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Backscattering factor measurements of gamma rays of the different thickness of pure concrete

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ABSTRACT

Backscattering peak is one of the main features of the pulse height spectrum from a gamma ray detector. This arises mainly from materials outside like source baking, photomultiplier tube housing, shielding etc. The effect of source backing on the relative importance of the backscattered peak for gamma ray using a NaI (Tl) scintillation detector is measured. Gamma energies in the range from 0.088 MeV to 1.253 MeV are used. Backscattering factor (F_b) measurements have been carried out ($2 > Fb \geq 1$) of various pure concrete thickness from 2 cm to 30 cm.

1. Introduction

The gamma-backscattering peak is useful technique in determining density, thickness, and composition of backscattering material. The distribution of gamma rays from a point source is modified when the source is placed on semi-infinite and homogeneous medium. Accurate knowledge of the angular distribution of the number and energy albedos of the backscatter photons from different materials is important in desiging reactor shields and other shield calculation in nuclear installations. The backscattering of gamma rays from shield materials has been the subject of extensive experimental investigation by many studies (Biswas, Sinha, & Roy, 1979, 1980; Fujita, Kobayashi, & Hyodo, 1964; Pozdneyev, 1967; Steyn & Andrews, 1967).

Most of authors used a conventional NaI (Tl) scintillation counter coupled with a multichannel analyzer. The backscattered gamma rays have a continuous energy distribution and in most of the measurements, it is necessary to apply corrections due to the variation of the detecting efficiency with photon energy. The information regarding thickness and density of material can be obtained by gamma ray back scattering technique. This technique is based on detecting gamma backscattering from the interior of an object surface when gamma made to strike on the target material. The gamma backscattering method is very useful for estimating the thickness of hot objects, unclean and corroded surfaces when ultrasonic method fail to use. The gamma backscattering technique is useful in investigating historical objects (Silva, Lopes, de Jesus, 1999). Water is a key reactant in cement hydration. The incorporation of water into a substance is called

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as hydration. Water and cement initially form a cement paste that begins to react and harden (concrete). This paste binds the aggregate particles through the chemical process of hydration. In the hydration of cement, chemical changes occur slowly, eventually creating new crystalline products, heat evolution, and other measurable signs. The properties of this hardened cement, called binder, control the properties of the concrete. It is the inclusion of water (hydration) into the product that causes concrete to set, stiffen, and become hard. The strength of the concrete is related to the water to cement mass ratio and the curing conditions. Most concrete is made with water to cement mass ratio ranging from 0.35 to 0.6. Concrete is frequently used as a gamma ray shield because of its low cost. It is also strong, durable and easy to handle. Concrete has wide applications as a radiation shielding material in almost all nuclear installations, when concrete is stratified with higher Z. It acquires a better shielding property (Biswas et al., 1979). This work was carried out using concrete to study the saturation thickness.

2. Materials and methods

This paper presents the measurement of source backscattering factor at distance 5 cm between source and detector of different thickness of pure concrete (2 cm–30 cm) using eight standard radioactive sources (Table 1). The arrangement and instruments used in this study were reported elsewhere (Almayahi, 2003).

A source backscattering factor (F_b) is defined by Tsoulfanidis (1983), Almayahi (2003)

$$F_b = \frac{N_b}{Ni} \times 100\% \quad (1)$$

N_b = Number of photons counted with source backing.
N_i = Number of photons counted without source backing.

The scattered concrete (10 cm × 10 cm) with different slabs thickness (2 cm–30 cm) is used. Ordinary Portland cement brought from Kufa cement plant was used throughout the present study. This cement conforms to the Iraqi standard specification 1984. The chemical composition and specification of this cement are presented in Table 2. Gamma spectroscopic measurement was performed using a NaI (Tl) detector (Spectrum Techniques, INC., USA) with diameter 1.76″ and thickness 1.56″. The system has efficiency of about 50% and an energy resolution (FWHM) of about 7.5% at energy at 662 keV (^{137}Cs) which is considered adequate to distinguish the gamma ray energies of interest in this study. A lead shielding in 5 cm thickness surrounds the detector. A constant counting time for calibration sources (^{60}Co, ^{137}Cs, ^{22}Na, ^{241}Am, and ^{226}Ra) from the International Atomic Energy Agency, for the background spectrum, and the distance between the source and the crystal face of 5 cm was adopted. Instrument calibration was done at multiple energies from 25 keV to 2500 keV (Almayahi, 2014).

Table 2 – Chemical composition and specification of Portland cement.

Chemical compound	Wight %	Specification (IOS)
CaO	61.94	… …
SiO_2	20.80	… …
Al_2O_3	5.52	… …
Fe_2O_3	4.00	… …
Mgo	1.85	≤5.00
SO_3	2.5	≤2.80
L.O.I	3.3	≤4.00
Free lime	0.97	… …
I.R	0.53	≤1.50
L.S.F	0.88	0.66–1.02
C_3A	10.95	… …

3. Results and discussion

The backscattering factor obtained for concrete with gamma ray energy rate 0.088, 0.129, 0.28, 0.662, 0.76, 0.835, 0.893 and 1.253 MeV. The backscattering factor increases with increasing scatterer thickness and becomes almost constant at some thickness called saturation thickness. A typical graph of $\mathbf{F_b}$ with scatter thickness is shows in Fig. 1a, b, c, d, where $\mathbf{2 < F_b \geq 1}$. From the Fig. 1a, b, c, d it was found that the count rate of gamma photons scattered from pure concrete increases up to steeply maximum value and then it slowly increases up to saturation value. Table 3 shows the extrapolated value of backscattering factor for concrete at different Gamma ray energies. The backscattering factor is important and depends on two variables which are thickness of the backing material and photon energy. As thickness→0, then F_b→1, this

Table 1 – Gamma ray sources used in this study.

Isotope	Activity (μCi)	Manufacture date	Working date	Half life	Correct activity (μCi)	Energy rate (MeV)
Barium-133	1	Jan 2009	April 2009	10.8 years	0.984	0.280
Cadmium-109	1	Feb 2009	April 2009	462 days	0.913	0.088
Cesium-137	1	Jan 2009	April 2009	30.2 years	0.994	0.662
Cobalt-57	1	Jan 2009	April 2009	272 days	0.795	0.129
Cobalt-60	1	Jan 2009	April 2009	5.3 years	0.967	1.253
Manganese-54	1	Jan 2009	April 2009	313 days	0.819	0.835
Sodium-22	1	Feb 2009	April 2009	2.6 years	0.956	0.893
Mixture Cs-137& Zn-65	0.5,1	Feb 2009	April 2009	30.2 years, 244 days	0.498,0.840	0.760