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Technical Note

Effect of physical, chemical and electro-kinetic properties of pumice samples on radiation shielding properties of pumice material

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ABSTRACT

Pumice has been used in cement, concrete, brick, and ceramic industries as an additive and aggregate material. In this study, some gamma-ray photon absorption parameters such as the total mass attenuation coefficients, effective atomic number and electronic density have been investigated for six different pumice samples. Numerous values of energy related parameters from low energy (1 keV) to high energy (100 MeV) were calculated using WinXCom programme. The relationship between radiation shielding properties of the pumice samples and their physical, chemical and electro-kinetic properties was evaluated using simple regression analysis. Simple regression analysis indicated a strong correlation between photon energy absorption parameters and density and SiO_2, Fe_2O_3, CaO, MgO, TiO_2 content of pumice samples in this study. It is found that photon energy absorption parameters are not related to electro-kinetic properties of pumice samples.

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1. Introduction

Pumice is a light-colored natural sponge-like material of volcanic origin mostly used in construction industry as supplementary cementations material or aggregate for producing light weight concrete. Pumice is also being used as a ceramic raw material and as an abrasive, especially in polishes, pencil erasers, cosmetic exfoliates, and for the production of stone-washed jeans. Because of being a porous material; pumice is widely used for absorption purposes (Anagnostakis et al., 2002; Stoulos et al., 2003; Turhan and Gündüz, 2008; Turhan, 2009). The radiation shielding of a material can be expressed with the total mass attenuation coefficients, effective atomic number and electronic density. Although there are some research about the use of pumice as building material for radiation shielding (Turhan et al., 2007; Akkurt et al., 2009), this is the first work performed to determine photon energy absorption parameters on different pumice samples and investigate the relationship between the physical and chemical properties of pumice samples and photon energy absorption parameters in our knowledge. With this study, the potential of pumice materials in radiation shielding as well as the relationship between physical, chemical and electro-kinetic properties and absorption parameters of pumice samples is identified.

Total mass attenuation coefficient, total effective atomic number and number of electron values of six different natural pumice samples at various photon energies were evaluated using the methodology presented in this article. In this study, physical, chemical and electro-kinetic properties of pumice samples were evaluated and the quantities such as the linear and the total mass attenuation coefficients (μ_t), the effective molecular ($\sigma_{t,m}$) atomic ($\sigma_{t,a}$) and electronic cross-sections ($\sigma_{t,e}$), the total effective atomic number (Z_{eff}) and the number of electrons per unit mass (N_E) of pumice samples were theoretically calculated using the results of X-ray fluorescence (XRF) of pumice samples.

2. Experimental tests

2.1. Physical, chemical and electro-kinetic properties of pumice samples

In the present study, six different pumice samples (P1–P6), were obtained from volcano-clastic formations located in Van (Erciş, Kocapınar), Ağrı (Patnos, Diyadin) and Bitlis (Adilcevaz) province in the Eastern Turkey.

Physical properties such as fineness, specific surface area and density of pumice samples were evaluated using standard tests as specified in (TS-25, 2008) and given in Table 1 (Tapan et al., 2013). Surface areas and porosity values of acidic pumices are given in Table 2 (Tapan et al., 2013).

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Table 1
Physical properties of pumice samples.

Pumice sample	Particle size			Blaine (cm^2/g)	Density (g/cm^3)
	>45 μm (%)	>90 μm (%)	>200 μm (%)		
P1	5.5	1.0	0.4	5261	2.84
P2	4.6	1.0	0.2	5355	2.55
P3	4.9	0.7	0.4	5367	2.50
P4	4.7	1.1	0.4	5110	2.56
P5	12.0	1.9	0.3	5270	2.63
P6	6.8	1.0	0.3	5787	2.68

Table 2
Surface area and porosity values of the pumice samples.

Pumice samples	S_{BET} (m^2/g)	S_{ext} (m^2/g)	S_{mic} (m^2/g)	S_{mezo} (m^2/g)	V_t (cm^3/g)	V_{mic} (cm^3/g)	V_{meso} (cm^3/g)	D_p (nm)
P1	7.53	4.68	2.86	4.67	0.01	0.002	0.008	5.76
P2	5.26	2.54	2.73	2.53	0.01	0.002	0.008	7.3
P3	3.9	1.86	2.04	1.86	0.005	0.0006	0.0044	5.91
P4	2.41	0.58	1.84	0.57	0.0005	0.0001	0.0004	7.43
P5	1.68	0.05	1.64	0.04	0.0016	0.0009	0.0007	10.73
P6	2.45	0.34	2.11	0.34	0.005	0.001	0.004	8.20

D_p: 4 V/A by BET. $S_{ext} = S_{meso} + S_{macro}$.

