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Original Research Article

A STUDY OF THE PROPERTIES OF LOCAL SHIELDING MATERIALS FOR DIAGNOSTIC X-RAYS

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Abstract: X-rays is one of the forms of radiation which is produced when highly energetic electrons hit a metal target and are harmful to man and his environment, but it could be attenuated or shielded depending on the type of medium through which it is produced or traveled. This research was done on the above basis and was carried out at University of JosHealth center using Ray-safe (X-ray Detector). The materials used were; Bricks, concrete, Aluminum, ceramic tiles, colour glass, wood, Perspex and white glass with their normal thickness. The linear attenuation coefficient (μ) of the materials were obtained as 1.03cm^{-1}, 1.05 cm^{-1}, 2.10 cm^{-1}, 1.00 cm^{-1}, 1.75 cm^{-1}, 0.14 cm^{-1}, 0.35 cm^{-1} and 1.65 cm^{-1} respectively. The result showed that, Aluminum has the highest linear attenuation coefficient (μ), due to its high level of interaction with the X-rays compared to the other materials and it also has the ability to stop/attenuate X-rays by introducing a thick aluminum sheet of 4.75cm between the X-ray source (tube) and the detector (Ray-safe). The results obtained clearly indicated that aluminum with the thickness 4.75cm would best shield/attenuate 77Vp and 6.3mAs of X-rays source effectively. From the finding of this study, it is recommended that Aluminum which is cheap and can be locally sourced and can be used in place of the industrial Lead of thickness 0.15cm that has the linear Attenuation coefficient of 63.50 cm^{-1}, which is more expensive in diagnostic X-rays. Now we will come to understand the fact that, the higher the X-rays (radiation) shielding, the higher the prevention of man and his environment from the harmful effect of X-rays beam (Radiation) produced.

Key words: X-rays, shielding, Radiation protection, Ionizing Radiation, Linear attenuation Gamma rays.

Introduction: Radiation is the energy transfer in a vacuum, or is the energy emitted as electromagnetic waves. In other words Radiation is simply a type of energy, the most familiar form of radiation is visible light (like that produced from the sun light). Other form, like X-rays and gamma rays are employed in a number of beneficial applications, including in medicine.

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Natural radiation exposure comes from the earth {rocks, soil and outer space (Cosmic rays)}

The field of radiography (which employs light energy X-rays) was discovered by Wilhelm Conrad Roentgen in 1895. While performing experiment on electricity, Roentgen noted that an energy "ray" was produced which passed through most objects including his own body. He also noted that these rays which he named as "X-rays" could be used to produce images of bones.

There are two from of radiation, these are: Ionizing and non-lionizing radiation. Ionizing radiation is radiation consisting of particles, X-rays, or gamma rays which produce ions in a medium through which it passes. It has high energy so that during the interaction with an atom it can remove bound electron from their orbits causing the atom to become charge or ionized. Ionized radiation has two different uses in medicine which are, for diagnostic and therapeutic application (Health Physics Society www.radiationanswere.org).

Radiation with energy above 13.6 eV is referred to the ionizing radiation; Ionizing radiation can induce detrimental biological effects in organs and tissues by depositing energy that may damage vital molecules in human body such as DNAs (Deoxyribonudeic acids). There are two mechanisms by which radiation ultimately effect cells, which are; Stochastic effect (Direct effects), and Deterministic effect (Indirect effects) of radiation.

Non-ionizing radiation is radiation that cannot ionize matter, that is; Radiation without enough energy to remove bound electrons from their orbits around atom; examples are micro-waves and visible light. Radiation with energy less than 13.6 eV is termed non-ionizing radiation (IAEA, 1973).

The types of radiation used in medicine are: X-rays, Gamma rays (ϒ) and positrons.

X-rays are electromagnetic waves of high energy and frequency with very short wave length, which are able to pass through many materials ranging from opaque to light, or they are forms of electromagnetic radiation with wave length rouging from 0.1 nm to $0.5x10^{-10}$ nm having energy levels same as that of speed of light as 3 x 10^{8} m/s, X-rays are radiation possessing high energy and penetrating capacity and are classifies as ionizing radiation which are extensively used for medical diagnosis and industrial purposes.

