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Modern Trends in Epoxy Based Materials Used for Shielding Am-Be Neutron Source

E. I. Khalil[1], H. Abo Elez[2], Dalia Anwar[3], M. Fayez-Hassan[4]

[1, 2, 3] Faculty of Science, Physics Department, Zagazig University, Zagazig, Egypt

[4]Experimental Nuclear Physics Department, Nuclear Research Centre, EAEA, Egypt

Abstract: ***This work introduces a modern neutron shielding supplies with different epoxy based materials. The method has a lot of advantages such as; the success of these materials to have small density, have better and low neutrons transmission trends, increases the strength properties, improve the impermeability of cement mortar and increases resistance to chemicals and salts. 5 Curie Americium–Beryllium neutron source was used for the purposes of sample irradiation in thermal neutron mode. Different ratios of sand, cement, gravel, boric acid and iron powder were finally mixed with epoxy before adding hardener. The foil activation method based on ^{115}In was used for thermal neutron monitoring. This new introduced shielding materials for thermal neutrons can be used successfully for nuclear reaction laboratories, in basic research field, radiotherapy laboratories and industrial applications.***

Keywords: Neutron, shielding, Neutron transmission, epoxy based shielding materials

1. Introduction

Radio-isotopic neutron sources (RINS) such as Americium–Beryllium (^{241}Am/Be), Pu/Be, Am/Li, ^{244}Cm/Be and ^{252}Cf with suitable activity are used in many industrial applications; neutron radiography, radiation therapy, explosives industries, basic nuclear research and other circumstances **[1-4]**. In addition the advantages and necessities of using such these (RINS) can be summarized as; they are portable, generate stable neutron fluxes (long life time), physically small size, sharp creation, calm to use and to shield, low cost, and successfully can be used to study the elements with short half-life **[5-8]**. Radiation shielding materials have been an attractive research area in nuclear, radiation physics and radiation protection. Facilities and radiation therapy equipment using RINS need to well shield all surrounding components including doors, walls, floors, and ceilings to eliminate health hazards **[9-12]**.The attenuation coefficient is a fundamental essential parameter for characterizing the penetration and diffusion of radiation in any medium. This discovery relates to radiation shielding material primarily proposed for shielding sources of high energy shortwave radiation such as are found in involvement with nuclear-powered steam raising installations. Thermal neutron transmission experiment was done in the NCSU PULSTAR reactor beam port . It shows that; by filling foam with water or boric acid solution, the attenuation got improved compared to bulk material and foam. By increasing the boric acid concentration and thickness of the layers, the samples even totally stopped the beam **[13]**. To characterize the material behavior against neutrons for ^{241}Am-Be neutrons, as well as to test alternative mixings including boron compounds in an effort to improve neutron shielding efficiency when comparing neutron attenuation against mass and linear shielding thickness, with regard to ordinary concrete. Although borated compounds with borax added show better neutron attenuation with respect to mass-thickness, the resulting reduction in density and structural properties makes them less practical also iron or steel is widely used for photon shielding due to its relatively high density, low cost and good structural and thermal properties and easy of fabrication polyethylene is used widely in shielding of D-T neutron generators **[14, 15]**. By adding B_4C into concrete showed that the addition of boron carbide particles to concretes able to increase the capability of neutron absorption compared to regular concrete. However concrete strength was reduced by the increasing of boron carbide in concretes, also and enriched boron carbide ($^{10}B_4C$) in various combinations and Boron fiber in composite form was found to be an excellent neutron attenuator **[16, 17]**. 78 cm shielding thickness can be used to reach to half value the original neutron efficiency even with using 5 Ci source (^{241}Am/Be) for total neutrons and non thermal one respectively. By using vermiculite loaded samples between ^{241}Am-Be source box and detector probe (BF_3 Proportional Counter). Vermiculite mineral has high-level thermal insulation capacity. To produce good materials which have high radiation shielding capacity and thermal insulation property . The neutron shielding performance of the neutron/gamma-ray shielding resin with Colemanite is almost the same as that of the polyethylene as measured with a ^{252}Cf neutron source **[18]**. New gel-type shielding material mainly consists of resin, lead powder and a boron compound, was developed. It was shown that newly developed gel-type shielding material has excellent shielding performance. Also produced steels have the same ability to moderate neutrons and to attenuate gamma rays **[19, 20]**. Our work aims to find modern neutron shielding supplies with epoxy based materials. The characteristic of these materials aims to be; easy formalization, low cost, lightweight, low density and have high attenuation neutrons trends such as different mixtures with modern epoxy.

