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GAMMA-RAYS ABSORPTION STUDIES OF PIPERIDINE ALKALOIDS

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Abstract: In this study, radiation shielding of different materials such as piperidine alkaloids Pseudopelletierine (GS1) Pelletierine (GS2) Ricinine (GS3) Methylisopelletierine (GS4) Coniine (GS5) Piperine (GS6) , is analyzed by calculating Mass attenuation coefficients and partial photon interactions theoretically at incident photon energy 1 keV to 100 GeV using XCOM software [1]. The values of these parameters have been found to change significantly with incident photon energy and composition of the piperidine alkaloids. Half value layer (HVL) and tenth value layer (TVL) has also been calculated; whose lower value reveals the good shielding ability for gamma rays. Hence it is concluded that GS6 shows the maximum shielding effectiveness and also GS1 and GS4 seem to have good radiation shielding. It is also analyzed that our calculated mass attenuation coefficient of NBS concrete by the present method are in excellent agreement with standard values given by ANSI/ANS-6.4.3 data.

Index Terms **- Piperidine alkaloids, Half value layer, Mass attenuation coefficients, and Tenth value layer.**

I. INTRODUCTION

Radiation protection is necessary, because radiation is all around us, in the air, the water, the food we eat. It causes us to feel unwell, and it can contribute to the eventual onset of disease. That's why we need effective ways of protecting ourselves from this bombardment. And nature has provided a ready-made solution.

Throughout history and even in modern times, the fruits of Piper nigrum (black pepper) have found extensive utilization both as a common kitchen spice and in diverse traditional medicinal practices. The significant therapeutic characteristics of P. nigrum fruits are largely attributed to the presence of piperine, a piperidine alkaloid, which constitutes approximately 2–7.4% of the fruit's composition.

The concentration of piperine in plants of the Piperaceae family may be influenced by the climatic conditions or the geographical location of their growth. Black peppercorns, which are the desiccated whole berries of the pepper vine, are the preferred form for traditional trading. Piperine serves as the primary alkaloid accountable for the spiciness, while the volatile (essential) oil contributes to the aroma and taste. Pharmacological and clinical investigations have demonstrated that piperine exhibits central nervous system depressant, antipyretic, analgesic, anti-inflammatory, antioxidant , and hepatoprotective properties. Notably, piperine is recognized as a bioenhancer. When referring to piperine as a bioenhancer, it is typically in relation to the bioavailability of other compounds that are ingested, such as nutrients and phytochemicals. Specifically, piperine has demonstrated the ability to augment the bioavailability of substances such as curcumin, resveratrol, and catechins. These are all examples of specific compounds found in certain foods or supplements, and piperine's ability to increase their bioavailability can potentially lead to greater health benefits. Studies have indicated that piperine can elevate the bioavailability of various drugs, with enhancements ranging from 30 to 200% . Piperine is a promising component in terms of its use in medicine for various purposes such as treating lymphedema , inhibiting the spread of prostate cancer and breast cancer , as well as many health benefits of piperine, especially against chronic diseases . Therefore, it is important that during the processing of food products, which are consumed by the general population, the piperine content does not decrease and its quality

and safety are maintained due to its importance to the human health [2]. pelletrierine , The root bark of the pomegranate tree contains pelletrierine , it is a colorless liquid and boil at 1060 at 21 mm pressure. In nature it is present in the form of racemic compound and hence optically in active. It is soluble in water, alcohol and ether. It has been used in the treatment of tapeworm infections.Pseudopelletierine is of special interest, since the first synthesis of cyclo-octatetraene (COT) began with this natural product. It is related to atropine and hence its constitution is established exactly in the same manner as that of atropine, viz. oxidation, twice exhaustive methylatioatalytic and finally catalytic reduction to give suberic acid. Ricinine constitutes one of the rare natural products containing a cyanide group. It is found to be present in castor-oil-seeds. It is optically in active, less toxic than other alkaloids and a weak base. Piperine is kernel of the ripe white pepper and in the unripe black pepper. PE has been used as a flavouring additive in brandy and as an insecticide for Houseflies. It is much less toxic than most of the other alkaloids. It is a solid, optically inactive, sparingly soluble in water, and forms salts with strong acids.it exhibits cis-trans isomerism. Coniine is the principal alkaloids of hemlock (coniium maculatum). The toxic properties of the poison hemlock were known since a very long time and its crude extracts was used by the ancient Greek as the official poison for the execution of criminal. Here Coniine gives special importance due to two reasons firstly it forms the major constituents of the hemlock alkaloids and second is coniine was the first natural compound to be synthesized mainly because of its simple constitution. It is a colorless liquid, readily soluble in organic solvents, with unpleasant odour and burning taste. Methylisopelletierine found to contain a ketonic group [3].

