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### Effect of Variations in Material Concentrations on The X-Ray Attenuation Coefficient Value: Study on Chicken Bone-Radiologic Phantom

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#### ABSTRACT

In the process of learning and research in the field of radiology, it is necessary to simulate body organ modeling (phantom) which has a character resembling the bones of the human body, this is done to obtain realistic radiographic image results and minimize the effects of x-ray radiation if human objects are used at the time of exposure. According to the Director-General of Livestock and Animal Health (2020), based on the results of the 2017 Basic Material Consumption Survey (VKBP) and the 2019 National Socio-Economic Survey (Susenas) conducted by BPS RI, broiler meat consumption is 12.79 kg /capita/year. Chicken meat that is consumed will leave bones that will become waste. This of course causes environmental problems due to the remaining bone that has no economic value. By utilizing chicken bone waste, it is necessary to study the mixture of making appropriate phantom materials to resemble real human bones, so that before this chicken bone powder is formed, it is necessary to study the mixture to obtain maximum results and according to the attenuation coefficient values. The research uses quantitative methods with an experimental approach. Research Result: The humerus bone was exposed which has an attenuation coefficient value ( $\mu$ ) of 0.351 cm<sup>-1</sup> as a reference for making a phantom mixture. Calculation of the attenuation coefficient value ( $\mu$ ) for Phantom 1 with a value of (0.279), Phantom 2 with a value of (0.284), and Phantom 3 with a value of (0.279). Based on the research, judging from the radiopaque level, the three variations of the chicken bone powder mixture were able to produce a radiopaque image on the radiographic film, so that it could be used as an alternative material for making phantoms.

**Keywords:** Phantom, chicken bone, attenuation coefficient

#### INTRODUCTION

Radiology is a medical science to sees parts of the human body by using radiation or radiation waves, both electromagnetic waves and mechanical waves. This makes the human body an important object that must be present in the X-ray shooting process<sup>3</sup> (Bontrager & John, 2010). X-rays can penetrate

objects in their path and also produce ionizing radiation. Radiation is the emission of energy through a material or space in the form of heat, particles, or electromagnetic waves from a radiation source (Santoso, 2013)<sup>12</sup>. X-ray radiation can cause effects on the body, both stochastic, non-stochastic, and genetic effects. To minimize the effects of radiation when

exposed to x-rays during laboratory and research practicums, phantom objects can be used instead of human objects to maximize practicum in projecting radiographic techniques.

Phantom is modeling or simulation of human body tissue whose composition and composition are made as closely as possible to parts of the human body. In the medical and radiological world, it is known that phantoms are used as a substitute for the human body when radiotherapy is carried out (Handoko, 2018)<sup>1</sup>. Phantom is used for research because if you use real body tissue, you must get permission from medical ethics<sup>15</sup> (Suwarno, 2015). Phantom radiology on the market is quite expensive. This is an obstacle for educational institutions to provide phantom radiology in the learning process. It is necessary to develop research on making phantoms using other materials that are more economical but can provide the same imaging results after being exposed to X-rays.<sup>8</sup> (Sofyan, 2017)

Indonesia is a country with the 4th largest population in the world. Based on data from the Central Statistics Agency (BPS) in 2013. This large population greatly affects the increase in the need for food. Currently, boiled chicken meat is consumed by many people, besides the delicious meat, the price is relatively cheap and easy to find. Apart from that, the meat that is consumed will leave bones which will later become waste. This of course causes environmental problems due to the remaining bone that has no economic value.<sup>14</sup> (Musdalifah, 2016)

Bone is also difficult to decompose so it can only pollute the environment. It is necessary for that alternative so that bone waste can be useful and have economic value. Chicken bones are composed of the main components of calcium phosphate (57.35%), collagen (33.3%), and calcium carbonate (3.85%)<sup>13</sup> (Septimus, 1961). So, in this study, chicken bones were used as a mixture for the manufacture of the

phantom which would be processed into powder using drying and milling methods as an alternative application of cortical bone phantom.<sup>11</sup> (Rahmania, 2017)

## METHOD

### Type and Design of Research

The type of research used is quantitative with an experimental approach in varying the mixture of chicken bone powder, Polyester Resin, Catalyst, and Alumina materials. The research was conducted at the Bali ATRO Laboratory (Bali Academy of Radiodiagnostic and Radiological Engineering).