2. Proposed Shielding Compositions

Sample No. 1; Normal concrete (N.C) sample (Fig. 1): It is made using fine ordinary sand added to Portland cement which is affine gray powder. The construction of N.C is completed by using water. The used water was clean and free of organic matter. The final mixture is pumped to small cylinder of 64.3 mm base diameter and 12.5 mm height then leaving it for 7 days for making concrete hard enough for light loads **[12]**.

Figure 1: Represts the shape of the prepared N.C Cylinder

Sample No. 2; heavy concrete (H.C) sample: it is a mixture of fine sand, Portland cement and gravel with water. Portland cement is a hydraulic binder used to combine elements such as sand and gravel. Gravel is a natural material collected from quarries, made out of crushed stones, or extracted from river beads. The used gravel size was lower than 5 mm. Then the mixture is pumped to the same cylinder leaving it to dry for 7 days. This sample and (N.C) were used for the purpose of comparison with the epoxy samples.

Sample No. 3; Poly poxy (765) sample: the epoxy is pumped to the small cylinder and left for 5 days to dry. The goodness of this epoxy it is strong in gluing and has excellent mechanical properties and high resistance for chemicals.

Sample No. 4; Composite marble epoxy sample: It is a mixture of sand, cement, gravel and special epoxy used for marble gluing. This mixture is pumped to the same cylinder for two days to dry. Marble glue is an adhesive composite used to connect parts of marble, granite and other stones in addition to fill holes and cavities that might occur.

Sample No. 5; pure marble epoxy Samples: were made using 100% special marble gluing epoxy. This is pumped to the same cylinder.

Sample No. 6; poly poxy (765) and boric acid mixture (P.B) pumped to the same cylinder for 4 days **[23]**.

Sample No. 7; (B. S) sample: is a mixture of boric acid and special epoxy used for marble gluing **[23]**. This mixture also pumped to the same cylinder for 2 days to dry.

Sample No. 8; (S. B. I) sample: is a mixture of boric acid, iron powder and special epoxy used for marble gluing. Chemical name of iron powder is carbonyl iron powder with many physical and chemical properties. Such as the form is powder, odorless, color is gray with 7.8 g/cm^3 density. Bulk density is from 2,000- 3,000 kg/m^3 with molar mass equals 55.85 g/mol. Its solubility in water is insoluble. The mixture is pumped to the same cylinder for only one day to dry. To get a homogenous structure all samples are mixed for 3 minutes. The compositions ratio of these introduced shielding materials are summarized and given in Table 1.

Table 1: Compositions ratio of shield materials used in this study

No.	Name	Compositions ratio%
1	Normal concrete (N.C)	sand =77 cement =15 water =8
2	Heavy concrete (H.C)	sand =29 cement =14 gravel =50 water =7
3	Poly poxy (765)	poly poxy =100
4	Composite marble epoxy	special epoxy=10 cement =14 sand =29 gravel =56
5	Pure marble epoxy	epoxy= 100
6	(P. B)	poly poxy =86.7 boric acid = 13.3
7	(B. S)	boric acid= 47.57 special epoxy=52.42
8	(S. B. I)	special epoxy= 44.42 boric acid = 24.02 Iron powder = 31.55

The advantages of using poly poxy 765 or marble epoxy can be reviewed as:

- Increases the bond strength of different building materials.
- Increases the strength properties, especially tensile and bending strength.
- Increases the elasticity and reduces shrinkage cracking.
- Improves the impermeability and increases resistance to chemicals and salts
- Added in dosage to get a water proofing mortar.
- Has no harmful effect.

3. Irradiation Technique & Method of Analysis

^{241}Am/Be isotopic neutron source of activity 5 Ci was used in this work. Foils activation technique have different advantages over counters because of their smallness. This property is required when one measures neutron flux in restrained areas or in places where the neutron flux descent is enormous and sufficient structure is to be calculated **[10]**.

Foils can be cut very thin and small. With smaller foils one can get more exhaustive information and the perturbation upon the neutron flux is smaller. But small foils mean lower foil activity and lower suitability in the flux determination. When measuring very high fluxes, very thin and small foils can be used to maintain minimum perturbation and resolution. In this work foils activation technique with indium foils were used to detect thermal neutrons. The Flux rates of the neutron field can be measured easily by this method. Gamma rays from the activated foils were measured using 70% HPGe detector. The irradiation facility is shown in Fig. 2 **[11]**.

