# A STUDY OF THE SHIELDING PROPERTIES OF POLY ETHYLENE GLYCOL-LEAD OXIDE COMPOSITE

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*SUMMARY: Finely ground powdered poly ethylene glycol and lead oxide were blended together by physical mixing. Discs of polymer-metal oxide composites were prepared using hydraulic press at 200 kN pressure. The gamma ray shielding properties of these materials were determined using a $^{60}Co$ $\gamma$ -ray source. The changes in attenuation coefficient ($\mu$), half value layer (HVL), tenth value layer (TVL) and relaxation length ($\lambda$) as a function of lead oxide concentration have been discussed. The results revealed that the shielding properties of poly ethylene glycol increased with the addition of lead oxide.*

*Key Words: Poly ethylene glycol, composites, radiation shields.*

## INTRODUCTION

Ionizing radiation is known to be harmful to human health and heredity (1). The attenuation of radiation can be achieved by either placing the source of radioactivity at a distance from the personnel and objects surrounding it or by constructing a shield effective enough to absorb most of the radiation before it penetrates the matter (2). Shielding is mostly required against X-rays and gamma rays, which are very penetrating (3-5). Various materials which are used for shielding include lead, copper, bismuth, steel, concretes and organic compounds such as oils, paraffins, plastics and rubber (6). The shields could take different forms like blocks, plates, rods, pellets etc., (7) which can act as fillers for ducts, trenches and penetrations. Shielding pellets are useful in areas that are irregular in shapes or inaccessible to personnel. These can be poured in to places or transported by air pressure or vacuum.

Gamma radiations are best absorbed by dense materials and heavy atoms such as lead and barium (8). Where there are no space limitations, lead oxide (PbO) finds widespread use in the form of glasses, while barium sulfate (baryte) is used as concrete aggregates (9). In addition to this, organic materials containing higher numbers of hydrogen atoms in a given volume such as poly ethylene etc., acts as an exceptional base material for neutron and gamma shielding (7). However these are much more easily damaged by ionizing radiation than ceramics and metals (6). The present study involving poly ethylene glycol (PEG) and PbO composites was carried out with the aim of exploring the possibility of using plastic and metal oxide composites for gamma radiation attenua-

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tion where ordinary blocks and rods can not be used e.g., in empty spaces between the walls, ducts, trenches etc.

## MATERIALS AND METHODS

**Materials**

Poly ethylene glycol (PEG); Fluka AG (Catalogue No 81260) having molecular weight 6000 was grounded to fine powder form in an agate mortar.

Lead oxide; Fluka AG 15338.

**Preparation of PEG-metal oxide composites**

Composites of PEG and lead oxide were prepared by physical mixing of calculated amounts of powders in a tumbler for 30 minutes. The metal oxide to PEG matrix ratios were fixed at 0.05, 0.1, 0.2 and 0.4. These composite powders were stored in a vacuum desiccator till further use.

**Preparation of discs**

Discs of PEG and PEG-PbO composite were prepared at 200 kN pressure on a hydraulic press at room temperature (25°C). These discs had a uniform diameter of 30 mm. The thickness of each disc was carefully measured using Mitutoyo's "Digimatic Micrometer MD-25M".

**Measurement of count rate**

The $^{60}$Co point source of strength 2μCi, prepared and supplied by Amersham International Ltd. U.K., was used in the present studies. It had a dose rate of 3.14 mR/hr at 4 mm. The discs of PEG and PEG-PbO composites were placed successively on the cobalt-60 source and the count rate recorded using a FAG FH 40 F4 Radiameter supplied by M/S FAG Kugelfisher Georg Schafer Germany, which utilizes a Geiger-Muller type detector for the measurement of radiation. The experimental set up has been described in the previous work (10).

## RESULTS AND DISCUSSION

The linear attenuation coefficient (μ), half value layer (HVL), tenth value layer (TVL) and relaxation length (λ) have been calculated from the count rates recorded for the discs of PEG and its composite with lead oxide. The results are presented in Table 1.

