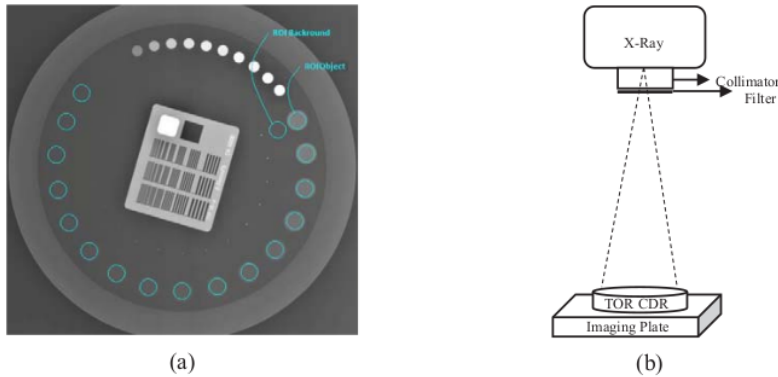


Figure 2. (a) Image of TOR phantom with a circular region of interests (ROIs) for calculating SNR and CNR (b) Experimental set up for image quality

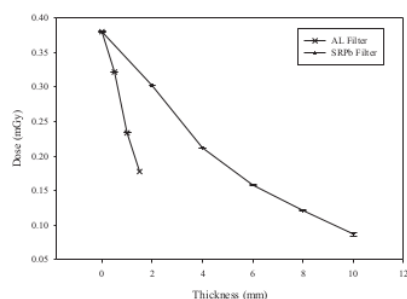
$$CNR = \frac{|PV_V - PV_B|}{\sqrt{\frac{\sigma_V^2 + \sigma_B^2}{2}}} \quad (2)$$

W  $PV_V$   $PV_B$  as defined as a mean pixel value in object region of interest (ROI) and  $SV_B$   $\sigma_V^2$   $\sigma_B^2$  the standard deviation of background. The ROI was circular with an area of  $9 \times 9 \text{ mm}^2$  (Fig. 2b).

### 3. Results

#### 3.1 Radiation dose

The measured radiation doses with/without Al and SR-Pb filter for various thicknesses are shown in Fig. 3. It shows that doses decrease with increase in the filter thickness of Al and SR-Pb. The SR-Pb filter with a thickness of 6 mm has an ability to reduce the radiation dose which is equivalent to a 1.5 mm Al, to a radiation dose of 0.1462 mGy.



**Figure 3.** The graph shows the radiation dose (mGy) for Al and SR-Pb filters with various thicknesses.

#### 3.2 Image quality

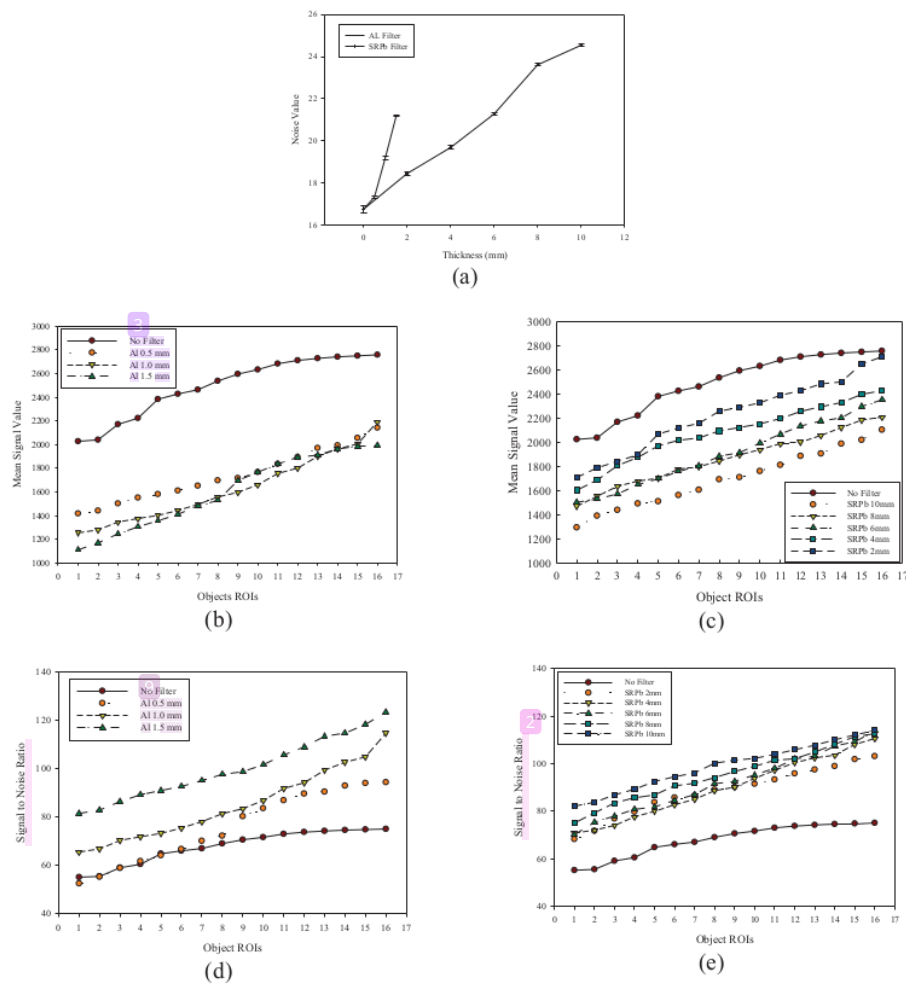
The increasing noise, signal and SNR value for using both SR-Pb and Al filters are depicted in Figure 4(a). It shows that the noise value of 6 mm SR-Pb is equivalent to 1.5 mm Al filter, which is 21.29 and 21.13 for 6 mm SR-Pb and 1.5 Al filter, respectively. In Figure 4(b and c) the signal value of the low-contrast objects of TOR CDR phantom for using both Aluminum and SR-PB filters are shown, which increases with a rise in thickness. Figure 4(d and e) shows the SNR of the low-contrast objects of TOR CDR phantom for using both filters, which increases with a thickness rise of both filters.

