THE EFFECT OF PUMICE RATE ON THE γ-RAY ATTENUATION FOR CONCRETE UNDER NaOH MEDIA

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INTRODUCTION

As radioisotopes emitting γ radiations have many applications in a large technological area, it is unavoidable to be protected against the effects of this ionizing radiation. In many cases, the shielding is the main rule to be protected from radiation. It carried out a great interest to study on γ – ray shielding owing to the fact that photons are emitted after many of the nuclear disintegrations and have greater penetration distances inside materials [1]. Photons interact with matter via photoelectric absorption, scattering (Compton and Rayleigh) and pair production processes [2, 3]. Partial attenuation coefficient of each constituent is expressed as a function of atomic number Z, gamma energy E_γ and atomic density N as follows [4]:

$$\begin{aligned} \mu_{photo} &\propto (NZ^a / E_\gamma{}^b)[1 - f(Z)] \\ \mu_{scattering} &\propto NZf(E_\gamma) \\ \mu_{pair} &\propto NZ^2 f(E_\gamma, Z) \end{aligned} \qquad (1)$$

where, the values of a and b change between 3 and 5 depending on E_γ. The sum of partial coefficients is called the total linear attenuation coefficient μ (cm^{-1}), which is defined as the interaction probability of a photon in a medium per unit path length. When a photon beam with I_0 initial magnitude is attenuated by an x cm thick shield, the I inference beam intensity reduces exponentially by below formula, namely Beer-Lambert Law [5].

$$I = I_0 e^{-\mu x} \qquad (2)$$

For an effective γ – ray shielding, materials with high Z and density are required. Although heavy metals, for example lead, are commonly used in some special cases, a general application is limited by some economical and physical considerations [2]. Instead, different types of concretes containing various aggregates are used in building construction. Especially, with the advancing concrete researches and knowledge, various types of concretes are used not only in ordinary buildings but also in nuclear research facilities, accelerators, hospitals, etc. as shielding materials. So, it became an important field to investigate the γ attenuation coefficients of concretes besides their other properties such as durability, heat resistance or porosity and sufficient data can be achieved from the related literature [4-10].

As concrete is the most commonly used construction material, and therefore shielding material, it can be used in various and the same amount harsh environments. Producing of this concrete is important if the buildings are critical such as hospital or power station. Although radiation shielding properties of different types of concrete have been investigated [7-9], the effects of chemicals on these properties are open questions in the literature. In these crucial environments concrete can be under the attack of acids, bases or biological agents. These agents make chemical reactions with concrete in different ways [10]. The literature clearly reports that, these kinds of attacks cause deteriorations in micro and macro structure of concrete, change concrete parameters negatively and reduce concrete performance. On the other hand, economical loss due to this process is an important world wide problem for the experts to solve [10-13].

From this point of view, the necessity of determining the effects of chemical attacks on the gamma attenuation coefficient of concretes is obvious since it is already an indispensable parameter. However, the literature is not rich about the subject. This experimental study aims to contribute to the literature by presenting the variation of γ attenuation coefficients for concretes containing different rates of pumice under basic NaOH media.

MATERIALS AND METHODS

Three types of concretes were used in the experiments: N (ordinary), NP (ordinary+pumice) and P (pumice) whose pumice rates were %0, %50 and %100, respectively. The pumice was obtained from Gölcük region and the Portland cement (PC 42,5) from Göltaş plant in Isparta (30^0 20' - 31^0 33' East longitudes and 37^0 18' - 38^0 30' North latitudes).

The radiation absorption experiments were held by using a ^{137}Cs isotope emitting 662 keV photons. The detector system was composed of a 3''x3'' NaI(Tl) scintillator, a MCA (Multi Channel Analyser), an amplifier and a high voltage source. The signals were recorded via Genie2000 (v3.0) software. Before the experiments, the detector was calibrated for three different photon energies by using standard ^{137}Cs (662 keV) source. The attenuated and unattenuated gamma ray spectrum obtained from ^{137}Cs (662 keV) source has been displayed in Fig. 1. It can be seen from this figure that the gamma ray was attenuated through concrete sample.