For sample irradiation and arrangements as shown in Fig. 3 the system were adjusted in the thermal neutron mode to notice the effect of the attenuation of neutrons through the proposed epoxy materials listed in Table 1.

It should be mentioned that a heavy and condensed hydrogenous material of caprolactam, cylinder of 7 cm base diameter and 2.5 cm height was used in the front of the proposed samples to reach high collimation and good satfactory thermal neutron mode.

4. Dose Transmission Factor

The rate at which each of these introduced materials reduces neutron doses can be determined by the absorption cross section which is related to the transmission factor of the materials. Thus, according to Sorenson et al. **[21, 22]**, dose transmission factor is considered to be the ratio of the shielded neutron dose to the unshielded neutron dose:

$$Dose\,Transmission\,Factor = \frac{Dose\ with\ shield}{Dose\ without\ shield}$$

This shows that the transmission factor of small dose is better off than the transmission factor of large dose values.

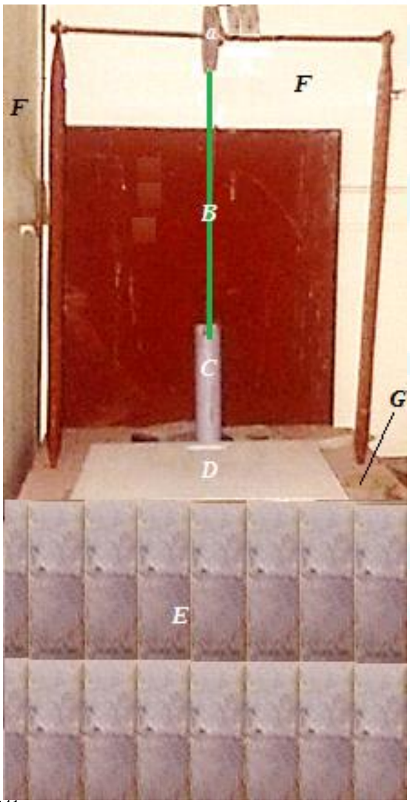

Figure 2: ^{241}Am/Be Neutron Irradiation Facility: a: moving pulley; B: moving wire; C: neutron source mounted inside Al cylinder; D: sample holder plate; E: lead shield; F: 2 meter wall of heavy concrete shielding and G: cubic steel tank filled with distilled water used as neutron housing.

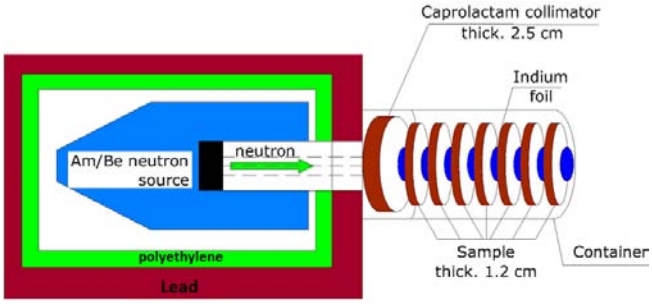

Figure 3: Shield samples arrangements and irradiation technique

5. Results and Discussion

In foils were used for measured the activity (transmission factor) measured after and before each sample. The spectra of the activated In foils were measured using a high resolution ORTEC hyper-pure germanium (HPGe) gamma-x detector of volume 100 cc , efficiency of 70 % and 2 keV energy resolution. A cylindrical lead-shield of 5 cm thickness, which contains inner concentric thin cylinders of Cu with a thickness of 5 mm, was used to shield the detector and to reduce the effect of background radiation. Standard ^{226}Ra gamma source were used for both energy and efficiency calibrations of the system.

The net area of the 416.9, 1097.3 and 1293.6 keV gamma lines used for this calculation. The irradiation time was 3 Hour, the cooling time was 120 sec. for each and the measuring time was 600 sec. for each gamma spectrum.

The presented samples were compared with normal concrete and heavy concrete as shown in table (1). Disks were made with the same thickness for the aim of comparison. Study the attenuation effect of the proposed samples show increase in the neutron attenuation up to (94.5%) as shown in table 2.

