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Measurement of Attenuation Coefficient and Stopping Power for Polymeric Composite Materials Used in Biological Shielding

Mukhtar Sinan Abdullah, Anas Mohammed Shakir, Ahmed Hafez Saleh, Mohammed Hamdallah Hamoud, Ahmed Mubder Jassim, Rashid Yasser Atwan
University of Fallujah College of Applied Science, Medical Physics

Introduction

Radiation is energy that moves from one place to another in the form of waves or particles. We are exposed to radiation in our daily lives through some of the most common sources of radiation, such as sunlight, microwaves in our kitchens, and the radios we listen to in our cars. Most of this radiation does not pose a threat to our health. In general, the risks of radiation are lower when exposed to low doses, but the risks can increase when exposed to large doses. Different measures must be taken, depending on the type of radiation, to reduce its effects on humans and the environment, allowing us to benefit from its many applications.[1] Radiation is found in every part of our lives, and radiation may occur naturally on Earth, and it can reach us from radiation coming from the space surrounding us. Radiation can also occur naturally in the water we drink, or in the soil, and in building materials, the radon element from the Earth, and the radioactive elements present in the Earth. Radiation may occur as a result of its manufacture by humans, such as Scientific research in the United States of America states that the average person receives doses of radiation amounting to 360 millirem per year, and the exposure rate to natural radiation is 80% and the second 20% to artificial radiation. In the year 1934, the scientist Enrico Fermi was conducting some experiments to obtain isotopes. It is well known that all the benefit of the using ionizing radiation could accrue to human being as a result. Exposure to this radiation is held according to the damage that results from it making man takes a negative attitude from all nuclear applications and even peaceful ones since everything that exists on the surface of the ground is exposed to the effect of ionizing radiation, like the cosmic radiation and radioactive materials in the ground or industrial sources used for medical purposes. However, depending on intensive studying of the results of nuclear experiment, these harms could be reduced to be equal with the damages caused by any technological or other industrial process. There are many ways to control the external exposure to

radiation and reduce it to the minimum levels. The covers or protective shields are particularly used for this purpose, and despite the fact that there are different materials used for shielding, lead is widely used because it has high reserve force that helps to reduce the thickness of the armors manufactured from which. Because of the breadth of the required areas to be protected especially in cases designing armors in hospitals, clinics and nuclear institutions, the use of lead is expensive and so concrete where other building materials are used to increase the thickness of the protective walls.[2] To manufacture armor with distinguished specifications Low cost of manufacturing, availability of locally manufactured materials, and ease of manufacturing. Calculations showed that this samples have an average attenuation coefficient in the photon energy range between 6 MeV and 0.125 MeV. The results of the study also showed that we can improve the shielding properties of PVA polymeric materials And make them global standards for the manufacture of biological shields. Through the results we can also We recommend that changes in the attenuation properties of the PVA polymer should be studied when material concentrations change Manufacturing them in order to know the changes that occur in their mechanical properties. Recently, polymer materials are preferable in radiation shielding applications due to their unique properties: flexibility, durability and low-cost production. These properties enthuse the researchers and, lately, elements or compounds have been mixed into polymer matrixes to create novel radiation shielding materials having the distinctive advantages of polymers. In this work, we used natural materials to calculate their stopping power and attenuation coefficient for radiation, for the purpose of using them as biological shields from ionizing radiation.

1-2 Aim of the Project

1. Use shields of natural origin at a lower cost, with the same quality, lighter weight, and better mechanical properties.
2. Manufacture of biodegradable polymeric materials (biodegradation or the process of disintegration of a substance into its primary elements by physico-chemical and biological methods) used in shielding, especially temporary shielding.
3. Measurement of shielding coefficients (attenuation coefficient and stopping power).

Previous Study

Many research workers have determined the values of different shielding parameters in various ways [3] to know the shielding effectiveness of the shielding materials developed with time.

1. researches and studies are conducted to design shields to protect from gamma rays that have high-penetration capability by discovering the attenuation coefficients for each material and to state its ability to block these rays. The attenuation coefficient of the gamma rays is measured with energies (295.2, 351.9, 583.1, 609.3, 911.1, 1460.8 keV for some building materials used in Jordan like ceramic, alabaster, granite, bricks, concrete and limestone by the researcher Awadallah et al.[4] and they find that among the selected samples, the granite is the best protective armor against radiation with linear attenuation coefficient $(29.2 \pm 0.9)\ m^{-1}$ at energy (295.2 keV) for gamma rays.
2. Also the researchers Mortazavi et al.[5] use different samples of concrete after being treated with high metals density as a shield of photons of high energy using package of gamma emitted from 60Co. In this research, effective and economical armor is produced to protect from gamma ray in high-energy atomic radiation rooms and nuclear power plants.
3. Cevik et al. [6] study the natural radiation and the coefficient of attenuation mass for 107 different Marble sample in Turkey where they find that the experimental values are consistent with the theoretical values.

