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STUDY ON MASS AND LINEAR ATTENUATION COEFFICIENTS OF PMMA AS HUMAN TISSUE-EQUIVALENT MATERIAL

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To research the improvements of clinical imaging of human tissues, tissue-equivalent materials are one of the reasonable strategies for evaluating the impact of radiation dosages on human tissues. Hence, considering mass and linear attenuation coefficients is a promising method to foresee the appropriate tissue-identical material. In this examination, we utilise the built-up estimations of elemental compositions (mass portion of every component) of PMMA material by numerous analyses in literature. XCOM program was utilised to figure estimations of mass attenuation coefficients of PMMA for various photon energies (0.015–2.0) MeV. The outcomes reveal that the estimations of mass and linear attenuation coefficients are high as the energies begin to decrease and diminish gradually with an expansion in photon energies. Making a sensible coordinating between mass and linear attenuation coefficients of PMMA as human tissue-equivalent material with mass and linear attenuation coefficients of lung, brain, muscle and blood human tissues has demonstrated a phenomenal match.

Keywords**:** *Human organs and tissues, linear attenuation coefficient, mass attenuation coefficient, tissue-equivalent materials.*

1. INTRODUCTION

Cancer treatment techniques, these days, are generally presented, for example, in chemotherapy, radiotherapy, brachytherapy and medical procedure [1]. The reason for brachytherapy is to put radioactive sources into the influenced part with an expanded portion, while the normal tissues get a limited portion of radiation. A fruitful brachytherapy treatment arranging measure needs to limit the progressions between the assessed and conveyed dosages [2], [3]. Numerous perspectives make this intrigue hard to show up at, for example, the quick decaying of dose close to tumour, mistakes in the techniques used to ascertain the dose and errors in assessment of the dose variety in heterogeneous regions. In spite of these aspects, significant accomplishments have been reached in the late decades because of accessibility of weak ^{137}Cs and strong ^{192}Ir sources of various plans notwithstanding the foundation of quality control techniques that can administer the exactness of the planned strategy. These days, numerous ways have been actualized to test the dose consumed close to sources by utilising the information base and reasonable phantoms. The phantoms, built in order to adjust to quality control norms, are produced using tissue-equivalent materials to simulate human tissues to be irradiated. From the clinical physical science perspective, human tissue-equivalent materials give a few issues in mimicking the human tissues in low and high energy ranges [4]. In many contemplated works, the dose conveyance in numerous human tissue substitutes was determined. Dose appropriations in water and delicate tissue apparitions and dosimetric boundaries of a ^{131}Cs source, utilising a Monte Carlo study have been determined [5]. It has been discovered that Polyethylene, Polystyrene, Perspex, and Nylon well reproduce fat and muscle, Plaster of Paris well mimics cortical bone, Polypropylene well mimics fat tissues and yellow bone marrow tissues, polycarbonate well mimics spongiosa. Specialists worked to decide on the portion brought about by the presence of in-homogeneities, in water phantoms, utilising ^{192}Ir source and Monte Carlo recreation code [6]. Dose circulations near ^{192}Ir source in various human tissue-comparable materials utilising three Monte Carlo codes have been concentrated by another gathering of specialists [7]. The discoveries of the last examinations investigated that radial dose functions were influenced in bone tissue and inferred that clinical aspects did not give enough exact dose assurance for some materials. These materials were compared with the reference materials found in report no. 44 of ICRU [8]. Further, to develop monetarily appropriate human tissue substitutes for phantom fabricate, atomic numbers and electron densities were resolved reliant on mass attenuation coefficient values. Fadhil et al. (2017) chose the elemental compositions and attenuation properties of gelatin for utilising it as a test materials to assess the impact of ionizing radiation on tissues [9]. Kurudirek and Özdemir (2011) tried the legitimacy of utilising tissue proportionate materials for dosimetric estimations [10].

