CHAPTER 4 – Results and Discussion

Results of the experimental μ/ρ for the industrial materials at 356keV and 662keV are presented in this chapter. Each experimental value is compared to an expected value derived from published reports from Hubbell and M. N. Alam. In the first part of this study, distilled water was used as a standard material for liquid samples in determining source-sample-detector distance that gives μ/ρ value with the nearest value predicted by calculations derived from Hubbell[3]. Experiment was repeated using two different samples, toluene and ethanol. Both have lower density than water, which are $0.84g/cm^3$ and $0.77g/cm^3$ respectively. This experiment only considered positions at small separations and for material densities around $1g/cm^3$. Presented in Table 4, Table 5 and Table 6 are the experimental values for gamma ray mass attenuation coefficient at 356keV for distilled water, toluene and ethanol respectively. In order to compare the results between experiment and published data, the relative difference is calculated using the following relation, RD.

$$\mathbf{RD} = \frac{\mu/\rho\ \textbf{(Theory)} - \mu/\rho\ \textbf{(Experiment)}}{\mu/\rho\ \textbf{(Theory)}}$$

The percentage values are also shown in Table 4, 5 and 6.

4. 1 Determination of μ/ρ for Distilled Water

Table 4. Values of mass attenuation coefficient at 356keV for distilled water

Position	Distance (cm) Detector-Sample-Source	Experimental μ/ρ (cm^2 / g) For Distilled Water	Published Data μ/ρ (cm^2 / g) For Distilled Water	% RD
1	5+10+5	0.121	0.111 (Derived from Hubbell, 1982)	9.0%
2	10+10+10	0.107		3.6%
3	10+10+5	0.112		0.9%
4	5+10+10	0.113		1.8%

Results at Table 4 show that the best result among the different positions is when the sample is nearer to the source followed by when sample is nearer to detector with %RD at 0.9% and 1.8% respectively. The experimental values 0.112cm^2/g and 0.113cm^2/g in Position 3 and 4 are in good agreement with the expected value, 0.111cm^2/g derived from Hubbell[3]. For position 2, distance between detector-to-sample and source-to-sample at 10cm, which coincidently is in the same dimension with the sample, the μ/ρ value 0.107cm^2/g is slightly lower (%RD=3.6%) than expected. However, this value is still reasonable within the range of the expected value. With detector-sample-source position at half sample size distances, the experiment value 0.121cm^2/g is 9.0% higher than expected. This is due to shorter distances where the incident beam is passed through the sample directly without being attenuated and this contributes to higher intensity of transmitted beam. From the results, it is suggested that with detector to sample and source to sample distances at

10cm and 5cm respectively, the mass attenuation coefficient can be determined accurately using the current set-up.

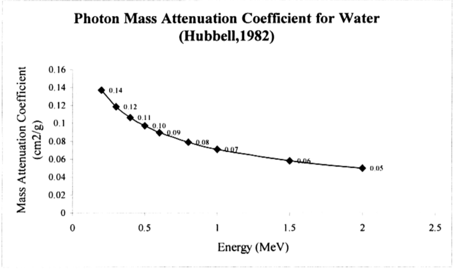

Figure 5. Theoretical curve of mass attenuation coefficient versus gamma ray energy for water

Table 5. Values of mass attenuation coefficient at 356keV for toluene

Position	Distance (cm) Detector-Sample-Source	Experimental μ/ρ (cm^2/g) For Toluene	Published Data μ/ρ (cm^2/g) For Toluene	% RD
1	5+10+5	0.111	0.108 (Derived from Hubbell, 1982)	2.8%
2	10+10+10	0.097		10.2%
3	10+10+5	0.107		0.9%
4	5+10+10	0.107		0.9%

The μ/ρ values for Toluene in Table 5 show that samples at position 3 and 4 gives the lowest percentage of relative difference between experiment and published data. Here both positions give the best experimental result compared to its expected value, 0.108cm^2/g. For position 1, the measured value of μ/ρ is in fairly good agreement with published data. With the sample placed 10cm away from both detector and source, the experimental μ/ρ value is 10.2% lower than published value. This value could be caused by the detection of scattered ray together with the transmitted ray and the total of which is comparable to the incident intensity. Hence, the transmission ratio was small and it influenced the measurement of the μ/ρ.