4. The researchers Akkurt et al. [7] conduct a study the linear attenuation coefficient for the samples of concrete containing Zeolite with different concentrations of (0%, 10%, 30%, and 50%). It is noted that the linear attenuation coefficient decreases with increasing concentration of Zeolite, and it is concluded that Zeolite is non- convenient to use as a protective shield from radiation.
5. Also the shield made from (Amethyst ore) is compared with shield made of concrete by researchers Korkt et al. [8] It is found that the shield (Amethyst ore) has more absorbency ability for gamma rays than concrete at the same gamma ray energy.
6. Moreover, Damla et al. [9] study the attenuation coefficients of gamma rays practically and theoretically in the number of materials such as sand, cement, bricks, tiles and other building material which used in Turkey, at range of gamma ray energy (81 - 1332) keV and they find that the cement is the most perfect armor visor radiation with mass attenuation coefficient (0.252 cm^2/g).
7. Almurayshid et al. tested the potential of polymer composites for radiation shielding and found that supplementing high-density polyethylene (HDPE) with additives enhanced the attenuation of beams, with the best shielding efficiency achieved at a 15% concentration of additives. More et al. studied the γ-ray attenuation properties of thermoplastic polymers used in nuclear medical diagnosis and treatment, comparing experimental, theoretical, and simulation values of attenuation parameters. Fontainha et al. prepared polymer-based composites for X-ray shielding in radiology procedures, finding that nanocomposites showed better attenuation features than microcomposites [3]. Sulaberidze et al. investigated composite materials for dielectric coatings, measuring mechanical characteristics such as strength, elasticity, and hardness. Another study by Fontainha et al. also focused on polymer-based composites for X-ray shielding, comparing the performance of micro and nanocomposites and demonstrating their suitability for radiology procedures.

The theoretical part

Introduction

Sources of Radiation:

Radiation is energy in the form of a particle or wave that flows through matter or space. It can be produced in one of two ways: either by radioactive decay of the nucleus of an unstable atom (radionuclide) or by interaction between particles and matter. [10]

Radiation sources People are exposed to natural sources of radiation as well as man-made sources on a daily basis. Natural radiation comes from many sources, including more than 60 naturally occurring radioactive substances found in soil, water and air. Radon is a natural gas that comes from rocks and soil, and is the main source of natural radiation. Every day, people are exposed to radionuclides through inhalation and ingestion from the air, food and water. People are also exposed to natural radiation from cosmic rays, especially at high altitudes. On average, 80% of the background radiation dose that humans receive annually comes from naturally occurring terrestrial and cosmic rays. Levels of exposure to background radiation vary geographically due to geological differences. Exposure in certain regions can be more than 200 times higher than the global average. Radiation exposure also comes from man-made sources ranging from nuclear power generation to medical uses of radiation for diagnostic or treatment purposes. Today, medical devices, including X-ray machines and CT scanners, are the most common man-made sources of ionizing radiation. Lifetime exposure to radiation comes from a variety of sources, both natural and man-made.

Classification of Radiation

1. Non-ionizing radiation

Non-ionizing radiation is lower-energy radiation that does not have enough energy to separate electrons from atoms or molecules, whether in matter or in living organisms. However, energy can cause these molecules to vibrate and thus produce heat. This is how microwave ovens work, for example. In general, non-ionizing radiation does not pose a risk to people's health. However, workers who regularly and directly deal with some sources of non-ionizing radiation may need special measures to protect themselves from the heat generated by these radiations. Some other examples of non-ionizing radiation include radio waves and visible light. Visible light is a type of non-ionizing radiation that the human eye can perceive. Radio waves are a type of non-ionizing radiation that we cannot see or perceive with our other senses, but these waves can be picked up by traditional radio devices.[11]

2. Ionizing radiation

Ionizing radiation is a type of energy released by certain atoms and is transmitted in the form of electromagnetic waves (gamma rays or Unstable elements that decay and emit ionizing radiation are called radionuclides. The unique properties of all radionuclides are determined by the type of radiation they emit, the energy of that radiation, and its half-life. Activity, which is used as a measure of the amount of radionuclides present, is measured in a unit called the becquerel (Bq), and one becquerel is equivalent to one decay process per second. The half-life is the time required for the activity of radionuclides to decline due to radioactive decay to half their initial value, and the half-life of a radioactive element is the time it takes for half of its atoms to disintegrate. Half-lives range from just a fraction of a second to millions of years (for example, the half-life of iodine-131 is 8 days while the half-life of carbon-14 is 5730 years).

Exposure to ionizing radiation Internal exposure to ionizing radiation occurs when radionuclides are inhaled, ingested, or otherwise enter the bloodstream (for example, by injection or through wounds). Internal exposure stops when the radionuclides are eliminated from the body, either spontaneously (through waste, for example) or as a result of treatment. [12]

3. Gamma radiation

They are photons with short wavelengths within the limits of 11−10 MtRa. The nucleus is often stimulated after the decay process. This energy is lost as an electromagnetic radiation known as a Gamma radiation instead of forming a beta particle or another particle. Gamma rays interact with matter by interacting with electrons in the envelopes of an atom. It slowly loses its energy in the material and can move to vast distances before stopping. Depending on the initial energy, Gamma rays can go from one meter to one meter in the air. [13]

Interaction of Gamma Radiation with Matter

The interaction of gamma rays with matter occurs through three main actions: the photoelectric effect, the Compton effect, and the production of pairs. The efficiency of each process depends on the amount of photon energy and number Atomic and density of the absorption medium.[14]

