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# Measurement of Linear and Mass Absorption Coefficients in some soil samples foruse in shields against Gamma-rays from different Nuclides.

**Abdu Hamoud Al-khawlany[1*], Khan A. R.[2] and Pathan J. M. [3]**

[1]Research Student Maulana Azad College, Dr. Babasaheb Ambedkar University, Aurangabad Maharashtra, India

[2]HOD, PG Department of Computer Science, Maulana Azad College, Aurangabad, Maharashtra India

[3]Assistance Professor, Department of Physics,Maulana Azad College, Aurangabad, Maharashtra India

## ABSTRACT

The liner and mass absorption coefficient of various soil samples (density ranges between 1.1308 and 1.3959gcm$^{-3}$) collected from four sites distributed in Aurangabad region of India have been determined for gamma ray sources $^{133}$Ba, $^{137}$Cs, $^{22}$Na, $^{60}$Co with gamma- ray energy of 0.360MeV, o.662MeV,1.28MeV and 1.33 MeV using gamma spectrometry NaI scintillator/PMT detector and MCA system. Attenuation coefficient is of interest to scientists and research in different areas of present day technology.Samples are prepared using standard techniques and the attenuation constants estimated are presented. It is found that the linear attenuation coefficient is in the range of 1.0520 to 1.0813, 1.0645 to 1.1603, 1.0387 to 1.1504 and 1.0336 to 1.1115 cm$^{-1}$ for $^{133}$Ba, $^{137}$Cs, $^{22}$Na and $^{60}$Co respectively. Also the mass attenuation coefficient is found in the range of 0.7687 to 0.9562, 0.7632 to 0.9648, 0.8130 to 0.9336 and 0.7794 to 0.9140 cm$^{2}$/gm for $^{133}$Ba, $^{137}$Cs, $^{22}$Na and $^{60}$Co respectively. The work presented is part of a survey recently conducted with larger database. In general, mass attenuation coefficients determined in this study can be used for determination of gamma emitters in any soil samples. This method is useful for the study of properties the soils in agriculture purposes.

## KEYWORDS-

Linear and mass attenuation coefficient, Gamma ray, Multichannel analyzer, Soil sample.

***Corresponding Author**

**Abdu Hamoud Al-khawlany**

Research Student Maulana Azad College, Dr. Babasaheb Ambedkar University, Aurangabad

Maharashtra, India-431001.

E mail –abdu.alkhawlany@gmail.comMob. No. - 9561496642

## INTRODUCTION

The gamma-ray attenuation technique is based on the interaction of radiation with matter. When the photons interact with certain material, they might be scattered or absorbed[1].The probability of interaction of this photon per unit of length of a given absorber characterizes its linear attenuation coefficient ($\mu$).However, $\mu$ depends on the material physical state and for this reason it is usually substituted by the mass attenuation coefficient ($\mu_m$ ),which is the $\mu$ divided by the density[2].Accurate measurements of $\mu$ are of interest in fundamental physics and applied fields such as radiation protection and dosimeter, nuclear diagnostics and medicine, soil science, and engineering. This physical property is used in many applications such as X-ray fluorescence, X-ray tomography, gamma-ray tomography, and gamma-ray attenuation.The study of attenuation coefficient of various materials has been an important part of research in Radiation Chemistry, Physics, agriculture and human health.

Aurangabad is an industrial hub with lot of industrial activity and monitoring of radioactivity and related aspects is one of the concerns. A property of soil like attenuation coefficient is widely used in industry, science and technology for a variety of applications[3,4]. The attenuation constant of a soil sample mainly depends on its constituents. Linear attenuation coefficient is one of the fundamental parameter that is important for characterization of the diffusion and penetration of gamma rays in a given medium[5]. Study of linear and mass attenuation of other materials of interest to biology and biotechnology such as proteins that is supposed to be most abundant macro molecule in living organisms has also been a subject of interest in this area[6,7]. Mass attenuation coefficients of gamma-rays in some compounds and mixtures of dosimetric and biological importance have been compiled in the energy range 1KeV to 20 MeV[8]. The prominent interactions between the photons and atoms are the photoelectric effect, the Compton scattering and the pair production processes in addition to other types of interactions in a wide range of energies, lot of work is documented along these lines[9,10]. The present work aims at the estimation of attenuation coefficient of selected soil samples from outskirts of Aurangabad, Maharashtra (India) as this is a historic region with a documented history and having monuments of world heritage for tens of centuries. Attenuation coefficient is a basic quantity used in calculation of penetration of radiation through materials. The linear attenuation coefficient, also called the narrow beam attenuation coefficient, is a quantity, which describes the extent to which the intensity of a beam is reduced as it passes through the material due to absorption in the sample.

