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2 ND INTERNATIONAL SCIENCE, ENGINEERING AND TECHNOLOGY COLLOQUIUM

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INTELLIGENT SOLUTIONS FOR A SUSTAINABLE WORLD

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PREFACE

Welcome to the 2nd International Science, Engineering and Technology Colloquium 2025 (ISETC 2025)!

It is with great pleasure that we present this year's colloquium, a distinguished gathering of scholars, researchers, and professionals dedicated to the advancement of applied sciences. Held virtually on 9th July 2025, ISETC 2025 serves as a platform to highlight cutting-edge research, foster meaningful networking, encourage collaborations, and explore innovative solutions to global challenges.

This year's theme, "The Power of Scientific Innovation: Intelligent Solutions for a Sustainable World" highlights our shared goal to solve global challenges through applied science. It celebrates innovation as a key to building a more sustainable and resilient future. We're proud to feature keynote speakers and presenters who bring fresh insights, bold ideas, and breakthroughs shaping tomorrow's world.

We would like to extend our heartfelt appreciation to the Faculty of Applied Sciences, Universiti Teknologi MARA, Perak Branch, Tapah Campus, for their outstanding support and assistance throughout the planning and execution of the event. Their dedication has been instrumental to the success of this colloquium. We would like to sincerely thank all participants and researchers for their valuable contributions. We also appreciate the reviewers for their careful evaluations and helpful feedback. Your hard work and support mean a lot to us.

As editors, we are proud to present this collection of proceedings. It is an honour to bring together the interesting and meaningful work of our speakers and authors. We hope the ideas shared will lead to new discoveries, encourage more research, and help solve global challenges through science and innovation.

Warm regards,

Dr. Emi Norzehan Mohamad Mahbob
Dr. Saiyidah Nafisah Hashim
Ms. Lili Widarti Zainuddin
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ISETC 2025 Proceedings Editors

EVALUATING RADIATION SHIELDING EFFECTIVENESS OF SELECTED PLASTIC AND POLYMER VIA ATTENUATION COEFFICIENT

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Abstract: The vast advancing medical, industrial, and nuclear fields increased the demand for lightweight, cost-effective, and ecological radiation shielding materials like plastic and polymers. Traditional metals, such as lead, can be harmful due to long-term exposure, as they possess toxic chemical properties that pose risks to both humans and the environment. This study aims to evaluate and compare the radiation shielding effectiveness of selected plastic and polymer materials by measuring their linear (μ) and mass attenuation coefficients (μ/ρ) under gamma radiation (Cobalt-60). Several commercially available plastics and polymers (high-density polyethylene and polystyrene) were selected. In this study, experiments were conducted using a detector to measure the linear and mass attenuation coefficients of the materials. It was found that the linear attenuation coefficients were 0.16 cm^{-1} and 0.08 cm^{-1} for high-density polyethylene and polystyrene. The linear attenuation coefficient (μ) was calculated using the Beer-Lambert law, and the results were compared to theoretical values from the NIST XCOM databases. Materials densities were measured to calculate the mass attenuation coefficient (μ/ρ). This study concluded that Polystyrene (plastic) and High-Density Polyethylene (poly) were able to play a role in shielding against gamma radiation. A more comprehensive exploration of composites in pure compounds beyond the current standard could enhance their effectiveness, leading the way for various uses in radiation shielding technologies

Keywords: *Radiation shielding, attenuation coefficient, plastic, polymer, gamma-ray*

INTRODUCTION

Gamma rays are the highest-energy and shortest-wavelength particles in the electromagnetic spectrum. Several advantages gamma rays are offered in multiple fields due to their unique properties. For example, gamma rays are widely used in nuclear imaging to provide detailed images of the body's internal structures, aiding in accurate diagnosis (Dendooven & Bubba, 2022). Gamma rays are useful in many areas, yet they can harm living cells, which is why maintaining environmental safety requires efficient gamma-ray shielding. Historically, heavy metals such as lead have been used as shielding materials. It is concerning, though, as lead is also known to be toxic and to harm the ecosystem. One promising candidate that has emerged is Plastic and Poly. These materials are well known for their characteristics, including lightweight and eco-friendliness, which make them suitable for a wide range of applications across various fields. This study aims to evaluate the radiation shielding effectiveness of selected plastic and polymer materials by measuring their linear and mass attenuation coefficient under gamma radiation (Cobalt-60). Several problems were identified that led to this research. There is limited research on the effectiveness of selected plastic and polymer thicknesses in blocking gamma rays, which is lead to the problem that led to this study. This research is highly relevant for various industries that depend on effective radiation shielding. This research aims not only to enhance scientific knowledge but also to offer practical solutions to modern challenges in radiation safety and material innovation. As a result, this study concludes that these chosen materials can play a role in shielding against gamma radiation. It also reveals that a pure non-composite sample can be effective on its own, even if the effect is not significant.