In this work, a methodology is created to research scatter and absorption properties of PMMA as a human tissue-proportional material. The interaction of photon with tissues is inspected fundamentally to the extent tissue attenuation coefficients inside the energy range utilised in brachytherapy (0.15–2.0 MeV). The linear attenuation coefficient (μ) is the probability of collaboration of photons per unit separation

in an engaging medium. The mass attenuation coefficient is a proportion of the average number of interactions that happen in a given mass-per-unit area of tissue [11]. The mass attenuation coefficient, μ_m ($\mu_m=\mu/\rho$) is of more vital importance than μ, it does not depend on the thickness and physical condition of the medium, it plays as a significant coefficient, since simply the atomic arrangement of the attenuator is considered and not its individual density. It is a proportion of material ability to ingest or dissipate radiation per unit of mass [12]. Then again tissue equivalent atomic number (Z_{eq}) is a noteworthy limit in anticipating and surveying the transport of photon progress in tissue and checking the radiation partition devoured by it. On the other hand, tissue equivalent atomic number (Z_{eq}) is a basic cutoff in foreseeing and reviewing the transport of photon flux in the irradiated tissue and consumed dose rate assessment. Scattering and absorption properties of a single element are identified with its thickness and atomic number, while for a composite material it is identified with its effective thickness and equivalent atomic number. The point of this examination is to drive and process photon interaction boundaries, for PMMA as a human tissue substitute, so as to apply the ideas of photon collaborations and dosimetry and to propose a valuable system ready to explore material tissue equivalence.

2. METHODOLOGY

The linear attenuation coefficient μ is the most noteworthy variable to depict the association between radiation entrance and absorption material along its way for each unit distance inside this tissue. It relies upon the atomic number of the material and the energy of the radiation. Taking into account Hubbell and Seltzer's (1997) speculation, the mass attenuation coefficient (μ/ρ) is the entire cross-section of the individual impact values for Rayleigh (σ_R), photoelectric impact (σ_τ), pair creation (κ) and Compton scattering (σ_c) divided by the atomic mass unit (m_u) having the estimation of 1.660 5402 × 10^{-24} g and the relative atomic mass of the absorber (A) as found in the next expression [13]:

$$\mu_m = \frac{\mu}{\rho} = \frac{\sigma_R + \sigma_C + \sigma_\tau + K}{m_u A}$$

.

To choose the appropriate tissue-equivalent material, the delayed consequences of mass attenuation coefficient is contrasted with that given in the ICRU no. 44 [8]. This report gives nuances of basic arrangements, mass densities, electron densities and interaction information of all tissues. XCOM photon cross-section information base, which is built up by the National Institute of Standards and Technology (NIST) in light of Hubbell and Seltzer tables, is the most helpful programming in mass attenuation coefficient estimations for some researchers [13],[14]. The last referenced programming is utilised in this work to figure the mass attenuation coefficient after inserting the values of the elemental composition taken from the literature [8], [9], [15], and [16]. Elemental composition (%) (weight part of tissue sections) of picked human tissue examples are presented in Table 1 and the same compositions for PMMA as a human tissue substitute are recorded in Table 2.

Table 1. Elemental Composition (%) of Some Human Tissues [8], [15]