Table 6. Values of mass attenuation coefficient at 356keV for ethanol

Position	Distance (cm) Detector-Sample-Source	Experimental μ/ρ (cm^2/g) For Ethanol	Published Data μ/ρ (cm^2/g) For Ethanol	% RD
1	5+10+5	0.118	0.113	4.4%
2	10+10+10	0.101	(Derived from	10.6%
3	10+10+5	0.122	Hubbell, 1982)	8.0%
4	5+10+10	0.120		6.2%

The μ/ρ values obtained for ethanol are shown in Table 6. The results show that the sample placed at the nearest distance from detector and source gives a 4.4% deviation from the expected value. However, this result can be said in fairly good agreement with the value from published data. Sample placed the furthest from detector and source gives μ/ρ value that is 10.6% lower than the published data. This result shows a similar trend with the previous Toluene result at position 1 and 2. At position 3 and 4, the experimental μ/ρ are 8.0% and 6.2% higher than published value. This is due to the ability of the incident gamma ray to pass through a relatively lower density (compared to water density) and more gamma ray is recorded at the detector.

Generally, for water, toluene and ethanol, the results suggest that with liquid density between $0.77 g/cm^3$ to $1 g/cm^3$, the experiment yields a good accuracy of μ/ρ at close proximity with the sample. The transmission configuration setup employed is suitable for reliable measurements of coefficient values as results agree fairly well with the published data at positions 3 and 4 for water and toluene and position 1 for ethanol.

4.2 Determination of μ/ρ for Selected Solids and Liquids

In the second experiment, the values of mass attenuation coefficient, μ/ρ are obtained for six liquid and four solid materials at two gamma ray energies 356keV and 662keV. The coefficient values obtained are presented in Table 7, 8, 9 and 10. The theoretical μ/ρ values for compounds are calculated using the mixture rule where element coefficient values were derived from Hubbell[3]. The experimental μ/ρ are compared with the derived values and the relative differences between them are shown in Table 7, 8, 9 and 10. For cement and brick samples, theoretical values not available in Hubbell and the experimental values were compared with published works by M.N. Alam[17]. An unknown sample of oil sludge made up mostly of hydrocarbons groups (largely oil, paraffin, tar and asphalts) is compared with a known sample olein. Plots of mass attenuation coefficient versus gamma energy are shown in Figure 7, 8, 9, 10, 11, 12, 13, 14, 15 and 16 for n-pentane, ethanol, toluene, olein, oil sludge, distilled water, polyethylene, cement, brick and concrete respectively. It is found that the experimental values are higher than the published data for samples with density 0.62g/cm^3 (n-pentane) and 0.77g/cm^3 (Ethanol). For samples with densities 0.84g/cm^3 (Toluene), 0.90g/cm^3 (Olein), 0.90g/cm^3 (Oil Sludge), 1.00g/cm^3 (Distilled Water), 0.90g/cm^3 (Polyethylene), 1.52g/cm^3 (Brick), 1.70g/cm^3 (Cement) and 2.28g/cm^3 (Concrete), the experiment values were generally found to be lower than the published data. Sensitivity optimisation is determined to be between 0.71 and 1.70 for the samples (except for polyethylene sensitivity, [(μ/ρ) x (ρ) x (x)] = 0.44 at 356keV. At 662keV, sensitivity optimisation is between 0.52 and 1.36 for all samples (except for polyethylene sensitivity = 0.32). For both sets of data, sensitivity optimisation is still within the acceptable range of $0.5 < [(\mu/\rho) \times (\rho) \times (x)] < 1.80$ but for polyethylene it falls below the minimum required.

4.2.1 Liquid Samples

In Fig. 7 (pg.36), it is shown that the experiment value for n-pentane at 356keV is 9.5% higher than published data and at 662keV the experiment value has deviated largely against the expected value of 0.090cm^2/g. This result is due to occurrence of incident gamma ray not being attenuated by the relatively low-density material thus it passes through and is recorded together with the transmitted ray. The larger deviation for 662keV could be contributed with the fact that at 662keV, n-pentane with mass thickness of 5.58g/cm^2 is not adequate to absorb gamma ray and to give a good value of μ/ρ.

For ethanol sample shown in Fig. 8 (pg.36), it is found that both μ/ρ values at 356keV and 662keV recorded a higher value compared to published data. A deviation of about 20% for both data points to the fact that the mass thickness of 8.09g/cm^2 is inadequate for gamma ray to interact in the 0.77g/cm^3 material. Some incident ray passes through the material without attenuation and is included in the transmitted ray count rate.

