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Radiation attenuation of boron doped clay for 662, 1173 and 1332 keV gamma rays

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Background: Radiation shielding properties is an important for a material wish can be used the photon attenuation coefficients of clay produced using different rate of boron have been measured for the purpose of radioactive waste disposal. *Materials and Methods:* The measurement has been performed using gamma spectrometer contains NaI (Tl) detector at the photon energies of 662, 1173 and 1332 keV. The mean free path and transmission rate of the samples were also obtained. *Results:* From the measurement of linear attenuation coefficients it was found that using boron in the clay increased the linear attenuation coefficients. *Conclusion:* It can be concluded from this work that the boron is effective to shield radiation and it can be used for storing of nuclear waste. **Iran. J. Radiat. Res., 2011; 9(1): 37-40**

Keywords: *Photon attenuation coefficient, radioactive waste, boron, clay, NaI (Tl).*

INTRODUCTION

The radioactive waste is hazardous for public and its disposal became one of the popular fields for scientists. Besides several options suggested, geological repository for disposal of radioactive waste is commonly used method for this purposes. On the other hand structure of this type repository is important as the long-lived and highly radiotoxic radioisotopes in the radioactive waste could become available. Although different types of materials can be used to shield those waste, the clay is proposed to be a candidate for this purpose (1). Clay is an interesting material and can be used in different purposes in different filed. Besides using in industry or medical field it is important to use clay in wall design and plastering. Thus plastering wall by clay could be an important method to dispose radioactive waste. Moreover the radiation shielding properties of the clay can be improved by adding boron into clay. Boron is an interesting element and can be used in a variety of different fields. With having about 60% of the world boron reserve, Turkey is important boron producer to the world. Besides using in different fields boronizing of the materials can provide extra benefit for different properties. This includes hardness of the materials (2) and also radiation shielding properties (3). As the radiation is used in a variety of different field, the radiation protection becomes important subject to be investigated in nuclear science. Having no mass and no charge, the shielding of gamma ray is more difficult than others as it can easily penetrate into matter. The radiation shielding of a material is expressed in term of linear attenuation coefficients which is defined as the probability of a radiation interacting with a material per unit path length. The magnitude of linear attenuation coefficients depends on the incident photon energy, the atomic number and the density of the shielding materials (4).

As the radiation shielding properties of materials is important, it has been studied widely for different materials including boron and boronising effect on the radiation shielding properties (5-11).

In this work the linear attenuation coefficients of clay in which boron has been used in different rate has been investigated to investigate boron effect.

MATERIALS AND METHODS

The five different types of clay samples in which different rate of boron used have

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been prepared to investigate their linear attenuation coefficients. The boron was used in the rate of 5%, 10%, 15%, 20% and 30% in clays which are tagged as BB1, BB2, BB3, BB4 and BB5 respectively.

The linear attenuation coefficient of clay samples were measured for gamma rays of energy 662, 1173 and 1332 keV which have been obtained from ^{137}Cs and ^{60}Co point sources respectively. The experiment has been performed using gamma ray spectrometer which consists of 3"×3" NaI(Tl) scintillation detector, amplifier and 16k multi channel analyzer (11). The schematic description of the experimental setup is shown in figure 1. For each sample, the gamma ray spectrum was recorded as a function of the thickness of the material and the area under the photo peak of the spectrum is used to evaluate the intensity N of the transmitted beam. Evaluating initial intensity N_o which is area under the photo peak obtained without any clay between detector and source, the linear attenuation coefficients (μ) can be extracted with the thicknesses of the material by the standard equation:

$$N = N_o e^{-\mu x}$$

Plotting Ln(N_0/N) versus x would give straight line and μ can be obtained from the value of the slope. A typical plot is shown in figure 2 (11).

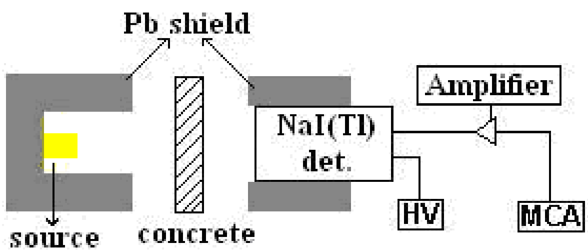

Figure 1. Schematic view of the experimental setup.