Element	Adipose ρ= 0.92 g cm^{-3}	Skin ρ= 1.10 g cm^{-3}	Muscle ρ= 1.04 g cm^{-3}	Brain ρ=1.03 g cm^{-3}	Blood ρ= 1.06 g cm^{-3}	Lung ρ= 1.05 g cm^{-3}	Soft ρ= 1.00 g cm^{-3}	Bone (compact) ρ= 1.85 g cm^{-3}	Bone (cortical) ρ= 1.85 g cm^{-3}
H	1.19E+01	1.00E+01	1.02E+01	1.11E+01	1.02 E+01	1.01 E+01	1.04 E+01	6.39E+00	4.72E+00
C	6.37E+01	2.28E+01	1.23E+01	1.25E+01	1.00E+01	1.02E+01	2.32E+01	2.78E+01	1.44E+01
N	7.97E-01	4.64E+00	3.50E+00	1.32E+00	2.96E+00	2.86E+00	2.48E+00	2.70E+00	4.19E+00
O	2.32E+01	6.19E+01	7.29E+01	7.37E+01	7.59E+01	7.57E+01	6.30E+01	4.10E+01	4.46E+01
Na	5.00E-02	7.00E-03	8.00E-02	1.84E-01	1.85E-01	1.84E-01	1.13E-01	0.00E+00	0.00E+00
Mg	2.00E-03	6.00E-03	2.00E-02	1.5E-02	4.00E-03	7.30E-02	1.30E-02	2.00E-01	2.20E-01
Si	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.00E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00
P	1.60E-02	3.30E-02	2.00E-01	3.54E-01	3.50E-02	8.00E-02	1.33E-01	7.00E+00	1.05E+01
S	7.30E-02	1.59E-01	5.00E-01	1.77E-01	1.85E-01	2.25E-01	1.99E-01	2.00E-01	3.15E-01
Cl	1.19E-01	2.67E-01	0.00E+00	2.36E-01	2.78E-01	2.66E-01	1.34E-01	0.00E+00	0.00E+00
K	3.20E-02	8.50E-02	3.00E-01	3.10E-01	1.63E-01	1.94E-01	1.99E-01	0.00E+00	0.00E+00
Ca	2.00E-03	1.50E-02	0.00E+00	9.00E-03	6.00E-03	9.00E-03	2.30E-02	1.47E+01	2.10E+01
Fe	2.00E-03	1.00E-03	0.00E+00	5.00E-03	4.60E-02	3.7E-02	5.00E-03	0.00E+00	0.00E+00
Zn	2.00E-03	1.00E-02	0.00E+00	1.00E-03	1.00E-02	1.00E-02	3.00E-03	0.00E+00	1.00E-02

Table 2. Elemental Composition (%) of PMMA as Human Tissue-Equivalent Material [9], [16]

Element	H	C	N	O	S
PMMA ρ=1.178 g cm^{-3}	2.40E-03	9.49E-01	4.71E-02	0.00E+00	1.00E-03

3. RESULTS AND DISCUSSION

3.1. Mass Attenuation Coefficients

Tissue-comparable materials are valuable for mimicking human tissues for photon interactions inside the determined energy regions. These materials should hold and disperse radiation comparably, inside commendable cutoff points, as illuminated human tissue. As far as possible, as suggested by the ICRU report no. 44, the precision for dose conveyance in radiotherapy methods should be inside ± 5 %. Materials having great tissue identicalness, normally utilized for apparition reproduction, ought to end up being appropriate in testing dosages for brachytherapy applications. Tissue-comparability of material portrays its ability to collaborate with radiation as genuine tissues did. The mass attenuation coefficient (μ_m) is a basic boundary for photon interactions with the material. It is an extent of the normal number of interactions between scene photons and matter occurring in a given mass-per-unit area of the material experienced. The calculated estimations of μ_m as a function of photon energy, for human tissues and PMMA as a human tissue substitute, is presented in Table 3.

Table 3. Variation of Mass Attenuation Coefficient for Human Tissues and PMMA for Photon Energies (0.015–2.0) MeV

