COMPARISON OF BENTONITE AND Sn DOPED BENTONITE SAMPLES UNDER THE EFFECTS OF PROTON AND ELECTRON IRRADIATION

Tahir Tilki[1)], Mert Şekerci[2)], Veli Çapalı[2)], Abdullah Kaplan[2)], Mustafa Yavuz[1)]
[1)]*Süleyman Demirel University, Faculty of Arts and Sciences, Department of Chemistry, Isparta, Turkey, tahirtilki@sdu.edu.tr, yavuzmustafa@sdu.edu.tr*
[2)]*Süleyman Demirel University, Faculty of Arts and Sciences, Department of Physics, Isparta, Turkey, mertsekerci@sdu.edu.tr, velicapali@sdu.edu.tr, abdullahkaplan@sdu.edu.tr*

In this study, the effects of proton and electron radiations have been investigated for bentonite which has a potential usage for radiation shielding for mentioned radiation types. Clay doped variations and bentonite itself have been investigated by using GEANT4 simulation program in the energy range from 1 MeV to 100 MeV incoming particle energies. Obtained results for stopping power and penetrating distance values have been compared for each sample. Also, numerical results for each simulation considering both particle induce situations have been given.

Introduction

Bentonite is an industrial raw material containing smectite-group clay minerals; montmorillonite in general is the main component and associated with other clay minerals such as kaolinite, bentonite and some non-clay minerals such as quartz, feldspar, mica, cristobalite etc. [1]. A particular physical and chemical character imparts bentonite high specific area and adsorption [1-4]. Bentonite is a naturally occurring mixed mineral soil that is composed primarily of montmorillonite, a commonly occurring aluminosilicate clay mineral. Because of isomorphous substitution, montmorillonite exhibits a permanent structural surface charge which attracts weakly bonded interlayer cations to neutralize that charge [5]. Bentonite, a very rich clay mineral, consists of layers of two tetrahedral silica sheets sandwiching one octahedral alumina sheet. Bentonite has permanent negative charge due to the isomorphous substitution of Al^{3+} for Si^{4+} in the tetrahedral layer and Mg^{2+} for Al^{3+} in the octahedral layer. This negative charge is balanced by the presence of exchangeable cations (Na^{+}, Ca^{2+}) in the lattice structure, which make it perform well in sorption of basic (cationic) dyes by cationic exchange mechanism [6, 7]. Typically, interlayer cations are inorganic (Na^{+}, Ca^{2+}); however, organic-clay complexes, known as organoclays, can be made by exchanging the clay's naturally occurring inorganic cations with a variety of organic cations. Bentonites are classified based on their major exchangeable cation types as Na-bentonite (Wyoming type), Ca-bentonite (fuller's earth) and Na/Ca-bentonite (mixed bentonites). Of these, Na-bentonites are well dispersed, viscous and have high swelling index and large electrical conductivity. However, Ca-bentonites are less dispersed and less viscous, and have low swelling index compared to Na-bentonite [1, 3, 8, 9].

Recently, the natural clay minerals, such as montmorillonite (MMT), kaolinite and pumice, are widely used in catalysis; as adsorbents, in nanocomposites, in sensors, electrode, as antibacterial materials, nuclear waste storage and pesticide carriers and so on. Bentonite is the commercial designation of a natural clay mineral, the main component of which is montmorillonite. Bentonite is widely used as adsorbent due to its high specific surface area. Na^{+}-bentonite carries a permanent negative charge in its structural framework and has little affinity for the anionic dyes. Bentonite is the clay rocks shifted from glassy igneous material such as volcanic ash or tuff [10-12].

Bentonites were used in numerous applications such as palletizing iron ores, foundry bond clay, ceramic, drilling mud, sealant, animal feed bond, bleaching clay, agricultural carrier, adhesive, catalyst, desiccant, emulsion stabilizer, cosmetic, paint, pharmaceutical, civil engineering, pillared organoclay and polymer-clay nanocomposites [12-14].

Clay is basically inert super charged minerals, and it gets its negative electromagnetic energy charge from the thermo dynamic heat and volcanic action that created it. When activated by water the clay awakens with a strength that radiates throughout the body, stimulating energy for the rebuilding and revitalization of latent cells, and starts a healing process. The body needs this energy to restore harmonic balance essential to healthy maintenance. In addition, this super power has the ability to absorb harmful, toxic substances from within the body, tightly bind them within the molecule, and carry them out of the body. Bentonite, an edible, mineral-rich clay, has been used for centuries to draw toxins away from intestinal walls while cleansing the colon. Another use for bentonite clay, which is very timely considering the recent natural and the Fukushima nuclear disaster in Japan, is adsorption of radiation. Not only does bentonite clay adsorb radiation from nuclear fallout, it also adsorbs any kind of radiation. According to a 2006 study published in Radiation Protection Dosimetry, which was performed by a team of scientists led by V. Correcher and entitled "Thermal Stability of the Thermoluminescence Trap Structure of Bentonite," bentonite clay was studied because of its known capabilities to break bond links, form hydrolyzed ions, and redox reactions. The study documented the "exponential distribution of trapped electrons." In another scientific study, bentonite clay was tested to determine its efficacy in reducing high-energy gamma irradiation of adenine [15].