Liner attenuation coefficient and mass absorption are two parameters widely used in the study of gamma rays. These parameters mainly depend on various factors including photon energy, nature of absorber and the medium through which radiation passes. The linear attenuation coefficient gives information about the effectiveness of a given material per unit thickness, in promoting photon interactions. The large value of attenuation coefficient is more likely to the given photon energy will interact in a given thickness of material. The magnitude of attenuation coefficient varies with material and its density, as we imply, with photon energy, while specific values of the attenuation coefficient will vary among materials forphotonsof specified energy. We studied the linear and mass attenuation coefficient in selected soil samples using gamma ray sources $^{133}Ba$, $^{137}Cs$, $^{22}Na$, $^{60}Co$ with gamma- ray energy of 360 KeV, 662KeV, 1280KeV and 1330KeV.

## EXPERIMENTAL SECTION

The soil samples were collected from four selected locations from outskirts of Aurangabad and standard initial preparations of the samples were implemented that includes drying, powdering and sieving. The location details of the four locations where from samples are drawn is shown in Fig. 1 and Table–1.


**Fig–1: The locations around Aurangabad where from samples are collected.**

**Table – 1: Location details showing latitude and longitude.**

| Spot. No | Sample Location | Latitude | Longitude |
|---|---|---|---|
| 1 | Harsul Tank | 19.926436 | 75.329620 |
| 2 | Ohar | 19.946103 | 75.313918 |
| 3 | Jatwada | 19.956592 | 75.285846 |
| 4 | Tanda Turn | 19.966837 | 75.273615 |

Gamma ray spectrometer with 2"x2"NaI(Tl) detector was used for measuring the intensity of gamma rays and the sources used were $^{133}$Ba , $^{137}$Cs, $^{22}$Na and $^{60}$Co with gamma-ray energy of 360KeV, 662 KeV, 1280KeV and 1330KeV respectively. It has been procured from the Bhabha Atomic Research Centre, Mumbai. It was well shielded by means of lead bricks. For the narrow beam setup, the gamma ray beam from the source was collimated by using a cylindrical lead block with a central hole ofdiameter 1cm. The transmitted beam was also collimated using a similar lead cylinder. The absorbers used were lead sheets of dimensions 5cm x 5cm and had thickness of 0.9 gm /cm$^2$. The detector was placed in a lead castle with proper shielding and arrangement was provided for placing the sample above the detector and at the top of the sample holder source with $\gamma$ ray source was mounted at a fixed place as shown in Fig. 2.