Compton Scattering

The Compton effect is the scattering of a photon due to its collision with a free charged particle, usually an electron.This effect causes a decrease in energy (increase in wavelength) of the photon, and it applies to high-energy electromagnetic radiation, such as gamma-ray photons and high-energy X-ray photons. Part of the photon's energy is transferred to the dispersed charged particle. There is what is called the inverse Compton effect, which is the transfer of the energy of a charged particle into a photon. But if the rays are of low energy (that is, their wavelength is much greater

than the particles scattered on them), then what is called Thomson scattering applies in this case.[15]

Pair production

Pair production is the creation of a subatomic particle and its antiparticle from a neutral boson. Examples include creating an electron and a positron, a muon and an antimuon, or a proton and an antiproton. Pair production often refers specifically to a photon creating an electron–positron pair near a nucleus. As energy must be conserved, for pair production to occur, the incoming energy of the photon must be above a threshold of at least the total rest mass energy of the two particles created. (As the electron is the lightest, hence, lowest mass/energy, elementary particle, it requires the least energetic photons of all possible pair-production processes). Conservation of energy and momentum are the principal constraints on the process.[16] All other conserved quantum numbers (angular momentum, electric charge, lepton number) of the produced particles must sum to zero – thus the created particles shall have opposite values of each other. For instance, if one particle has electric charge of (+1) the other must have electric charge of (−1), or if one particle has strangeness of (+1) then another one must have strangeness of (−1).[17]

Gamma Ray Attenuation

When γ-rays fall on a mass of matter, they interact with it through all interactions, resulting in attenuation or weakening of γ-rays as they pass through the material.

The resulting attenuation of radiation varies depending on the type and material passing through it.[18] Mass attenuation coefficient (obtained by dividing the linear attenuation coefficient by the density of the absorbent material). which is actually more important than the linear attenuation coefficient. This is because...

All mass attenuation coefficients are independent of the actual density and physical state (gas, liquid or solid) for the absorber. In addition, the mass attenuation coefficient is approximately

Independent of the atomic number at Z/A = 0.45 ± 0.05 where Z = atomic number and A=The mass number of the absorber.

Moreover, the mass attenuation coefficient facilitates comparison between radiation protection efficiency of shielding materials.[19]

Calculation of Total Mass Attenuation Coefficient) m**(**

We can sometimes use the mass attenuation coefficient when characterizing an absorbing material. The mass attenuation coefficient is defined as the ratio of the linear attenuation coefficient and absorber density (μ/ρ). where ρ is the material density, and ρ.l is the mass thickness. The measurement unit was used for the mass attenuation coefficient cm2g-1. For intermediate energies, the Compton scattering dominates, and different absorbers have approximately equal mass attenuation coefficients. This is due to the fact that the cross-section of Compton scattering is proportional to the Z (atomic number).[20] Therefore the coefficient is proportional to the material density ρ. At small values of X-ray energy, where the coefficient is proportional to higher powers of the atomic number Z (for photoelectric effect $\sigma f \sim Z3$), the attenuation coefficient μ is not a constant.

(Nuclear Power, “Shutdown Margin" SDM, 2018)

And the relationship between and m is given by the following equation [21]

$$\mu = m \times \rho \qquad (1)$$

The total mass attenuation coefficient, $()_{\text{compound or mixture}}$ for any chemical compound or mixture of elements is given by mixture rule [20]

$$(\mu/\rho)_{compound} = \Sigma_i (\mu/\rho)_i w_i \qquad (2)$$

where wi and () i are the weight fraction and mass attenuation coefficient of the ith constituent element, respectively. For a chemical compound, the fraction by weight (wi) is given by,

$$w_i = \frac{n_i A_i}{\sum_j n_j A_j} \qquad (3)$$

where A_i is the atomic weight of the ith element and n_i is the number of formula units and $iw_i=1$.

The total linear attenuation coefficient, compound or mixture of the compound or mixture can then be simply found by multiplying the total mass attenuation coefficient, $()_{compound}$ with its density,

ρ. Thus,

$$\mu_{compound} = \left(\frac{\mu}{\rho}\right)_{compound} \times \rho \qquad (4)$$

Stopping Power

The Stopping power and energy dissipation of charged particles through matter has been a subject of great interest for 100 years [23,24,25] because of its wide areas of application, such as ion implantation, fundamental particle physics, nuclear physics, radiation damage, radiology [24,25]. Heavy charged particles traversing matter lose energy primarily through the ionization and excitation of atoms [26]. The stopping power is defined as the mean energy loss per unit path length -dE/dx. It depends on the charge and velocity of the projectile and, of course, the target material [27,28]. Early investigations of the energy loss of charged particles traversing matter arrive at a general stopping power formula [28].

If an ion beam penetrates through matter, it loses energy due to collisions with electrons (electronic stopping) and target nuclei (nuclear stopping) [29]. The total stopping power is then just the sum of the stopping powers due to electronic and nuclear interactions [30,31]. At low energies the total energy loss is usually described in terms of electronic stopping power [32]. The nuclear component of the stopping power can also be ignored [29]. The possible phenomena contributing to the electronic stopping in the velocity region well below the light velocity are [31]:

1. Momentum Exchange in a Collision between the Ion and a Free Electron in the Target Material.
2. Ionization of the Ion.
3. The Ion Captures an Electron.
4. Excitation of the Ion.
5. Excitation of a Target Atom
6. Ionization of a Target Atom.
7. Collective Effects Such as the Polarization or the Plasmon Excitation

Stopping power of a medium can be defined as the average unit of energy loss suffered by the charge particles per unit path length in the medium under consideration. [33,34,35,36].