The mass attenuation coefficient (μ/ρ) is a measure of probability of interaction that occurs between incident photons and matter per unit mass per unit area. The knowledge of mass attenuation coefficients of X rays and gamma photons in biological, chemical and other important materials is of significant and practical interest for industrial, biological, agricultural, defence and medical applications [4]. Accurate values of photon mass attenuation coefficients are required to provide essential data in diverse fields such as nuclear diagnostics (computerized tomography), nuclear medicine, radiation protection, radiation dosimetry, gamma ray fluorescence studies, radiation physics, shielding, security screening and etc[5].

The mass attenuation coefficient values of partial photon interaction processes such as photoelectric effect, Compton scattering, pair production and total are available in the form of software package XCOM from Berger and Hubbell [6, 7] by substituting the chemical composition/weight fraction of compound/mixture, the mass attenuation coefficient of the shielding materials will be generated in the energy range 1 keV - 100 GeV [8]. Hubble are published tables of mass attenuation coefficients and the mass energy absorption coefficients for 40 elements and 45 mixtures and compounds for 1 keV to 20 MeV in 1982.Hubbell and Seltzer replaced these tables in form of tabulation for all elements having $1 \leqslant Z \leqslant 92$ and for 48 additional substances for dosimetric interest [10]. The reports on attenuation coefficients measured by researchers reported [11-22] for different energies for various samples in solid, liquid.

ANSI/ANS-6.4.3 (1991) standard has been administratively withdrawn in August 2001, but the work is in progress for updating this much used standard by a working group chartered in 2007 by the American Nuclear Society (ANS). Recently, a study has been made for the purpose of updating gamma-ray mass attenuation coefficients for high-Z engineering materials that are presented in the current ANS standard [4].This prompted us to study the mass attenuation coefficient (μ/ρ) of Piperidine Alkaloids. Recently we studied the measurement of total and partial mass attenuation coefficients of oxide glasses [11]. The research paper on mass attenuation coefficients measured by researchers reported [12-22] for different energies for various samples in solid, liquid.

In the present work, the Total and partial mass attenuation coefficient have been calculated for Piperidine Alkaloids for all photon interactions (coherent, incoherent, photoelectric, pair production and total photon interaction [with coherent]) in the energy range 1 keV - 100 GeV. The variations of Total and partial mass attenuation coefficient with energy are shown graphically for the all photon interactions.

The chemical formulae of different piperidine alkaloids are as shown in Table1

Table 1: Chemical formula of piperidine alkaloids [3]

Piperidine Alkaloids	Chemical Formula
Pseudopelletierine (GS1)	$C_9H_{15}NO$
Pelletierine (GS2)	C_8H_5ON
Ricinine (GS3)	$C_8H_8N_2O2$
Methylisopelletierine (GS4)	$C_9H_{17}NO$
Coniine (GS5)	$C_8H_{17}N$
Piperine (GS6)	$C_{17}H_{19}O_3N$

II. Interaction of Radiation with Matter

Nuclear radiations (α, β, γ-rays) have been used for a long time and serious accidents leading to confirmed and suspected deaths of persons arising from direct and indirect effects of radiations have occurred. In different applications of radiations it is observed that, over-exposure is harmful and under-exposure is ineffective. Gamma rays and ultraviolet radiations, for instance, produce electrons through the well-known mechanism of photoelectric, compton and pair production [23].

III. Theory

3.1 Calculation of Mass Attenuation Coefficient

The absorption coefficient of piperidine alkaloids is dependent on its content and gamma - ray energy. This work describes a study of content dependence on measurements of attenuation of gamma - radiation at gamma-ray energy of piperidine alkaloids.The attenuation of gamma rays expressed as:

$$I = I_o \exp(-\mu x) \quad (1)$$

Where Io is the number of particles of radiation counted during a certain time duration without any absorber, I is the number counted during the same time with a thickness x of absorber between the source of radiation and the detector, and μ is the linear absorption coefficient. This equation may be cast into the linear form,

$$\log I = \log I_o - \mu x$$

i.e. $\mu x = \log (I_o / I)$

$$\mu = (1/x) \log (I_o/I) \quad (2)$$

The mass absorption coefficient of piperidine alkaloids , μm defined as,

$$\mu_m = \mu/\rho \quad (3)$$

Where, μm is the mass attenuation coefficient and ρ is the density of piperidine alkaloids . The unit of μ is cm-1 and that of μm is cm2/gm.