Toluene sample (Fig.9, pg. 37) with density of 0.84g/cm^3, its μ/ρ value record a good result at 356keV with only a 3.7% lower than expected. However, at energy 662keV, the material could be penetrated easily by gamma ray. Its mass thickness of 8.82g/cm^2 was inadequate to record good interaction between radiation and the material.

In Fig. 10 (pg. 37), the olein sample with density 0.90g/cm^3, the μ/ρ also record a lower value than published data. The deviation is about 10% lower at 356keV and about 14% lower at 662keV for mass thickness of 8.06g/cm^2 of olein. Two liquid samples, olein and oil sludge have the same density of 0.90g/cm^3. Without knowing the exact chemical composition of the oil sludge sample, its mass attenuation was reasonably determined to be comparable to the mass attenuation coefficient of olein (Fig.11). Olein consists of Palmitic acid (35%), Oleic acid(50%) and Linoleic acid(15%)- a combination of C16 and C18, whereas the oil sludge consists mainly of paraffinic(C6) and some asphaltic(C60) hydrocarbons. Olein consists of a combination of C, H and O elements and sludge contains C and H elements only. The coefficient value for olein is (0.100 ± 0.011) cm^2/g and oil sludge is (0.102 ± 0.011) cm^2/g. In this case, the result for a known sample could be taken to represent the coefficient value for an unknown sample with similar density and chemical makeup. This is particularly helpful in cases where the gamma absorption technique is applied when making measurements to determine deposits or build-up of material in an industrial pipeline. Thickness measurement may be required for several purposes: to assess the depth of deposits on the inner wall of pipes and process vessels; to check for voids in concrete and in similar materials; to measure metal thinning by corrosion or erosion. In many cases, deposition of material only occurs in some parts of a long pipeline or part of chemical plant installation and the process material is an intermediate material that may be hazardous, flammable or corrosive acids. To acquire a sample of that particular process material is impractical and inconvenient. Hence, by using a known material to estimate an unknown material's coefficient values, we can perform the thickness measurement by gamma ray absorption technique with confidence.

In Figure 12, the result for distilled water is compared with published data from Hubbell, which is 0.111cm^2/g at 356keV and 0.086cm^2/g at 662keV. The μ/ρ value is 0.091cm2/g at 356keV, 18% lower and 0.069cm2/g at 662keV, 19.8% lower. Physical requirements call for a thickness of absorbing material sufficient for the occurrence of a statistically significant number of interactions with minimal occurrence of multiple scattering. Water mass thickness of 13.0g/cm^2 is overestimated for this transmission ratio measurement. This suggests that if the thickness of the absorber is greater than one mean free path, multiple scattering could affect the measured value of the attenuation coefficient. Theoretically, the published data at 356keV and 662keV shows that for liquid density less than 1g/cm^3 each mass attenuation coefficient for each sample is almost comparable to the mass attenuation coefficient value for water. Referring to Table 7, at 356keV, derived coefficient values for n-pentane, ethanol, toluene, olein and sludge are between 0.108 cm^2/g to 0.116cm^2/g and these are comparable to derived coefficient value for water, 0.111cm^2/g. In effect, theoretically μ/ρ for water provides a good reference when estimating μ/ρ of an unknown material with a comparable density with water. Shown in Fig.12a, the coefficient value for water lies at mid-point among the liquid samples considered. In this experiment, olein (density 0.90g/cm3) has given a good comparison to the unknown oil sludge (density 0.90g/cm2) sample with their comparable experimental coefficient values.

4.2.2 Solid Samples

Experimental coefficient values for solid samples are shown in Table 8 for 356keV and Table 10 for 662keV energy respectively. The values are compared to published data from Hubbell[3] and M.N. Alam[17]. The lightest sample is polyethylene (0.90g/cm3) and the most dense is the concrete block (2.28g/cm3). Mass thickness, x of the sample was determined by multiplying density of material, ρ and its thickness, t.

Comparison of the experimental value and published value from Hubbell[3] for polyethylene is shown in Fig.13. Coefficient values from Hubbell[3] are derived from Fig.13a. The experimental μ/ρ is about 15% lower at 356keV and 18.2% lower at

662keV compared to Hubbell[3]. The lower values are attributed to underestimation of the mass thickness, which affected the accuracy of the transmission ratio measurement. This digression is also reflected in the design sensitivity factor, which was found to be less than the minimum limit.