Gamma rays (γ) are electromagnetic radiation with short wave length (10^{-10} meter) and high frequency. Gama rays being the third types of radiation discovered by Villard in 1900, found out that they are not changed particles, they are identical with X-rays, the difference is in their origins. Photons originating from the nucleus are gamma rays, while the photon emitted during transition in the electron orbits of an electrons are X-rays. Gamma rays are produced in the disintegration of radioactive nucleus and in the decay of certain subatomic particles, they have no mass and no charge, they are unaffected by electric and magnetic fields, they are very penetrating and heavy shielding materials like lead and concrete are needed to stop them (science @ NASA, 2007).

In diagnostic medical imaging equipment which can be classified as ionizing radiation are; conventional X-ray, computed tomography (CT), fluoroscopy, mammography and Digital X-rays, while for that of non-ionizing radiation is magnetic resonance Imaging (MRI).

Stochastic effect (Direct effects) on cells is the damage to the DNA (Deoxyribonucleic acid) nucleuses or some other cellular component critical to the cell; it is referred to as direct effect. Such an interaction may affect the ability of the cell to reduce and thus survive. If enough atoms are affected such that, the chromosomes do not replicate properly, or there is a significant alteration in the information carried by the DNA molecule, then the cell may be destroyed by direct interference with its life-sustaining system (Martin and Harbison, 1986).

Deterministic effect (Indirect effects) on cells is the decompositions of water in the cell. If a cell is exposed to radiation, the probability of the radiation interacting with the DNA molecules is very small since these critical components make up such a small part of the cell. When radiation interacts with water, it may break the bonds that hold the water molecule together, producing fragment such as hydrogen (H) and hydroxyls (OH). These fragment may recombine or may interact with other fragment or ions to form compounds such as water which would not harm the cell, however, they could combine to form toxic substances such as hydrogen peroxide (H_2O_2), which can contribute to the destruction of the cell (Demir and Keles,2006; Elschot et al.,2010).

However, there is a need to prevent or minimize such biological effects or damage by shielding the radiation. Shielding is based on the principle of attenuation, which is the ability to reduce waves or rays by blocking or bouncing particles through a barrier material.

Materials and Methods: The list of materials and equipment used for this research in University of Jos Health Center include; Stationary X-rays machine, Ray-safe (X-rays Detector), Vernier caliper, scale balance, two retort stands, meter rule and measuring tape. The materials or samples used are; Aluminum, concrete, Bricks (molded clay), Perspex, ceramic tiles, wood, color glass, white glass and polyvinear tiles.

The plate 2, below shows a typical X-ray machine and the setup of the equipment and material for this research work.

Plate 1A. Ray-safe

Plate 1B.Vernier Caliper

Plate 1C. Scale Balance

Methods/Procedures of the Experiment: After setting up the equipment, the Detector (Ray-Safe) was clamped with the aid of one of the Retort stand clamp parallel to the X-ray tube of the X-ray machine without clamping any of the samples (materials) on the other Retort stand clamp. The free air X-rays dose, I_o was determine, that is; does measured without shielding materials (samples) using the detector (Ray-safe).

Further-more, one of the shielding materials sample (molded Bricks) was clamped on the second Retort stand between the X-ray tube (source of X-rays) of the X-ray machine and the Ray-safe (Detector) of 70cm below the X-rays tube and 10cm above the Ray-safe (Detector) parallel to each other. The exposure factor of kilo-volt 77kv and milli-ampere second 6.3 mAs was set and then exposed the fire button on the control panel of X-ray machine in the control

room to expose the shielding material (sample), which the X-ray dose that passed through the shielding material (sample) were detected and measured by the Ray-safe (Detector) beneath the shielding material, and we recorded the reading as I_x, which is the dose measured with shielding material (Bricks) with the thickness x. The same procedures was repeated for other eight (8) shielding materials which include; Aluminum, concrete, Perspex, ceramic tiles, wood, colour glass and white glass keeping the exposure factor (killo-volt and milli-ampere second) at constant values of 77kv and 6.3mAs respectively.
Then we recorded the reading for each materials as I_x, (dose measured shielding material) with the thickness x respectively.
The linear attenuation coefficient (μ) of the materials was obtained theoretically using equation (1) indicated below, for each of the shielding materials (samples) and the reading was tabulate as shown in the table1 and table 2 below.

$$\mu = -\ln \frac{I_x/I_o}{x} \quad (1)$$

The above expression is used to determine the linear attenuation coefficients for various materials.

