# 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 recognizes 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 the (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.

The measurements of hardness for all samples of rubber have been measured 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 manufacture a rubber composite absorbed water suitable for fabricate 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 as effective in terms of the sports and medical role and our composite maybe associated with exercise of period of physiotherapy. The preparing process is 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 obtained by adding a double weights for both liquid and powder. All samples leave in water after preparing for about (60 to 1440 h).

The practical part deal 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 absorb water because of swelling the hydrophobic polymer [6]. The density decreases because of increasing volume. The hardness also decrease after addition because polymer molecules diffuses through rubber that make it more flexible, results also show the masses increasing because of absorbing water.

The property of hardness improved from (62-63 HA) in liquids respectively while with powder improved from (67-71 HA) [7].
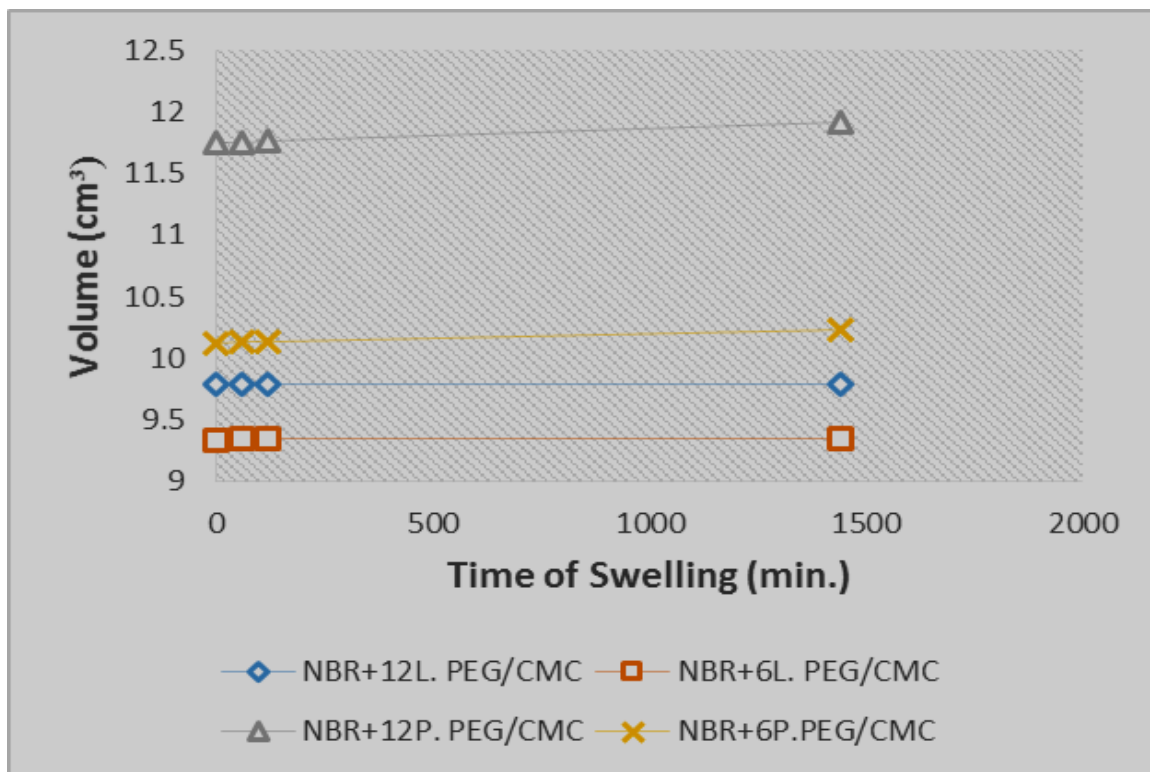
The mass is increasing from (10.8 g) to (12.3 g) in (3 cm) diameter rubber-polymer composite, then expected for each (3 cm) of new samples have the ability of absorbing (1.7 g) of water. The symbols (L and P) in Figure (2) respectively represent the configuration of composites is liquid or powder [7].
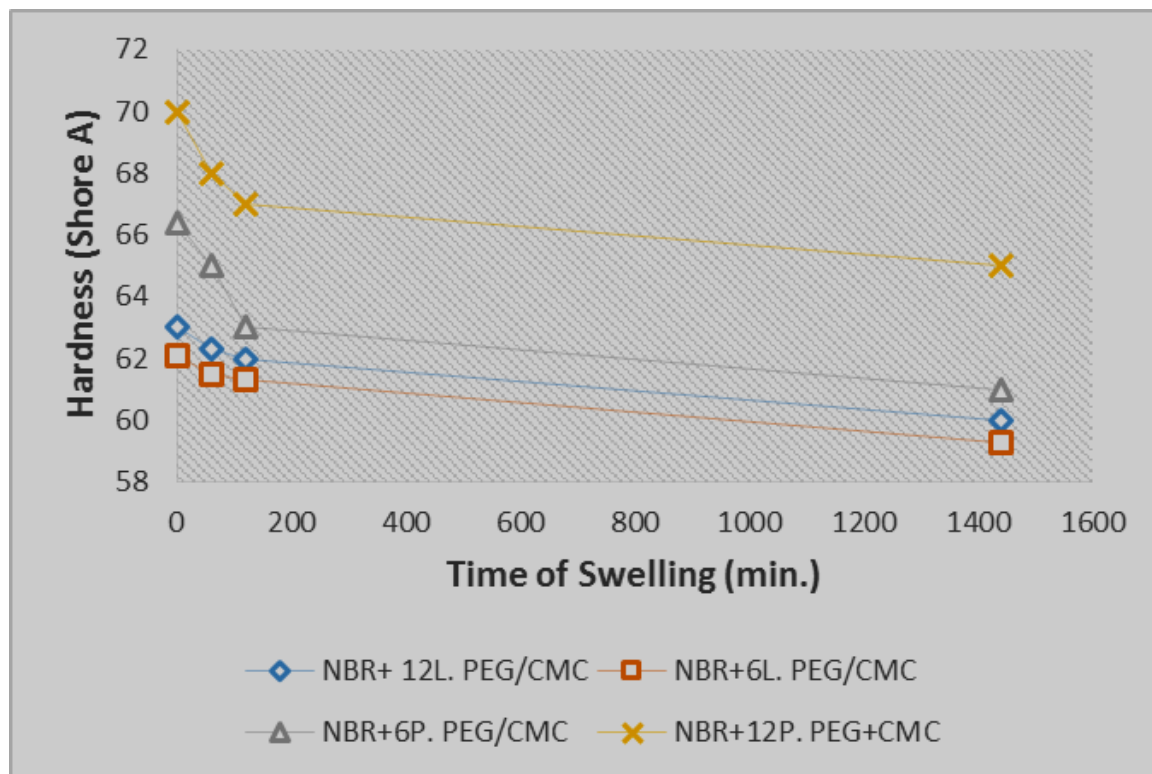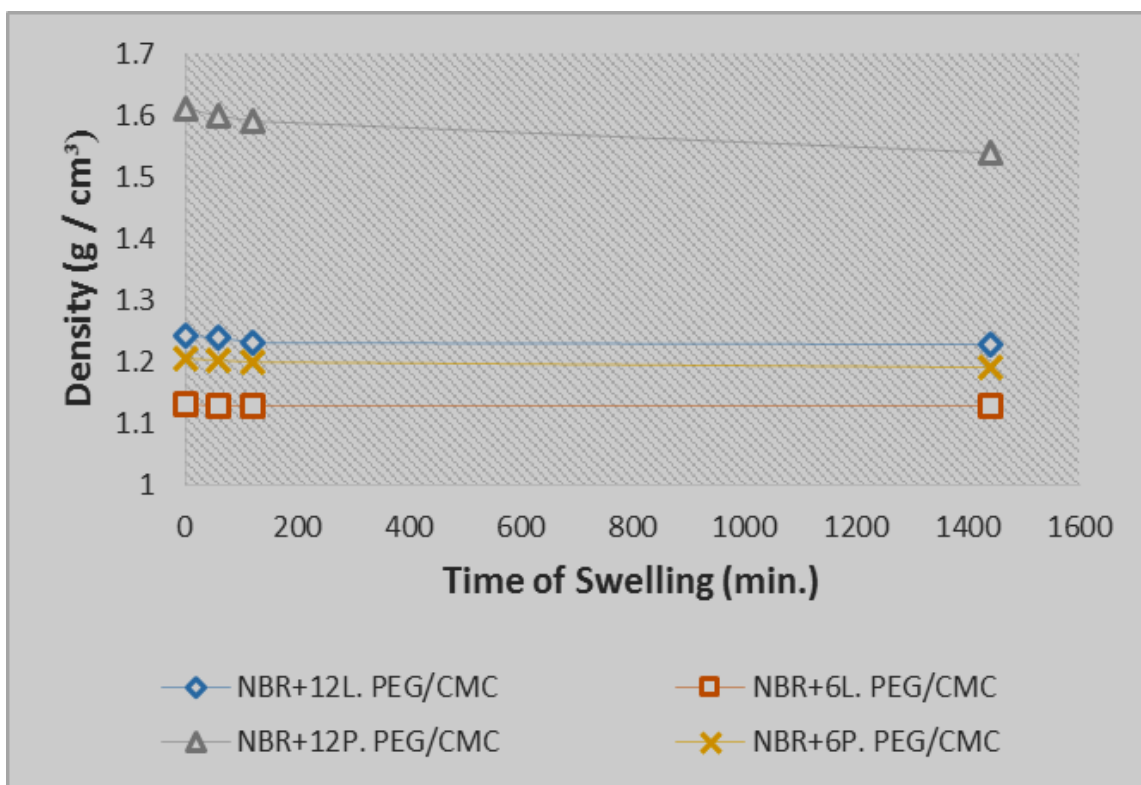