Bentonite clay is made up of flat rectangular particles, which, when hydrated, have a powerful negative charge, giving them an amazing ability to pull to their surface, and hold on to, positively charged ions, similar to the way a magnet will pull and hold on to iron filings. This makes bentonite clay a powerful therapy that can be used to not only remove radiation from the body but also heavy metals, pollutants, bacteria, fungus, viruses and even parasites. Bentonite clay can be used internally, mixed with water, or externally in baths as well as in poultices and compresses [16].

Experimental

Chemical composition and some physical properties of bentonite have been given in the Table 1 and Table 2, respectively.

Table 1. Chemical composition of bentonite

Constituent	Percentage present
SiO_2	58 %
Al_2O_3	19 %
MgO	1 %
Fe_2O_3	3 %
CaO	2 %
Soduim, as Na_2O_3	4 %
Loss on ignition	13 %

Table 2. Some physical properties of bentonite

Parameter	Data
Color	Gray, green
Specific gravity	2.6
Liquid limit	187 %
Plastic limit	47 %
Plasticity index	140 %
Optimum moisture content	25 %
Maximum dry unit weight	1.6 kN/m^3

With the help of other science branches like engineering, computational sciences and chemistry, we now able to produce more effective materials for both running these power plants more efficiently and protecting our environment more safe. For such cases when testing a situation was not able to perform due to economical limitations, time saving or experimental difficulties, computer based simulation techniques help us to understand the mechanisms and possible outcomes of the investigated situation with a realistic outcome. One of the most used and preferred simulation technique which is Monte Carlo method employed by a well-known and wide range of use program called GEANT4 [17]. GEANT4 has been developed and keeping its development process with the contributions of many scientists, engineers and researchers from a wide range researchers. The popularity of the program depends to its capabilities and so much realistic results. With the help of GEANT4 code, in this study we aimed to investigate bentonite material and clay doped variations of bentonite which have a potential usage for shielding at the nuclear power plants.

Results and Discussion

Bentonite itself also 5 %, 10 % and 15 % clay doped variations have been investigated in this study. Completed simulation study results for bentonite and its clay doped different variations have been given in this section. For each material sample, stopping power and penetrating distance results for proton and electron induced situations within the 1-100 MeV energy region have been studied and results related with proton induced situation have been given in Fig. 1 while electron induced situation results have been represented in Fig. 2. In addition to the plotted graphs, obtained outcomes numeric results have been given in Table 3 for proton induced and in Table 4 for electron induced situations at the end of text.

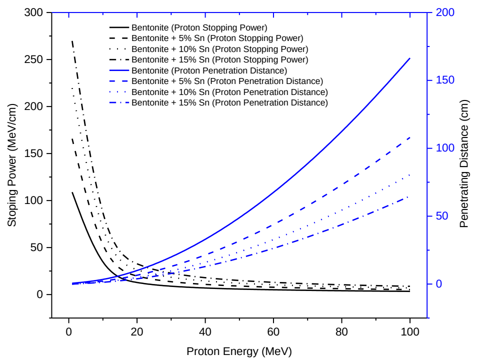

Fig. 1. Stopping power and penetrating distance results on bentonite and it's clay doped variations for proton induced situation

As seen from Fig. 1, with the increasing of incident particle energy, penetrating distance of the particle increases too yet the most acceptable values have been obtained with the 15 % clay doped variation of bentonite. At the maximum energy of incoming particles which is 100 MeV, the penetrating distance of the particles for bentonite itself has been located almost around 175 cm while the values for 15 % clay doped bentonite has been obtained almost around 75 cm. On the other hand, the stopping power values have shown a declining decrease with the increase of incoming particle energy and the most acceptable results have been obtained for 15 % clay doped variation of bentonite.

