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Test of Gamma Radiation in Synthetic Water Absorbed Rubber

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ABSTRACT

The aim of this research is to study the effect of the nuclear spectrum that is found in a new synthetic belt manufactured from a rubber composite with water and salt absorbed proprieties suitable for medical, sport and everyday wear. Rubber pastes from Nitrile Butadiene Rubber (NBR), were prepared in the laboratory by mixing different proportions. The hardness, time of swelling, mass and volume for pure NBR were measured, then four mixtures of (PEG-CMC) were added in the form of gels and powders as polymer composites to absorbed water by creating porosities inside the rubber. This model was examined by means of a sodium iodide detector in order to determine the proportion of radiation within the installation material. The results were all within the allowable limits globally.

***Keywords*:** Nuclear Spectrum, NBR, Medical Belts, PEG and Sodium iodide detector

1. INTRODUCTION

Nitrile rubber, also known as (Buna-N, Perbunan), acrylonitrile butadiene rubber, and NBR, is a synthetic rubber copolymer of acrylonitrile (ACN) and butadiene. Trade names include Nepal, Krynac and Europrene.

It is used in the automotive and aeronautical industry to make fuel and oil handling hoses, seals and grommets, since ordinary rubbers cannot be used. It is used in the nuclear industry to make protective gloves. NBR ability to withstand a range of temperatures from −40 to 108 °C, makes it an ideal material for aeronautical applications. Nitrile butadiene is also used to create molds goods, footwear, adhesives, sealants, sponges, expanded foam and floor mats [1].

PEG 6000 is a water-soluble and waxy solid that is used extensively in the several industries such as rubber, textile, paper, metal, wood, pharmaceutical, cosmetics and coating. PEG is recognized by many characteristic such as, highly compatible to various kinds of organic compounds, high boiling point, easy control of the degree of condensation, controllable hygroscopic property, less toxicity and less skin irritation [2].

Sodium carboxymethyl cellulose (Na-CMC) or cellulose gum is a cellulose derivative with carboxymethyl groups ($-CH_2-COOH$) bound to some of the hydroxyl groups of the glucopyranose monomers that make up the cellulose backbone. CMC is used as a lubricant in nonvolatile eye drops and artificial tears [3].

Primordial radionuclides are ^{238}U, ^{232}Th and their decay products as well as the radioisotopes of ^{40}K. All of these spectrometric measurements indicate that the three components of the external radiation field, namely from the gamma-emitting radionuclides in the ^{238}U and ^{232}Th series and ^{40}K, make approximately equal contributions to the externally incident gamma radiation dose to individuals in typical situations both outdoors and indoors [4].

The knowledge of specific activities or concentrations and distributions of the radionuclides in these materials of the radionuclides are of interest since it provides useful information in the monitoring of environment radioactivity. Gamma radiation emitted from naturally occurring radioisotopes, also called background radiation, represents the main external source of irradiation of the human body. Natural environmental radioactivity and the associated external exposure due to gamma radiation depend primarily on installation material, and appear at different levels in the materials [5-11].

2. PREPARATION OF (PEG-CMC) - NBR COMPOSITE

Rubber pastes from NBR have been prepared laboratory by mixing different proportions as shown in the Table (1). The hardness, time of swelling, mass and volume for pure NBR have been measured then, four mixtures of (PEG-CMC) were added in the form of gels and powders, then the same measurements were returned and compared with pure.

Table 1. The composition of the rubber composites.

No.	Recipe Ingredients	1	2	3	4
		Loading Level (pphr) Part per hundred rubber			
1	NBR	100	100	100	100
2	Activator (zinc oxide)	3	3	3	3
3	Activator (stearic acid)	1	1	1	1
4	Carbon black N.326	60	60	60	60
5	Castor oil	10	10	10	10

6	Anti-Oxidant (IMQ)	3	3	3	3
7	Accelerator (TMTD)	2	2	2	2
8	Accelerator (MBTS)	1	1	1	1
9	Sulfur	1.5	1.5	1.5	1.5
10	PEG-CMC Powder (6P)	6	-	-	-
11	PEG-CMC Powder (12P)	-	12	-	-
12	PEG-CMC Liquid (6L)	-	-	6	-
13	PEG-CMC Liquid (12L)	-	-	-	12

In the beginning, 81.5 g from NBR rubber paste was divided into four equal pieces and then polymer blends added to it as (6 g and 12g powder from PEG-CMC) also (6 mL and 12 mL liquid from PEG-CMC), respectively. Figure (1) shows that the prepared samples after polymer blends addition:

Fig. 1. Rubber samples after addition of polymer blends.