The experiment values for brick are 0.084cm^2/g and 0.065cm^2/g at 356keV and 662keV respectively. Compared to a study by M.N. Alam[17] for soils and building materials, these values are 14.3% and 12.2% lower at the respective energies as shown in Fig.15. In this experiment the sample thickness, t is 7cm and it is 2cm longer than used by M.N. Alam. This difference has contributed to the lower experimental values as the mass thickness is varied by 3.09g/cm^2.

Figure 14 shows the comparative values of experiment and published data for the cement sample. The μ/ρ value 0.090cm^2/g at 356keV is in good agreement with M.N. Alam[17] for cement. The relative difference between experiment and the published value is 3.2%. However, a difference of 14.1% is found with results at 662keV, i.e. the μ/ρ value is 0.061cm^2/g and the published value is 0.071cm^2/g.

For the most dense sample which is concrete (2.28g/cm^3), the μ/ρ value are 0.083cm^2/g and 0.066cm^2/g at 356keV and 662keV respectively. Compared to Hubbell[3] data, these values differ by 17.0% and 14.3% at the respective energies. In this measurement, experiment design falls in the optimisation region for both relative sensitivity and statistical error. An attempt is made to make the sensitivity as large as possible and to minimise the statistic error whereby sensitivity is calculated to be 1.70 for 356keV and 1.36 for 662keV. These values fall under their respective acceptable interval, which are between 0.50 and 1.80 for sensitivity and between 1.02 and 3.46 for statistical error.

i) At 356keV:

Table 7. Comparison of experimental and theoretical mass attenuation coefficients (cm^2/g) for liquid samples at 356keV at Detector-to-Source (100cm)

No	Material	Density, ρ (g/cm^3)	Experimental μ/ρ (cm^2/g)	Published Data (cm^2/g)	%RD
1	n-pentane (C_5H_{12})	0.62	0.127±0.015	0.116	9.5%
2	Ethanol (C_2H_5OH)	0.77	0.135±0.018	0.113	19.5%
3	Toluene ($C_6H_5CH_3$)	0.84	0.112±0.014	0.108	3.7%
4	Olein	0.90	0.100±0.012	0.112	10.7%
5	Oil Sludge	0.90	0.102±0.012	unknown	unknown
6	Distilled Water	1.0	0.091±0.016	0.111	18.0%

Table 8. Comparison of experimental and theoretical mass attenuation coefficients (cm^2/g) for solid samples at 356keV at Detector-to-Source (100cm)

No	Material	Density, ρ (g/cm^3)	Experimental μ/ρ (cm^2/g)	Published Data (cm^2/g)	%RD
1	Polyethylene	0.90	0.097±0.011	0.114	14.9%
2	Brick	1.52	0.084±0.004	0.098	14.3%
3	Cement	1.70	0.090±0.003	0.093	3.2%
4	Concrete	2.28	0.083±0.005	0.100	17.0%

ii) At 662keV:

Table 9. Comparison of experimental and theoretical mass attenuation coefficients (cm^2/g) for industrial materials at 662keV at Detector-to-Source (100cm)

No	Material	Density, ρ (g/cm^3)	Experimental μ/ρ (cm^2/g)	Published Data (cm^2/g)	%RD
1	n-pentane (C_5H_{12})	0.62	0.124±0.043	0.090	37.8%
2	Ethanol (C_2H_5OH)	0.77	0.105±0.010	0.087	20.7%
3	Toluene ($C_6H_5CH_3$)	0.84	0.100±0.011	0.084	19.0%
4	Olein	0.90	0.074±0.008	0.086	13.9%
5	Oil Sludge	0.90	0.074±0.008	unknown	unknown
6	Distilled Water	1.0	0.069±0.011	0.086	19.8%

Table 10. Comparison of experimental and theoretical mass attenuation coefficients (cm^2/g) for industrial materials at 662keV at Detector-to-Source (100cm)

No	Material	Density, ρ (g/cm^3)	Experimental μ/ρ (cm^2/g)	Published Data (cm^2/g)	%RD
1	Polyethylene	0.90	0.072±0.001	0.088	18.2%
2	Brick	1.52	0.065±0.005	0.074	12.2%
3	Cement	1.70	0.061±0.001	0.071	14.1%
4	Concrete	2.28	0.066±0.009	0.077	14.3%

ii) At 662keV:

Table 9. Comparison of experimental and theoretical mass attenuation coefficients (cm^2/g) for industrial materials at 662keV at Detector-to-Source (100cm)