Results of Experiment: The experiment was carried out using the exposure factor of kilovolt 77 kv and milliampere second of 6.3 mAs on the control panel. The dose rate without the shielding material that is; free air measurement of X-rays is 458 μGy.
The distance between the X-ray tube and the cauch is 100cm.
The distance between the Ray-safe (Detector) and the cauch is 20cm.
The distance between the Ray-safe (Detector) and the material is 10cm.
The distance between the Ray-safe (Detector) and the X-ray tube is 80cm, and the distance between the material and the X-ray tube is 70cm.
The results for the experiment are given in the tables 1and 2 below:

Table 1. Materials and their parameter calculated.

S/N	Materials	Volume (cm^3)	Mass (g)	Density ρ(gcm^3)	Halt value layer, HVL, x(cm)
1	Bricks	264.50	460.00	1..73	0.69
2	Concrete	161.30	790.00	4.89	0.66
3	Aluminum	31.68	80.00	2.52	0.34
4	Ceramic tiles	108.00	210.00	1.94	0.69
5	Colour glass	84.90	175.00	2.06	0.39
6	Wood	158.40	55.00	0.34	4.95
7	Perspex	46.10	50.00	1.08	1.98
8	White glass	84.90	174.00	2.04	0.42

Table 2. Density, Linear attenuation coefficient, Transmitted intensity and mass attenuation coefficient of the various materials.

S/N	Materials	Thickness, x (cm)	Transmitted intensity, I_x (µGy)	Linear attenuation Coefficient, µ (cm^{-1})	Mass attenuation coefficient, µ/ρ($cm^2 g^{-1}$)
1	Bricks	2.16	50	1.03	0.59
2	Concrete	2.69	27	1.10	0.21
3	Aluminum	0.27	53.2	2.10	0.83
4	Ceramic tiles	0.93	180	1.00	0.51
5	Colour glass	0.46	204	1.75	0.84
6	Wood	1.00	397	0.14	0.41
7	Perspex	0.29	413	0.35	0.32
8	White glass	0.49	204	1.65	0.80

The chart below describes the Linear Attenuation Coefficient level of the materials used in this research which shows that aluminum has the highest on the chart.