Energy (MeV)	adipose	Skin	Muscle	Brain	Blood	Lung	Soft	Bone compact	Bone cortical	PMMA
0.015	9.44E-01	1.40E+00	1.57E+00	1.59E+00	1.58E+00	1.59E+00	1.43E+00	6.12E+00	8.38E+00	7.42E-01
0.02	4.86E-01	6.66E-01	7.37E-01	7.47E-01	7.41E-01	7.46E-01	6.80E-01	2.70E+00	3.66E+00	3.91E-01
0.03	2.68E-01	3.13E-01	3.33E-01	3.37E-01	3.34E-01	3.36E-01	3.18E-01	9.10E-01	1.19E+00	2.27E-01
0.04	2.17E-01	2.33E-01	2.41E-01	2.43E-01	2.41E-01	2.42E-01	2.35E-01	4.76E-01	5.90E-01	1.89E-01
0.05	1.98E-01	2.04E-01	2.08E-01	2.09E-01	2.08E-01	2.08E-01	2.05E-01	3.22E-01	3.77E-01	1.74E-01
0.06	1.88E-01	1.89E-01	1.91E-01	1.93E-01	1.91E-01	1.91E-01	1.90E-01	2.53E-01	2.83E-01	1.66E-01
0.08	1.75E-01	1.73E-01	1.74E-01	1.76E-01	1.74E-01	1.74E-01	1.74E-01	1.95E-01	2.06E-01	1.56E-01
0.1104	1.62E-01	1.59E-01	1.60E-01	1.61E-01	1.60E-01	1.60E-01	1.60E-01	1.64E-01	1.66E-01	1.45E-01
0.15	1.49E-01	1.47E-01	1.47E-01	1.48E-01	1.47E-01	1.47E-01	1.47E-01	1.45E-01	1.44E-01	1.33E-01
0.2	1.37E-01	1.34E-01	1.34E-01	1.36E-01	1.34E-01	1.34E-01	1.35E-01	1.31E-01	1.29E-01	1.22E-01
0.3	1.19E-01	1.17E-01	1.17E-01	1.18E-01	1.17E-01	1.17E-01	1.17E-01	1.13E-01	1.11E-01	1.07E-01
0.35	1.12E-01	1.10E-01	1.10E-01	1.11E-01	1.10E-01	1.10E-01	1.11E-01	1.07E-01	1.05E-01	1.01E-01
0.5	9.73E-02	9.57E-02	9.58E-02	9.65E-02	9.58E-02	9.57E-02	9.60E-02	9.24E-02	9.09E-02	8.72E-02
0.613	8.91E-02	8.77E-02	8.78E-02	8.84E-02	8.78E-02	8.77E-02	8.80E-02	8.46E-02	8.32E-02	7.99E-02
0.6616	8.62E-02	8.48E-02	8.49E-02	8.55E-02	8.49E-02	8.48E-02	8.51E-02	8.18E-02	8.05E-02	7.73E-02
1.173	6.57E-02	6.46E-02	6.47E-02	6.52E-02	6.47E-02	6.46E-02	6.48E-02	6.24E-02	6.13E-02	5.89E-02
1.2529	6.35E-02	6.25E-02	6.26E-02	6.30E-02	6.25E-02	6.25E-02	6.27E-02	6.03E-02	5.93E-02	5.69E-02
1.3325	6.15E-02	6.05E-02	6.06E-02	6.11E-02	6.06E-02	6.06E-02	6.07E-02	5.84E-02	5.75E-02	5.52E-02
1.33782	6.05E-02	6.04E-02	6.05E-02	6.09E-02	5.95E-02	6.04E-02	6.06E-02	5.83E-02	5.74E-02	5.51E-02
1.5	5.79E-02	5.69E-02	5.70E-02	5.74E-02	5.70E-02	5.70E-02	5.71E-02	5.50E-02	5.41E-02	5.19E-02
1.6	5.59E-02	5.50E-02	5.51E-02	5.55E-02	5.51E-02	5.51E-02	5.52E-02	5.32E-02	5.23E-02	5.02E-02
1.7	5.42E-02	5.33E-02	5.34E-02	5.38E-02	5.34E-02	5.34E-02	5.35E-02	5.15E-02	5.07E-02	4.86E-02
1.8	5.25E-02	5.17E-02	5.18E-02	5.22E-02	5.18E-02	5.18E-02	5.19E-02	5.00E-02	4.92E-02	4.71E-02
1.9	5.10E-02	5.03E-02	5.03E-02	5.07E-02	5.03E-02	5.03E-02	5.04E-02	4.86E-02	4.79E-02	4.58E-02
2.0	4.96E-02	4.89E-02	4.90E-02	4.93E-02	4.89E-02	4.89E-02	4.90E-02	4.73E-02	4.66E-02	4.45E-02

As can be seen from the information recorded in the table, except for bone tissues, the estimations of 7 human tissues and tissue-equivalent material are near one another for a similar photon energy and the contrast between them exists in the range of 0.0 % – 7.0 %. The outcomes are likewise plotted in Fig. 1 for photon energy region between 0.015 and 2.0 MeV. It very well may be seen in the figures that the estimations of all materials decline quickly with photon energy up to about 0.5 MeV, then the qualities decline gradually up to 2 MeV. This variation is because of the variety of partial photon interaction cross-sections.