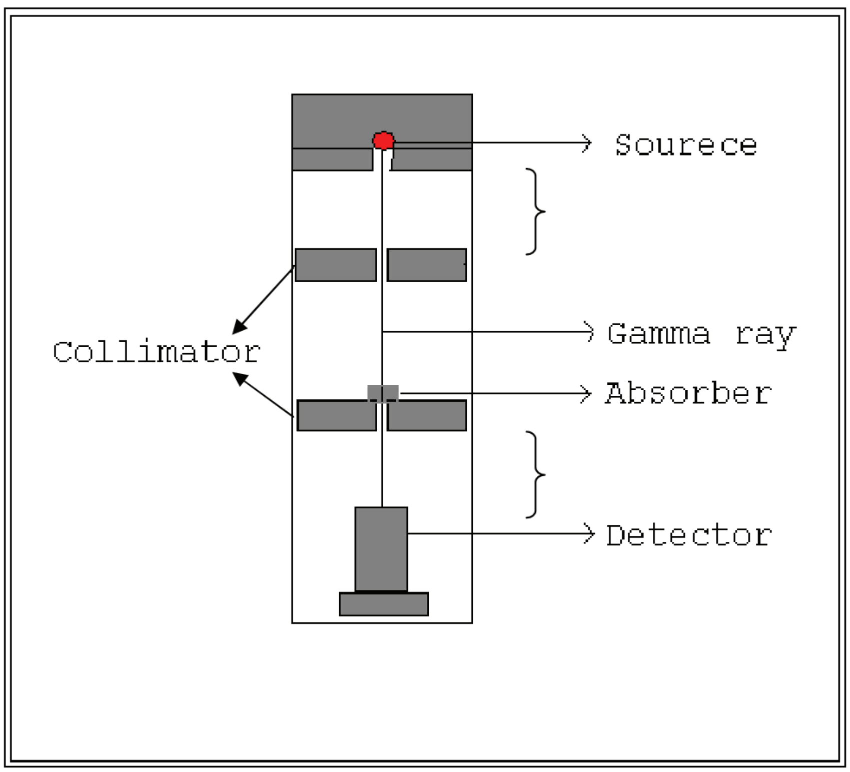



**Fig-2: Schematic diagram of Experimental apparatus used for measuring the mass attenuation coefficient.**

The multichannel analyzer used with the gamma-ray spectrometer had 8 K channels and the channel numbers were set corresponding to the γ ray photo-peak of radiation sources energy. The sample cell was a cylindrical container made of plastic and the powdered soil sample after due preparation was placed in the cell and the sample cell was placed in the sample holder provided in the detector housing. Diameter of the sample cell was 4.2 cm and height was 5.1 cm thus the available volume is 70.62 $cm^3$.

Once the gamma ray scintillation counter assembly is ready and set to appropriate channel background count was found taking several readings. The incident gamma ray intensity $I_o$ was determined using the standard source keeping the channel number at the photo-peak of the gamma radiation used, and no sample in the sample cell. For determination of gamma intensity I at different sample thickness the sample cell was filled with fixed amount of soil sample (say 1, 2 … cm thick layer) and kept between the source and detector in the sample holder present in the lead castle. Counting was done for suitable time interval and several trials were used and the average count was recorded for each sample thickness used. From the count representing the γ ray intensity, background count was subtracted to find I. A graph is plotted using $I_o$ (incident γ ray intensity) and I (transmitted γ ray intensity) versus the thickness for each sample as shown in some Figures 3–6.