3.2 Calculation of half value layer (HVL) and tenth value layer (TVL)

Half –value layer (HVL) is the thickness of the attenuator that reduces the intensity of photon beam to half of its original value (I0), i.e. (½) I0 and is given by

$$HVL = 0.693/\mu$$

also, the tenth-value layer, TVL, is defined as the thickness of the attenuator that reduces the photon beam intensity to one tenth of its original value (I0), i.e. (1/10)I0.

$$TVL = 2.303/\mu$$

The HVL and TVL are expressed in units of distance (cm).Since, the linear attenuation coefficient varies with photon energy, HVL and TVL are also energy dependent quantities.

IV. RESULT AND DISCUSSION

4.1 Mass attenuation coefficient of selected materials as a function of chemical composition and incident photon energy:-

The results of the present investigation are shown graphically in figs. 1-6, where μ is given as a function of incident photon energy in all photon interaction processes. In the present work, the effect of chemical formulae of chosen piperidine alkaloids on μ and the variations of μ with incident photon energy for all interactions are discussed in the following paragraphs.

Variation of total mass attenuation coefficients of all Piperidine Alkaloids with incident photon energy (MeV) for all types of interaction process is studied from fig. 1. Mass attenuation coefficient (μ) for the total photon interaction processes is initially high and decreases sharply with increase in incident photon energy up to 110 keV. Above 110 keV the rate of decrease of μ (total) with incident photon energy is less and above 23 MeV μ (total) increases slightly with further increase in incident photon energy. This behavior is due to dominance of different interaction processes in different incident photon energies i.e. below 110 keV photo electric process is dominant, from 110 keV to 23 MeV Compton scattering and above 23 MeV pair-production process is dominant. It is also clear in fig. 1 that the piperidine alkaloids GS6, contains a higher percentage of heavy element , has higher values of μ(total) in lower energy region and high energy region where as it is slightly lower in middle energy region as compared to other piperidine alkaloids.

The above observations of fig. 1 can also be extended to the other figures (2-6) in which the effect of chemical formulae of chosen piperidine alkaloids on μ is investigated for partial photon interactions (photo-electric effect, coherent and incoherent scattering, pair production in the electric field, and pair production in the nuclear field) for same choosing piperidine alkaloids. From fig. 2, it is observed that the value of μ (photo) decreases rapidly with increase in incident photon energy for all the selected materials. It may due to reason that photo-electric cross-section varies inversely with incident photon energy as E3.5. In the lower energy region values of μ(photo) of all the piperidine alkaloids are almost same but as the incident photon energy increases there is considerable increase in difference of values of μ(photo) of all the Piperidine Alkaloids as μ(photo) is further strongly dependent on atomic number of interacting materials as z4-5.

In figs. (3,4) it is observed that the values of μ(incoh.) firsly increases with increase in incident photon energy and after 35 Kev values of μ(incoh.) decreases where as the values of μ(coh.) decrease sharply with increase in incident photon energy for all chosen samples. This decrease in values with increase in incident photon energy may be due to the reason that μ(coh.) and μ(incoh.) is inversely proportional to incident photon energy E. The variations in the values of μ(coh.) due to chemical composition is low but it is almost same in case of incoherent scattering. From the above results it is interpreted that decreasing rate of values of μ(photo) with incident photon energy is higher than μ(incoh.) decreasing rate. And the variation in μ(photo) due to chemical composition can be seen clearly which is not significant in case of μ(incoh.). Above results clearly explain the variation of μ(total) below 4 MeV in fig. 1.

The variation of μ for pair production in electric field and nuclear fields are shown in figs 5-6 respectively. In both cases, the values of μ(pp) increases slightly with increase in incident photon energy up to 390 MeV but beyond this incident energy the values of μ(pp) remains almost constant. It may be due μ(pp) is directly proportional to logE. For pair production in the nuclear field, the values of μ(pp) of chosen samples show significant variation (fig. 6) but slight variation is observed for μ(pp) in the electric field (fig. 5). It may be due to pair production in nuclear field is Z2 dependent, whereas the Z dependence of pair production in the electric field is almost linear. In the high incident photon energy range, the variation is observed in μ(total) (fig. 1) is because of Z2 – dependence of the pair production in the nuclear field.

4.2 HVL and TVL as a function of incident photon energy

Figs. (7-8) explain the dependence of radiation shielding on HVL and TVL for all selected samples. It is concluded that values of HVL and TVL increases sharply in the energy region of 1 keV to 110 keV whereas increasing rate is comparatively lower in the energy region of 110 Kev to 23 MeV and beyond this incident photon energy the HVL and TVL values tends to remain constant. Moreover, the sample which has low value of HVL and TVL has good radiation shielding for gamma rays than other samples. Using HVL and TVL for the selected samples, it is concluded that GS6 shows the maximum radiation shielding and also GS1 and GS4 seem to have good shielding effectiveness.