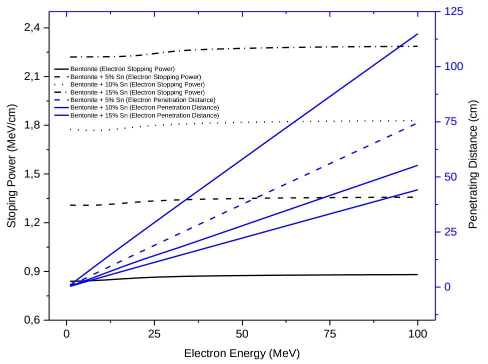

Fig. 2. Stopping power and penetrating distance results on bentonite and it's clay doped variations for electron induced situation

Fig. 2, represents the results for electron induced situation for each studied material as stopping power

Table 3. Stopping power and penetrating distance results on bentonite and its clay doped variations for proton induced situation

	Bentonite		Bentonite + 5% Sn		Bentonite + 10% Sn		Bentonite + 15% Sn	
Proton (MeV)	Stoping Power (MeV/cm)	Penetration (cm)	Stoping Power (MeV/cm)	Penetration (cm)	Stoping Power (MeV/cm)	Penetration (cm)	Stoping Power (MeV/cm)	Penetration (cm)
1	108.903	0.611227	165.745	0.0402262	219.659	0.0304051	269.783	0.0248011
10	20.6163	2.7718	31.6395	1.80951	42.2976	1.3561	52.4224	1.0964
20	11.9021	9.4424	18.293	6.15293	24.4923	4.6013	30.403	3.7122
30	8.63546	19.4553	13.2828	12.6639	17.7989	9.4628	22.1132	7.62676
40	6.878	32.5338	10.5846	21.1642	14.19	15.8047	17.6383	12.7299
50	5.7721	48.4812	8.8855	31.5252	11.9164	23.5319	14.8175	18.9452
60	5.00975	67.1384	7.7138	43.6441	10.3477	32.5659	12.8702	26.2098
70	4.4499	88.3686	6.8532	57.4318	9.1949	42.8432	11.4388	34.4471
80	4.0209	112.05	6.19335	72.8063	8.3108	54.306	10.3405	43.6839
90	3.68114	138.106	5.6707	89.7014	7.6105	66.9	9.4704	53.8047
100	3.40517	166.483	5.2461	108.058	7.0415	8.0575	8.7633	64.7947

Table 4. Stopping power and penetrating distance results on bentonite and its clay doped variations for electron induced situation

	Bentonite		Bentonite + 5% Sn		Bentonite + 10% Sn		Bentonite + 15% Sn	
Electron (MeV)	Stoping Power (MeV/cm)	Penetration (cm)	Stoping Power (MeV/cm)	Penetration (cm)	Stoping Power (MeV/cm)	Penetration (cm)	Stoping Power (MeV/cm)	Penetration (cm)
1	0.83886	0.948723	1.30823	0.610104	1.7743	0.4516	2.2208	0.36163
10	0.844811	11.8138	1.306212	7.62019	1.76248	5.6397	2.22159	4.50309
20	0.86095	23.5203	1.32929	15.1974	1.7922	11.7525	2.2242	8.99225
30	0.868204	35.0807	1.33969	22.6869	1.8056	16.8132	2.2585	13.433
40	0.87233	46.5684	1.34562	30.1327	1.8132	22.3378	2.2679	17.8497
50	0.874987	58.0127	1.34943	37.5523	1.81821	27.8439	2.27391	22.2518
60	0.876821	69.4283	1.35207	44.9546	1.82162	33.3376	2.27806	26.6444
70	0.878153	80.8235	1.53399	52.3445	1.82409	38.8227	2.28108	31.0302
80	0.879155	92.2039	1.35543	59.7256	1.82597	44.3014	2.28336	35.4111
90	0.879929	103.573	1.35654	67.0998	1.82739	49.7752	2.28511	39.7882
100	0.880539	114.933	1.35742	74.4686	1.82852	55.245	2.28649	44.1624

axis located on the left side while penetrating distance values located on the right. For electron induced situation, similar to proton induced one, the 15 % clay doped bentonite has the lowest penetrating distance value which also increases with the increase of incoming particle energy but ends at an acceptable level. Unlike represented in Fig. 1, the stopping power values stay almost constant for each clay doped variations of bentonite at different levels. The highest stopping power rate as MeV per cm has been obtained for 15 % clay doped bentonite material as given in Fig. 2.

Conclusion

In this study, our aim was to investigate the effects of proton and electron induced situations on bentonite itself and different rate clay doped bentonite materials. To simulate the effects of mentioned particles on studied materials bentonite, 5, 10 and 15 % clay doped variations of bentonite, GEANT4 simulation program has been used. With the comparisons for each investigated material in the manners of penetrating distance and stopping power values, it has been obtained that the 15 % clay doped bentonite variation has the most acceptable and reasonable results to serve the use of shielding material.

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