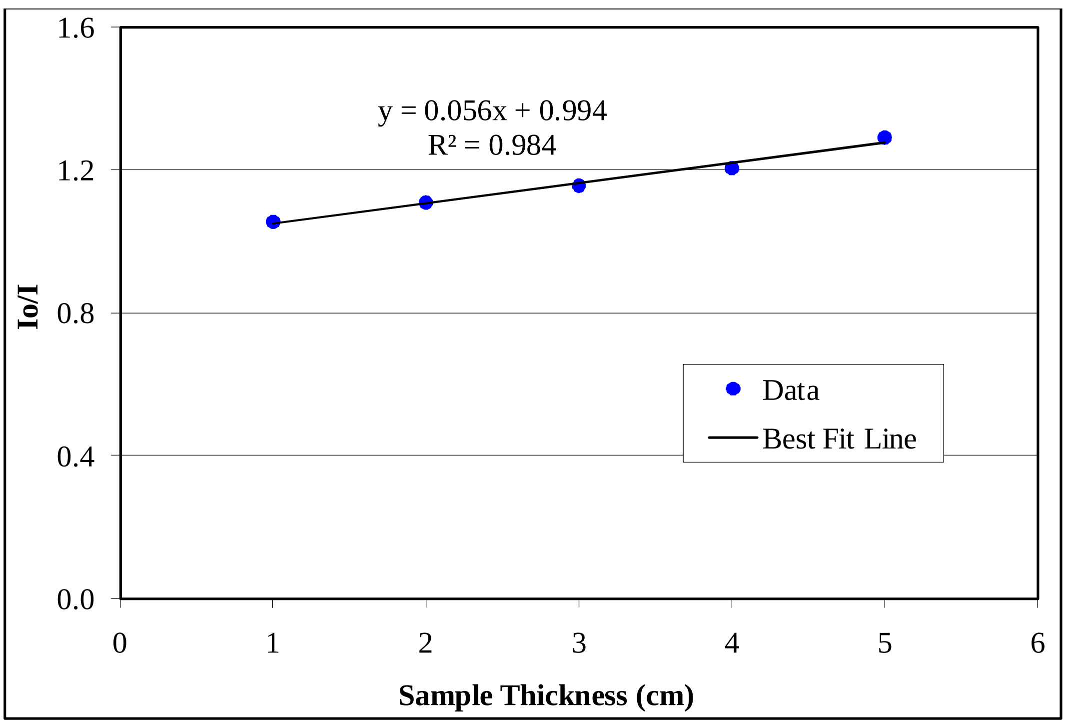
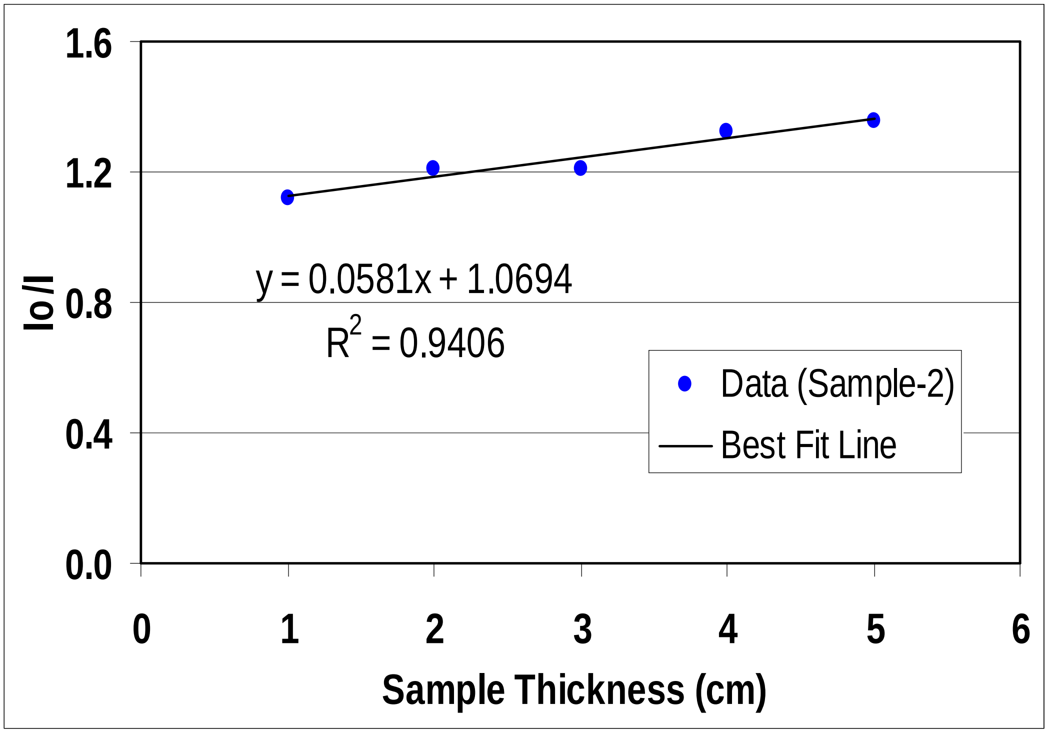
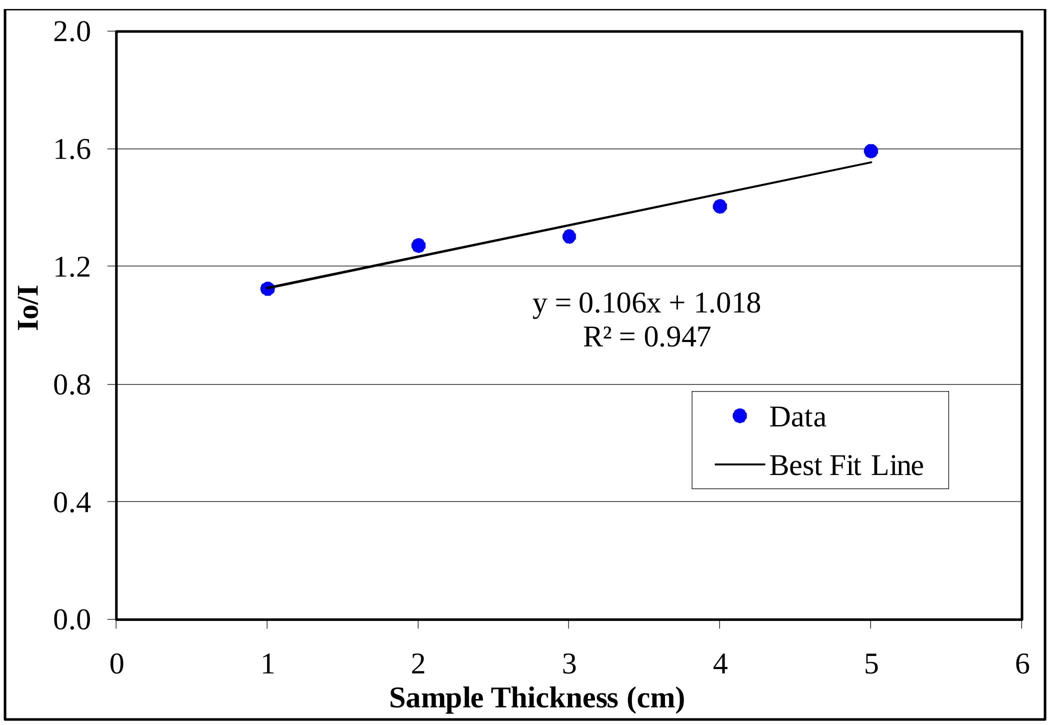