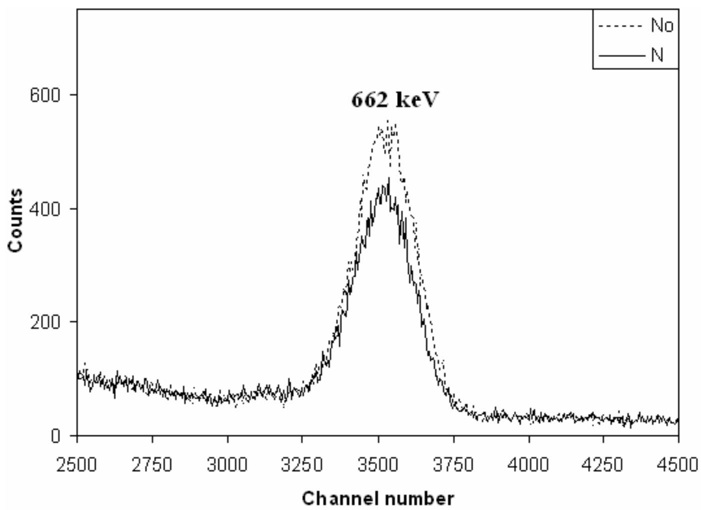

Figure 1. The attenuated and unattenuated gamma ray spectrum .

In order to investigate chemical effect on the gamma ray attenuation, 1 M NaOH (sodium hydroxide), a well known base, solution was prepared. Before placing the concretes in the solution, the linear attenuation coefficients of 5x5x2 cm^3 dimensional concrete slabs were measured. Then they were placed in separate beakers, each filled with the solution. The concrete samples were kept in NaOH media for a 6 months period. For determining the variation in the μ, each concrete slab was tested once a month. The concrete slabs were dried under low temperature (≈30°C) for a while to avoid the aqueous effect of the solution on the surface of concrete slab before measurements.

The total linear attenuation coefficients of concrete samples were calculated via

$$\mu = (1/x)\ln(I_0/I) \quad (3)$$

where the quantities are as mentioned for Eq. 2. The values of I_0 and I were measured in detector and recorded by Genie2000. For comparing experimental values, theoretical μ values were calculated by XCOM code, a web based code to determine the mass attenuation coefficients (μ/ρ, where ρ is the density) for elements, mixtures and compounds [14]. For this purpose, chemical percentages of concrete constituents were entered to the program and linear attenuation coefficients were obtained at 1 keV-100 GeV energy range.

RESULTS AND DISCUSSION

The effect of NaOH solution on total linear attenuation coefficients of N, NP and P type concretes, which contain different rates of pumice, were investigated at 662 keV gamma energy. Also, the comparison of experimental and theoretical data obtained by XCOM code was given. The results of the experimental study are given in the following figures (Fig. 2-3) for NP and P type concrete.

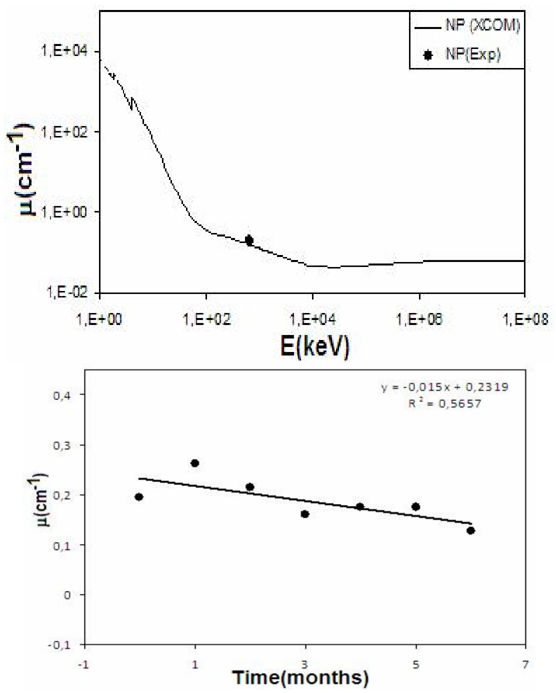

Figure 2. Comparison of experimental and theoretical data for NP type concrete (above) and variation of μ by time (below).

