



Experimental and Theoretical Assessment of Gamma Ray Shielding Properties of Selected Transition Metal Salts.

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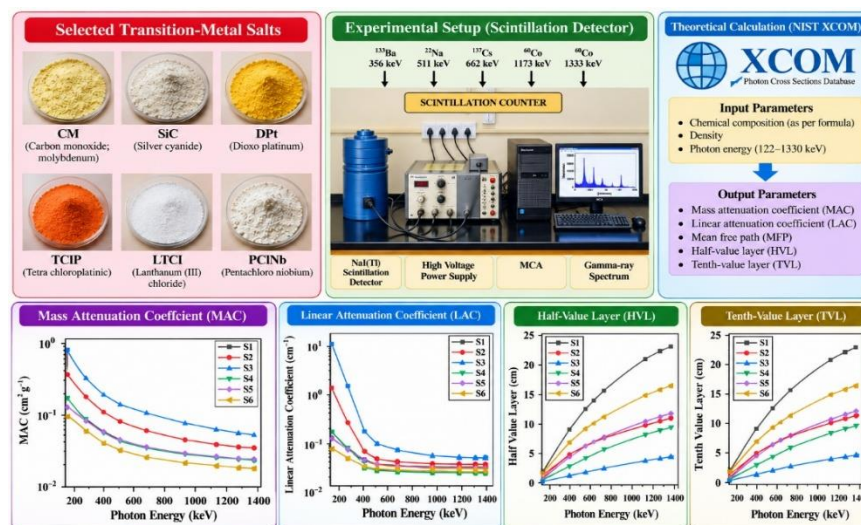
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Abstract

The present study investigates the gamma-ray attenuation and shielding characteristics of six selected transition-metal salts, designated as CM, SiC, DPt, TCIP, LTCl, and PCINb, using experimental measurements and theoretical calculations over the photon-energy range of 122–1330 keV. The experimental mass attenuation coefficients (MACs) were determined from gamma-ray transmission measurements and compared with theoretical values calculated using the NIST XCOM database. The linear attenuation coefficient (LAC), mean free path (MFP), half-value layer (HVL), and tenth-value layer (TVL) were evaluated to provide a comparative assessment of the shielding performance of the investigated materials. The results demonstrate that the MAC and LAC generally decrease with increasing photon energy, whereas the MFP, HVL, and TVL increase, indicating that greater material thickness is required to attenuate higher-energy gamma photons. Among the investigated samples, S3 exhibits the highest MAC and LAC values and the lowest MFP, HVL, and TVL values over the studied energy range, suggesting superior gamma-ray attenuation performance relative to the other samples. The theoretical and experimental MAC values show generally good agreement, although a deviation observed for S5 at 1170 keV requires further verification. The findings highlight the influence of material composition and density on photon attenuation and identify S3 as a promising candidate for further radiation-shielding investigations. Additional experimental validation and assessment of mechanical properties, cost, and practical application requirements are necessary before recommending these materials for specific radiation-protection applications.

Keywords: Gamma-ray attenuation; mass attenuation coefficient; XCOM; transition-metal salts; radiation shielding; mean free path; photon–matter interactions; theoretical and experimental analysis.



Graphical Abstract

1. Introduction

Gamma-ray attenuation in materials is an important area of research in radiation physics because of its applications in nuclear energy, medical diagnostics, radiotherapy, industrial radiography, radiation monitoring, and radiation protection. Gamma rays are highly penetrating electromagnetic radiations that interact with matter through different physical processes, primarily the photoelectric effect, Compton scattering, and electron–positron pair production [1-4]. The probability of these interactions depends on the incident photon energy, the elemental composition of the absorbing material, and its physical density [5–8]. A comprehensive understanding of these interactions is essential for evaluating the performance of materials intended for radiation-shielding applications.

The attenuation of gamma radiation is commonly described by the exponential attenuation law, which relates the transmitted photon intensity to the thickness of the absorbing material and its linear attenuation coefficient. The mass attenuation coefficient (MAC) is particularly important because it expresses the attenuation capacity per unit mass thickness and allows comparisons between materials of different densities. Other important shielding parameters include the linear attenuation coefficient (LAC), half-value layer (HVL), tenth-value layer (TVL), and mean free path (MFP). The HVL and TVL represent the thicknesses required to reduce the initial photon intensity to one-half and one-tenth, respectively, whereas the MFP describes the average distance a photon travels before an interaction. These parameters provide complementary information for evaluating the attenuation efficiency and practical shielding requirements of different materials [9-10].

The dominant photon-interaction mechanism varies with incident energy and absorber composition. At relatively low photon energies, the photoelectric effect generally contributes substantially to attenuation, particularly in materials containing elements with higher atomic numbers. At intermediate energies, Compton scattering becomes increasingly important, while pair production becomes energetically possible above 1.022 MeV. The relative contributions of these processes determine the energy dependence of the MAC and related shielding parameters [11-13]. Therefore, evaluating attenuation over a broad energy range is necessary to establish the suitability of a material for different radiation environments. The energy range considered in the present study, 122–1330 keV, covers photon energies relevant to investigating the changing contributions of the principal gamma-ray interaction mechanisms.

