Comparison of Radiation Interaction of Clay and Autoclaved Aerated Concrete Bricks for Radiation Shielding Properties

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Abstract

This research studied the radiation interaction of gamma rays with clay and autoclaved aerated concrete bricks. The clay and autoclaved aerated concrete bricks were determined by used gamma rays spectrometer with Compton scattering arrangement for energy variation and analyzed the composition by X-ray Fluorescence Spectroscopy (XRF). The results were determined mass attenuation coefficient values from theory by WinXCom program and experiment respectively. The Z_{eff} and the N_{el} value were studied for radiation shielding properties of the clay and autoclaved aerated concrete bricks. This research was found that the clay brick had good radiation properties than autoclaved aerated concrete. The experimental values had good agreement with theoretical values.

Keywords: autoclaved aerated concrete, clay brick, mass attenuation coefficient

1. Introduction

Humans have studied and researched in many ways. To make advances in science and technology Science and technology have a role in human's daily life in both industrial aspect agricultural aspect medical aspect including how to use the ray to preserving food by using solar powered oven ,Nuclear power plant by using radioactive substances ,X-raying ,Radiation destroys cancer cells , MRI or CT Scan and so on[1]. As mentioned Radiation is very useful to humans ,However we have to know and understand the correct way to using because radiation also dangerous to a creature, for example, the explosion of nuclear reactor of Chernobyl nuclear power plant in Ukraine on date 26 April 1986 and Earthquake in Japan on date 11 March 2011 which makes reactor lack of coolant the increasing of heat is making melt and radiation leakage ,but radiation is a particular that unable to be known by the human senses, so it unable to know that you already got radiation into your body or not for the safety a person who concern about radioactive need to find the solution to protect damage from radioactive for reduce risk from receiving radioactive by unreasonable based on the principle from International Radiation Protection Organization ALARA (As Low As Reasonably Achievable) by spend the least time to work Use the longest distance and use radiation shielding for protect the body to gain the excessive radiation standard[2]. Nowadays for prevent X-ray and gamma rays materials used for radiation shielding include lead, concrete, steel[3]. From the principle as said so study Interaction between gamma rays and clay bricks and autoclaved aerated concrete. Which used for housing to study radiation shielding properties [4].

In the present there is a high amount of usage gamma rays. It needs to prevent the danger of gamma rays, coupled with the utilization. The residency or house in the present are made from clay bricks or and autoclaved aerated concrete, hence house is a very important factor for prevent radiation that cannot be avoided such as Living near industrial plants or a place where the source of radiation[5]. This research takes 2 of clay bricks and autoclaved aerated concrete to study interaction between ray with clay bricks and autoclaved aerated concrete.

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2. Research objective

2.1 Study radiation interaction between clay and autoclaved aerated concrete bricks for radiation shielding properties.

2.2 Compare the value from experiment and theory values of clay and autoclaved aerated concrete bricks.

3. Materials and methods

3.1 Measurement of physical properties of samples

The samples, while the measurement of physical properties was measured density of samples following the relation:

$$\rho = \frac{W_a}{W_a - W_b}\rho_b \quad \textbf{(1)}$$

where ρ is density of sample, W_a is the weight of sample in air, W_b is the weight of sample in water and ρ_b is the density of water.

The analysis of element composition to identify the weight percent in the samples were measured with X-ray fluorescence spectrometer (XRF), Minipal-4, Panalytical. XRF is helpful and accurate analytical instrument widely used for determining element composition in unknown materials. The present weight percent of element composition of samples.

3.2 Gamma-ray shielding studies procedure

The shielding properties of samples were calculated with two processes, first: theoretical calculation were calculate with WinXCom program, second: experimental calculation were calculation with the data from experimental procedure.