LITERATURE REVIEW

The principles of radiation shielding are based on the fundamental concept of reducing exposure to ionising radiation by using materials that can attenuate it. Finding proper shielding helps minimise exposure to gamma radiation, thereby protecting individuals from its harmful effects. According to a study by Elsayed (2023), based on their scientific report, polymers that are composed of C, H, and O constituent elements can be used as tissue substitute materials. For simulated results, XCOM values were found to be very close to experimental results, making them a suitable alternative method for experimentation (Vahabi et al., 2017). These studies provide proof for the present work, which widens the opportunity to evaluate the radiation shielding effectiveness of selected plastics and poly via the attenuation coefficient.

MATERIALS AND METHODS

In the current study, four plate samples of material (plastic and poly) were chosen from the Radiation Absorber Set for the experiment. Firstly, sample identification was performed using Fourier Transform Infrared Spectroscopy (FTIR) analysis for each selected plastic and poly. Although FTIR does not confirm the exact chemical composition, it helps in observing the functional groups present in each sample. Therefore, the results were obtained based on the assumption that the plates were a pure form of their respective materials. Based on the results, it was assumed that the plastic sample was Polystyrene, and the poly sample was High-Density Polyethylene. Once the materials were identified, each thickness of each material was measured to examine how this factor affects gamma ray shielding performance. Following that, the experiment was set up, using the SPECTECG ST350 Counter detector as the detector, and the radioactive source used is Cobalt-60, which is widely used in gamma ray experiments because it emits gamma radiation. This experiment was conducted for a one-hour period to ensure more consistent and reliable results. From the data collected, the intensity of radiation was calculated, and applied the Beer-Lambert law's formula for intensity, *I* as follows:

$$I = I_0 e^{-\mu x} \qquad \textbf{(1)}$$

For the slope of the graph and according to the equation:

$$\mu = m\rho + c \qquad \textbf{(2)}$$

It was found the linear attenuation coefficient of each sample and the mass attenuation coefficient (μ/ρ), which is the ratio of the linear attenuation coefficient, μ (cm^{-1}) to the density, ρ (g cm^{-3}) (Al-khawlany et al., 2019). Finally, the experimental data results were compared to theoretical values from the NIST XCOM database, allowing for an assessment of the accuracy and potential of these alternative materials as radiation shields.

RESULTS

Plastic Sample

Figure 1 illustrates the relationship between In(I/I_0) and the plastic samples at two different shielding thicknesses, 0.030 inch and 0.040 inch. The observed negative slope demonstrates that as the thickness increases, the transmission decreases, consistent with the Beer-Lambert law. The attenuation coefficients determined from the graph are approximately -0.0023 cm^{-1} and -0.0011 cm^{-1} for the 0.030 inch and 0.040-inch samples, respectively. The smaller slope observed for the 0.040-inch sample suggests a slightly reduced attenuation per unit thickness, which may be attributed to experimental uncertainties. Overall, the trend confirms the expected exponential attenuation behavior in the plastic material.