Reliable determination of photon attenuation parameters can be achieved through experimental measurements and theoretical calculations. The XCOM photon cross-section database, developed by Berger and Hubbell and subsequently expanded by Berger et al., provides photon interaction cross sections and mass attenuation coefficients for elements, compounds, and mixtures over a wide energy range. The database enables theoretical estimates based on elemental composition and mass fractions. Comparing experimentally measured MAC values with XCOM-derived values is useful for assessing experimental reliability and identifying possible differences arising from

material composition, density, measurement geometry, and experimental uncertainty. Earlier investigations of photon cross sections and attenuation coefficients have established an important foundation for the systematic evaluation of radiation-shielding materials [14-17].

Conventional shielding materials, particularly lead, are widely used because of their high density and effective attenuation of penetrating radiation. However, their toxicity, weight, handling requirements, and environmental considerations have encouraged research into alternative materials with suitable shielding performance [18-19]. Lead-free composites, metallic alloys, ferrites, and other transition-metal-containing materials have consequently attracted attention for their potential applications in radiation protection. Their performance depends on several factors, including elemental composition, density, photon energy, and the physical characteristics of the prepared material. Reviews of conventional and emerging shielding materials emphasize the importance of balancing attenuation efficiency with practical considerations such as material safety, cost, durability, and ease of fabrication [20-21].

Previous studies have investigated the gamma-ray shielding properties of metallic alloys, ferrite nanoparticles, and other compound materials using experimental measurements and theoretical approaches [22]. In particular, ferrite-based materials have been examined for their energy-dependent attenuation behaviour, demonstrating the importance of elemental composition and material density in determining shielding performance [23]. Investigations of metallic alloys have also contributed to the development of alternative shielding materials for applications requiring specific combinations of physical and radiation-interaction properties [24-25]. Despite these developments, the shielding performance of individual materials must be evaluated under comparable irradiation conditions to establish meaningful relationships between composition, photon energy, and attenuation behaviour. In the present investigation, six selected materials, designated as CM, SiC, DPt, TCIP, LTCl, and PCINb, are examined to evaluate their gamma-ray attenuation characteristics through an integrated experimental and theoretical approach. The experimental mass attenuation coefficients are determined over the photon-energy range of 122–1330 keV and compared with corresponding theoretical values calculated using the XCOM database. The variation of MAC with photon energy and the corresponding changes in mean free path are analysed to compare the attenuation behaviour of the investigated samples. The novelty of this study lies in the systematic comparative evaluation of all six selected materials within a common experimental and theoretical framework, providing a consistent basis for assessing their relative gamma-ray attenuation performance. The comparison between experimental and theoretical results further supports the assessment of measurement reliability and the applicability of XCOM calculations to the investigated materials. The findings are expected to provide useful information for identifying promising candidates for further radiation-shielding investigations. Their practical suitability will depend on the measured attenuation performance, material density, mechanical stability, cost, and application-specific requirements.

2. Materials and Methods:

2.1. Investigated materials

Six selected materials containing transition metals or other heavy elements were considered for the investigation of gamma-ray attenuation and radiation-shielding characteristics. The materials were designated as CM, SiC, DPt, TCIP, LTCl, and PCINb, according to the abbreviations supplied in the original dataset. Their reported chemical formulae, densities, and molar masses are summarized in Table 1. These parameters are important for evaluating the energy-dependent photon attenuation behaviour and for calculating the theoretical mass attenuation coefficients using the XCOM photon cross-section database [1,2].

The chemical composition of an absorber plays a significant role in its interaction with gamma radiation. The elemental mass fractions determine the theoretical mass attenuation coefficient, while the material density is required to obtain the linear attenuation coefficient and related shielding parameters. The theoretical mass attenuation coefficient of a compound or mixture can be estimated using the elemental mixture rule [1,2]:

$$\left(\frac{\mu}{\rho}\right)_{\text{mix}} = \sum_i w_i \left(\frac{\mu}{\rho}\right)_i \dots\dots\dots 1$$

where $(\mu/\rho)_{\text{mix}}$ is the mass attenuation coefficient of the compound, w_i represents the mass fraction of the i^{th} constituent element, and $(\mu/\rho)_i$ is the corresponding elemental mass attenuation coefficient at a specified photon energy.

Table 1. Physical and chemical parameters of the investigated materials.