No	Material	Density, ρ (g/cm³)	Experimental μ/ρ (cm²/g)	Published Data (cm²/g)	%RD
1	n-pentane (C_5H_{12})	0.62	0.124±0.043	0.090	37.8%
2	Ethanol (C_2H_5OH)	0.77	0.105±0.010	0.087	20.7%
3	Toluene ($C_6H_5CH_3$)	0.84	0.100±0.011	0.084	19.0%
4	Olein	0.90	0.074±0.008	0.086	13.9%
5	Oil Sludge	0.90	0.074±0.008	unknown	unknown
6	Distilled Water	1.0	0.069±0.011	0.086	19.8%

Table 10. Comparison of experimental and theoretical mass attenuation coefficients (cm^2/g) for industrial materials at 662keV at Detector-to-Source (100cm)

No	Material	Density, ρ (g/cm³)	Experimental μ/ρ (cm²/g)	Published Data (cm²/g)	%RD
1	Polyethylene	0.90	0.072±0.001	0.088	18.2%
2	Brick	1.52	0.065±0.005	0.074	12.2%
3	Cement	1.70	0.061±0.001	0.071	14.1%
4	Concrete	2.28	0.066±0.009	0.077	14.3%

LIQUID SAMPLES

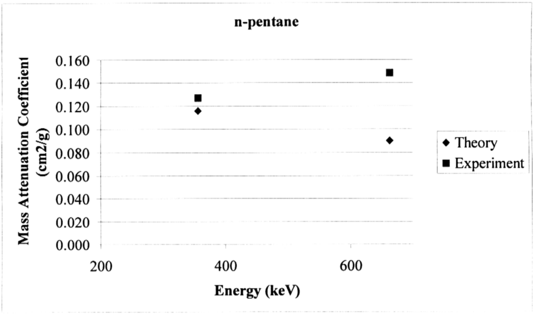

Fig. 7. Mass Attenuation Coefficient at 356keV and 662keV for n-pentane

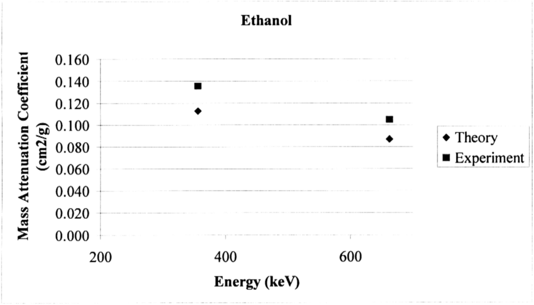

Fig. 8. Mass Attenuation Coefficient at 356keV and 662keV for ethanol

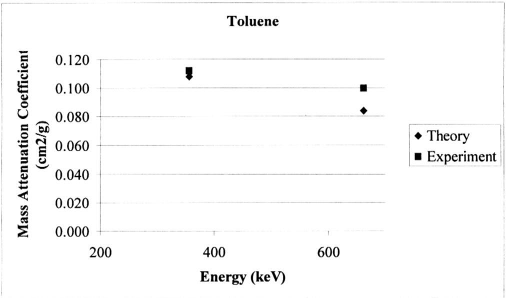

Fig. 9. Mass Attenuation Coefficient at 356keV and 662keV for Toluene

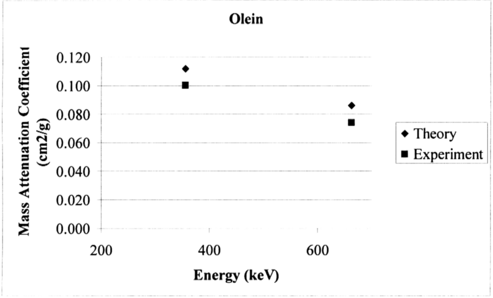

Fig. 10.Mass Attenuation Coefficient at 356keV and 662keV for Olein

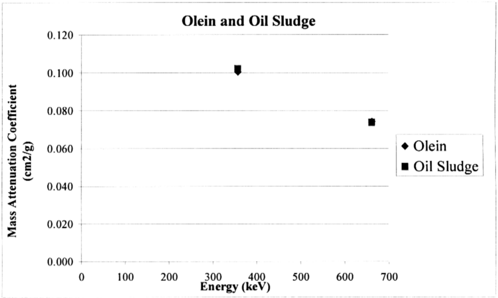

Fig. 11.Mass Attenuation Coefficient for Oil Sludge compared to Olein

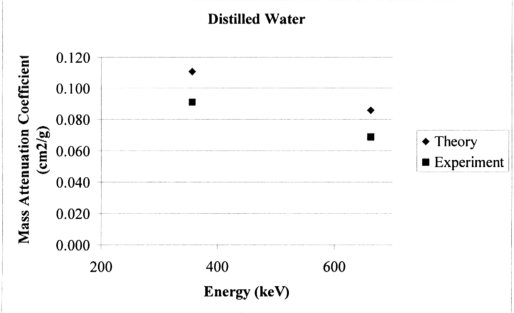

Fig. 12.Mass Attenuation Coefficient at 356keV and 662keV for Distilled Water

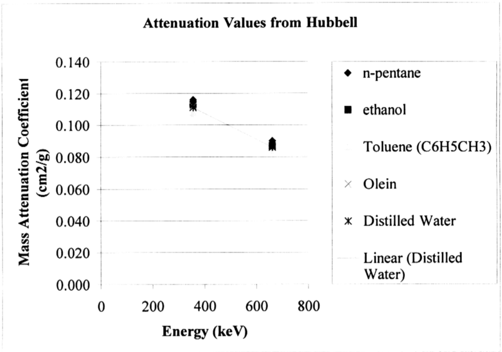

Fig. 12a. Theoretical comparison of mass attenuation coefficient for water with other liquid samples as derived from Hubbell[3]

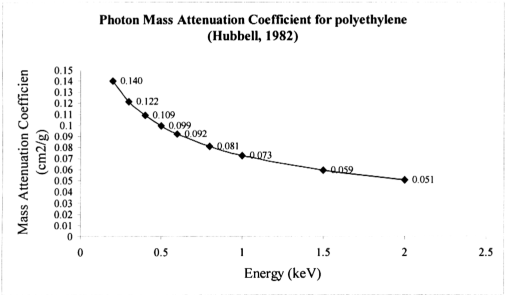

Fig. 13a. Variation of mass attenuation coefficient with gamma energy for polyethylene