Stopping power consists of two components: collisions and radiative. The first is the most important for α- particles, resulting from the collision interaction between the incident particles and atomic electrons. Mass collision stopping power is widely used to reduce the dependence on the medium density (ρ) [35]. The total stopping power can be obtained from SRIM-2003 program [34], which calculates the stopping power and range of ions (10eV- 2GeV/amu) in matter using a quantum

mechanical treatment of ion-atom collision (the manual of SRIM refers to the moving atom as an "ion", and all target atoms as "atom"). A full description of the calculation was given by Ziegler and Biersack [34]. Stopping power of a medium can be defined as the average unit of energy loss suffered by the charge particles per unit path length in the medium under consideration. [35]

The energy loss in matter has been calculated by many physicists, but the basic, classic derivation was due to Bloch who improved a calculation by Bethe; hence the Bethe-Bloch Formula.

The rate of energy loss is given by (– dE/dx); dE/dx being a loss of energy, is a negative quantity. The calculation of dE /dx is done in such a way as to determine the energy deposited in the medium (positive) – hence the explicit negative sign for the loss of energy of the particle.

The derivation of the formula is quite long, but we can guess that there are various forms of the formula, which are essentially the same – it just depends on the way particular authors have wanted to parametrize the quantities appearing in the formula. You will not be expected to remember the exact expression. You should also note that "x", distance, is not always expressed in meters but often in units of mass per metre2, square meter. This latter parameter comes from multiplying the length parameter by the density of the material. This is a more convenient and useful unit of material thickness as far as experimentalists are concerned. The full expression for the Bethe-Bloch formula can be written as:

$$-\frac{dE}{dx} = \left(\frac{e^2}{4\pi\varepsilon_o}\right)^2 \frac{4\pi N_A Z_\rho}{mc^2\beta^2 A}\left[\ln\left(\frac{2mc^2\beta^2}{I}\right) - \ln(1-\beta^2) - \beta^2\right] \qquad (5)$$

The quantity -dE/dx is known as the stopping power and is denoted as S.

The range is simply defined as the distance a particle moves in a medium before all its energy is lost. This can be determined from the stopping power provided we know the the form of S from zero energy up to the initial energy of the particles in the incident beam.

Used Materials

Polyvinyl alcohol

Polyvinyl alcohol (PVA) C2H4O is a linear synthetic polymer produced via partial or full hydrolysis of polyvinyl acetate to remove the acetate groups. The amount of hydroxylation determines the physical characteristics, chemical properties, and mechanical properties of the PVA. [37] The resulting PVA polymer is highly soluble in water but resistant to most organic solvents. The higher the degree of hydroxylation and polymerization of the PVA, the lower the solubility in water and the more difficult it is to crystallize. [38] Due to its water solubility, PVA needs to be crosslinked to form hydrogels for use in several applications. The crosslinks, either physical or chemical, provide the structural stability the hydrogel needs after it swells in the presence of water or biological fluids. [39]

PVA is a polymer with excellent properties such as water solubility, biodegradability, non-toxicity, and non-carcinogenicity. It can be used to make hydrogels using chemical or physical processes, and its chemical formula is (PVA has sufficient tensile strength and sufficient flexibility. PVA is generally plasticized with a variety of materials Low-molecular chemicals containing mostly polar groups increase deformability [40]. Which form hydrogen bonds with the hydroxyl groups of the PVA chain (with or without water assistance), which reduces direct hydrogen bonding between large PVA molecules [41]. [Since the polyvinyl-type polymer containing a carbon-carbon main chain is rarely For biodegradation, one of the most important and desired properties of PVA may be its relatively high biodegradability in the environment [42].The physicochemical properties of PVA have been re-evaluated recently, and great efforts have been made in developing PVA-based

biodegradable polymeric materials with better biodegradable properties. A desirable chemical for use in applications Industrial and medical [43].

Natural Polysaccharides:

Animal Origin Polysaccharides:

Chitin is a biological polysaccharide that is the primary component of the cell sides of fungi, the rigid structure that covers the bodies of insects, many arthropods, and some animals. Chitin is a polymer composed of acetylglucosamine moieties linked by 1,4-glycose bonds. The bonding is similar to the bonding of glucosamine molecules in cells, and therefore chitin molecules are practically a cell molecule, as each glucose monomer has one hydroxyl replaced by an acetylenic group. This substitution enables the production of an additional hydrogen bond between closely related sugar chains, which strengthens the produced material. Industrially, this material is used to make surgical threads due to the softness and strength of the produced thread. It is only matched in hardness among biological materials by keratin. [44]

Plant Origin Polysaccharides:

Starch is (C6H10O5)n, which is a polymer of glucose with the chemical formula: C6H12O6. It consists of the condensation of more than 300 units of alpha-glucose, which is stored in the plant and is found in granules with a cellulose coating that does not tear apart except by boiling. When a grain of starch is present in water, by dissolving it, the water becomes turbid, but after a while the starch precipitates due to the presence of an insulating layer between the starch and the water, represented by the cellulosic vesicles. Surrounding the starch molecules, when water is boiled, the cellulose vesicles rupture, and then the starch spreads into the solution. When the amount of starch is large, the solution becomes gelatinous. For your information, starch gives a blue color with iodine. Starch is decomposed by the enzyme salivary amylase into high dextrins, which give a bronze-blue or brown color with iodine, followed by the erythrodextrins stage, which gives a red or orange-red color with iodine, followed by the acrodextrins stage, which does not give any color with iodine, and then the final stage, which is maltose.