4.3 Standardization of the procedure

In order to check the reliability of present method, values of mass attenuation coefficient of NBS concrete calculated using XCOM program are compared with mass attenuation coefficient of NBS concrete values given by ANSI/ANS-6.4.3 data[24] for energies ranging from 1 Kev-100 GeV. From fig. 9 it can be analyzed that our calculated mass attenuation coefficient of NBS concrete are in excellent agreement with standard data. This gives confidence in our results for the piperidine alkaloids.

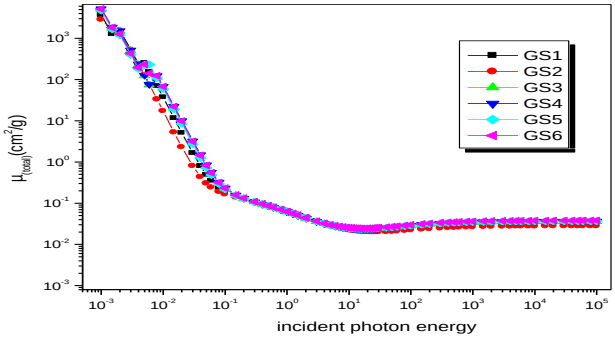

Fig.1: Variation of total mass attenuation coefficients of all piperidine alkaloids with incident photon energy (MeV) for all types of interaction process

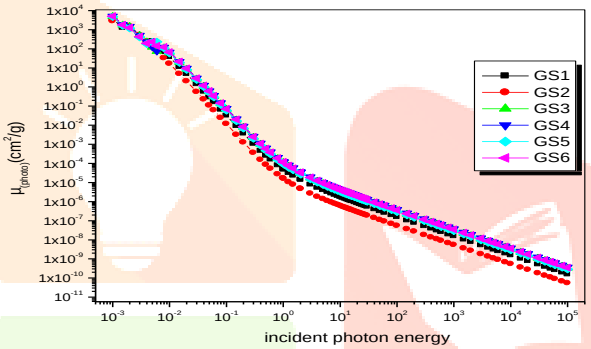

Fig.2: Variation of mass attenuation coefficients of all piperidine alkaloids with incident photon energy (MeV) for photo electric absorption.

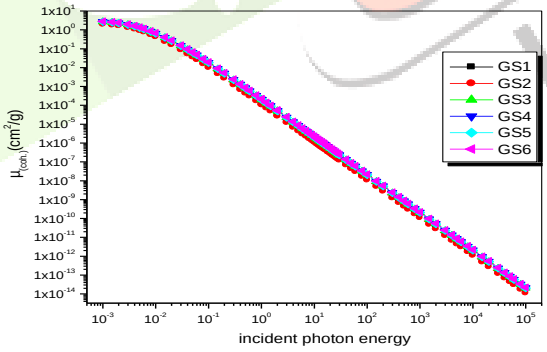

Fig.3: Variation of mass attenuation coefficients of all piperidine alkaloids with incident photon energy (MeV) for coherent scattering

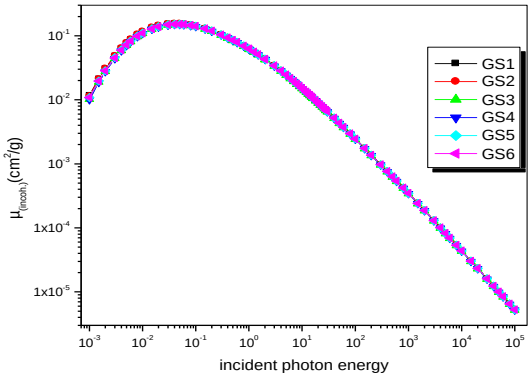

Fig.4: Variation of mass attenuation coefficients of all piperidine alkaloids with incident photon energy (MeV) for incoherent scattering.