**(A)**
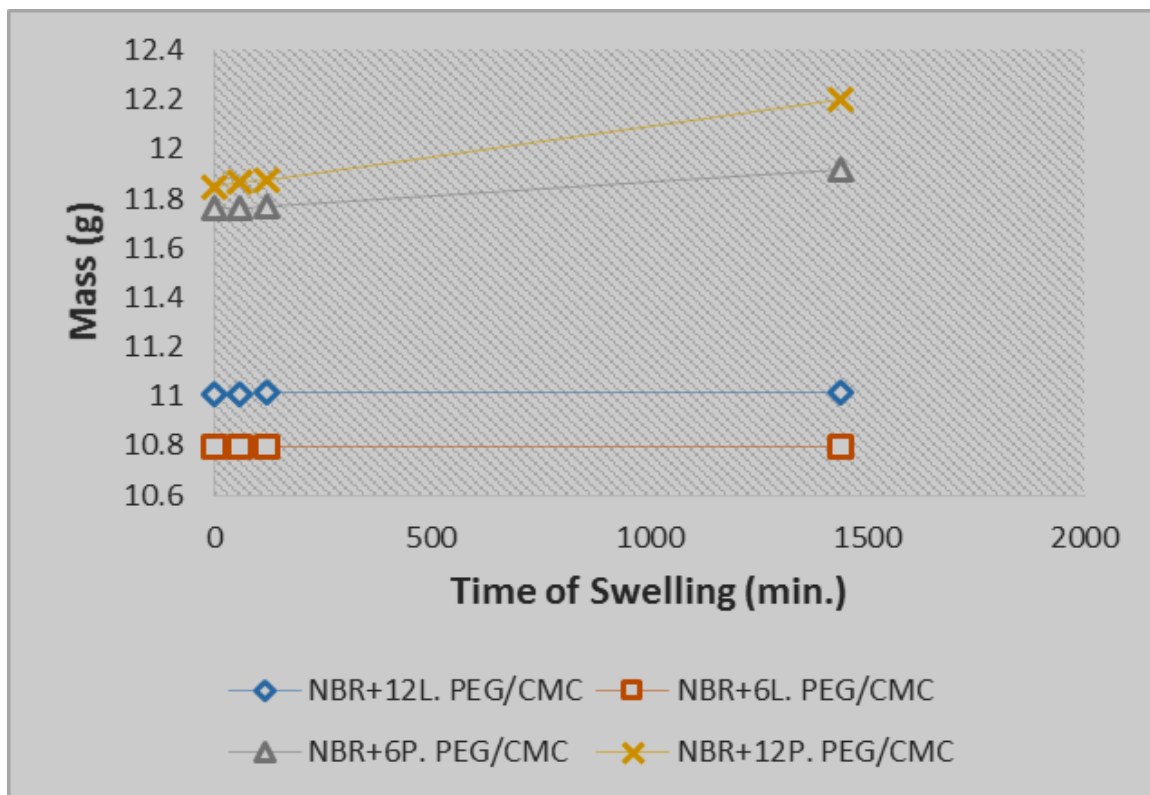
**(B)**



**(C)**

**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) $\varepsilon_{ff}$ the detector efficiency of the specific $\gamma$-ray, I is the intensity of the $\gamma$-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·kg$^{-1}$ of $^{226}$Ra, 0.7 Bq·kg$^{-1}$ of $^{232}$Th, and 13 Bq·kg$^{-1}$ of $^{40}$K produces the same gamma radiation dose rates. The index is given:

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

where $C_{Ra}$, $C_{Th}$ and $C_K$ are the average activity concentration in the sample in $Bq \cdot kg^{-1}$ 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 effective dose ($0.7$ $Sv \cdot Gy^{-1}$) the indoor to outdoor ratio (1.4), the oufdtdoor 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:

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

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

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

## 4. 4. The External and Internal Hazard Index

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

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