Sample Code	Material name as supplied	Chemical formula	Density (g cm ⁻³)	Molar mass (g mol ⁻¹)
S1	Carbon monoxide; molybdenum	C ₆ MoO ₆	1.960	264.02
S2	Silver cyanide	AgCN	3.943	133.8856
S3	Dioxo platinum	PtO ₂	10.200	227.08
S4	Tetra chloroplatinic	PtCl ₄	4.303	336.90
S5	Lanthanum (III) chloride	LaCl ₃	3.840	245.26
S6	Pentachloro niobium	NbCl ₅	2.750	270.17

2.2. Theoretical and Experimental Evaluation of Gamma-Ray Attenuation

The theoretical mass attenuation coefficients of the investigated materials were evaluated using the XCOM photon cross-section database developed by the National Institute of Standards and Technology [26]. The calculations were performed over the photon-energy range of 122–1330 keV, corresponding to the energy interval considered in the experimental investigation. The XCOM database provides photon interaction coefficients for individual elements, compounds, and mixtures and is widely used in radiation-attenuation calculations [27].

The calculated MAC values were used to evaluate the linear attenuation coefficient, mean free path, half-value layer, and tenth-value layer, wherever the required parameters were available. The linear attenuation coefficient was obtained from the mass attenuation coefficient and material density using

$$\mu = \rho \left(\frac{\mu}{\rho}\right) \dots\dots\dots 2$$

where μ is the linear attenuation coefficient (cm⁻¹), ρ is the material density (g cm⁻³), and μ/ρ is the mass attenuation coefficient (cm²g⁻¹).

The mean free path was calculated as

$$\text{MFP} = \frac{1}{\mu} \dots\dots\dots 3$$

while the half-value layer and tenth-value layer were determined using

$$\text{HVL} = \frac{\ln 2}{\mu} \dots\dots\dots 4$$

$$\text{TVL} = \frac{\ln 10}{\mu} \dots\dots\dots 5$$

These parameters were used to compare the relative gamma-ray attenuation characteristics of the selected materials at different photon energies [28-30]

The experimental mass attenuation coefficient was calculated from the measured incident and transmitted gamma-ray intensities using the Beer–Lambert attenuation law. The experimental setup and measurement procedure were kept identical for all investigated materials to ensure consistency and enable a reliable comparison of their gamma-ray attenuation characteristics.

The mass attenuation coefficients (MACs) of the prepared transition metal salt samples were experimentally determined using a NaI (Tl) scintillation detector manufactured by Nucleonix Systems Pvt. Ltd., Hyderabad, India. Gamma-ray photons with energies of 356 keV from ¹³³Ba, 511 keV from ²²Na, 662 keV from ¹³⁷Cs, and 1173

and 1333 keV from ^{60}Co were used for the measurements. These selected photon energies enabled the investigation and comparison of the gamma-ray attenuation characteristics of the prepared transition metal salts across a broad energy range [31-32].



Fig. 1. NaI (Tl) scintillation detector.

2.3. Theoretical Evaluation Using NIST XCOM

The theoretical mass attenuation coefficients (MACs) of the investigated transition metal salts were calculated using the NIST XCOM photon cross-section database. The elemental composition of each salt was specified according to its chemical formula, and the calculations were performed at photon energies corresponding to those used in the experimental measurements, namely 122, 356, 511, 662, 1173, and 1333 keV. XCOM provides photon interaction cross sections and mass attenuation coefficients for elements, compounds, and mixtures over a wide range of photon energies [33].

The total mass attenuation coefficient was obtained from the XCOM output by considering the relevant photon interaction processes, including coherent scattering, incoherent scattering, photoelectric absorption, and pair production wherever applicable. The theoretical linear attenuation coefficient (LAC) was subsequently calculated using the following expression:

$$\mu = \left(\frac{\mu}{\rho}\right) \rho \dots\dots\dots 6$$

where μ represents the linear attenuation coefficient (cm^{-1}), μ/ρ denotes the mass attenuation coefficient obtained from XCOM ($\text{cm}^2 \text{g}^{-1}$), and ρ is the density of the corresponding transition metal salt (g cm^{-3}). The consistency of this calculation depends on using the appropriate density and chemical composition for each investigated sample [34]

3. Results and Discussion

3.1 Linear Attenuation Coefficient (LAC)

The linear attenuation coefficient (LAC) is an important parameter for evaluating the gamma-ray shielding performance of materials. It describes the reduction in the intensity of a gamma-ray beam as it passes through an absorbing medium.

Table 2. Linear Attenuation Coefficient (LAC)

Energy	S1	S2	S3	S4	S5	S6
122	1.0859	2.9391	29.2578	11.3711	4.3786	1.4035
356	0.2202	0.4813	2.5309	1.0124	0.5403	0.3028
511	0.1705	0.3573	1.4304	0.5821	0.3693	0.2368
662	0.1464	0.3016	1.0385	0.4274	0.2999	0.2041
1170	0.1071	0.2166	0.6114	0.2560	0.2064	0.1499
1280	0.1025	0.2071	0.5760	0.2415	0.1969	0.1435
1330	0.1015	0.2051	0.5689	0.2386	0.1949	0.1422

The attenuation behaviour depends on photon energy, elemental composition, material density, and the probabilities of photon interactions within the absorber. Materials with higher LAC values generally provide greater attenuation per unit thickness and may therefore be more effective for gamma-ray shielding applications [35].