SOLID SAMPLES

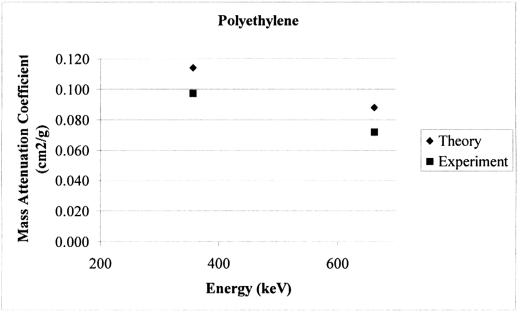

Fig. 13.Mass Attenuation Coefficient at 356keV and 662keV for Polyethylene

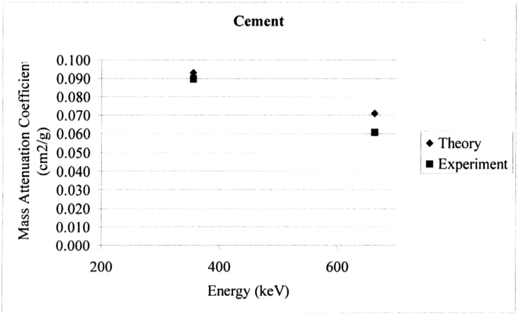

Fig. 14.Mass Attenuation Coefficient at 356keV and 662keV for Cement

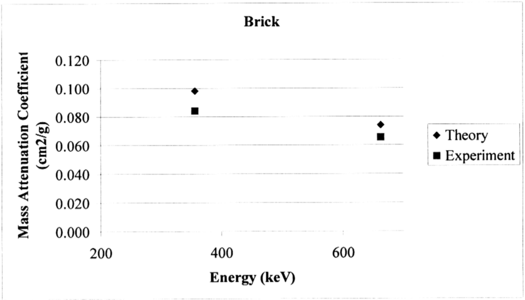

Fig. 15.Mass Attenuation Coefficient at 356keV and 662keV for Brick

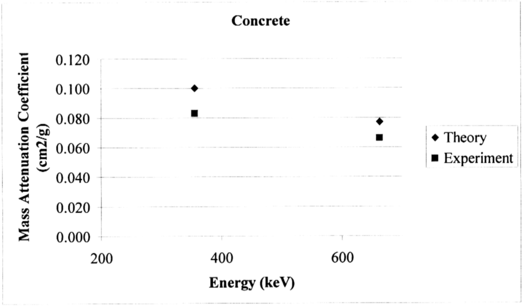

Fig. 16.Mass Attenuation Coefficient at 356keV and 662keV for Concrete

Calculations for Experiment and Derived Values of μ/ρ in Experiment 2

i) At 356keV

No	Material	Experiment	Derived Value
1	n-pentane C_5H_{12}	μ/ρ =(1/tρ) ln (I_o/ I) = (1/ 9x0.62) ln (327591/161363) = 0.109cm^2/g	μ/ρ = w_C(μ/ρ_C) + w_H(μ/ρ_H) = (0.832351)(0.100cm^2/g) + (0.167648)(0.197cm^2/g) = 0.116cm^2/g
2	Ethanol (C2H5OH)	μ/ρ = 1/tρ ln (I_o/ I) = (1/10.5x0.77) ln (415137/138979) = 0.135cm^2/g	μ/ρ = w_C(μ/ρ_C) + w_H(μ/ρ_H) + w_O(μ/ρ_O) = (0.526048)(0.100cm^2/g) + (0.132442)(0.197cm^2/g) + 0.341508)(0.100cm^2/g) = 0.113cm^2/g
3	Toluene (C6H5CH3)	μ/ρ = 1/tρ ln (I_o/ I) = (1/9x0.84) ln (299997/111662) = 0.112cm^2/g	μ/ρ = w_C(μ/ρ_C) + w_H(μ/ρ_H) = (0.912482)(0.100cm^2/g) + (0.087518)(0.197cm^2/g) = 0.108cm^2/g
4	Polyethylene	μ/ρ = 1/tρ ln (I_o/ I) = (1/5x0.90) ln (9715/6269) = 0.097cm^2/g	μ/ρ = w_C(μ/ρ_C) + w_H(μ/ρ_H) = (0.856277)(0.100cm^2/g) + (0.143723)(0.197cm^2/g) = 0.114cm^2/g