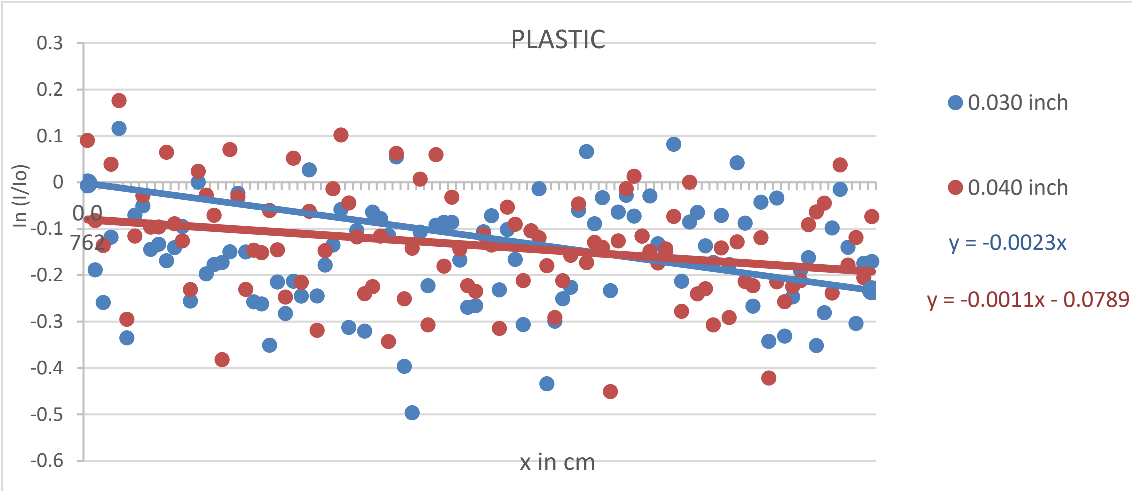

Figure 1. Legend shows Plastic legend of In(I/Io) versus thickness (x) in cm

Polymer Sample

Figure 2 presents plots of ln(I/Io) against thickness for polymer sheets with thicknesses of 4 mil and 8 mil. Both sets of data exhibit negative slopes, confirming that photon intensity decreases as material thickness increases. The linear regression yields slopes of $-0.0583\ cm^{-1}$ for the 4 mil sheet and $-0.2452\ cm^{-1}$ for the 8 mil sheet, indicating a much higher attenuation rate in the thicker polymer. This finding implies that the polymer material offers more effective radiation shielding than the plastic sample under identical conditions. The enhanced shielding performance is likely due to the polymer's greater effective atomic number and density, which increases photon–matter interaction.

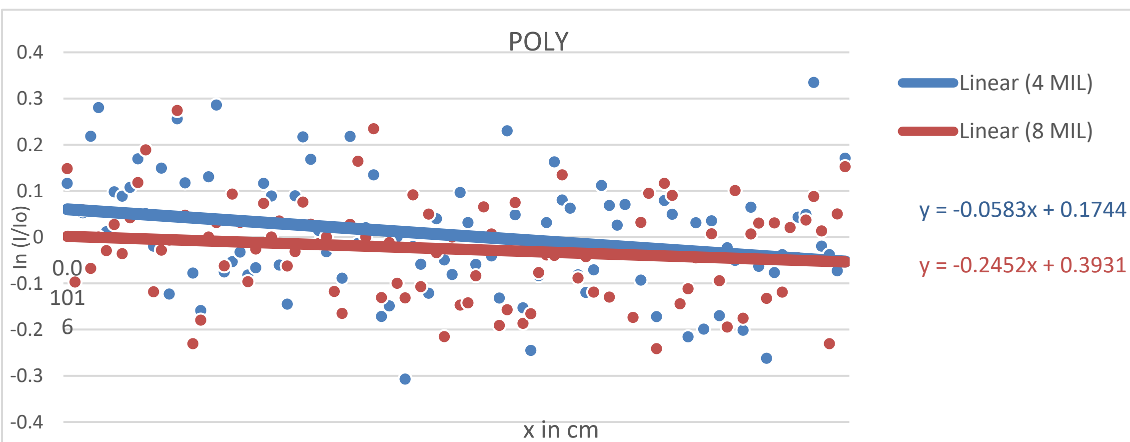

Figure 2. Legend shows Poly legend of In(I/Io) versus thickness (x) in cm

Comparative Analysis

Table 1. Linear attenuation coefficient, density and mass attenuation coefficient for each absorber

Absorber	Average Initial Intensity Before Passing Through the Absorber, ΔIo	Average Intensity of the Radiation After Passing Through the Absorber, ΔI	Thickness of the Absorber, t (cm)	Linear Attenuation Coefficient, μ (cm^{-1})	Density of the Absorber, p (g/cm^3)	Mass Attenuation Coefficient, (cm^2/g)
Plastic 0.030	0.0428	0.0366	0.0762	0.001784	0.7756	0.00178
Plastic 0.040	0.0428	0.0374	0.1016	0.08	1.0044	0.0796
Poly 4 MIL	0.0428	0.04299	0.01016	0.1186	0.9573	0.1239
Poly 8 MIL	0.0428	0.04170	0.02032	0.1622	0.9418	0.1722