RESULTS AND DISCUSSION

The linear attenuation coefficients of clay containing different rate boron have been measured and the results were displayed in figure 3. It can be seen from this figure that the linear attenuation coefficients increased with the increasing boron rate in the clay samples. The correlation between the linear attenuation coefficients and the boron concentrations in the clay is used to confirm the linearity. As can be also seen from figure 3 that the correlation coefficients are R^2 = 0.90, 0.64 and 0.87 for 662, 1173 and 1332 keV photon energies, respectively. It is obvious that

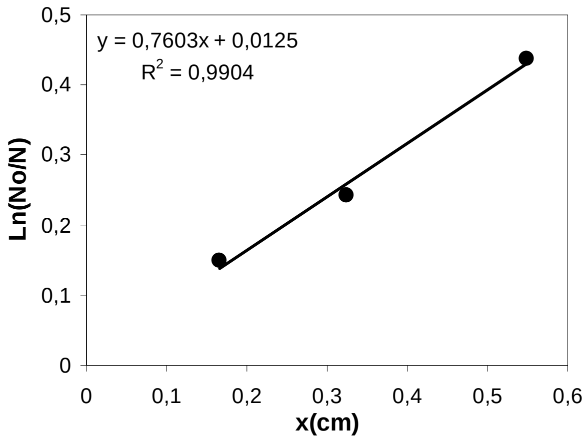

Figure 2. Linear attenuation coefficients from the measuring N and N_o as a function of thickness.

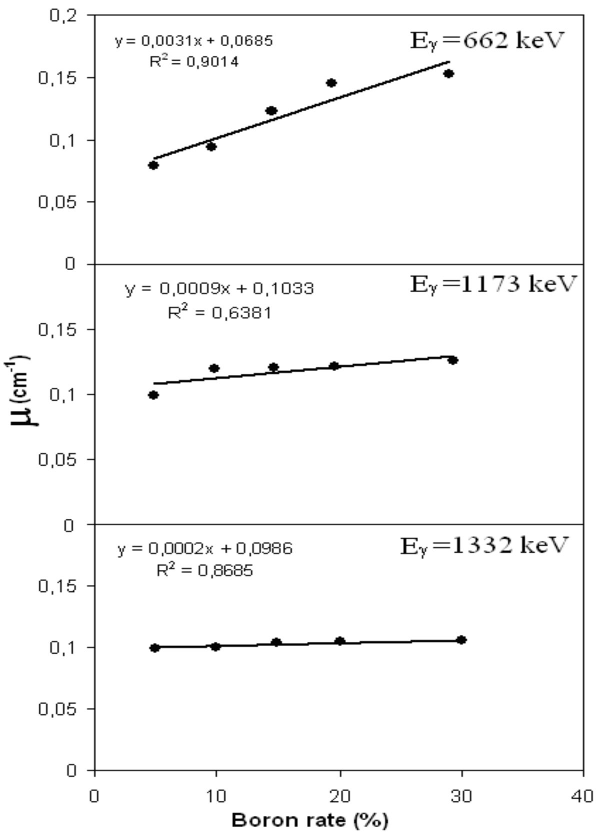

Figure 3. The measured linear attenuation coefficients of samples as a function of boron rate in clay.

boron is effective to prevent for radiation transmission. The variation of the linear attenuation coefficients with the photon energies have been displayed in figure 4 where it can be seen that it decreased with the increasing photon energies as seen in other measurements [10,11].

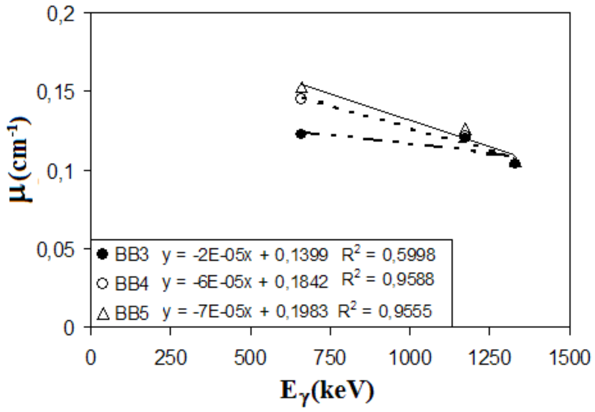

Figure 4. The measured linear attenuation coefficients of samples as a function of photon energies.

The mean free path (mfp) is defined as the average distance between two successive interactions of photons and it is given as:

$$mfp = \frac{1}{\mu}$$

It has been obtained from the measured linear attenuation coefficients at photon energies of 662, 1173 and 1332 keV and the results are displayed in figure 5 as a function of boron rate. It is clearly seen from this figure that the clay contains lower rate boron can lost its energy in short distance while higher rate of boron needs long distance. As the radiation shielding depends on material's density, it is important to plot linear attenuation coefficients against clay density. This is displayed in figure 6 where it is clearly seen that the linear attenuation coefficients increased with the increasing clay density.