The measurements of hardness for all samples of rubber have been performed by using digital hardness tester type, (TIME GROUP SHORE A HARDNESS TESTER), model: TH200, with measuring range (0~100) HA and measurement deviation within (20~90) HA, with error (±1 HA).

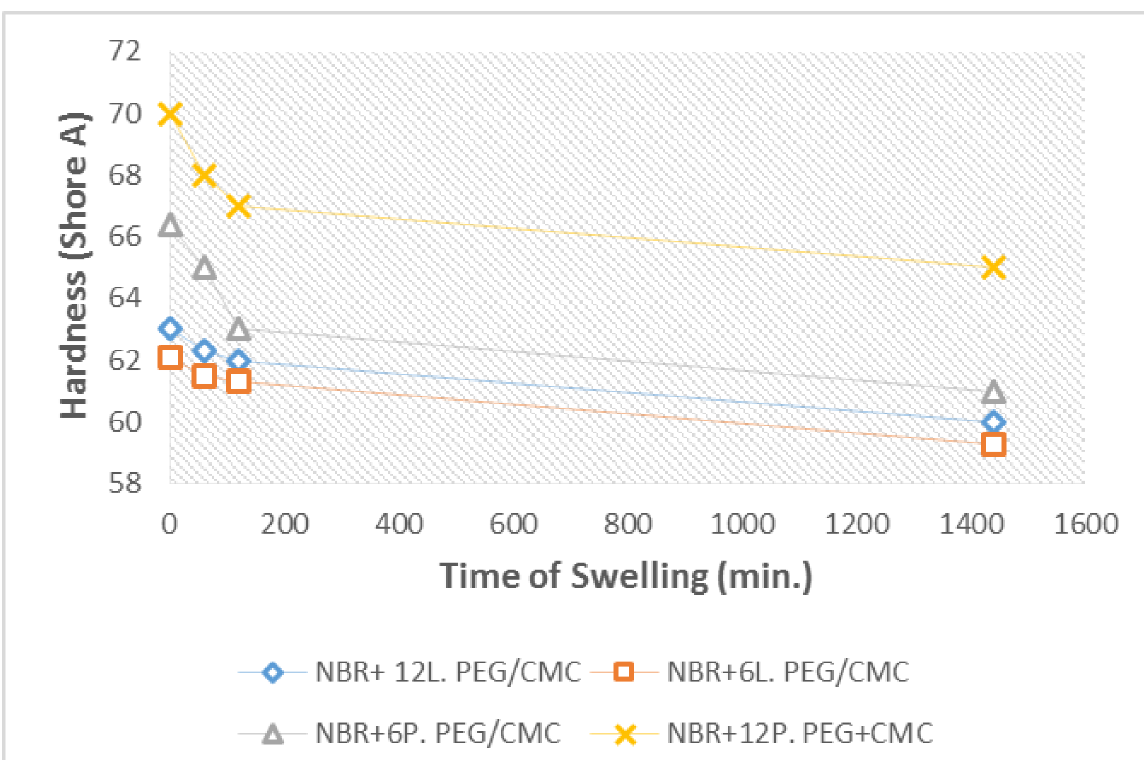
3. PRACTICAL PART

The idea of this study is to manufacture a rubber composite absorbed water suitable for fabricating regime and sport belts by adding non-allergic and non-toxic polymers, such as PEG and CMC to rubber for absorbing water; when excessive sweating appears, as effective in terms of the sports and medical role, our composite maybe associated with exercise of period of physiotherapy. The preparing process relies on adding firstly (3 mL) of PEG and (3 mL) CMC as liquid blend to the rubber paste and repeat the same weights as a powder. Secondly, another samples are obtained by adding a double weights for both liquid and powder. All samples are left in water, after preparing for about (60 to 1440 h).