5	Olein 35%Palmitic Acid	μ/ρ = 1/tρ ln (I_o/ I) = (1/9x0.90) ln (9774/4349)	μ/ρ(Palmitic Acid) = w_C(μ/ρ_C) + w_H(μ/ρ_H) +

	50% Oleic Acid 15%Linoleic Acid	**= 0.100cm²/g**	**$w_O(\mu/\rho_O)$ = (0.751798)(0.100cm²/g) + (0.126186)(0.197cm²/g)+ (0.122016)(0.100cm²/g) = 0.039cm²/g** **μ/ρ(Oleic Acid) = $w_C(\mu/\rho_C) + w_H(\mu/\rho_H) + w_O(\mu/\rho_O)$ = (0.767585)(0.100cm²/g) + (0.121679)(0.197cm²/g)+ (0.110736)(0.100cm²/g) = 0.056cm²/g** **μ/ρ(Linoleic Acid) = $w_C(\mu/\rho_C) + w_H(\mu/\rho_H) + w_O(\mu/\rho_O)$ = (0.773119)(0.100cm²/g) + (0.115347)(0.197cm²/g)+ (0.111535)(0.100cm²/g) = 0.017cm²/g** **μ/ρ(Olein)= μ/ρ(Palmitic Acid) + μ/ρ(Oleic Acid) + μ/ρ(Linoleic Acid) = 0.112 cm²/g**

6	Distilled Water	**$\mu/\rho = 1/t\rho \ln (I_o/ I)$** **$= 1/(13x0.10) \ln (9851/3013)$** **$= 0.091 cm^2/g$**	**$\mu/\rho = w_H(\mu/\rho_H) + w_O(\mu/\rho_O)$** **= 0.197cm2/g)(0.114474) + (0.885526cm2/g)(0.100)** **$= 0.111 cm^2/g$**
7	Brick	**$\mu/\rho = 1/t\rho \ln (I_o/ I)$** **$= (1/7.1x1.52) \ln (9781/3939)$** **$= 0.084 cm^2/g$**	**Taken from M. N. Alam** **$\mu/\rho = 0.098\ cm^2/g$**
8	Cement	**$\mu/\rho = 1/t\rho \ln (I_o/ I)$** **$= (1/5x1.70) \ln (10383/4844)$** **$= 0.090 cm^2/g$**	**Taken from M. N. Alam** **$\mu/\rho = 0.093\ cm^2/g$**
9	Concrete	**$\mu/\rho = 1/t\rho \ln (I_o/ I)$** **$= (1/9x2.28) \ln (10372/1900)$** **$= 0.083 cm^2/g$**	**Taken from Hubbell** **$\mu/\rho = 0.100\ cm^2/g$**