The LAC values of the six selected transition-metal salts (S1–S6) were evaluated over the photon energy range of 122–1330 keV, as presented in Table 1. The results indicate a decreasing trend in the LAC with increasing photon energy for all six samples. This behaviour can be attributed to the energy dependence of the principal photon interaction mechanisms, namely the photoelectric effect, Compton scattering, and pair production, which becomes energetically possible above 1.022 MeV [36]. At lower photon energies, photoelectric absorption can contribute significantly to attenuation, particularly in materials containing high-atomic-number elements. At intermediate energies, Compton scattering generally becomes increasingly important, while pair production may contribute at higher energies depending on the elemental composition of the material [37].

Among the investigated samples, S3 exhibits the highest LAC at every measured photon energy, decreasing from 29.2578 at 122 keV to 0.5689 at 1330 keV. In contrast, S1 exhibits the lowest LAC throughout the investigated energy range, decreasing from 1.0859 to 0.1015 over the same energy interval. The comparatively high LAC values of S3 suggest better gamma-ray attenuation per unit thickness than the other samples, provided that the reported values and units are correct. Similar experimental and theoretical investigations of metallic alloys and other shielding materials have demonstrated the importance of composition and photon energy in determining attenuation performance [38].

Overall, the results indicate that S3 has the greatest potential for gamma-ray shielding among the six samples based on the reported LAC values. However, a comprehensive assessment should also consider material density, mass attenuation coefficient, half-value layer (HVL), and practical thickness requirements before identifying the most suitable shielding material.

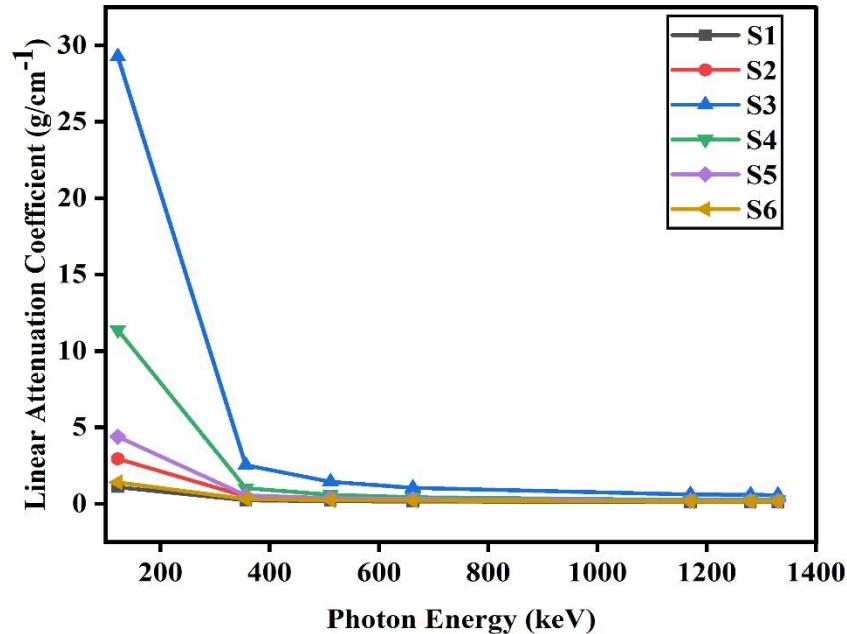


Figure 3. Linear attenuation coefficient (LAC) of the selected Transition-Metal Salts

3.2 Mass Attenuation Coefficients:

Figure 4. illustrates the variation in the theoretical and experimental mass attenuation coefficients (MACs) of the six selected transition-metal salts (S1–S6) as a function of photon energy over the range of 122–1330 keV. The theoretical values are represented by black square markers, whereas the experimental values are indicated by red circular markers. The close overlap of the two curves for most samples demonstrates generally good agreement between the calculated and measured MAC values. Comparisons between measured and calculated attenuation parameters are widely used to assess the reliability of theoretical predictions and the suitability of materials for radiation shielding [39].

Table 3. Theoretical and experimental mass attenuation coefficients of the selected transition-metal salts

Energy (keV)	S1 (Theor.)	S1 (Expt.)	S2 (Theor.)	S2 (Expt.)	S3 (Theor.)	S3 (Expt.)	S4 (Theor.)	S4 (Expt.)	S5 (Theor.)	S5 (Expt.)	S6 (Theor.)	S6 (Expt.)
122	0.5540	0.5502	0.7454	0.7421	2.8684	2.8645	2.6426	2.6402	1.1403	1.1382	0.5104	0.5085
356	0.1124	0.1095	0.1221	0.1198	0.2481	0.2454	0.2353	0.2331	0.1407	0.1378	0.1101	0.1076
511	0.0870	0.0848	0.0906	0.0879	0.1402	0.1376	0.1353	0.1336	0.0962	0.0931	0.0861	0.0828
662	0.0747	0.0711	0.0765	0.0741	0.1018	0.0990	0.0993	0.0973	0.0781	0.0728	0.0742	0.0716
1170	0.0547	0.0518	0.0549	0.0522	0.0599	0.0563	0.0595	0.0569	0.0538	0.0718	0.0545	0.0525
1280	0.0523	0.0492	0.0525	0.0499	0.0565	0.0540	0.0561	0.0548	0.0513	0.0502	0.0522	0.0506
1330	0.0518	0.0482	0.0520	0.0489	0.0558	0.0531	0.0554	0.0522	0.0508	0.0473	0.0517	0.0501