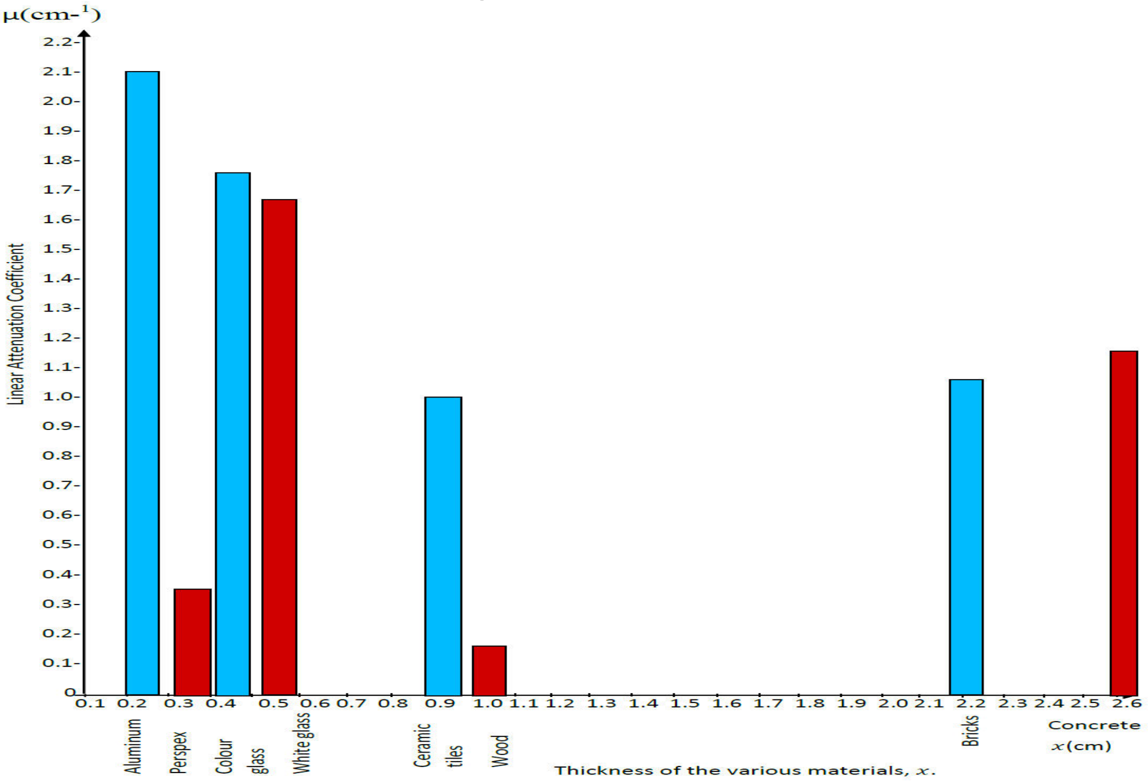

Fig.1. Linear attenuation coefficients of the different materials.

Discussion: Table 1, shows the Volume, Masses, Density and Half – value layer of the various materials with their normal thickness (that is; they are of different thicknesses) used for this research work, as it is seen in the table the materials are of different thicknesses. In this research we are only interested in the attenuation or shielding of the materials with their normal thickness respectively.

Table 2, gives the Thickness (X), Transmitted intensity (I_x), Linear attenuation coefficients (μ) and Mass attenuation coefficient, again from the table 2, the next column bears the transmitted intensity, I_x of the various materials which is the amount of radiation that were able to pass through the materials respectively. From the table, its shows that concrete seems to bear the less transmitted intensity compared to other materials because its thickness is greater than others, and Bricks is the second due to the same reason with that of concrete, Aluminum is the third when consider the transmitions of radiation. If the Aluminum were as thick as Concrete and Bricks its transmitted intensity would have been lesser than that of Concrete and Bricks because it molecules are tightly bound together compared to other materials.

The Linear Attenuation Coefficient (μ) of the various materials shows that, Aluminum bears the highest linear attenuation coefficient compared to the rest of the materials. Aluminum sheet is the highest due to its tightly bounded molecules, as a result; it is seen the level of interaction is high because radiation has to interact with the molecules to be able to penetrate through the materials, At this stage, some of the radiation (X-rays) are being stopped or cannot go for further interactions due to the bounds molecule are closely packed together. Then at this stage, they are said to have being attenuated or undergone attenuation while some that were able to pass or penetrate through are called the transmitted intensity, I_x. From the materials provided, the linear Attenuation coefficient of Aluminum is next to that of industrial Lead of thickness 0.15cm which has Linear Attenuation coefficient of 63.50cm^{-1}, therefore; Aluminum can be used in place of industrial Lead. On the other hand wood bears the lowest linear attenuation coefficient due to its low level of interaction, because the molecules of the wood are not as tightly bounded as that of aluminum that is why its level of interaction seems to be lowest which proved that wood cannot play a role in attenuating radiation.

Furthermore; it is observed that concrete happens to be the second on the scale of preference when going linearly in terms of radiation attenuation after Aluminum.

Conclusion: In conclusion; from the results obtained in this research work, it is shown that aluminum sheet has the highest linear attenuation coefficient (μ) value of thickness 4.75cm which can be used as alternative materials that would substitute lead of thickness 0.15cm, at a lesser cost and readily available compared to lead.

Also we can clearly understand the fact that, the higher the X-rays (radiation) shielding the higher the prevention of Man and environment from the negative effect of X-ray beam produced.

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