### Population and Samples

The population in this study was all phantom materials from chicken bone powder. The research sample used was 3 types of variations in the mixture of phantom material from chicken bone powder, namely a mixture of phantom 1,2, and 3.

### Data Analysis

Tests were carried out. Data analysis was carried out from the results of the comparison of variations in the mixture of phantom materials to the Attenuation Coefficient value of each sample including the control sample (os humerus).

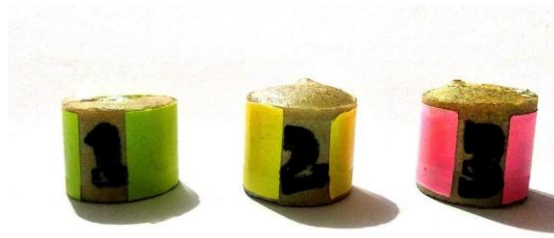
## RESULT

This research is early-stage research conducted by making variations of a mixture of phantom material with chicken bone powder. First of all, the chicken bones that have been collected are washed and dried in the sun. The next process is milling to make chicken bone powder. A measure of the variation of the phantom mixture is made according to table 1.

**Table 1: Phantom Material Concentration**

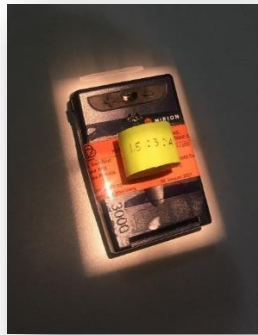
TYPE OF PHANTOM	CONCENTRATE		
	BONE POWDER	RESIN	ALUMINATE
PHANTOM 1	3 ml	7 ml	10 ml
PHANTOM 2	4 ml	7 ml	10 ml
PHANTOM 3	5 ml	7 ml	10 ml

Each variation of the mixture is poured into a glass cup and a stirring process is carried out to unite the ingredients after the mixed ingredients are put in a 0.5-inch pipe mold with a height of 4.5 cm that has been prepared. Wait a few moments until the mixture hardens and is removed from the pipe mold so that the phantom results are obtained as shown in Figure 1 below.



**Fig 1: Phantom 1, Phantom 2, Phantom 3**

After the manufacture of the Phantom is complete, the Phantom material is exposed using an x-ray plane using the exposure factor of the humerus as a control sample using (kV 48, mA 100, s 2.5) and collimating the area of a dosimeter then exposing each Phantom and also exposing the Os. Humerus as a control sample.



**Fig 2: Exposure to the research sample.**

From the measurement results, the radiation intensity value is recapitulated and the average value of the distribution of each Phantom is calculated. From table 2 it can be seen the average radiation intensity value of Phantom and Os humerus.

**Table 2: The average value of radiation intensity**

NAME	RADIATION INTENSITY	EXPOSURE 1	EXPOSURE 2	EXPOSURE 3	AVERAGE
Phantom 1	It	9	10	10	9,67
	10	34	39	44	39
Phantom 2	It	8	9	9	8,67
	10	31	36	41	36
Phantom 3	It	8	9	9	8,67
	10	30	35	40	35
Os Humerus	It	5	5	5	5
	10	22	29	36	29

One of the qualities of the radiographic image is influenced by the density of the radiograph or the degree of blackness of a radiographic film. Therefore, the researcher also considers this by calculating the attenuation coefficient value for each research sample using the attenuation coefficient formula, namely.  $= I_o \cdot e^{-\mu t}$ . Then the results of the attenuation coefficient of the research sample are obtained in table 3.

**Table 3: The Value of the Attenuation Coefficient of the Research Sample.**

RESEARCH SAMPLE VARIATION	ATTENUATION COEFFICIENT VALUE
Phantom 1	0,297
Phantom 2	0,284
Phantom 3	0,279
Os Humerus	0,351

## DISCUSSION

The variation of the 3 phantom mixture was done by making a mixture ratio in the amount of chicken bone powder alone without changing the supporting mixture such as resin and alumina. Aims to determine the difference in density values in each sample. The use of boiler chicken bones as the main ingredient is because boiler chicken bones are currently a waste of community food, this of course causes environmental problems due to bone scraps that have no economic value.<sup>14</sup> (Musdalifah, 2016). Chicken bones are also composed of the main components, namely calcium phosphate (57.35%), collagen (33.3%), and calcium carbonate (3.85%)<sup>13</sup> (Septimus, 1961). This of course can be used as a reference for basic materials that resemble bone structure in general, besides that, chicken bones have also been used as an alternative application of cortical bone phantom using drying and milling methods.<sup>11</sup> (Rahmania, 2017)