As shown in Table 3, the theoretical and experimental MAC values generally decrease with increasing photon energy for all six samples. The decrease is particularly pronounced between 122 and 356 keV, after which the MAC values decline more gradually. This behaviour is consistent with the changing probabilities of photon interactions as energy increases. Similar energy-dependent trends have been reported in experimental and theoretical investigations of transition-element compounds, spinel ferrites, and particle-reinforced shielding composites [40].

At 122 keV, S3 exhibits the highest theoretical MAC of $2.8684 \text{ cm}^2 \text{ g}^{-1}$, closely followed by S4 at $2.6426 \text{ cm}^2 \text{ g}^{-1}$. Their experimental values are 2.8645 and $2.6402 \text{ cm}^2 \text{ g}^{-1}$, respectively. In contrast, S6 exhibits the lowest theoretical MAC at this energy, with a value of $0.5104 \text{ cm}^2 \text{ g}^{-1}$. These results suggest that S3 and S4 have comparatively stronger mass-normalized attenuation at lower photon energy than the other investigated samples.

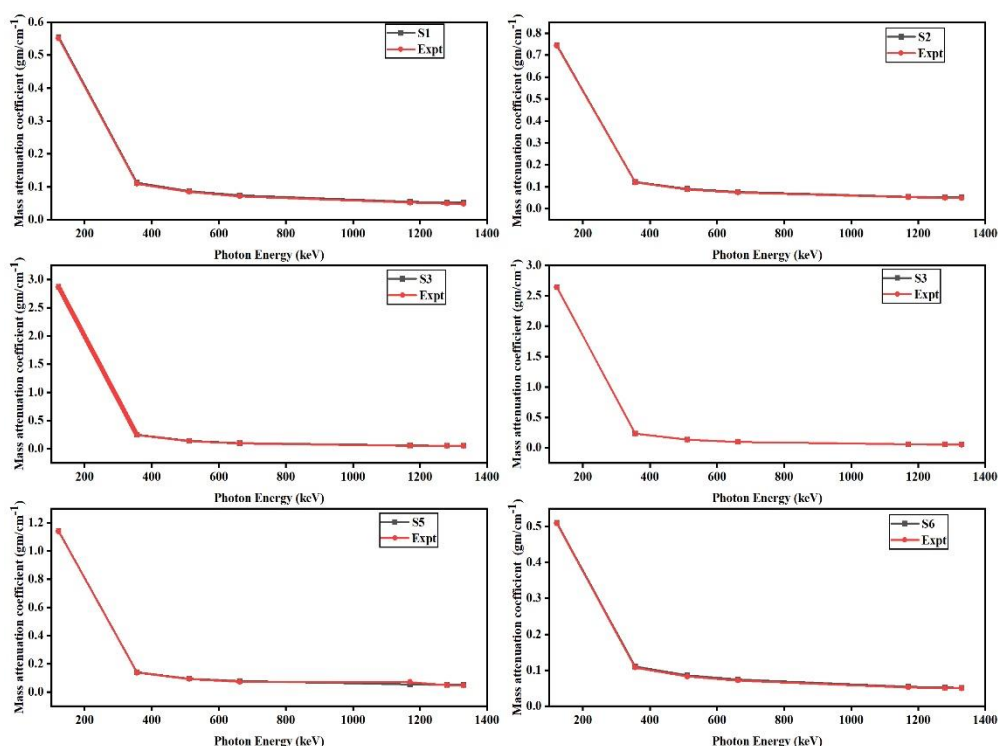


Figure 4. Experimental and Theoretical mass attenuation coefficient (MAC) of the selected Transition-Metal Salts.

At 1330 keV, S3 retains the highest theoretical MAC ($0.0558 \text{ cm}^2 \text{ g}^{-1}$), followed by S4 ($0.0554 \text{ cm}^2 \text{ g}^{-1}$), S2 ($0.0520 \text{ cm}^2 \text{ g}^{-1}$), S1 ($0.0518 \text{ cm}^2 \text{ g}^{-1}$), S6 ($0.0517 \text{ cm}^2 \text{ g}^{-1}$), and S5 ($0.0508 \text{ cm}^2 \text{ g}^{-1}$). The differences between the samples are considerably smaller at this energy than at 122 keV. This indicates that the relative influence of chemical composition on MAC varies with photon energy. The behaviour is consistent with published studies of ferrites and transition-metal compounds, in which composition-dependent differences are more pronounced in energy regions where photoelectric absorption contributes strongly [41].