3.2.1 Theoretical and Experimental calculation

In this part, the data from XRF, weight percent of element composition of each samples were input in WinXCom. The mass attenuation coefficient (μ_m) in unit (cm^2/g) were calculated with energy range from 223 - 662 keV, based on the rule of mixture:

$$\mu_m = \sum_i w_i (\mu_m)_i \quad \textbf{(2)}$$

where w_i is the weight fraction of element i in samples and $(\mu_m)_i$ is mass attenuation coefficient for individual element i in samples. The value of mass attenuation coefficient μ_m depends on density of the samples, can be used to determine the total atomic cross-section ($\sigma_{t,a}$) following relation:

$$\sigma_{t,a} = \frac{(\mu_m)_{soils}}{N_A \sum_i^n (w_i / A_i)} \quad \textbf{(3)}$$

where N_A is Avogadro's number and A_i is the atomic weight of each element *i* of the samples. Furthermore, the total cross-section ($\sigma_{t,el}$) is following relation:

$$\sigma_{t,el} = \frac{1}{N_A} \sum_{i}^{n} \frac{f_i A_i}{Z_i} (\mu_m)_i = \frac{\sigma_{t,a}}{Z_{eff}} \tag{4}$$

where f_i is the number of atoms of element *i* relative to the number of atom of all elements in samples, Z_i is the atomic number of element *i* in element composition in samples and Z_{eff} is effective atomic number of samples explain with following relation:

$$Z_{eff} = \frac{\sigma_{t,a}}{\sigma_{t,el}} \tag{5}$$

The electron density (N_e) can be defined as the number of electrons per unit mass, and it can be mathematically written as follows [4-9]:

$$N_e = \frac{\mu_m}{\sigma_{t,el}} \tag{6}$$

4. Results and discussion

1. The component element of samples by XRF are result show in table 4.1 and 4.2.

Table 4.1 clay bricks's component elements

Compound	Si	K	Ca	Ti	Mn	Fe	Zn	Rb	Sr	Zr	Pb
Conc (%)	48.387	13.275	4.985	3.058	0.476	28.988	0.095	0.297	0.055	0.255	0.128

Table 4.2 autoclaved aerated concrete brick's component elements

Compound	Si	K	Ca	Ti	Mn	Fe	Cu	Zn	Rb	Sr	Zr
Conc (%)	13.776	1.073	78.162	0.547	0.098	6.013	0.025	0.039	0.031	0.139	0.098

2. The density of samples by Archimedes is principle with 4-position scales from AND company model HR-200 are show in Table 4.3.

Table 4.3 The average density of samples

Sample (brick)	Density (g/cm^3)
AAC	2.5241
Clay	2.5239

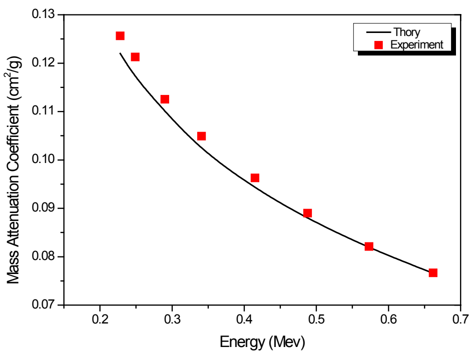
3. The mass attenuation coefficient of clay and autoclaved aerated concrete bricks for theoretical and experimental values are show in Table 4.4, Figure 1 and Table 4.5, Figure 2 respectively.

Table 4.4 Mass attenuation coefficient, μ_m of clay brick

Energy (Mev)	Theoretical value, μ_m (cm^2/g)	Experimental value, μ_m (cm^2/g)
0.228	1.22E-01	1.21E-01
0.249	1.17E-01	1.17E-01
0.29	1.10E-01	1.09E-01
0.341	1.02E-01	1.02E-01
0.415	9.41E-02	9.41E-02
0.488	8.78E-02	8.74E-02
0.573	8.18E-02	8.11E-02
0.662	7.66E-02	7.61E-02