Table 2: Sample density and its neutron attenuation of the proposed shield material

No.	Sample	Density (gm/cm^3)	Neutron attenuation at (d=7.8 cm)
1	Normal concrete (N.C)	2.3	85%
2	Heavy concrete (H.C)	2.5	89%
3	Poly poxy (765)	1.77	92%
4	Composite marble epoxy	2.43	93%
5	Pure marble epoxy	0.88	90%
6	(P.B)	1.48	94%
7	(B.S)	0.975	94.3%
8	(S.B.I)	1.375	94.5%

Figure.4 shows the result of the selected samples which give high attenuation of thermal neutrons. The result of sample No. 5 which called pure marble epoxy, at 7.8 cm distance from Am/Be neutron source making high neutron attenuation reached 90%. Sample of (P.B) is better than relation pure marble epoxy in neutron attenuation reached 94% at the same distance from the source. After adding boric acid 47.5 % to sample (5) we get sample (B.S) making increase in neutron attenuation at the same distance reached 94.3% instead of 90%. With the same method by adding powder iron to sample (7) give sample (8) which also making increase in neutron attenuation reached to 94.5% as shown from the results.

In Ref. **[12]** Basher et al. used system of 5 Ci (Americium–Beryllium) neutron source and introduced an epoxy composite with shielding efficiency reached to 6.3 and 6.78 cm shielding thickness to get half value of the original neutron efficiency for total and non thermal neutrons respectively. Turgay et al. **[9]** studied neutron shielding properties of some vermiculite-loaded samples and found the attenuation lengths of 4.5 MeV neutrons 15: 73 cm for different vermiculite composition ratios. Our work shows that, samples no. 7 and 8 are the best samples (which consist of a mixture of boric acid and special epoxy used for marble gluing). Because of these samples have low density (ρ=0.98 & 1.38 gm/cm^3) and give approximately completely neutron attenuation reached to more than 94% at 7.8 cm distance from Am/Be neutron source.

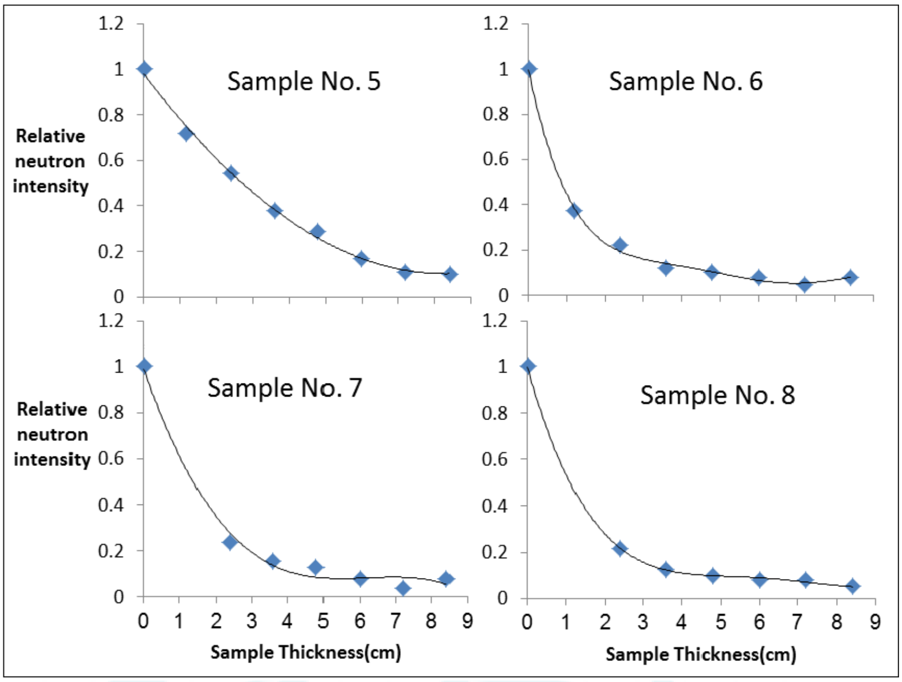

Figure 4: Represents the measured dose transmission factor against the thickness of selected epoxy disks

6. Conclusions

In this work we used anew modern sample (B.S) for neutron shielding. The method depends on creating mixtures with some materials with different type of epoxy base. This material has low density with high neutron absorption efficiency. We suggest that; physicist who interest in neutron application, especially in the mobile mode, can use such material which can suppress more than 94% of neutron in path range of (~7cm). The proposed materials have good hardness and can have different form easily.

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