Table 2. Comparison of Experimental and Theoretical values

Experimental, Plastic (0.1016 cm) Thickness			Theoretical (XCOM)			Experimental, Poly (0.02032 cm) Thickness			Theoretical (XCOM)		
Linear Attenuation Coefficient, μ (cm^{-1})	Density of Plastic (g/cm^3)	Mass Attenuation Coefficient, μ/ρ (cm^2/g)	Linear Attenuation Coefficient, μ (cm^{-1})	Density of Plastic (g/cm^3)	Mass Attenuation Coefficient, μ/ρ (cm^2/g)	Linear Attenuation Coefficient, μ (cm^{-1})	Density Of Poly (g/cm^3)	Mass Attenuation Coefficient, μ/ρ (cm^2/ g)	Linear Attenuation Coefficient, μ (cm^{-1})	Density of Poly (g/cm^3)	Mass Attenuation Coefficient, μ/ρ (cm^2/g)
0.0800	1.0044	0.0796	0.06840	1.05	0.06515	0.1622	0.942	0.1722	0.0650	0.941	0.0691

Type of Parameters	Percentage Difference (%)	Type of Parameters	Percentage Difference (%)
Linear attenuation coefficient, μ (cm^{-1})	15.63	Linear attenuation coefficient, μ (cm^{-1})	85.53
Density of Plastic (g/cm^3)	4.44	Density of Poly (g/cm^3)	0.11
Mass Attenuation Coefficient, μ/ρ (cm^2/g)	19.96	Mass Attenuation Coefficient, μ/ρ (cm^2/g)	85.44

Reference: National Institute of Standards and Technology's (NIST) XCOM database

Table 1 shows summarize experimental data extracted from Figures 1 and 2, presenting initial and final radiation intensities, thicknesses, linear attenuation coefficients (μ), densities (ρ), and mass attenuation coefficients (μ/ρ) for each sample. While Table 2 shows a comparison of the experimental results with theoretical values from the NIST XCOM database. In Table 1, Poly consistently show a higher (μ) and (μ/ρ) values than plastic. Higher density values in polymers shows contribute to their superior attenuation compared to Plastics. While Table 2 reveals that plastics align better with theoretical predictions than Poly. Comparing Figures 1 and 2, polymers demonstrate steeper slopes than plastics, indicating their smaller half-value layers (HVL) and thus superior radiation shielding capability. The experimental results confirm that material composition and density strongly influence attenuation properties. These findings align with theoretical expectations that polymers containing higher-Z elements and greater density exhibit better radiation shielding performance than lighter plastics.

DISCUSSION

The objective of this study is to evaluate and compare the radiation shielding effectiveness of selected plastic and polymer materials by measuring the linear and mass attenuation coefficients under gamma radiation (Cobalt-60). The calculated percentage differences, using the equation $\frac{\Delta V}{[\frac{\sum V}{2}]} \times 100$, were used to compare experimental and theoretical values.

Considering the low density and thickness of the materials, percentage differences between the linear attenuation coefficients and mass attenuation coefficients are theoretically expected to fall between 15% and 25%. However, higher deviations about 85% were observed, likely due to the high sensitivity of polymers to light structural variations. Despite this, the materials exhibited measurable attenuation. While their shielding capabilities in pure form may be limited, enhancing these materials with various composites or increasing their density may yield superior outcomes. In this study, mechanisms such as Compton scattering and photoelectric absorption influenced the radiation attenuation. Additionally, the rich presence of hydrogen (C-H) compounds in the material composition contributes to neutron moderation, further supporting their potential shielding efficiency. According to the Beer-lambert Law, increased material content enhances photon-electron interactions that can improve attenuation.

The study has limitations that impacted the results. The components used were prefabricated from a radiation kit set, and FTIR was utilized to make chemical content assumptions. Besides that, estimating that the equipment had been used for 10 years might reduce the result accuracy because of source decay and material degradation.

CONCLUSION

In conclusion, the linear and mass attenuation coefficients of plastic and polymer materials under Cobalt-60 gamma radiation show that their radiation shielding efficacy primarily influenced by density and thickness. Significant deviations from expected values suggest that other factors, such as internal composition and material aging affecting the attenuation performance. The potential of engineered polymers is achievable as substitutes for traditional shielding materials. Future research should concentrate on improving composite compositions and investigate minimum effective thickness and density required for adequate radiation protection.

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Sekian, terima kasih.

Setuju.

"BERKHIDMAT UNTUK NEGARA"

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Saya yang menjalankan amanah,

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