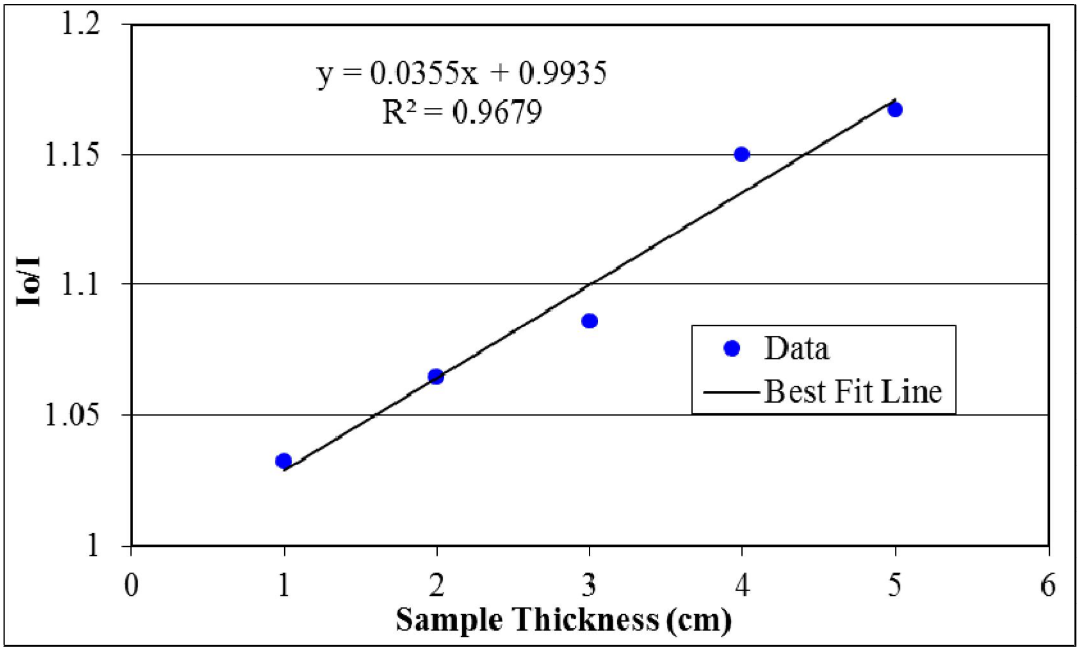

**Fig-3: The thickness versus Io/I for the soil sample–1 using Ba–133 of Energy 360keV**.




**Fig–4: The thickness versus Io/I for the soil sample–2 using Cs–137 of Energy 660keV.**




**Fig–5: The thickness versus Io/I for the soil sample–3 using Na–22 of Energy 1280keV.**




**Fig–6: The thickness versus Io/I for the soil sample–4 using Co–60 of Energy 1330keV.**

It is seen from all Figures above that all the points lay well along a straight line, the points plotted represent the actual data i.e. the value of $I_o/I$ corresponding to each thickness of the sample and the straight line joining to those points is the leas square fit straight line. The equation shown in the inset of the graphs is the equation to the fitting straight line and the coefficient of x is the slope (m) and the constant in the equation is the intercept on the y–axis (c), the values of m and c are used in calculation of the attenuation constant $\mu$ and $\mu_m$.

## RESULT AND DISCUSSION

The linear attenuation coefficient and mass attenuation coefficient for soil samples from four selected locations (S1 – S4) are shown in Tables 2–5.