The linear attenuation coefficient was calculated from the plot of log of the count rate versus the shield thickness, (2,8) as shown in Figure 1. The equation for which can be written as :

$$\text{Log } I(X) = \text{Log } Io - 0.4343\ \mu X$$

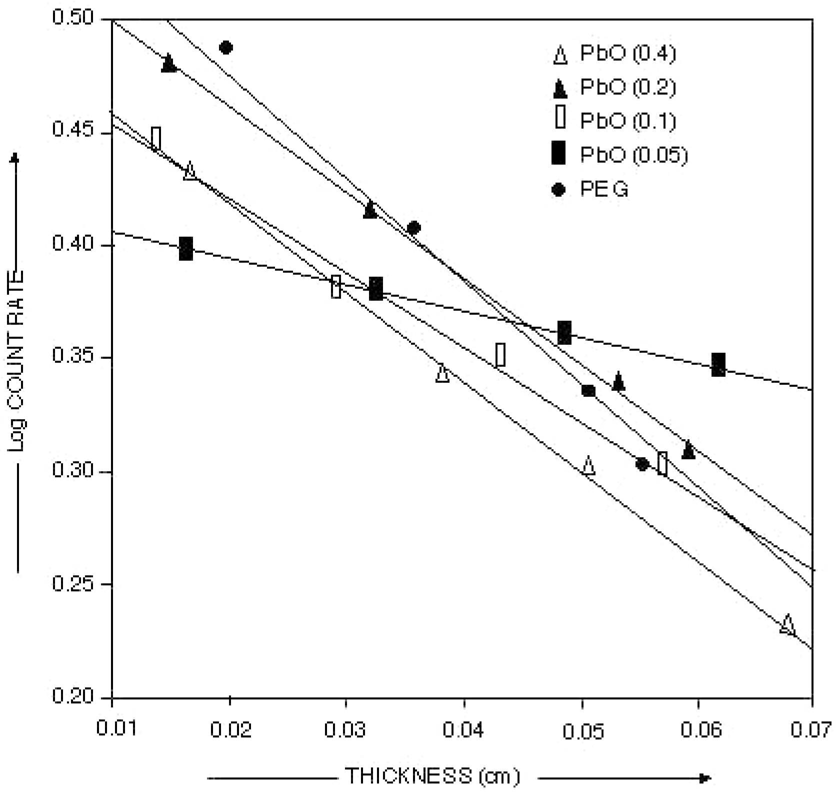
where I(X) = count rate for the radiation that has not been involved in any collision during passage through a shield of thickness X, Io = count rate in the absence of shielding material and μ = attenuation coefficient. The slope of the straight line is equal to -0.4343 μ. This equation is a good approximation for the intensity measurements in thin shields, because scattered photons have a minimum possibility of reaching the observation source. Hence, there is no need to incorporate build up factor.

The linear attenuation coefficient for PEG-6000 is 6.7 $cm^{-1}$ and reaches a maximum value of 9.5 $cm^{-1}$ for the composite containing 40% of lead oxide. An increase in shielding effects as depicted in Table 1 is evident for the composites. The improved shielding capability of PEG-PbO composite can be explained on the fact that lead is one of the best shielding materials [μ= 0.0703 $cm^{-1}$ for 1 Mev γ-rays] (11). Thus, the blending of PbO in the polymer matrix results in an increase

Table 1: Shielding properties of PEG composite of Pbo.

| | Ratio of lead oxide in the composite | | | | |
|---|---|---|---|---|---|
| Property | PEG | 0.05 | 0.1 | 0.2 | 0.4 |
| μ ($cm^{-1}$) | 6.7 | 6.4 | 7.5 | 8.6 | 9.5 |
| HVL (cm) | 0.103 | 0.11 | 0.09 | 0.08 | 0.07 |
| TVL (cm) | 0.344 | 0.36 | 0.31 | 0.26 | 0.24 |
| λ (cm) | 0.149 | 0.16 | 0.13 | 0.12 | 0.11 |
| ρ (g/ml) | 2.834 | 2.956 | 3.099 | 3.558 | 3.717 |

Figure 1: Determination of Attenuation Coefficients.




in the probability of interaction between the incident gamma radiation and the shield atoms. This point is further verified from the data (see Table 1) about densities (r) of these pellets. 2.834 g/cc true density of PEG is enhanced to 3.717 g/cc for the composite containing 40% PbO.

The half value layer (HVL) and tenth value layer (TVL) i.e., the thicknesses of additional layer of the shield required to reduce the detector response by a factor of 2 and 10 respectively (5), were also calculated (Table 1) from the results obtained for linear attenuation coefficients using the following relationships (4):

$$HVL = 0.693 / \mu$$

$$TVL = 2.303 / \mu$$

The results presented in Table 1 suggest that the composite containing 40% of PbO has greater shielding capability than those having lower concentrations of PbO. As the aim of the present work was to investigate the radiation shielding properties of PEG when mixed with heavy metal oxides, the composites containing ≥50% PbO were not studied. The same trend is observed for the relaxation length, (i.e., the distance from the source required to reduce the detector response by a factor of e).

It can be concluded that PEG-PbO composites can act as shields against low dose rates from gamma radiation sources. These may be moulded into different shapes thus making them useful fillers in empty spaces like ducts, trenches and penetrations.

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