The comparison also indicates close agreement between theoretical and experimental values for most samples and energies. Such agreement has been reported in studies that compare measured gamma-ray attenuation with Monte Carlo simulations and theoretical calculations [42]. Differences between the two datasets may result from measurement uncertainties, sample thickness, density determination, chemical composition, counting statistics, and detector-related effects.

One important exception occurs for S5 at 1170 keV: the reported experimental value of $0.0718 \text{ cm}^2 \text{ g}^{-1}$ is substantially greater than the theoretical value of $0.0538 \text{ cm}^2 \text{ g}^{-1}$ and the neighbouring experimental values. This point should be verified before publication. Overall, the supplied data identify S3 as having the highest MAC across the investigated energy range, although final material selection should also consider density, mechanical stability, cost, and the required shielding thickness.

3.3 Mean Free Path (MFP)

Figure 5 presents the variation in the mean free path of the six selected transition-metal salts (S1–S6) over the photon energy range of 122–1330 keV. The results show that the MFP generally increases with increasing photon energy for all six samples. This behaviour indicates that photons travel greater average distances before interacting with the material at higher energies. Similar energy-dependent variations in MFP have been reported in investigations of ceramic materials, dielectric materials, polymer composites, and alternative gamma-ray shielding materials [43].

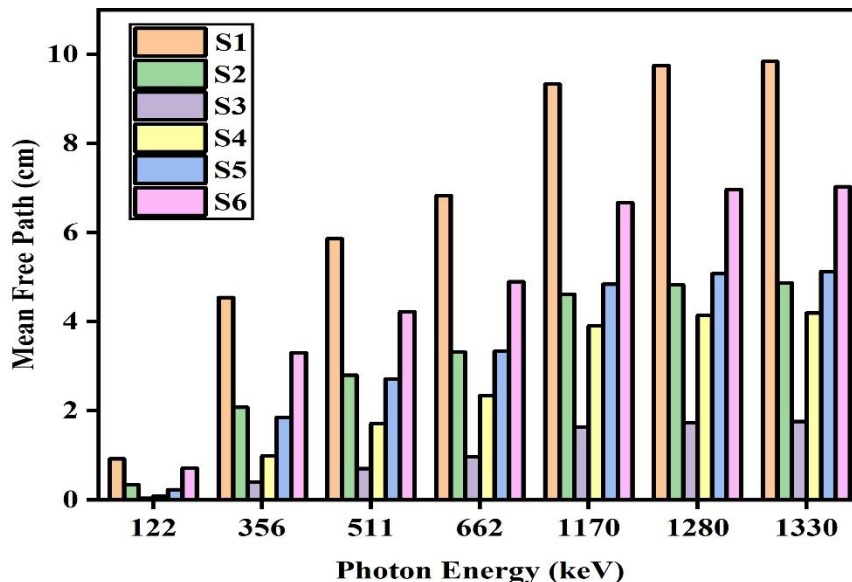


Figure 5. Mean free path (MFP) of the selected Transition-Metal Salts.

At 122 keV, S3 exhibits the lowest MFP, followed by S4, S5, S2, S1, and S6 according to the plotted values. As the photon energy increases, the MFP of each sample increases, although the extent of the increase varies with material composition. At higher photon energies, S3 maintains a comparatively low MFP, whereas S1 exhibits the highest MFP. These results suggest that S3 offers better attenuation per unit thickness than the other investigated samples, while S1 requires a greater thickness to achieve a comparable reduction in the uncollided photon intensity.

The differences in MFP among the samples can be attributed to variations in their elemental compositions, densities, and corresponding linear attenuation coefficients. Materials with higher linear attenuation coefficients generally exhibit lower MFP values, meaning that photons are more likely to interact over shorter distances. This relationship has also been demonstrated in experimental studies of tungsten-based shielding materials and magnetite- or serpentine-modified ceramics [44-45]. Overall, Figure 5 indicates that S3 has the most favourable MFP characteristics among the investigated samples over the studied photon energy range. The increasing MFP at higher energies also highlights the need to consider photon energy when designing effective gamma-ray shielding systems. Nevertheless, the final assessment of shielding performance should consider MFP together with the linear attenuation coefficient, half-value layer, material density, and practical thickness requirements [46-47].

3.4 Half Value Layer (HVL)

Figure 6 illustrates the variation in the HVL of the six selected transition-metal salts (S1–S6) over the photon energy range of 122–1330 keV. The results show that the HVL increases with increasing photon energy for all investigated samples. This behaviour is consistent with the corresponding decrease in the linear attenuation coefficient as photon energy increases. Similar energy-dependent variations in HVL have been reported in experimental investigations of ferrite nanocrystals, dielectric materials, alloys, and radiation-shielding composites [48-51].

Among the investigated samples, S3 exhibits the lowest HVL throughout the measured energy range, increasing from approximately 0.04 cm at 122 keV to 1.22 cm at 1330 keV. This indicates that S3 requires the smallest material thickness to reduce the incident gamma-ray intensity by half. In contrast, S1 exhibits the highest HVL, increasing from approximately 0.6 cm at 122 keV to 6.8 cm at 1330 keV. Therefore, based on the plotted data,

S3 demonstrates the most favourable shielding characteristics, whereas S1 requires a substantially greater thickness to achieve the same attenuation.