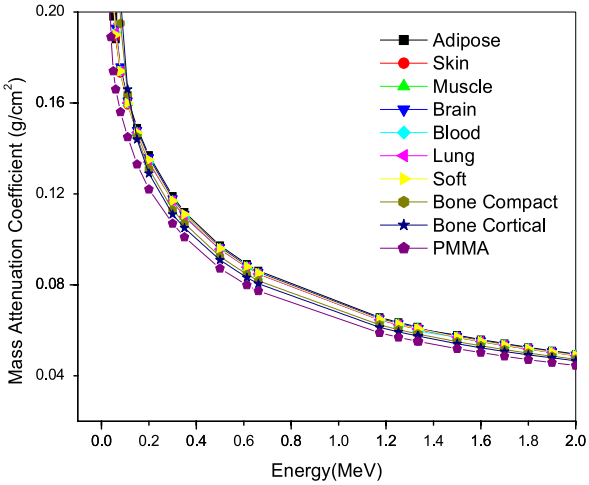

Fig. 1. Variation of mass attenuation coefficient of human tissues and PMMA for photon energies (0.015-2.0) MeV.

However, μ_m values decrease rapidly with photon energy until the photon energy outperforms the binding energy of the electrons and Compton scattering turns into the prevalent interaction. In the Compton range of energies, μ_m value of different materials does not change in a huge amount, since it is autonomous of atomic number Z_{eq}. It follows that the contribution of Compton scattering to μ_m is independent of Z_{eq} but depends only on the material electron density (number of electrons per unit volume), which is almost the same for all materials except hydrogen. The mass attenuation coefficient continues lessening with energy until pair production begins to get possible. The quality of pair production occurs at energies significantly more noticeable than the edge of energy of 1.02 MeV, which is out of our interest in the energy range used in brachytherapy. At last, it should be noticed that qualities will be utilised to drive different photon interaction boundaries, for example, linear attenuation coefficient, which will encourage correlation of radio-physical properties of the chosen tissue-equivalent material (PMMA) with the relating human tissues.

3.2. Linear Attenuation Coefficients

Linear attenuation coefficient (μ) is a helpful boundary for assessing the usage of tissue proportionate materials in dosimetric applications. It is the fundamental boundary required in deciding photon transmission in issue. Computed values of (μ) for the chosen human tissue and PMMA as a human tissue substitute, for the photon energy range of 0.015 to 2 MeV are arranged in Table 4. Estimation of linear attenuation coefficients relies upon the photon energy, chemical composition and, to some extent, electron density or physical density of the investigated materials. The energy reliance of μ values is shown in Fig. 2. It very well may be seen from the figure that the state of variety of μ with energy, for all the examined materials, was like each other; however, every one of them changed by a factor comparing to its physical thickness and chemical content. It is observed that the most elevated μ values over all the photon energy run were found for both compact and cortical bone tissues that credited to moderately high thickness and the plenitude of high atomic number inside their chemical contents.

Table 4. Variation of Linear Attenuation Coefficient of Human Tissues and PMMA for Photon Energies (0.015–2.0) MeV