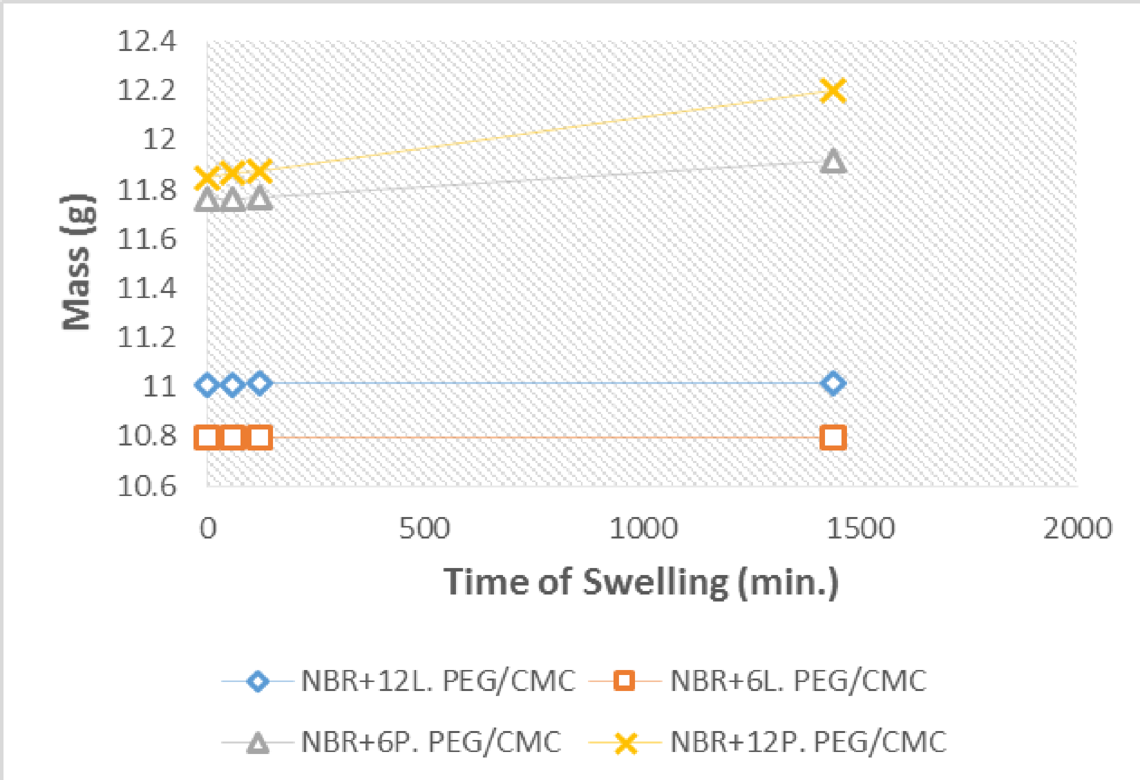
The practical part deals with using/ involving up to date and accurate laboratory to study mechanical properties of rubber before and after adding polymers. These properties are volume, density, hardness, and mass. Results show that the volume is increasing after addition because the composite absorbs water due to the swelling of hydrophobic polymer [6]. The density decreases because of increasing volume. The hardness also decreases after addition because polymer molecules diffuse through rubber that makes it more flexible; results also show increasing the mass because of absorbing water.

The property of hardness is improved from (62-63 HA) in liquids, respectively while with powder improved from (67-71 HA) [7].

The mass is increasing from (10.8 g) to (12.3 g) in (3 cm) diameter rubber-polymer composite, then expected for each (3 cm) of new samples have the ability of absorbing (1.7 g) of water. The symbols (L and P) in Figure 2, respectively represent the configuration of composites as liquid or powder [7].