As for nutrition, starch is a carbohydrate and is found mainly in bread, potatoes, rice, and pasta. Its caloric value is about 400 calories per 100 grams (dry). [45]

Description of the starch substance

It is a very fine powder that crumbles between the fingers when pressed. It is practically insoluble in cold water and alcohol. It is odorless and has a distinct mild taste. It has many types, including:

- Wheat starch
- Potato starch
- Corn Starch
- Rice starch.

Silica and Cement

Silica SiO2 and cement Ca2SiO4C2H4O are utilized in radiation shielding due to their excellent attenuation properties against ionizing radiation[46][47][48][49][50]. Silica-based materials, such as radiation-shielding glass, offer effective protection against gamma rays by exhibiting low percentages of transmitted photons, low half-value layers, and mean free paths due to their high density and atomic number. On the other hand, cement-based materials, like concrete, are preferred for shielding purposes due to their ability to attenuate gamma radiation and stop fast neutrons effectively. The incorporation of specific additives, like iron slag, in cement mortars enhances their radiation shielding capabilities, making them suitable for applications requiring protection from

various radiation sources. Overall, silica and cement-based shields provide cost-effective and efficient protection against ionizing radiation in diverse fields such as nuclear medicine, industry, and space technology.

Results and Discussion

In this study, the mass attenuation coefficient (μ_m) and stooping power has been calculated three mixtures at different concetrations as shown in the table below at photon energy range 0.001 MeV-100000 MeV.

Table (3-1): Sample ID, chemical formula, and concentration for the mixtures.

Sample ID	Chemical formula	Concertation
A1	C2H4O+C32H52O20N4+SiO2 (PVA+Chitin+Silica)	0.8+0.15+0.05
A2	C2H4O+C32H52O20N4+SiO2 (PVA+Chitin+Silica)	0.6+0.3+0.1
B1	C2H4O+C6H10O5+Ca2SiO4C2H4O (PVA+Starch+Cement)	0.8+0.15+0.05
B2	C2H4O+C6H10O5+Ca2SiO4C2H4O (PVA+Starch+Cement)	0.6+0.3+0.1

Total Mass Attenuation Coefficient

In this study, In the present work, the mass attenuation coefficient, μ/ρ (cm^2/g) for different chemical compound has been taken from Hubbell and Seltzer (1995) and the total mass attenuation coefficient for four mixtures Polyvinyl alcohol + Chitin + Silica (Sample A1 and A2) and Polyvinyl alcohol + Starch + cement (Sample B1 and B2) have been calculated using XCOM at the photon energy of range from 0.001 MeV to 20 MeV.

Figures (3-1 and 3-2) show the mass attenuation coefficient as a function of photon energy. It is observed that the highest mass attenuation coefficient over an approximate energy range 0.001 MeV to 0.128 MeV except at very low energy range (about 0.001 MeV to 0.0017 MeV). From this figure, it is seen that the mass attenuation coefficient for tow samples rises abruptly to a maximum value at the approximate photon energy 0.0017 MeV and then decreases with the increase in photon energy (i.e. a peak is observed at about 0.0017 MeV). The highest mass attenuation coefficient is due to its containment of high atomicnumbered elements which are more effective for gamma-ray attenuation. This can be explained by the three interactions of gamma rays with materials-photoelectric effect, pair production and Compton effect by which the incident photon dissipates its energy. Among the three interactions, photoelectric effect is favored by low energy photons and high atomic numbered absorbers and hence the ordinary concrete has the highest mass attenuation coefficient over that low energy range because photoelectric effect predominates at this range. When the incident photon energy is equal to the ionization or binding energy of an electron of the absorber atom, then the probability of ejection of that electron (i.e. photoelectric cross section) becomes the maximum. The peak is an indication of that and denotes the minimum photon energy required to eject the differently bound electrons. Thus the peak is found due to the absorption k-edge of the high Z elements that are present in mixtures.

As the photon energy increases, from Fig. (3-1 and 3-2), it is seen that mass attenuation coefficient decreases (and so as the photoelectric effect) and when the photon energy exceeds 0.125 MeV, the mass attenuation coefficient of all the shielding materials approximately possess the same value over a certain energy range. The reason is that at this intermediate energy range, Compton scattering predominates all the way and at this range, the ratio of atomic number to the atomic weight (Z/M) for all elements on which the mass attenuation coefficient depends is approximately equal to ½ except for hydrogen and the heavy elements (John et al., 1967). This means that at those energies where Compton scattering is the dominant process, values of mass attenuation coefficient tend to be roughly the same for all elements and almost all materials have, on a mass basis, about the same gamma ray attenuation properties. When the photon energy exceeds 1.02 MeV, the pair production

starts to be dominant for all thesamples and increases with the increase of photon energy which is also responsible for the increase in mass attenuation coefficient. For the reasons discussed above, from Figure (3-1 and 3-2) , it isclear that all the present sample mixtures possess approximately the same mass attenuation coefficient over an approximate photon energy range 0.127 MeVe 100000 MeV.