Energy (MeV)	adipose	Skin	Muscle	Brain	Blood	Lung	Soft	Bone compact	Bone cortical	PMMA
0.015	8.68E-01	1.54E+00	1.63E+00	1.64E+00	1.67E+00	1.67E+00	1.43E+00	1.13E+01	1.55E+01	8.74E-01
0.02	4.47E-01	7.32E-01	7.67E-01	7.69E-01	7.85E-01	7.83E-01	6.80E-01	4.99E+00	6.78E+00	4.60E-01
0.03	2.47E-01	3.45E-01	3.47E-01	3.47E-01	3.54E-01	3.52E-01	3.18E-01	1.68E+00	2.21E+00	2.67E-01
0.04	2.00E-01	2.56E-01	2.50E-01	2.51E-01	2.56E-01	2.54E-01	2.35E-01	8.80E-01	1.09E+00	2.23E-01
0.05	1.82E-01	2.24E-01	2.16E-01	2.16E-01	2.20E-01	2.18E-01	2.05E-01	5.95E-01	6.97E-01	2.05E-01
0.06	1.73E-01	2.08E-01	1.99E-01	1.99E-01	2.03E-01	2.01E-01	1.90E-01	4.68E-01	5.23E-01	1.96E-01
0.08	1.61E-01	1.91E-01	1.81E-01	1.81E-01	1.85E-01	1.83E-01	1.74E-01	3.61E-01	3.80E-01	1.84E-01
0.1104	1.49E-01	1.75E-01	1.66E-01	1.66E-01	1.69E-01	1.68E-01	1.60E-01	3.03E-01	3.07E-01	1.70E-01
0.15	1.37E-01	1.61E-01	1.53E-01	1.52E-01	1.56E-01	1.54E-01	1.47E-01	2.68E-01	2.67E-01	1.57E-01
0.2	1.26E-01	1.48E-01	1.40E-01	1.40E-01	1.42E-01	1.41E-01	1.35E-01	2.42E-01	2.39E-01	1.44E-01
0.3	1.09E-01	1.28E-01	1.22E-01	1.21E-01	1.24E-01	1.23E-01	1.17E-01	2.09E-01	2.06E-01	1.25E-01
0.35	1.03E-01	1.21E-01	1.15E-01	1.15E-01	1.17E-01	1.16E-01	1.11E-01	1.97E-01	1.94E-01	1.18E-01
0.5	8.95E-02	1.05E-01	9.96E-02	9.94E-02	1.02E-01	1.00E-01	9.60E-02	1.71E-01	1.68E-01	1.03E-01
0.613	8.20E-02	9.64E-02	9.13E-02	9.11E-02	9.30E-02	9.21E-02	8.80E-02	1.57E-01	1.54E-01	9.41E-02
0.6616	7.93E-02	9.32E-02	8.83E-02	8.81E-02	8.99E-02	8.90E-02	8.51E-02	1.51E-01	1.49E-01	9.10E-02
1.173	6.04E-02	7.11E-02	6.73E-02	6.71E-02	6.86E-02	6.79E-02	6.48E-02	1.15E-01	1.13E-01	6.94E-02
1.2529	5.84E-02	6.87E-02	6.51E-02	6.49E-02	6.63E-02	6.56E-02	6.27E-02	1.12E-01	1.10E-01	6.71E-02
1.3325	5.66E-02	6.66E-02	6.30E-02	6.29E-02	6.42E-02	6.36E-02	6.07E-02	1.08E-01	1.06E-01	6.50E-02
1.33782	5.56E-02	6.64E-02	6.29E-02	6.28E-02	6.31E-02	6.35E-02	6.06E-02	1.08E-01	1.06E-01	6.49E-02
1.5	5.32E-02	6.26E-02	5.93E-02	5.92E-02	6.04E-02	5.98E-02	5.71E-02	1.02E-01	1.00E-01	6.11E-02
1.6	5.15E-02	6.05E-02	5.73E-02	5.72E-02	5.84E-02	5.78E-02	5.52E-02	9.84E-02	9.68E-02	5.91E-02
1.7	4.98E-02	5.87E-02	5.55E-02	5.54E-02	5.66E-02	5.60E-02	5.35E-02	9.53E-02	9.38E-02	5.72E-02
1.8	4.83E-02	5.69E-02	5.39E-02	5.38E-02	5.49E-02	5.44E-02	5.19E-02	9.25E-02	9.11E-02	5.55E-02
1.9	4.69E-02	5.53E-02	5.24E-02	5.22E-02	5.33E-02	5.28E-02	5.04E-02	8.99E-02	8.86E-02	5.39E-02
2.0	4.57E-02	5.38E-02	5.09E-02	5.08E-02	5.19E-02	5.14E-02	4.90E-02	8.75E-02	8.62E-02	5.24E-02