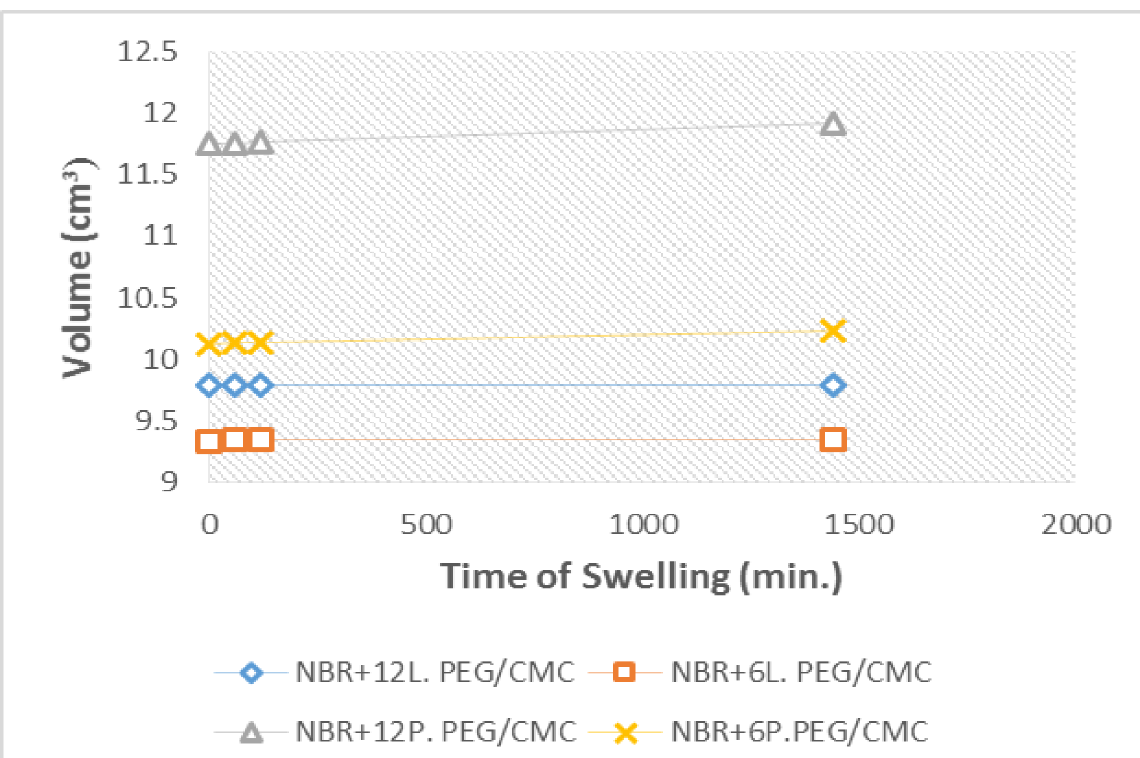


(A)



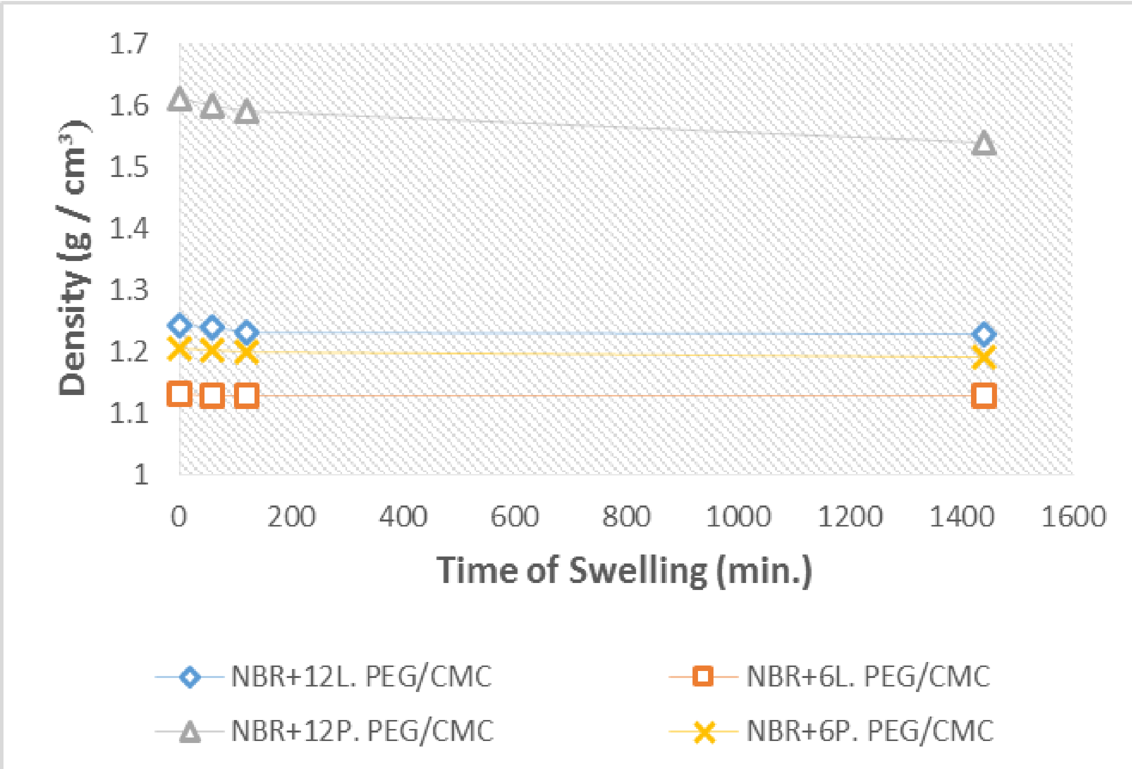
Mass (g)
12.4
12.2
12
11.8
11.6
11.4
11.2
11
10.8
10.6
0
500
1000
1500
2000
Time of Swelling (min.)
NBR+12L. PEG/CMC
NBR+6L. PEG/CMC
NBR+6P. PEG/CMC
NBR+12P. PEG/CMC