**Table–2: Attenuation coefficient of soil samples using Ba–133 of Energy 360 keV:**

| **Sample. No** | **Soil density(ρ) gm/cc** | **Slope(m)** | **Intercept on Y axis(c)** | **Linear absorption Coefficientμ ($cm^{-1}$)** | **Mass attenuation Coefficient (μ/ρ) ($cm^2/g$)** |
|---|---|---|---|---|---|
| 1 | 1.3959 | 0.0566 | 0.9940 | 1.0730 | 0.7687 |
| 2 | 1.2662 | 0.0786 | 0.9525 | 1.0520 | 0.8308 |
| 3 | 1.2322 | 0.0580 | 0.9998 | 1.0713 | 0.8694 |
| 4 | 1.1308 | 0.2267 | 0.8249 | 1.0813 | 0.9562 |

**Table–3: Attenuation coefficient of soil samples using Cs–137 of Energy 662 keV:**

| Sample. No | Soil density($\rho$) gm/cc | Slope(m) | Intercept on Y-axis(c) | Linear absorption Coefficient$\mu$ ($cm^{-1}$) | Mass attenuation coefficient($\mu/\rho$)($cm^2/g$) |
|---|---|---|---|---|---|
| 1 | 1.3959 | 0.0894 | 0.9406 | 1.0654 | 0.7632 |
| 2 | 1.2662 | 0.0581 | 1.0694 | 1.1430 | 0.9027 |
| 3 | 1.2322 | 0.0939 | 1.0446 | 1.1603 | 0.9416 |
| 4 | 1.1308 | 0.2492 | 0.8092 | 1.0910 | 0.9648 |

**Table–4: Attenuation coefficient of soil samples using Na–22 of Energy 1280 keV:**

| Sample. No | Soil density($\rho$) gm/cc | Slope(m) | Intercepton Y-axis(c) | Linear absorption Coefficient$\mu$ ($cm^{-1}$) | Mass attenuation Coefficient($\mu/\rho$)($cm^2/g$) |
|---|---|---|---|---|---|
| 1 | 1.3959 | 0.1702 | 0.8973 | 1.1349 | 0.8130 |
| 2 | 1.2662 | 0.2004 | 0.7849 | 1.0387 | 0.8203 |
| 3 | 1.2322 | 0.1068 | 1.0188 | 1.1504 | 0.9336 |
| 4 | 1.1308 | 0.0361 | 0.9998 | 1.0406 | 0.9202 |

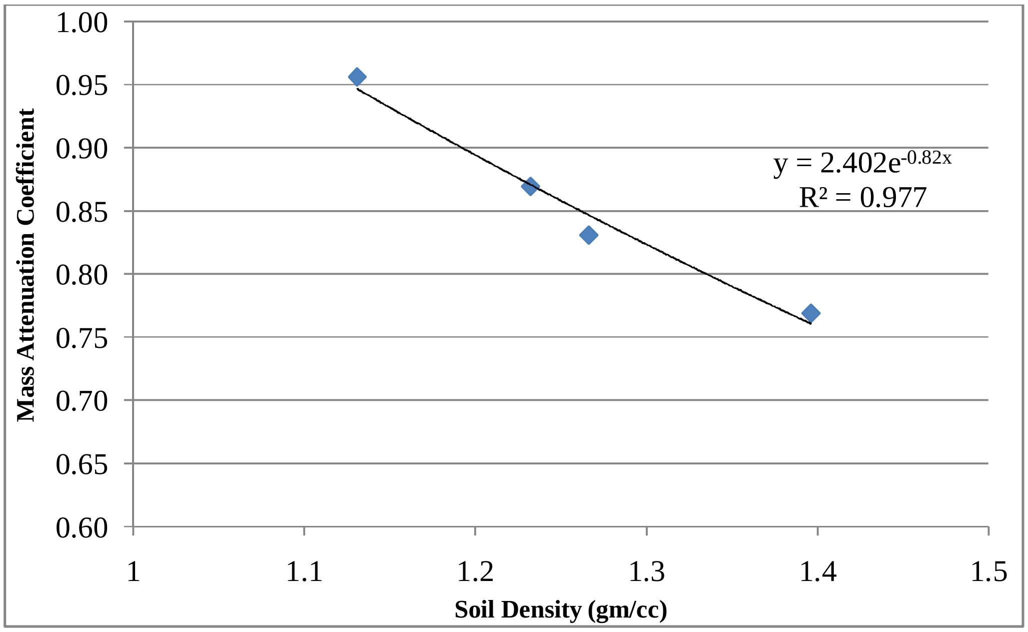
**Table–5: Attenuation coefficient of soil samples using Co–60 of Energy 1330 keV:**

