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GAMMA RAY ATTENUATION MEASUREMENTS IN CLAY BRICKS AT 1173 AND 1333 keV.

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ABSTRACT

The total mass attenuation coefficients are determined in clay bricks at photon energies 1173 and 1333 keV by transmission method in a good geometry set up. Gamma photons are emitted from source of ^{60}Co. The measurement has been performed using a gamma spectrometer which contain 2"×2" NaI(Tl) detector connected to 8K Multi-Channel Analyzer (MCA). The results are in good agreement with the theoretical calculations of X-COM and comparison with earlier experimental data is also made.

INTRODUCTION

With the increasing use of gamma ray emitting isotopes in industry, medicine, agriculture, etc., the study of attenuation coefficients of gamma radiation in materials has become an important subject (Hubbell, 1969). Large number of gamma ray attenuation measurements, compilations and calculations in elements have been published [Conner et al., (1970), Nageswara Rao et al., (1984), Polat et al, (2005), Veigele (1973), Storm and Isreal (1970), Hubbell (1971), Hubbell and Veigele (1976), Hubbell (1982) and Chantler (1995)].However the data on gamma ray attenuation coefficients in building materials seems to be very limited [Alam et al., (2001), Sailinas et al., (2006), Awadallah & Imran (2007), Medhat (2009) and Tuscharoen et al., (2013)].

Heavy elements such as lead (Pb) or Tungsten (W) are ideal material to be used in radiation shielding. On the other hand, they cannot be used directly in building construction due to durability and also economic problem.

Building walls are constructed mostly with clay bricks. The clay brick is one of the most important and also economic materials used in building construction, even though it is less effective shielding materials than lead. Alam et al., (2001) have measured the attenuation coefficients for soil samples and building materials in Bangladesh. Awadallah and Imran (2007) have measured gamma ray attenuation coefficients for lime stone, bricks and concrete in Jordan. Medhat (2009) has measured mass attenuation coefficients of various types of building materials in Egypt.

In view of the importance and applicability of the study of gamma ray mass attenuation coefficients in clay bricks, it is therefore considered worthwhile to undertake a systematic study of these materials in the energies 1173 &1333 keV.

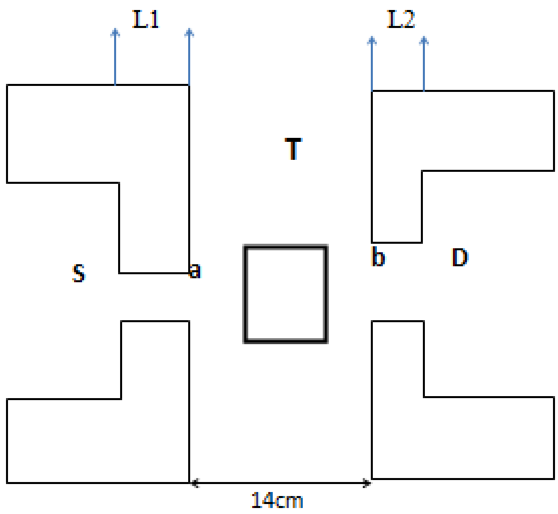
The present report deals with the gamma ray attenuation measurements in two types of bricks, one is prepared with the sea water and another with ground water in the energies 1173 &1333 keV. The results are compared with the theoretical calculation of X-Com [Burger & Hubbell (1987)] and they are in good agreement with each other. However, experimental data given by Medhat (2009) are found to be lower at energies1173 and 1333keV.

Experimental Details:

The mass attenuation coefficients were determined by performing transmission experiments in narrow beam geometry as shown in fig.1. A reasonable amount of lead shielding was used around the source and detector to prevent detection of scattered radiation from surrounding objects. For the low energy measurements the probability of coherent scattering interactions is relatively high and so very good collimation is required to reduce the contribution of Rayleigh scattered photons reaching the detector. Tight collimation reduces the absolute detection efficiency so that high activity sources must be employed that is around 10 mCi strength. At higher energies the probability of elastic scattering becomes much smaller and so scattered radiation is less important which reduces the need for such close collimation. Therefore, source strengths in the range 10-20 µCi were found to be adequate for the higher energy measurements. The radioactive sources of strength around 10µCi were procured from BRIT, Mumbai, India and details of the source are given in table-1.

Table-1: Radioactive isotope used in the present work.