(B)



Volume (cm³)
12.5
12
11.5
11
10.5
10
9.5
9
0
500
1000
1500
2000
Time of Swelling (min.)
NBR+12L. PEG/CMC
NBR+6L. PEG/CMC
NBR+12P. PEG/CMC
NBR+6P.PEG/CMC

(C)



(D)

Fig. 2. The effect of additives on mechanical properties of NBR.

4. THEORY CONCEPTS

4. 1. The Activity Concentration

The activity concentrations of the radionuclides in the measured samples were computed using the following relation [8].

$$C\,(Bq\,/\,kg) = \frac{C_a}{I \times \varepsilon_{ff} \times M_s} ----------- (1)$$

where C_a is the net gamma counting rate (counts per second) ε_{ff} the detector efficiency of the specific γ-ray, I is the intensity of the γ-line in a radionuclide and M_s is the mass of the sample (kg).

4. 2. The Radium Equivalent Activity (Ra_{eq})

The Ra_{eq} index represents a weighted sum of activities of the above mentioned natural radionuclides and is based on the estimation that 1 $Bq\cdot kg^{-1}$ of ^{226}Ra, 0.7 $Bq\cdot kg^{-1}$ of ^{232}Th, and 13 $Bq\cdot kg^{-1}$ of ^{40}K produces the same gamma radiation dose rates. The index is given by:

$$Ra_{eq} = C_{Ra} + (1.43C_{Th}) + (0.077C_k) ----- (2)$$

where C_{Ra}, C_{Th} and C_K are the average activity concentrations in the sample in Bq·kg^{-1} of ^{226}Ra, ^{232}Th, and ^{40}K respectively [8].

4. 3. The Annual Effective Dose Equivalent

The annual effective dose equivalent to the population can be calculated using the conversion coefficient from absorbed dose in air to the effective dose (0.7 Sv·Gy^{-1}), the indoor to outdoor ratio (1.4), the outdoor occupancy factor 0.2 and the indoor occupancy factor 0.8. Therefore, the annual effective doses outdoors and indoors equivalent are calculated by using the relations [9], as follows:

$$D_{outdoor}(mSv/yr) = [D_r(mGy/hr) \times 24hr \times 365.25d \times 0.2 \times 0.7Sv/Gy] \times 10^{-6} --- (3)$$

$$D_{indoor}(mSv/yr) = [D_r(mGy/hr) \times 24hr \times 365.25d \times 1.4 \times 0.8 \times 0.7Sv/Gy] \times 10^{-6} ...(4)$$

The corresponding worldwide values of D_{out} and D_{in} and D_{tot} are 0.08, 0.42 and 0.50 mSv·y^{-1}, respectively.