ii) At 662keV

No	Material	Experiment	Derived Value
1	n-pentane C_5H_{12}	**μ/ρ =(1/tρ) ln (I_o/ I)** **= (1/ 9x0.62) ln (875443/438511)** **= 0.124cm^2/g**	**$\mu/\rho = w_C(\mu/\rho_C) + w_H(\mu/\rho_H)$** **= (0.832351)(0.077$cm^2$/g) + (0.167648)(0.153$cm^2$/g)** **= 0.090$cm^2$/g**
2	Ethanol (C2H5OH)	**μ/ρ = 1/tρ ln (I_o/ I)** **= (1/10.5x0.77) ln (873088/476785)** **= 0.105cm^2/g**	**$\mu/\rho = w_C(\mu/\rho_C) + w_H(\mu/\rho_H) + w_O(\mu/\rho_O)$** **= (0.526048)(0.077$cm^2$/g) + (0.132442)(0.153$cm^2$/g) + 0.341508)(0.077$cm^2$/g)** **= 0.087$cm^2$/g**
3	Toluene (C6H5CH3)	**μ/ρ = 1/tρ ln (I_o/ I)** **= (1/9x0.84) ln (45260/24167)** **= 0.100cm^2/g**	**$\mu/\rho = w_C(\mu/\rho_C) + w_H(\mu/\rho_H)$** **= (0.912482)(0.077$cm^2$/g) + (0.087518)(0.153$cm^2$/g)** **= 0.084$cm^2$/g**
4	Polyethylene	**μ/ρ = 1/tρ ln (I_o/ I)** **= (1/5x0.90) ln (44612/32296)** **= 0.0.072cm^2/g**	**$\mu/\rho = w_C(\mu/\rho_C) + w_H(\mu/\rho_H)$** **= (0.856277)(0.077$cm^2$/g) + (0.143723)(0.153$cm^2$/g)** **= 0.0.088$cm^2$/g**
5	Olein 35%Palmitic Acid	**μ/ρ = 1/tρ ln (I_o/ I)** **= (1/9x0.90) ln** [illegible]	**μ/ρ(Palmitic Acid)** **$= w_C(\mu/\rho_C) + w_H(\mu/\rho_H) +$**

	50% Oleic Acid 15%Linoleic Acid	**(44895/24665)** **= 0.074cm^2/g**	**$w_O(\mu/\rho_O)$** **= (0.751798)(0.077cm^2/g) + (0.126186)(0.153cm^2/g)+ (0.122016)(0.077cm^2/g)** **= 0.030cm^2/g** **μ/ρ(Oleic Acid)** **= $w_C(\mu/\rho_C) + w_H(\mu/\rho_H) + w_O(\mu/\rho_O)$** **= (0.767585)(0.077cm^2/g) + (0.121679)(0.153cm^2/g)+ (0.110736)(0.077cm^2/g)** **= 0.043cm^2/g** **μ/ρ(Linoleic Acid)** **= $w_C(\mu/\rho_C) + w_H(\mu/\rho_H) + w_O(\mu/\rho_O)$** **= (0.773119)(0.077cm^2/g) + (0.115347)(0.153cm^2/g)+ (0.111535)(0.077cm^2/g)** **= 0.013cm^2/g** **μ/ρ(Olein)= μ/ρ(Palmitic Acid) + μ/ρ(Oleic Acid) + μ/ρ(Linoleic Acid)** **= 0.086 cm^2/g**
6	Distilled Water	**$\mu/\rho = 1/t\rho \ln (I_o/ I)$**	**$\mu/\rho = w_H(\mu/\rho_H) + w_O(\mu/\rho_O)$**

		= 1/(13x0.10) ln (44712/18252) = 0.069cm²/g	**= (0.114474)(0.153 cm²/g) + (0.885526)(0.077 cm²/g) = 0.086cm²/g**
7	Brick	**μ/ρ = 1/tρ ln (I_o/ I) = (1/7.1x1.52) ln (45460/22397) = 0.065cm²/g**	**Taken from M. N. Alam μ/ρ = 0.074 cm²/g**
8	Cement	**μ/ρ = 1/tρ ln (I_o/ I) = (1/5x1.70) ln (44822/26723) = 0.061cm²/g**	**Taken from M. N. Alam μ/ρ = 0.071 cm²/g**
9	Concrete	**μ/ρ = 1/tρ ln (I_o/ I) = (1/9x2.28) ln (45206/11652) = 0.066cm²/g**	**Taken from Hubbell μ/ρ = 0.077 cm²/g**