| Sample. No | Soil density($\rho$) gm/cc | Slope(m) | Intercepton Y-axis(c) | Linear absorption Coefficient$\mu$ ($cm^{-1}$) | Mass attenuation Coefficient($\mu/\rho$)($cm^2/g$) |
|---|---|---|---|---|---|
| 1 | 1.3959 | 0.0713 | 0.9885 | 1.0880 | 0.7794 |
| 2 | 1.2662 | 0.0566 | 1.0070 | 1.0787 | 0.8519 |
| 3 | 1.2322 | 0.0524 | 1.0469 | 1.1115 | 0.9020 |
| 4 | 1.1308 | 0.0355 | 0.9935 | 1.0336 | 0.9140 |

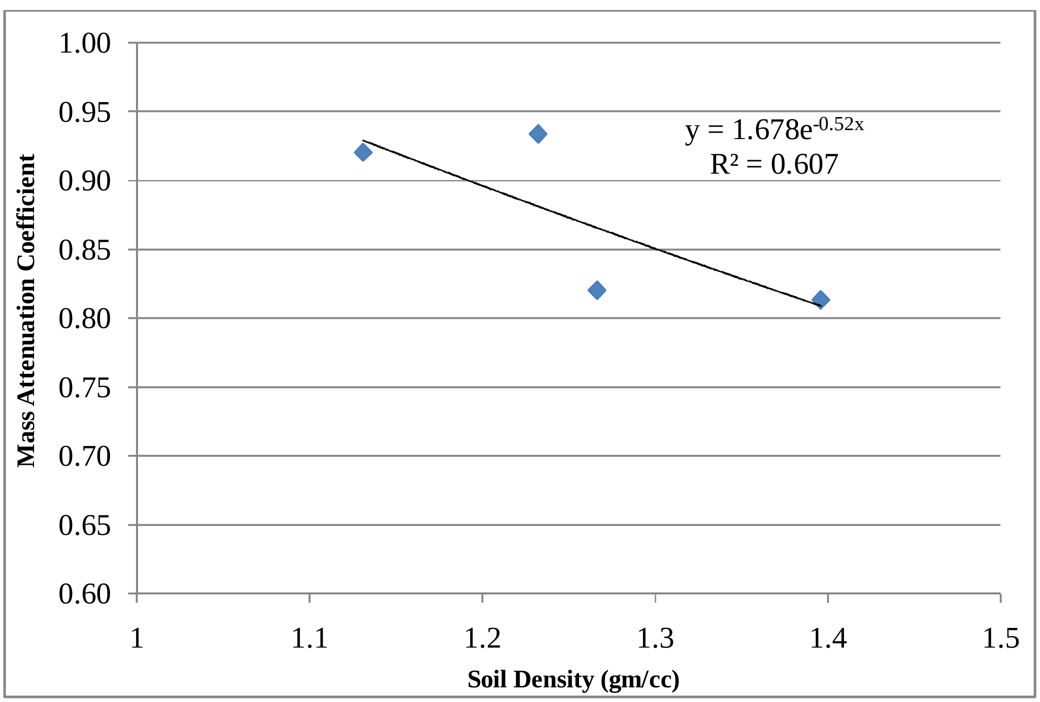
The linear and mass attenuation coefficients of soil samples collected from four selected locations from the outskirts of Aurangabad, Maharashtra, India, has been determined for gamma radiation from $^{133}$Ba,$^{137}$Cs, $^{22}$Na and $^{60}$Co with $\gamma$ ray energy of 360KeV,662 KeV,1280KeV and 1330KeV using gamma ray spectrometry.From the slope of the above Figures and according to the equation $\mu = m\rho + c$ it was found that the linear attenuation coefficient of soil samples and the ratio of the linear attenuation coefficient $\mu$ ($cm^{-1}$) to the density $\rho$ (gm $cm^{-3}$) is called the mass attenuation coefficient ($\mu/\rho$) and has the dimension of area per unit mass ($cm^2$/gm). In the present study, the mass attenuation coefficient has been calculated using the following relation,$\mu_m = \mu/\rho$

Where, $\rho$- is the density of the thin absorber and $\mu$-is the linear attenuation coefficient.It was observed that the experimental values of number of particles of radiation counted without absorber