Source	Energy (keV)	Half-Life (Years)
^{60}Co	1173 &1333	5.3



S= Source, D = Detector, T = Target,
Slit diameters: a = 4 mm, b= 10 mm.
Length of the collimator : L1=8cm,
L2=5cm

Fig.1. Schematic diagram of the experimental setup.

A 2"×2" NaI(Tl) crystal detector with the energy resolution 8% at 662 keV and 8K Multi-Channel Analyzer (MCA) plug-in-card were used with associated electronics to record the pulse-height spectra's of γ-radiations emitted by radioactive sources. The clay bricks were prepared with sea water and ground water separately.

The table-2 shows the average density and thickness of the clay bricks. The percentage of elemental compositions of the investigated clay bricks are given in table-3.

Table-2: Average density and thickness of clay bricks.

Clay Bricks	No. of Samples	Thickness (cm)	Density (g/cm^3)
Prepared with Sea Water	3	9	1.871±0.037
Prepared with Ground Water	3	10	1.412±0.028

Table-3: Percentage of elemental compositions of the investigated clay bricks.

Element	Clay brick prepared with sea water	Clay brick prepared with ground water
H	-	-
O	57.44	56.78
Na	3.30	-
Al	9.49	10.46
Si	25.21	26.67
K	4.56	1.75
Ca	-	0.70
Fe	-	3.65

For each sample, counts were taken in the following sequence, back ground, no sample, sample, sample, no sample, and so on [Conner et al., (1970)]. Different parts of the sample are exposed to the beam. The counting sequence was continued in most cases until counting statistics contributed less than 0.5% error.

The mass attenuation coefficients (cm^2/g) are obtained from the Beer – Lambert Law:

$$\frac{\mu}{\rho} = \frac{1}{t\rho}\, ln\left(\frac{Io}{I}\right)$$

where't'is the sample thickness (cm), and 'ρ' is material density (g/cm^3), I_o and I are the net counts under the photo peak, without sample and with sample, respectively. I_O and I were obtained for same counting time and experimental conditions. Interpolations from tabulated theoretical values of the mass attenuation coefficients for clay bricks were obtained using XCOM [Burger & Hubbell, (1987)].

The errors in the present investigations are due to (i) counting statistics, (ii) non uniformity of the sample, (iii) density measurements and (iv) scattered radiation reaching the detector within the accepted maximum angle of scattering. In the present investigation this angle was around 3º and the error due to this factor was about 0.3%. The counting statistics were such that the error was less than 0.5%. The fractional error arising due to non uniformity of the sample was estimated to be in the order of 0.2%. The error in the density measurement is less than 2%. Therefore, the overall error was estimated to be less than 2.25%.

3. Results and Discussion:

The mass attenuation coefficients μ/ρ for clay bricks were determined for energies of 1173 & 1333 keV in a good geometry setup. The measured mass attenuation coefficients are given in table-4 along with the theoretical mass attenuation coefficients calculated by the XCOM programme [Burger & Hubbell, (1987)]. One observes a good agreement between present experimental and theoretical values. The experimental values done by Medhat (2009) are also included in the table-4, but these values are lower than present experimental values.

In present measurements there is not much difference between mass attenuation coefficients for clay bricks prepared with sea water and ground water in the energies1173 &1333 keV. A user can go for either sea water or ground water for the preparation of clay bricks.

The figures in last column of table-4 correspond to the theoretical mass attenuation coefficient of water (XCOM). One observes that the mass attenuation coefficients of clay bricks (prepared by sea and ground water) are around 10% lower than the theoretical mass attenuation coefficient of water for those energies presented in table-4. However we infer here that the clay brick is attenuating less than the water for the incident radiation. In future, measures should be taken to prepare clay bricks in such a way that it attenuate maximum radiation incident on it.

Table-4: Mass attenuation coefficients in clay bricks.

Energy (keV)	Clay Bricks Prepared with Sea water	Clay Bricks prepared with Ground Water	Clay bricks (a)	H_2O (XCOM) (b)
1173	0.0576±0.0012 [0.0585]**(b)**	0.0577±0.0012 [0.0585]**(b)**	0.050	0.0653
1333	0.0540±0.0011 [0.0548]**(b)**	0.0555±0.0011 [0.0548] **(b)**	0.050	0.0612

(a): Medhat (2009), (b):Burger & Hubbell, (1987).

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