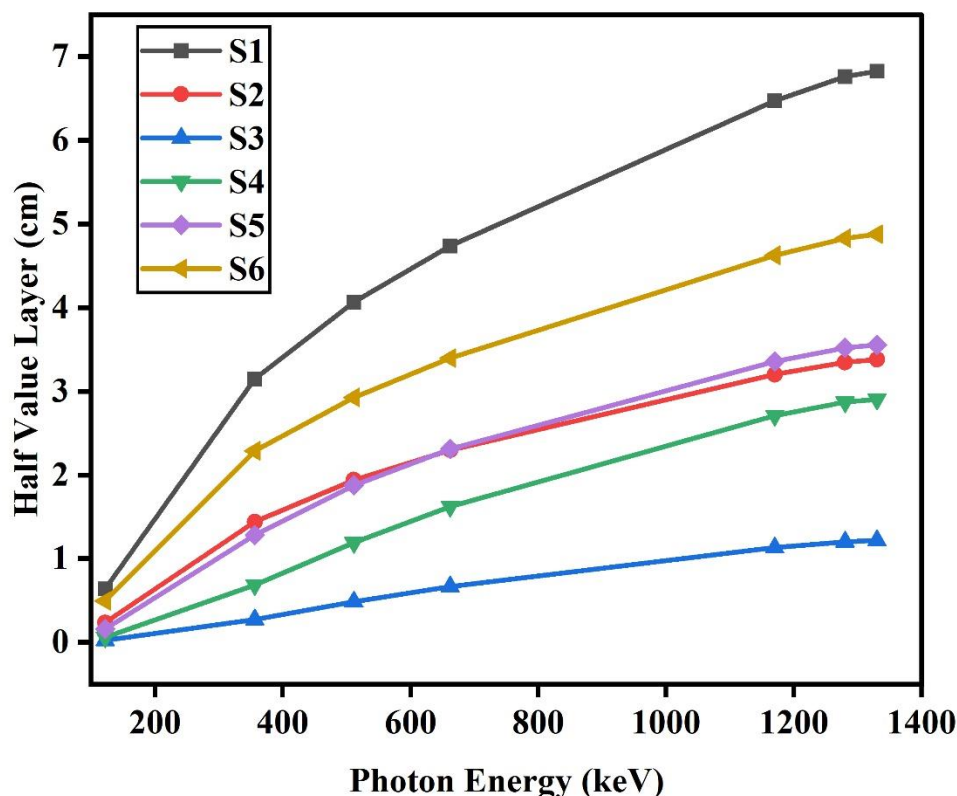


Figure 6. Half Value Layer (HVL) of the selected Transition-Metal Salts.

The remaining samples exhibit intermediate HVL values. S4 generally shows lower HVL values than S2, S5, and S6, while S6 exhibits relatively high values across the energy range. At 1330 keV, the approximate order from lowest to highest HVL is S3, S4, S2, S5, S6, and S1. The differences between the samples reflect the influence of their composition and density on photon attenuation. Comparable relationships between HVL and shielding performance have been observed in studies of boro-silicate glasses, mineral-based shielding materials, and metal-filled polymer composites [52].

Overall, Figure 6 demonstrates that the required shielding thickness increases with photon energy for all six samples. S3 appears to be the most effective material based on its consistently lower HVL, while S1 is the least favourable in terms of thickness requirements. These findings support the potential application of S3 in gamma-ray shielding; however, practical selection should also consider density, mechanical strength, cost, and the intended radiation environment.

3.5 Tenth Value Layer (TVL)

Figure 7 illustrates the variation in the TVL of the six selected transition-metal salts (S1–S6) over the photon energy range of 122–1330 keV. The TVL increases with increasing photon energy for all six samples. This behaviour is consistent with the reduction in the linear attenuation coefficient at higher photon energies, indicating that greater material thickness is required to achieve the same attenuation. Similar trends have been reported in investigations of polymer composites, bentonite-based materials, and other gamma-ray shielding systems [53–56].