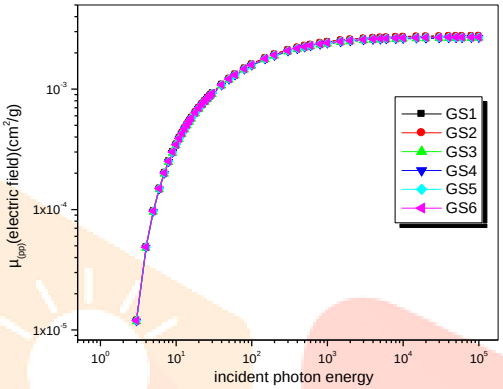

Fig.5: Variation of mass attenuation coefficients of all piperidine alkaloids with incident photon energy (MeV) for pair production in the electric field

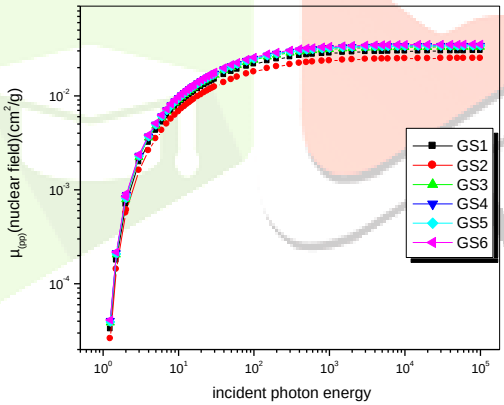

Fig.6: Variation of mass attenuation coefficients of all piperidine alkaloids with incident photon energy (MeV) for pair production in the nuclear field

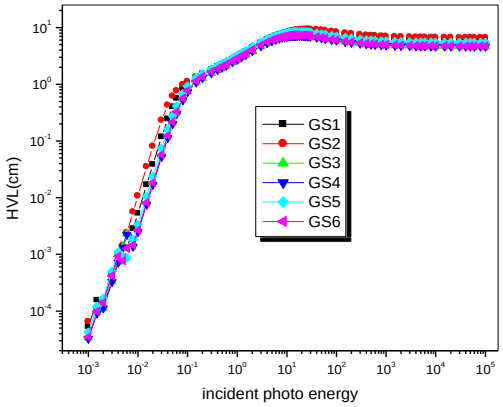

Fig: 7. Comparison of half value layer of all the samples for chosen energy range

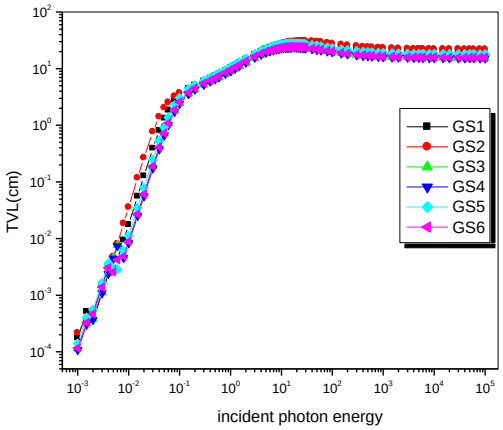

Fig: 8. Comparison of tenth value layer of all the samples for chosen energy range.

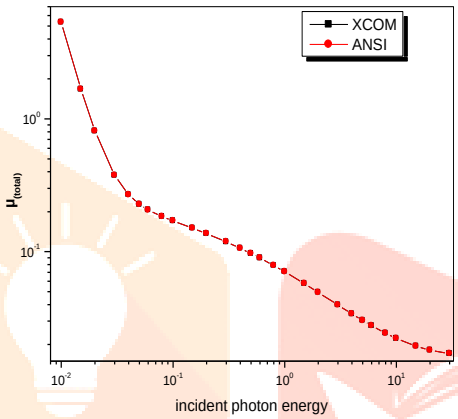

Fig. 9. Comparison between ANSI data base and present work with respect to the calculated values of mass attenuation coefficient for NBS concrete at energy range 1 Kev-100GeV.

V. CONCLUSION

Mass attenuation coefficient (μ) of chosen samples for the total photon interaction processes is high initially and decreases rapidly with increase in gamma photon energy up to 110 keV. After 110 keV the variation of μ with incident photon energy is less and above 23 MeV μ increases slightly with increase in photon energy. This behavior is due to dominance of different interaction processes in different incident photon energies i.e. below 110 keV photo electric process is dominant up to 110 keV after that Compton scattering up to 23 MeV and pair-production process is dominant above 23 MeV. Mass attenuation coefficient is helpful for detail study in shielding effectiveness of different types materials /mediums.

Piperidine alkaloids GS6, contains a higher percentage of element such as , has higher values of μ(total) in lower energy region and high energy region where as it is slightly lower in middle energy region as compared to other Piperidine Alkaloids .

Using HVL and TVL for the selected samples, it is concluded that GS6 shows the maximum radiation shielding and also GS1 and GS4 seem to have good shielding effectiveness.

VI. Acknowledgement

We are grateful to Berger and Hubbell for providing the convenient computer program XCOM with the help of National Institute of Standards and Technology (NIST), Gaithersburg. [1].

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