Chemical analysis of pumice samples was carried out using X-ray fluorescence (XRF Spectro IQ) as given in Table 3 (Tapan et al., 2013). The crystal structure of the pumice samples were checked by X-ray Powder Diffraction. By comparing the positions of the diffraction peaks against that of the ICDD cards (International Centre for Diffraction Data), the target material was identified.

Without performing XRD analysis of the pumice samples, various photon absorption parameters cannot be determined. It is based on computations utilizing NIST cross section/attenuation data for photon-atom interaction processes that are available to all on the WinXCom/XCOM and from them deriving the secondary quantities effective atomic number and electron density for these materials. But these computations are not present for composite of unknown content. This state is real motivation to resort to the description of various photon absorption parameters.

The XRD patterns of all pumice samples are given in Fig. 1 (Tapan et al., 2013). By comparing the positions of the diffraction peaks against that of the ICDD cards and also literature values it was found that P1, P2, P3 and P4 samples do not have a crystalline structure and very broad reflection (peak) between 20° and 30° (2θ) which confirmed the presence of amorphous nature of these materials. On the other hand, the little crystalline mineral phases were observed in P5 and P6 samples. They were identified as Anorthite (JCPDS Card File No: 73-1435), Hornblende (JCPDS Card File No: 71-1062), Orthoclase (JCPDS Card File No: 76-0823), Biotite (JCPDS Card File No: 83-1366) and crystalline quartz (JCPDS Card File No: 76-0823). Briefly, XRD patterns of all of the pumice samples show that main structure is amorphous (Tapan et al., 2013).

Table 3
Concentration of compounds in Pumice group.

Compounds	P1	P2	P3	P4	P5	P6
SiO_2	71.813	77.653	76.781	75.812	76.7659	72.245
Al_2O_3	12.737	14.019	13.979	14.074	13.926	15.682
Fe_2O_3	5.525	1.663	1.964	1.955	2.485	3.921
CaO	2.019	0.521	0.491	0.521	1.032	1.654
MgO	0.643	0.000	0.000	0.000	0.010	0.000
TiO_2	0.502	0.100	0.120	0.110	0.170	0.341
Na_2O	2.612	1.243	1.142	2.195	1.423	1.574
K_2O	4.038	4.720	5.451	5.263	4.158	4.442
P_2O_5	0.030	0.040	0.030	0.030	0.020	0.120
Cl	0.080	0.040	0.040	0.040	0.010	0.020

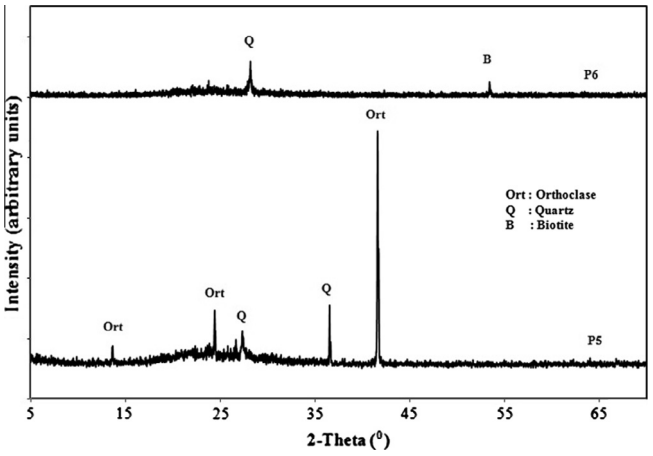

Fig. 1. XRD patterns of pumice samples.

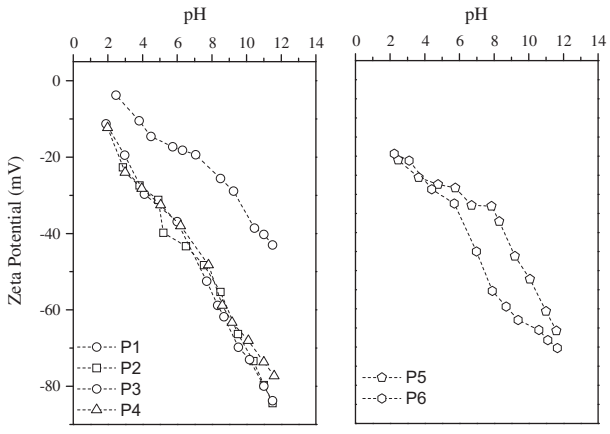

Fig. 2. Zeta potential of pumice samples.

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