Table 4.5 Mass attenuation coefficient of autoclaved aerated concrete

Energy (Mev)	Theoretical value, μ_m (cm^2/g)	Experimental value, μ_m (cm^2/g)
0.228	1.27E-01	1.27E-01
0.249	1.22E-01	1.19E-01
0.29	1.13E-01	1.12E-01
0.341	1.05E-01	1.04E-01
0.415	9.57E-02	9.57E-02
0.488	8.90E-02	8.86E-02
0.573	8.28E-02	8.21E-02
0.662	7.75E-02	7.71E-02



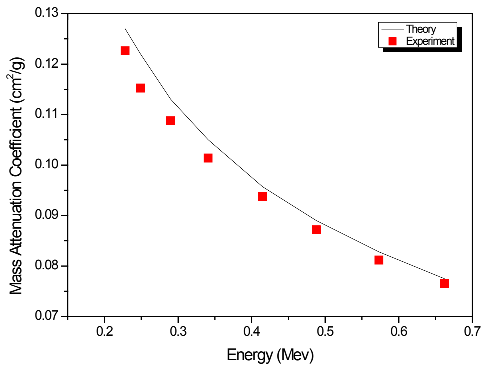


Figure 1 Mass attenuation coefficient and energy of clay brick (left) and autoclaved aerated concrete (right)

The mass attenuation coefficient and energy of clay brick and autoclaved aerated concrete were decrease with increasing gamma-rays energy. The two samples had same trend. The clay brick has more mass attenuation coefficient at all of the same gamma-rays energy.

4. The effective atomic number of clay and autoclaved aerated concrete bricks for theoretical and experimental values are show in Table 4.5, Figure 3 and Table 4.6, Figure 4 respectively.

Table 4.6 Effective atomic number, Z_{eff} value of the clay bricks.

Energy (Mev)	Theoretical value, Z_{eff} (electron/atom)	Experimental value, Z_{eff} (electron/atom)
0.25	1.14E+01	1.14E+01
0.29	1.14E+01	1.13E+01
0.34	1.13E+01	1.13E+01
0.42	1.13E+01	1.13E+01
0.49	1.13E+01	1.12E+01
0.57	1.13E+01	1.12E+01

Table 4.7 Effective atomic number, Z_{eff} value of the bricks of autoclaved aerated concrete.

Energy Mev	Theoretical value, Z_{eff} (electron/atom)	Experimental value, Z_{eff} (electron/atom)
0.23	2.08E+01	2.07E+01
0.25	2.04E+01	2.00E+01
0.29	2.00E+01	1.98E+01
0.34	1.97E+01	1.96E+01
0.42	1.95E+01	1.95E+01
0.49	1.94E+01	1.93E+01

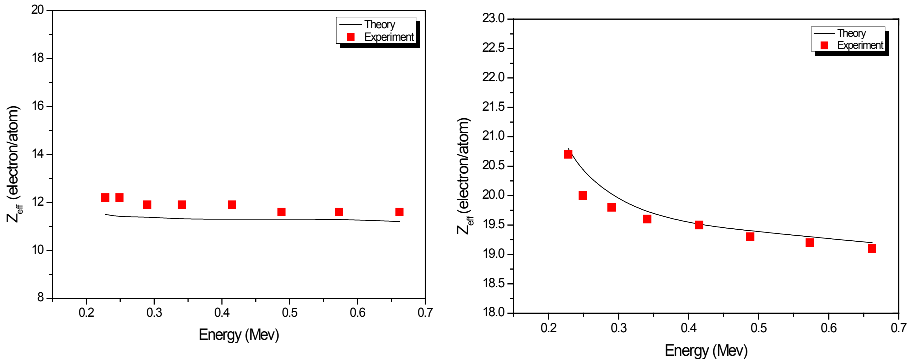


Figure 2 Effective atomic number, Z_{eff} value and energy of the clay bricks(left) and autoclaved aerated concrete(right)

The effective atomic number and energy of clay brick has small decrease with increasing gamma-rays energy and autoclaved aerated concrete was clearly decrease with increasing gamma-rays energy. The autoclaved aerated concrete has more effective atomic number at all of the same gamma-rays energy.