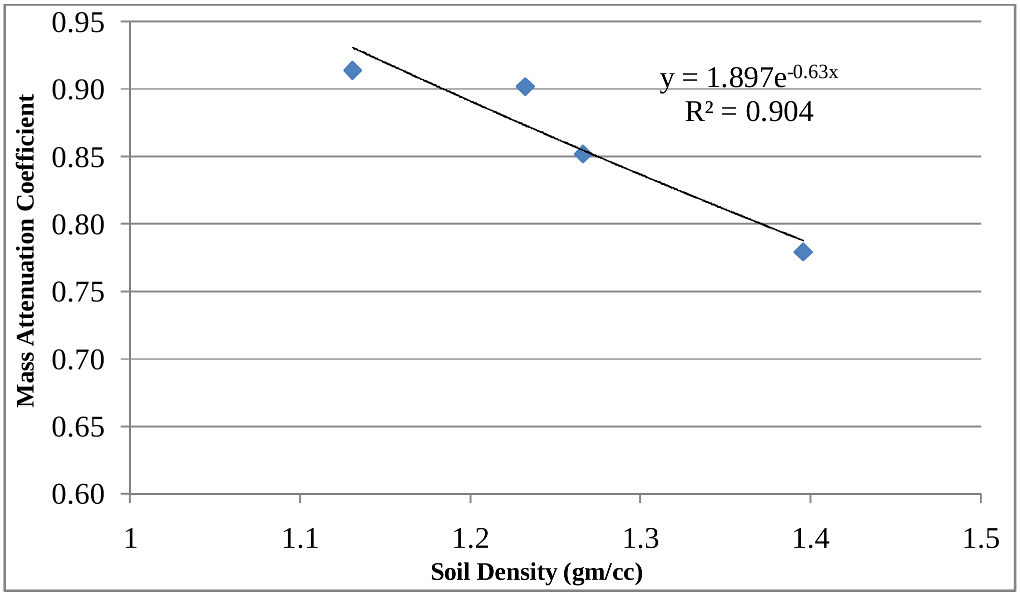
($I_0$) per number of particles of radiation counted with absorber (I) were linearly increased with increasing thickness. Also, as the density of soil increases, mass attenuation coefficient decreases exponentially as shown in the Figures.7–9. This confirms the contribution of photoelectric absorption, Compton scattering and pair production to the absorption of gamma rays by the soil samples.




**Fig–7: The mass attenuation coefficient versus the soil density using Ba–133 of Energy 360 keV.**




**Fig–8: The mass attenuation coefficient versus the soil density using Na–22 of Energy 1280 keV.**




**Fig–9: The mass attenuation coefficient versus the soil density using Co–60 of Energy 1330 keV.**

It is found that the linear attenuation coefficient is in the range of 1.0520 to 1.0813, 1.0645 to 1.1603, 1.0387 to 1.1504 and 1.0336 to 1.1115 $cm^{-1}$ for $^{133}Ba$, $^{137}Cs$, $^{22}Na$ and $^{60}Co$ respectively with γ ray energy of 360KeV, 662 KeV, 1280KeV and 1330KeV. Also the mass attenuation coefficient is found in the range of 0.7687 to 0.9562, 0.7632 to 0.9648, 0.8130 to 0.9336 and 0.7794 to 0.9140 $cm^2/gm$ for $^{133}Ba$, $^{137}Cs$, $^{22}Na$ and $^{60}Co$ respectively. The work presented is part of a survey recently conducted with larger database.

## CONCLUSION

The liner and mass attenuation coefficients values for various soil samples collected from different area of Aurangabad-Maharashtra, India were measured by using gamma-ray spectrometry NaI(Tl) detector for gamma radiation sources $^{133}Ba$,$^{137}Cs$, $^{22}Na$ and $^{60}Co$ with γ ray energy of 360KeV,662 KeV,1280KeV and 1330KeV. The mass attenuation coefficient values are useful for quantitative evaluation of interaction of gamma radiations with soil samples. It can be concluded from this work as density increases the mass attenuation coefficient of soil samples decreases .This gives the validity of exponential absorption law $I = I_0\ e^{-\mu x}$where, x is thickness of the soil sample. This method is useful for the study of properties the soils in agriculture purposes. The linear and mass attenuation coefficient depends on soil density, sample composition and photon energy E.

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