The use of Unsaturated Polyester Resin (Unsaturated Polyester) in this research aims to facilitate the process of making phantoms because the unsaturated polyester resin is a liquid resin with fairly low viscosity, hardens at room temperature with the use of a catalyst without producing gas during setting like many resins. other thermosets<sup>10</sup> (Nurmaulita, 2010). The addition of the use of a catalyst can be done because in general, the catalyst has 2 functions, namely accelerating the reaction towards equilibrium or the activity function and increasing the desired reaction product or the selectivity function<sup>9</sup> (Nasikin and Susanto, 2010). The function of alumina powder in this study is as a supporting material because alumina powder is widely used as a substitute for artificial joints, dental implants, cochlear implants (hearing aids), and medical equipment. Alumina is also known as a porous compound so it is used as an adsorbent<sup>6</sup> (Ghababazade, et al., 2007). Alumina has properties such as good biocompatibility, good corrosion resistance, and high wear resistance. These properties make alumina material very suitable for hip replacement where the joints are prone to friction<sup>7</sup> (Jati, 2020).

It can be seen from Table 2 that the average value of the radiation intensity of each phantom is different, but the difference in the value of  $I_t$  and  $I_0$  in the 3 variations of the phantom is not very significant. In the humerus bone, the value of radiation intensity after passing through the sample ( $I_t$ ) is constant, namely 5.

In this case, it shows the homogeneity and distribution of the density of the humerus bone has a uniform pattern structure, while the three variations of the phantom are different. This can be caused because in some parts of the phantom the density and density are not the same or are less homogeneous.

The need for a good mixing and stirring system of materials will be able to increase uniformity and homogeneity. Stirring time can expand the contact area with increasing stirring speed thereby increasing the homogeneity of a mixture<sup>2</sup> (Barkat et al., 2013). In addition, according to Wilda (2011),<sup>16</sup> stirring or agitation is a process that shows the induced movement of a material or mixture where the agitation process will form a circulation pattern that will affect the homogenization process.

The attenuation coefficient ( $\mu$ ) can also be defined by the ability of a material to absorb incident radiation. If there is radiation that comes to an object, the value of the intensity of radiation entering the material and the value of the intensity of radiation coming out of the material will be different, this is due to the attenuated nature of the material<sup>5</sup> (Tantra, 2014). Table 3 shows the attenuation coefficient values of each test sample showing that there are significant differences in the attenuation coefficient values between the test samples and control samples, which are significant because there are differences in the atomic number of the constituent materials, the density of the material, and the quality of the radiation produced is not the same. However, judging from the radiopaque level, the variation of the chicken bone powder mixture can produce a radiopaque image on the radiographic film, so it can be used as an alternative material for making phantoms.

The mixed variation of Phantom 2 has the closest attenuation coefficient value to Os humerus. The difference in the attenuation coefficient value is not very influential because when viewed from the humerus bone structure, everyone must also have a different attenuation coefficient value, this is due to differences in bone density. Factors causing low bone density are divided into irreversible factors and modifiable factors. Factors that cannot be changed are genetics (heredity, race, and hormones), gender, and age. While the factors that can be changed include nutritional status, nutrient intake, and exercise habits<sup>4</sup> (Daly, 2007).

The concentration of chicken bones is one of the influential factors in displaying the desired intensity. In

addition, the dose of alumina and resin as an adhesive plays an important role in forming a solid phantom intact with the desired intensity results. Things that need to be considered in making phantom with chicken bone powder are at the stirring stage. The purpose of stirring is for the homogeneity of one or several phases in the concentration of components, physical properties, and temperature.

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## CONCLUSION

The value of the attenuation coefficient in all research samples shows a significant difference between all phantoms and os. The humerus studied, however, when viewed from the radiopaque level, the variation of the chicken bone powder mixture was able to produce a radiopaque image on the radiographic film, so it could be used as an alternative material for making phantoms. The attenuation coefficient value closest to Os humerus is the mixed variation of Phantom 2.

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