5. The electron density of clay and autoclaved aerated concrete bricks for theoretical and experimental values are show in Table 4.8, Figure 5 and Table 4.9, Figure 6 respectivel

Table 4.8 Electron density, N_{el} value of clay bricks.

Energy (Mev)	Theoretical value, N_{el} ($x10^{23}$electron/gram)	Experimental value, N_{el} ($x10^{23}$electron/gram)
0.228	3.04	3.02
0.249	3.03	3.02
0.29	3.01	2.99
0.341	3.00	2.98
0.415	2.99	2.99
0.488	2.98	2.97
0.573	2.98	2.96
0.662	2.98	2.96

Table 4.9 Electron density, N_{el} value of autoclaved aerated concrete.

Energy (Mev)	Theoretical value, N_{el} ($x10^{23}$electron/gram)	Experimental value, N_{el} ($x10^{23}$electron/gram)
0.23	3.24	3.23
0.25	3.19	3.13
0.29	3.13	3.09
0.34	3.08	3.06
0.42	3.04	3.04
0.49	3.03	3.01

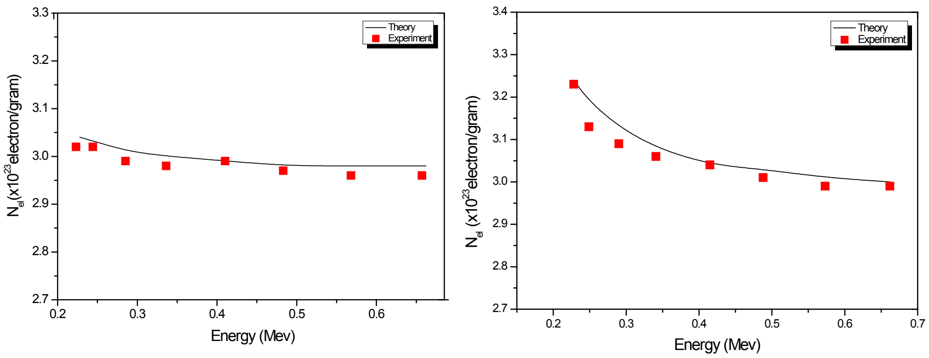


Figure 3 Electron density, N_{el} value and energy of clay bricks(left) and autoclaved aerated concrete.(right).

The electron density and energy of clay brick has small decrease with increasing gamma-rays energy and autoclaved aerated concrete was clearly decrease with increasing gamma-rays energy. The autoclaved aerated concrete has more electron density at all of the same gamma-rays energy.

5. Conclusions

This research has made an experiments for study interaction between radiation of gamma-rays and the clay brick aerated bricks to compare that which one has a best radiation shielding property from 2 samples are clay brick and aerated brick without chemical added then begin the experiments study property of both bricks the result can be concluded that

Property of clay brick and aerated brick from component analysis in both samples of bricks by using spectrometer x-rays energy distribution type. The result of chemical component in samples found high amount of Si , Ca and Fe which are the main components of both bricks ,but clay brick has Pb(0.128%) which not found in aerated brick and aerated brick contain Cu(0.025%) which this not available in clay brick.

Density (ρ) of clay brick and aerated brick from measurement of density of clay brick and aerated brick sample by used Archimedes' s principle with 4-position scales obtain the density of clay brick is 1.7 density value is 2.5241 and density of aerated brick is 1.8 density value is 2.5239 respective.

Mass attenuation coefficient from measurement of gamma-rays spectrometer then calculate mass attenuation coefficient of experiment and compare from theory which get from program winxcom we found that mass radioactive attenuation coefficient of clay brick and aerated brick are in the energy period 0.228 ,0.249 ,0.29 ,0.341 ,0.415 ,0.488 ,0.573 ,0.662 respective. The result shows that clay brick has a better shielding property than aerated brick.

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