From Figure (3-1 and 3-2) is seen that at very low photon energy range, photoelectric absorption predominates over both the coherent and incoherent (Compton Effect) scattering for a certain energy range and after that, Compton effect becomes the dominating interaction till the ending value (100000 MeV) of the range. From this figure, it is also noticed that pair production begins at 1.1 MeV.

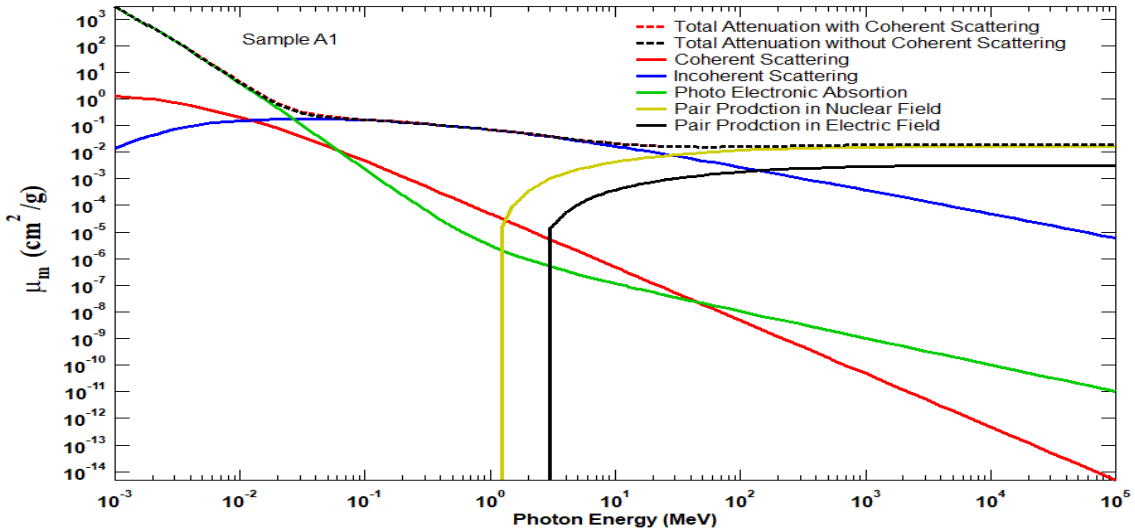

Fig. 3-1: Mass attenuation coefficient, μ_m (cm^2/g) versus incident photon energy of sample A1 for total and partial interactions.

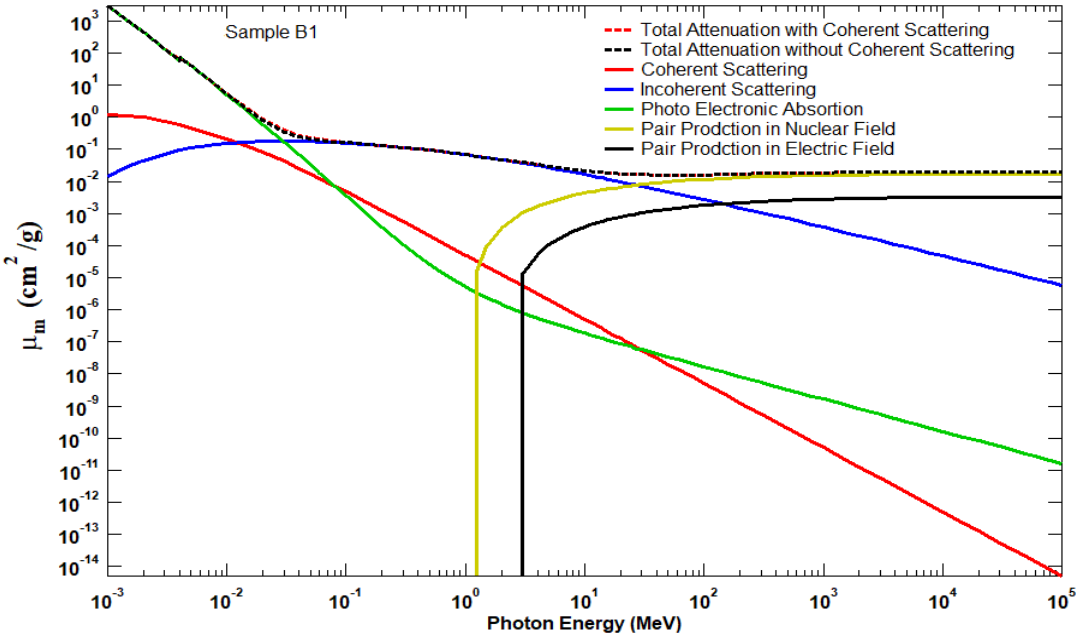

Fig. 3-2: Mass attenuation coefficient, μ_m (cm^2/g) versusincident photon energy of sample B1 for total and partialinteractions.

Figures 3-3 and 3-4 show the mass attenuation coefficient for various mixtures at different concentrations. From these figures, it is observed that the mass attenuation coefficient of samples A1 and B1 is slightly less than that of samples A2 and B2. This difference can be explained by the higher concentrations of Chitin, Silica, Starch, and Cement in samples A2 and B2.