4. 4. The External and Internal Hazard Index

The external (H_{ex}) and internal (H_{in}) hazard index, due to the emitted γ-rays of the soil samples, were calculated and examined according to the following criteria as:

$$H_{ex} = \frac{C_{Ra}}{370} + \frac{C_{Th}}{259} + \frac{C_k}{8410} \leq 1 ---------------------------- (5)$$

$$H_{in} = \frac{C_{Ra}}{185} + \frac{C_{Th}}{259} + \frac{C_k}{8410} -------------------------------- (6)$$

The value of H_{ex} must be lower than unity in order to keep the radiation hazard insignificant. This is the radiation exposure due to the radioactivity from a construction material, limited to 1.5 mGy·y^{-1}. The maximum values of H_{ex} equal to unity correspond to the upper limit of Ra_{eq} (370 Bq·kg^{-1}).

An additional hazard index, so called representative (radioactivity) level index, was calculated by using the formula as:

$$I_{\gamma} = \frac{C_{Ra}}{150} + \frac{C_{Th}}{100} + \frac{C_k}{1500} -------------------------------- (7)$$

The value of $I\gamma$ must be less than unity in order to keep the radiation hazard as in-significant [10].

5. RESULTS AND DISCUSSION

5. 1. The Specific activity Concentration

Analysis of activity concentration of ^{40}K, ^{238}U, ^{232}Th radionuclides in sample is shown in **Tables 2 & 3**:

Table 2. Radionuclides and intensity associated efficiency.

Radionuclides	Energy (KeV)	$I\gamma$	Efficiency %
K-40	1460	0.106	0.030
Bi-214	1764	0.170	0.021
Tl-208	2614	0.360	0.011

Table 3. Specific activities of radionuclides.

Sample	Ra_{eq} Bq/Kg	AD nGy/h	Effec. Dose Rate ($mSv\cdot y^{-1}$)		Hazard Index		Activity Concentr. Index (I_γ)
			Out.	In.	External ($H_{ex} \leq 1$)	Internal ($H_{in} \leq 1$)	
Rubber	41.808	21.183	0.026	0.014	0.113	0.136	0.333
World average	370	55	1	1	1	1	1

Table 4. Effects such as the radium equivalent and the absorbed dose rate and Hazard Index.

Sample	Activity Concentration [Bq/kg]		
	^{40}K	^{238}U	^{232}Th
Rubber	337.976±20.760	8.488±3.470	5.102±2.550
World average	400	35	30

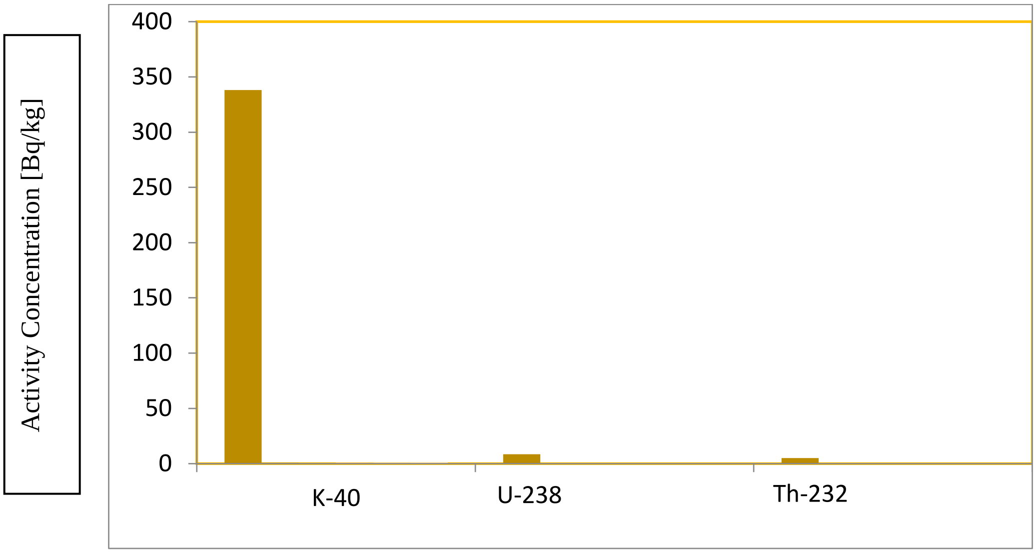


Fig. 3. Specific activities of radionuclides ^{40}K, ^{238}U, ^{232}Th.