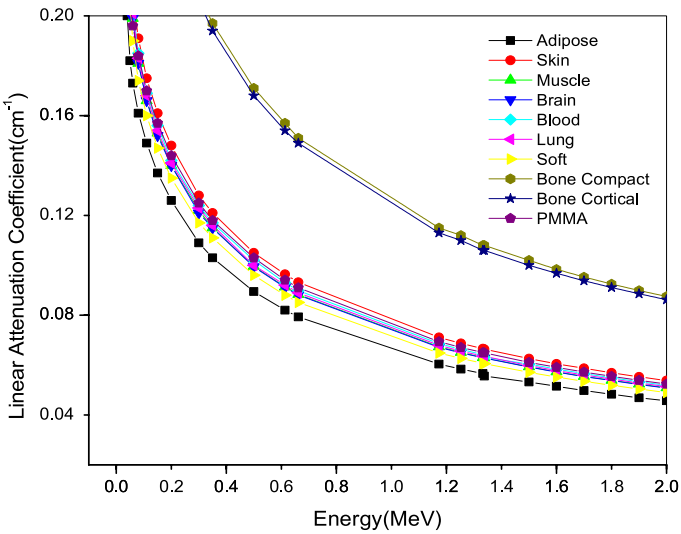

Fig. 2. Variation of linear attenuation coefficient of human tissues and PMMA for photon energies (0.015-2.0) MeV.

To analyse the PMMA as a human tissue substitute, the energy reliance of its μ values is contrasted and that of human tissues as shown in Fig. 3. It is seen from the figure and tables that PMMA has μ estimation of 0.091 cm^{-1} at photon energy of 0.662 MeV, and 0.065 cm^{-1} at photon energy of 1.33 MeV. Then again, blood and lung tissue have μ estimations of 0.0899 and 0.0890 cm^{-1} at photon energy of 0.662 MeV, and 0.0631 and 0.0635 cm^{-1} at photon energy of 1.33 MeV, separately. Their normal μ esteem is 0.0895 with the greatest partial contrast of 1.7 % at 0.662 MeV and normal μ estimation of 0.0633 cm^{-1} with maximum fractional difference of 2.7 % at 1.33MeV. Since the most extreme partial distinction is the smallest between all bends of the gathering of human tissues contrasted with PMMA as a human tissue substitute, which shows that PMMA might be helpful to mimic blood or lung tissue inside the photon energy range under consideration. Likewise, PMMA simulates well muscle and brain tissues inside the considered energy range.

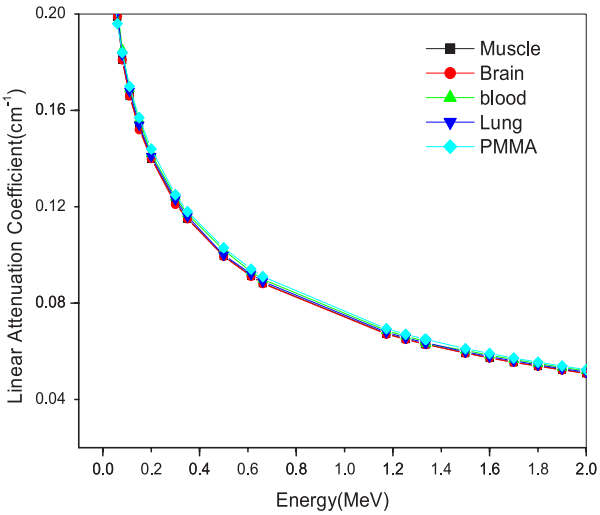

Fig. 3. Variation of linear attenuation coefficient of selected human tissues and PMMA for photon energies (0.015-2.0) MeV.

4. CONCLUSIONS

Brachytherapy is a huge strategy for disease treatment where radioactive fixed sources are used to pass on radiation at a short division by intracavitary, interstitial and surface utilizations. A sensible method to inspect the legitimacy of patient treatment plan, before it is executed, is to gauge dose conveyance around sources, at distances of clinical interest using phantoms incorporating tissue equivalent materials. These materials must have similar radiophysical properties to have the option to re-enact diverse human tissues. To inspect and choose a fitting tissue-equivalent material, the method proposed in this examination includes approval of material tissue comparability. All the radio-physical properties and boundaries related with it should be considered and contrasted with that of the comparing human tissue. In the cur-

rent work, exhaustive examinations of the gamma-beam attenuation and absorption boundaries have been done for PMMA as a tissue comparable material and the results stood out from that of nine picked human tissues for the photon vitality accommodating in brachytherapy applications. The results showed that the maintenance and dissemi-nate properties of PMMA tissue-equivalent materials depended upon its density, chemical composition and photon energy range. The outcomes additionally proposed that PMMA as a human tissue substitute demonstrated a phenomenal match to muscle, brain, blood, and lung human tissues.