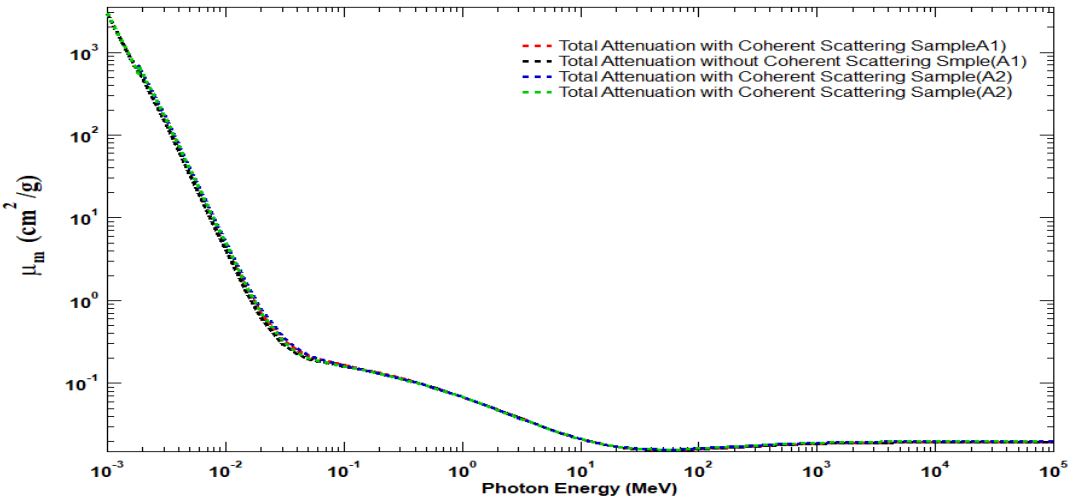

Fig. 3-3: Mass attenuation coefficient, μ_m (cm^2/g) versusincident photon energy of samples A1 and A2 for total interactions.

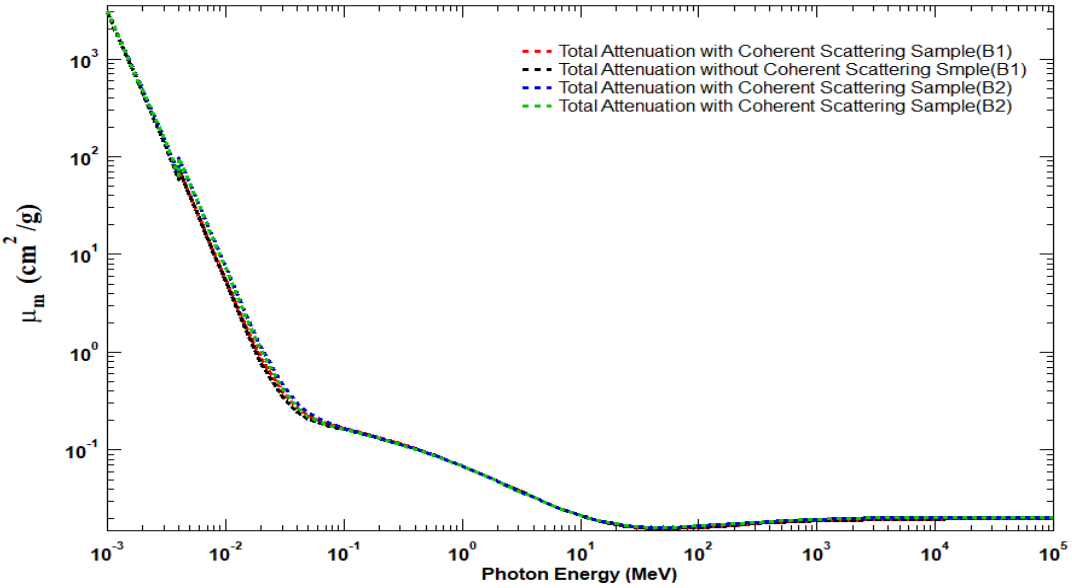

Fig. 3-4: Mass attenuation coefficient, μ_m (cm^2/g) versusincident photon energy of samples B1 and B2 for total interactions.

Stopping Power

The ESTAR used to calculate the stopping power for the two mixtures as shown in figures (3-5 and 3-6). The two figures showing the following:

1. The rate of stopping power is proportional to the square of the atomic number.
2. The total stopping power rate (dE / ρdX) increases rapidly at low energies to the maximum value and gradually decreases with increasing power.
3. Due to the specific energy dependence of the energy loss (or stopping power curve), high-energy particles lose a small amount of energy, dE/dx. However, the energy loss doubles when

the particles slow down at the peak of the energy loss curve. For high initial energies, the coefficients are large, translating into maximum energy loss in the smallest thickness, which gradually decreases with the decreasing coefficient absorption towards lower energies.