The signal difference between the object, background, and CNR for both filters are depicted in Figure 5. It is seen that their usage increased the signal difference between the object and background compared to without filters, while their CNRs decreased.

### 4. Discussion

Low-energy X-ray is absorbed by objects or patients [11], with its probability dependent on the atomic number and the density of the material it passes through. In addition, the higher the atomic number, the larger the density of the material, and the coefficient attenuation of X-ray.

The use of additional filter absorbs the low-energy X-ray and therefore the average beam is increased [12-14]. The standard filter is Al or Cu, however, some materials are recently developed as filter, such as SR [9] and SR-Pb [6] which has never been compared to Al. This study shows that SR-Pb with a thickness of 6 mm and above has the ability to reduce the radiation dose equivalent to Al filter of 1.5 mm thickness (Fig.3).

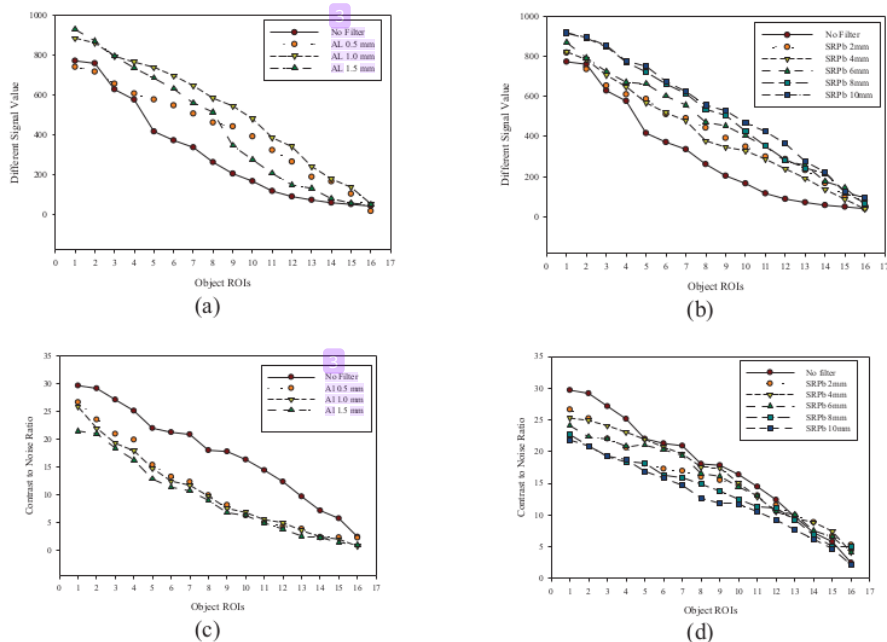


**Figure 4.** (a) The noise value of the Al and SR-Pb filter, (b) The mean signal value of the Al filter, (c) the mean signal value of the SR-Pb filter (d) the SNR value of Al filters, and (e) the SNR of SR-Pb filter.

The utilization of Al and SR-Pb as filters slightly increases the value of SNR, however, it is not an indicator used to improve image quality because the decrease in noise is not due to its in-depth analysis. From this study, it is found that the noise value increases, due to a rise in signal quality, while the CNR decreases with the addition of filters. It is proven that the image quality slightly decreases with the use of Al and SR-Pb, and insignificantly degraded.

The impact of Al and SR-Pb filters on the resulting image quality was compared which showed that SR-Pb can be used as an alternative filter. The advantages of SR-Pb compared to Al is found in its ability to easily follow the organ's shape. This allows SR-Pb to be used as an additional filter, and an organ

shield in the CR examination. However, SR-Pb requires more thickness to produce the same absorption by Al, and its homogeneity at thicknesses of 8 and 10 mm was due to less stirring time. Nevertheless, the previous study [6] showed that the homogeneity of SR-Pb was quite good.



**Figure 5.** (a) the different signal value of Al filters, (b) the different signal value of SR-Pb filters, (c) the CNR value of Al filters, (d) the CNR of SR-Pb filters.

### 5. Conclusions

The SR-Pb synthesis has been successfully made with a percentage of Pb of 5 wt%. Its comparison to the standard Al filter has also been carried out, which showed that SR-Pb at a thickness of 6 mm and 1.5 mm has the ability to reduce radiation dose by 58%, and 53%, respectively. The use of SR-Pb slightly decreases the image quality which is marked by the decrease of CNR, which also occurred to Al. In conclusion, SR-Pb has the potential to be used as an additional filter on CR and as an organic shield. □

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