Through the current work, we found potassium value (337.976 Bq/Kg), was Al uranium (8.488 Bq/Kg) and Thrum (5.102 Bq/Kg), as shown in Figures 3 and 4, then everyone within the global allowable limits, as shown in Tables 3 and 4. The results indicate that the rubber material is free of radiation, possible to deal with it safely.

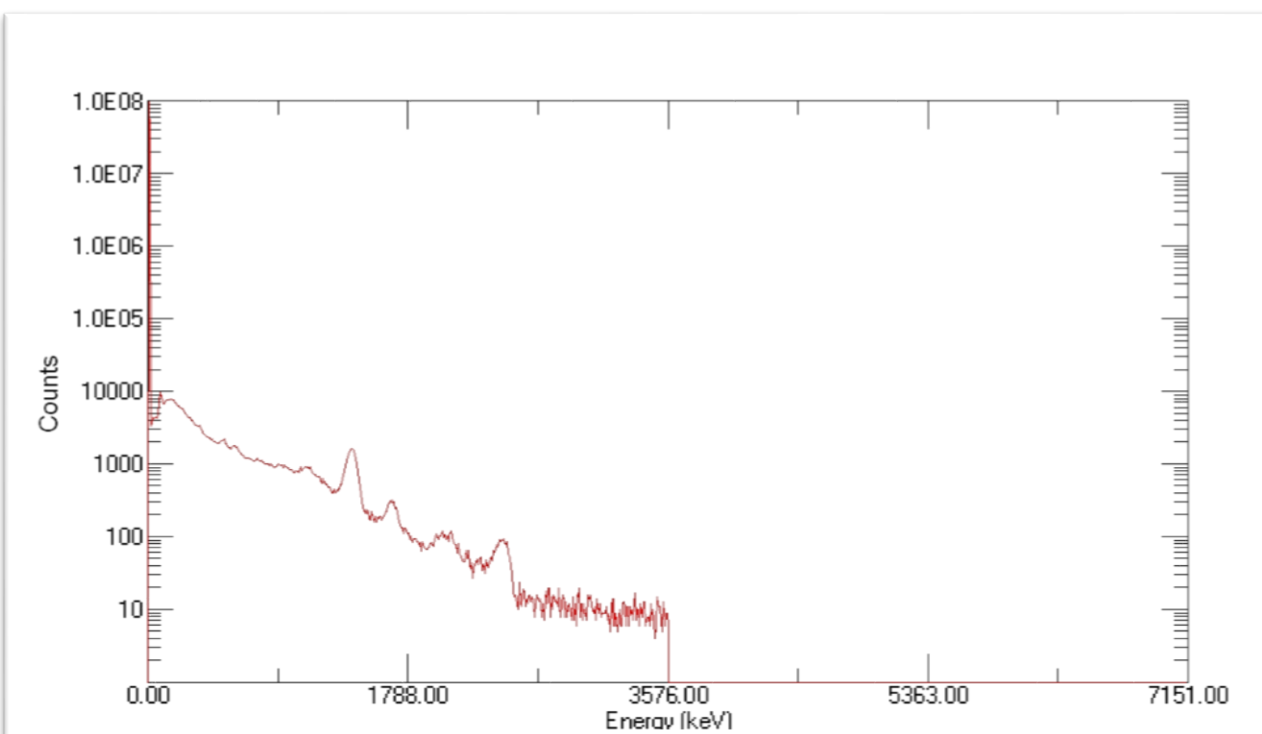


Fig. 4. Nuclear spectrum for rubber sample

6. CONCLUSIONS

1- Adding (PEG-CMC) to NBR rubber makes it as water absorber rubber.
2- The manufactured rubber composite is suitable for fabricating regime sport, and medical belts.
3- The detection process made on the rubber material appears that to be free of radiation and possible to deal with it safely, according to the current work results.

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