The transmission rate through a material is also important parameter to test radiation shielding properties of this material. This is obtained and the results were displayed in figure 7. It is clearly seen that while smaller thickness of clay contains low rate boron is required to stop gamma-rays, larger thickness is required for lower boron rate added in clay to stop same energy photons. Other important point would be indicated in this figure that it is easier to stop lower energy photon than high energy photons. The effectiveness of γ-ray shielding can be defined in terms of the half value layer (HVL) or the tenth value layer (TVL) of a material. The HVL and TVL are the thicknesses of an absorber that will reduce the γ-radiation to half and to tenth of its intensity respectively. Those are obtained as:

$$x_{1/2} = \frac{In\ 2}{\mu},$$

$$x_{1/10} = \frac{In\ 10}{\mu}$$

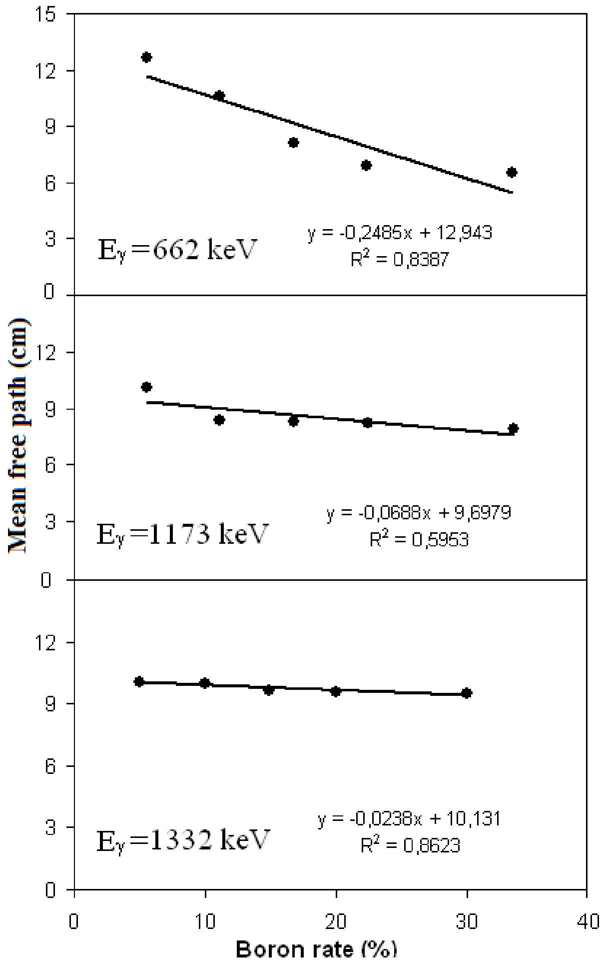

Figure 5. Variation of mean free path with the boron rate in clay.

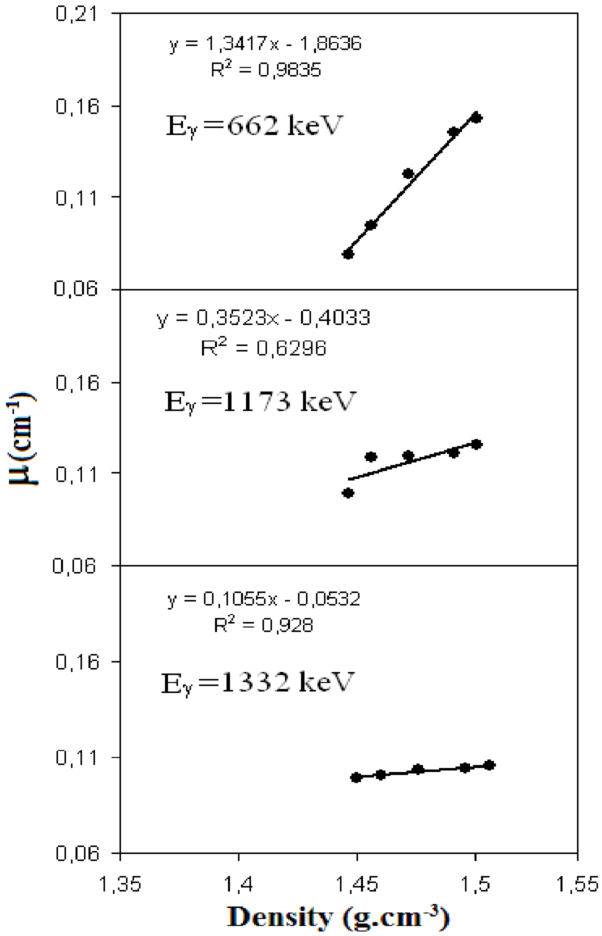

Figure 6. The linear attenuation coefficients of samples as a function of densities.