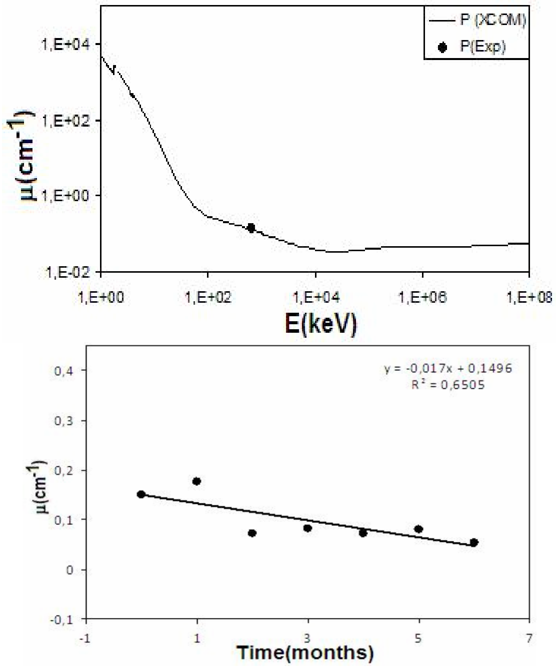

Figure 3. Comparison of experimental and theoretical data for P type concrete (above) and variation of μ by time (below).

From the figures, the good agreement between experimental and theoretical data of each concrete can clearly be seen. Besides this, theoretical data shows that, with increasing γ energy attenuation characteristics vary at different energy regions. This is more likely due to the different interaction processes of photons at different energy ranges.

The figures also present how the attenuation coefficients of each concrete type were affected by basic NaOH solution during 6 months period. The first of seven data points at each figure (Figs 2-3) corresponds to the data taken before placing the concrete in the solution. As seen from figures, the linear attenuation coefficient of each concrete decreases by time. This is more likely to that chemical effects damaged the concrete structure by forming additional micro cracks. In Fig.4 the μ has been displayed as a function of pumice rate used in concrete. It can be seen from this figure that the μ has decreased with the increasing pumice rate in concrete. This could be due to decreasing of concrete density using pumice in concrete.

It is clearly seen from this work that the μ decreased with the NaOH chemical media and also with the increasing pumice rate in concrete. This could also be the results of the porous structure of pumice, allowing chemicals deep inside and forming more cracks with respect to concretes containing less pumice.

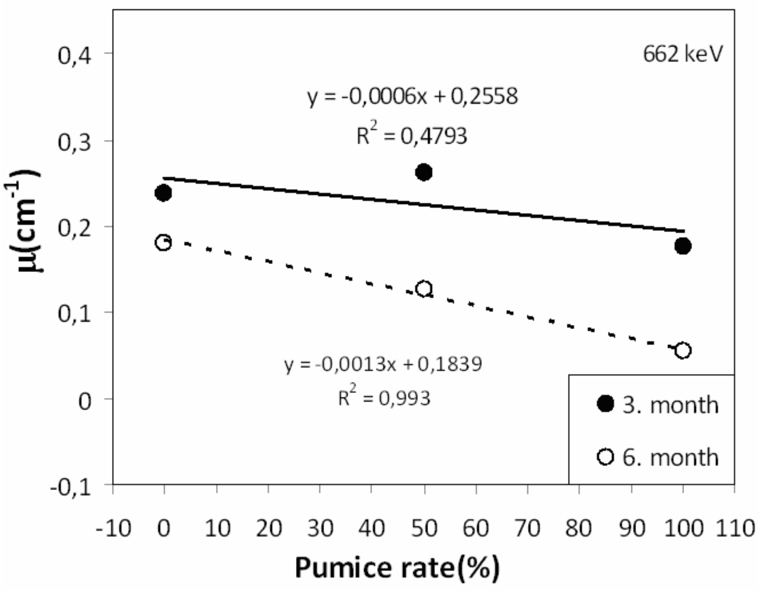

Figure 4. The variation of μ with the pumice rate used in concrete.

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