REFERENCES

1. Misra, R., Acharya, S., & Sahoo, S.K. (2010). Cancer Nanotechnology: Application of Nanotechnology in Cancer Therapy. *Drug Discov Today, 15*, 842–850.
2. Verhaegen, F., & Seuntjens, J. (2003). Monte Carlo Modelling of External Radiotherapy Photon Beams. *Phys Med Biol, 48*, 107–164.
3. Palmer, A., Bradley, D., & Nisbet, A. (2012). Physics-Aspects of Dose Accuracy in High Dose Rate (HDR) Brachytherapy: Source Dosimetry, Treatment Planning, Equipment Performance and In Vivo Verification Techniques. *J Contemp Brachytherapy, 4,* 81–91.
4. Yohannes, I., Kolditz, D., & Langner O. (2012). A Formulation of Tissue-and Water-Equivalent Materials Using the Stoichiometric Analysis Method for CT-Number Calibration in Radiotherapy Treatment Planning. *Phys Med Biol, 57,* 1173–1190.
5. Yazdani, M., & Mowlavi, A.A. (2007). Determining TG-43 Brachytherapy Dosimetry Parameters and Dose Distribution for a ^{131}Cs Source Model CS-1. *Iran J Radiat Res*, 5, 85–90.
6. Chandola, R.M., Tiwari, S., & Kowar, M.K. (2010). Effect of In-Homogeneities and Source Position on Dose Distribution of Nucletron High Dose Rate Ir-192 Brachytherapy Source by Monte Carlo Simulation. *J Cancer Res Ther*, *6*, 54–57.
7. Hsu, S.M, Wu, C.H., & Lee, J.H. (2012). A Study on the Dose Distributions in Various Materials from an Ir-192 HDR Brachytherapy Source. *PLoS One, 7,* e44528.
8. ICRU Report No. 44. (1989). *Tissue Substitutes in Radiation Dosimetry and Measurement*. ICRU, Bethesda.
9. Fadhil, F., Abdalsattar, H., & Rajaa, M. (2017). Calculating the X-ray Attenuation Coefficients of Gelatin as Human Tissue Substitute. *Austr J Bas and Appl Sci*, 21–29.
10. Kurudirek, M., & Özdemir, Y. (2011). Energy Absorption and Exposure Buildup Factors for Some Polymers and Tissue Substitute Materials: Photon Energy, Penetration Depth and Chemical Composition Dependence. *J Radiol Prot, 31* (1), 117–28.
11. Gupta, S., & Sidhu, G.S. (2014). Computation of Mass Attenuation Coefficient, Energy Absorption and Exposure Build-Up Factors for Teeth in the Energy Range 0.015–15 MeV up to 40 mfp. *IJETR, 2 (7).*
12. Hopkins, D.N. (2010). *Determination of the Linear Attenuation Coefficient and Buildup Factors of MCP-96 Alloy for Use in Tissue Compensation and Radiation Protection* [Master Thesis]. USA: Ball State University Muncie.
13. Hubbell, J.H, & Seltzer, S.M. (1997). *Tables of X-ray Mass Attenuation Coefficients and Mass Energy-Absorption Coefficients* (version 1.03) (online). Available at http://physics.nist.gov/xaamdi. National Institute of Standards and Technology, Gaithersburg, MD. Originally published as NISTIR 5632, National Institute of Standards and Technology, Gaithersburg, MD.

14. Gerward, L., Guilbert, N., Jensen, K.B., & Levring H. (2001). X-ray Absorption in Matter. Reengineering XCOM. *Rad Phys Chem, 60,* 23–24.
15. Hubbell, J.H., & Seltzer, S.M. (1995). *Tables of X-Ray Mass Attenuation Coefficients and Mass Energy-Absorption Coefficients from 1 keV to 20 MeV for Elements Z ¼ 1 to 92 and 48 Additional Substances of Dosimetric Interest.* Gaithersburg: National Institute of Standards and Technology.
16. ICRP. (2003). *Basic Anatomical and Physiological Data for Use in Radiological Protection* (vol. 89). Reference values. ICRP publication.