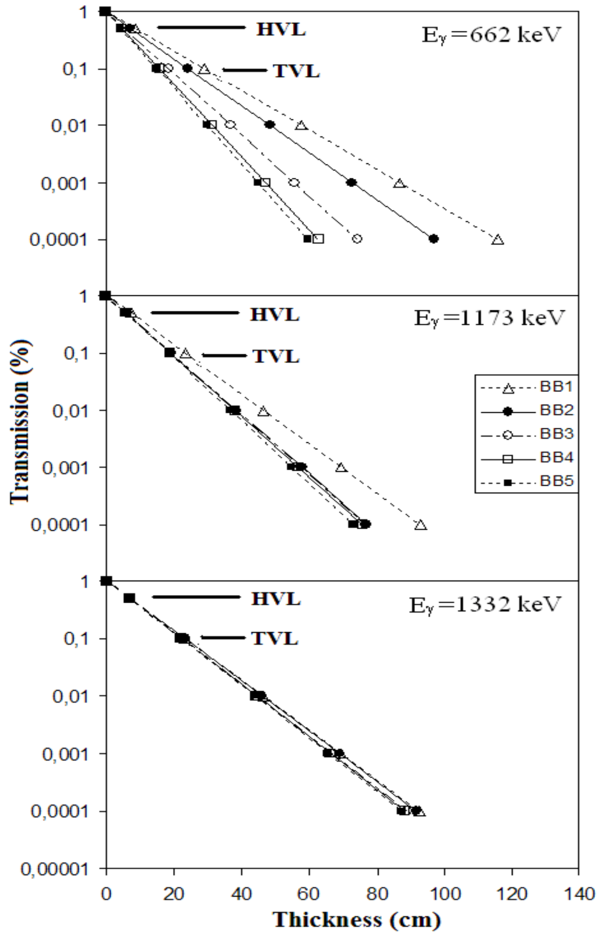

Figure 7. The transmission rate of clay as a function of thickness at different photon energies (The HVL and TVL have been indicated).

The HVL and TVL are indicated in figure 7 where it can be seen that the HVL and TVL are bigger for low boron rate when compared with the high boron rate in clay. It can be concluded from this work that the boron is effective to shield radiation.

REFERENCES

1. Gysemans M and Mors H (2000) Determination of ^{75}Se, ^{95}Zr, ^{237}Np and ^{241}Am activities in Boom Clay samples from laboratory migration experiments using g-ray spectrometry. *App Rad and Isot, 53: 209-213.*
2. Adnan C, Sahin O, Ucar N (2009) Mechanical Properties of Boronized AISI 316, AISI 1040, AISI 1045 and AISI 4140 Steels. *Acta Physica Polonica A, 115: 694-698.*
3. Akkurt I, Adnan C, Akyildirim H, Mavi B (2008) The effect of boronizing on the radiation shielding properties of Steel. *Z Naturfors A, 63:445-447.*
4. Woods J (1982) Computational Methods in Reactor Shielding. Pergamon, New York.
5. Icelli O, Erzeneoglu S, Boncukcuoglu R (2004) Experimental studies on measurements of mass attenuation coefficients of boric acid at different concentration. *Ann Nucl Energy, 31: 97–106.*
6. Bashter II (1997) Calculation of radiation attenuation coefficients for shielding concretes. *Ann Nucl Energy, 24:1389.*
7. El-Sayed A (2002) Calculation of the cross-sections for fast neutrons and gamma-rays in concrete shields. *Ann Nucl Energy, 29:1977.*
8. Akkurt I, Basyigit C, Kılıncarslan S, Mavi B, Akkurt A (2006) Radiation shielding of concretes containing different aggregates. *Cem and Conc Comp, 28:153–157.*
9. Kharita MH, Takeyeddin M, Alnassar M, Yousef S (2008) Development of special radiation shielding concretes using natural local materials and evaluation of their shielding characteristics *Prog in Nucl Energy, 50:33-36.*
10. Akkurt I, Mavi B, Akkurt A, Basyigit C, Kilincarslan S, Yalim HA (2005) Study on Z-dependence of partial and total mass attenuation coefficients. *J of Quant Spect and Rad Trans, 94:379-385.*
11. Akkurt I, Akyıldırım H, Mavi B, Kilincarslan S, Basyigit C (2010) Photon attenuation coefficients of concrete includes barite in different rate. *Ann Nucl Ener, 37:910-914.*