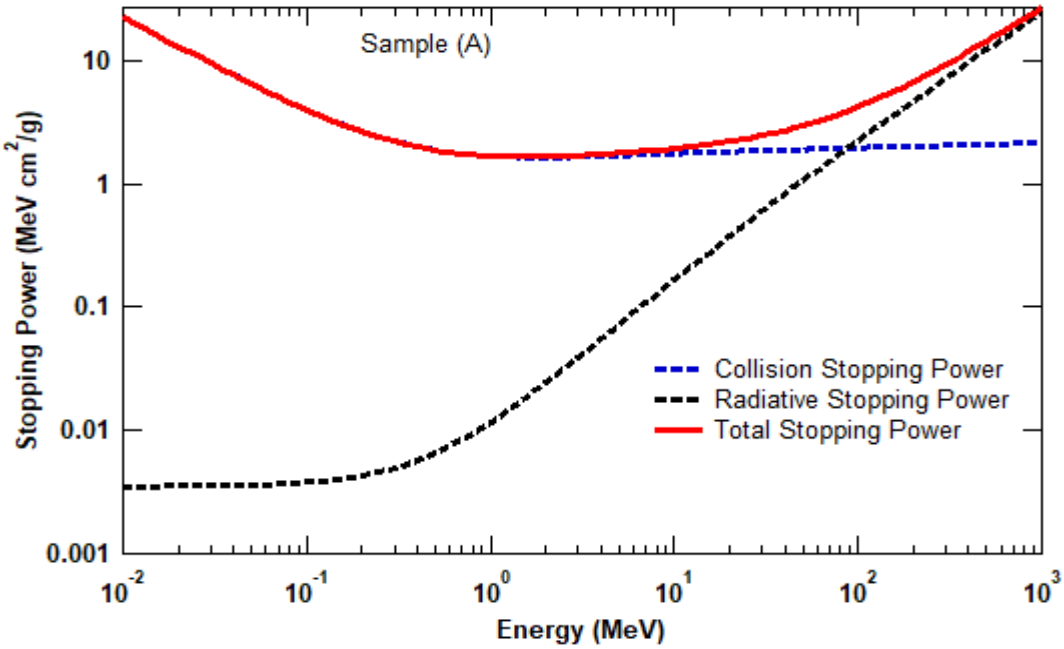

Figure 3-5: The stopping power as a function of electron energy for sample A1.

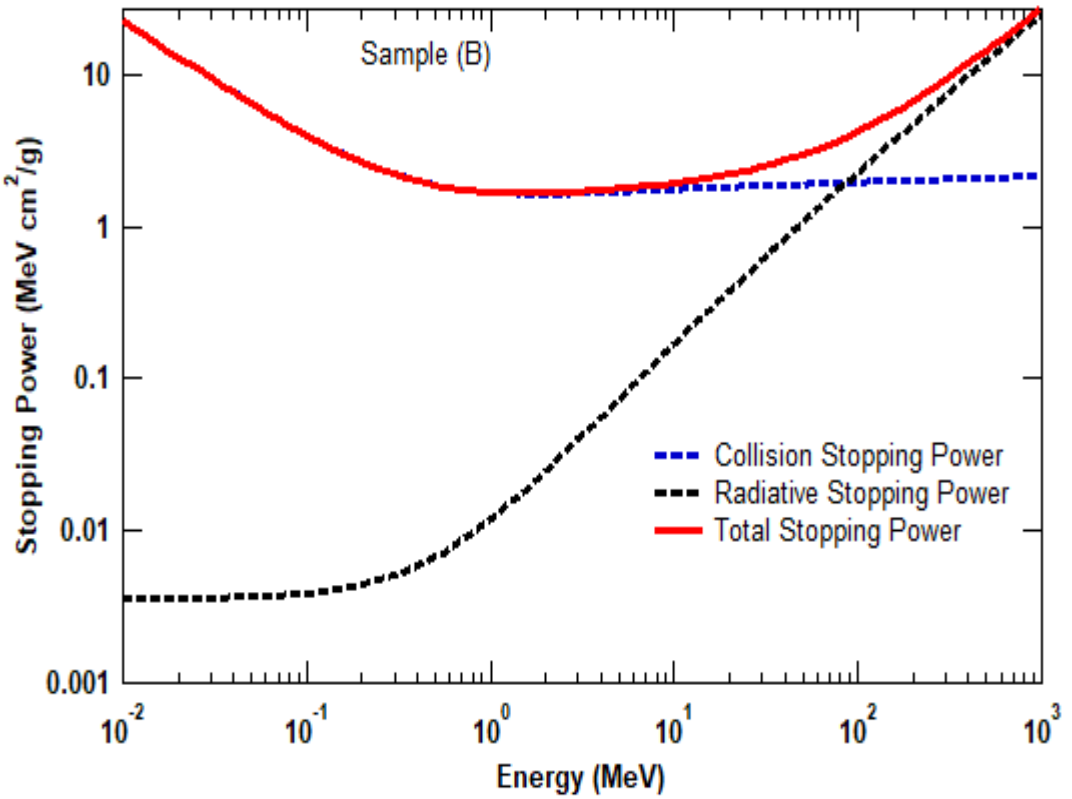

Figure 3-6: The stopping power as a function of electron energy for sample B.

Conclusion

The present study concludes that the shielding effectiveness of any shielding mixtures depends on the types of chemical composition and the concentration of the elements that it contains. To design and select an appropriate shielding material, all the nuclear parameters associated with it should be studied thoroughly. In the current research, the gamma ray attenuation parameters have been studied for different mixtures and constrains, and it has been found that this mixtures possesse medial gamma-ray attenuation characteristics among the sample mixturess over a certain photon energy range (0.127 MeV 100000 MeV) and at this energy range, it can be used as a biological shielding against gamma rays considering the cost, local availability and ease of fabrication.

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