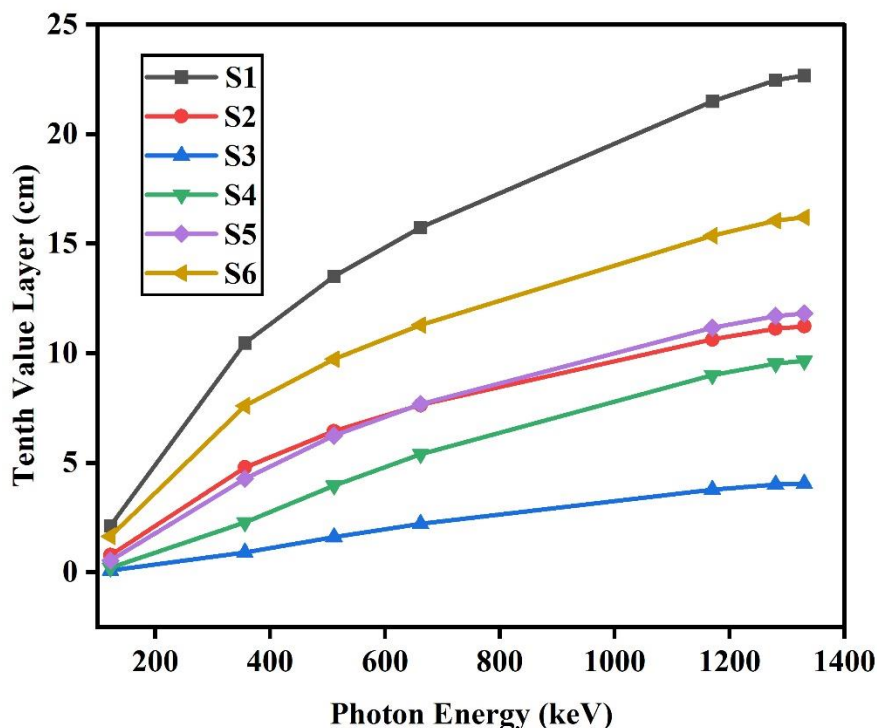


Figure 7. Tenth Value Layer (TVL) of the selected Transition-Metal Salts.

Among the investigated samples, S3 exhibits the lowest TVL throughout the studied energy range, increasing from approximately 0.1 cm at 122 keV to 4.1 cm at 1330 keV. This indicates that S3 requires the smallest thickness to reduce the incident gamma-ray intensity to 10% of its initial value. In contrast, S1 exhibits the highest TVL, increasing from approximately 2.1 cm at 122 keV to 22.6 cm at 1330 keV. Consequently, S3 demonstrates the most favourable shielding characteristics based on TVL, whereas S1 requires a substantially greater thickness to achieve an equivalent attenuation level.

The remaining samples show intermediate TVL values. At 1330 keV, the approximate order from lowest to highest TVL is S3, S4, S2, S5, S6, and S1. The differences in TVL reflect variations in the attenuation properties of the investigated materials, which are influenced by their chemical composition and density. A lower TVL is particularly desirable in applications where space, weight, and material thickness are important design considerations [57].

Overall, Figure 7 demonstrates that the shielding thickness required to achieve 90% attenuation increases with photon energy for all six samples. S3 appears to be the most promising candidate based on its consistently lower TVL, while S1 exhibits the least favourable performance in terms of thickness requirements. These results should be interpreted alongside the mass attenuation coefficient, linear attenuation coefficient, half-value layer, and mean free path for a comprehensive assessment of gamma-ray shielding performance.

4. Conclusions:

The present study investigated the gamma-ray attenuation and shielding characteristics of six selected transition-metal salts, designated as CM, SiC, DPt, TCIP, LTCl, and PCINb, through experimental measurements and theoretical calculations over the photon-energy range of 122–1330 keV. The experimental mass attenuation coefficients (MACs) were compared with theoretical values obtained using the XCOM database, and the corresponding shielding parameters, including the linear attenuation coefficient (LAC), mean free path (MFP), half-value layer (HVL), and tenth-value layer (TVL), were examined to evaluate the relative attenuation performance of the investigated materials.

The results demonstrated that the MAC decreased with increasing photon energy for all six samples, indicating the energy-dependent nature of gamma-ray interactions with matter. The theoretical and experimental MAC values showed generally close agreement, supporting the applicability of XCOM-based calculations for comparative attenuation studies. However, the deviation observed for sample S5 at 1170 keV requires verification against the original experimental measurements before definitive conclusions are drawn.

Among the investigated samples, S3 exhibited the highest MAC and LAC values across the studied energy range, indicating comparatively strong gamma-ray attenuation. This sample also showed the lowest MFP, HVL, and TVL, demonstrating that a smaller thickness of S3 is required to achieve a given level of attenuation. In contrast, S1 exhibited the highest MFP, HVL, and TVL values, indicating comparatively lower attenuation efficiency per unit thickness. The differences among the samples highlight the important role of elemental composition and density in determining gamma-ray shielding performance.

Furthermore, the increase in MFP, HVL, and TVL with increasing photon energy indicates that greater material thickness is required to achieve equivalent attenuation at higher energies. These findings emphasize the importance of evaluating multiple shielding parameters rather than relying on a single attenuation coefficient when comparing candidate materials.

Overall, S3 appears to be the most promising candidate among the six investigated samples based on the reported attenuation parameters. The combined experimental and theoretical approach provides a useful basis for comparing their gamma-ray interaction characteristics and identifying materials for further radiation-shielding research. Nevertheless, practical application requires additional assessment of measurement uncertainties, chemical composition, mechanical stability, cost, and long-term material performance. Verification of the anomalous experimental MAC value for S5 at 1170 keV is also necessary before finalizing the results. Further investigations involving additional experimental validation and radiation-transport simulations would help establish the suitability of these materials for specific radiation-protection applications.

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