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

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 $mGy \cdot y^{-1}$. The maximum values of $H_{ex}$ equal to unity correspond to the upper limit of $Ra_{eq}$ (370 $Bq \cdot kg^{-1}$).

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 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 as show in the Table (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·y$^{-1}$) | | Hazard Index | | Activity Concentr. Index ($I_\gamma$) |
|---|---|---|---|---|---|---|---|
| | | | 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.** Shows the effects such as the radium equivalent and the absorbed dose rate and HazarIndex.

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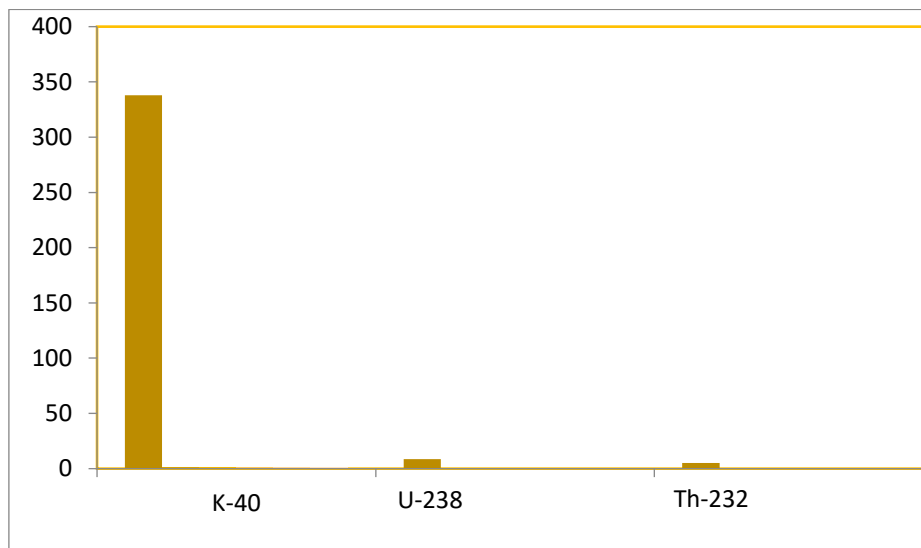
**Fig. 3.** Show Specific activities of radionuclides $^{40}$K, $^{238}$U, $^{232}$Th.

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 Figure (3) and (4) then everyone within the global allowable limits as shown in Tables 3 and 4 this indicate that the rubber material free of radiation, possible to deal with them safely.
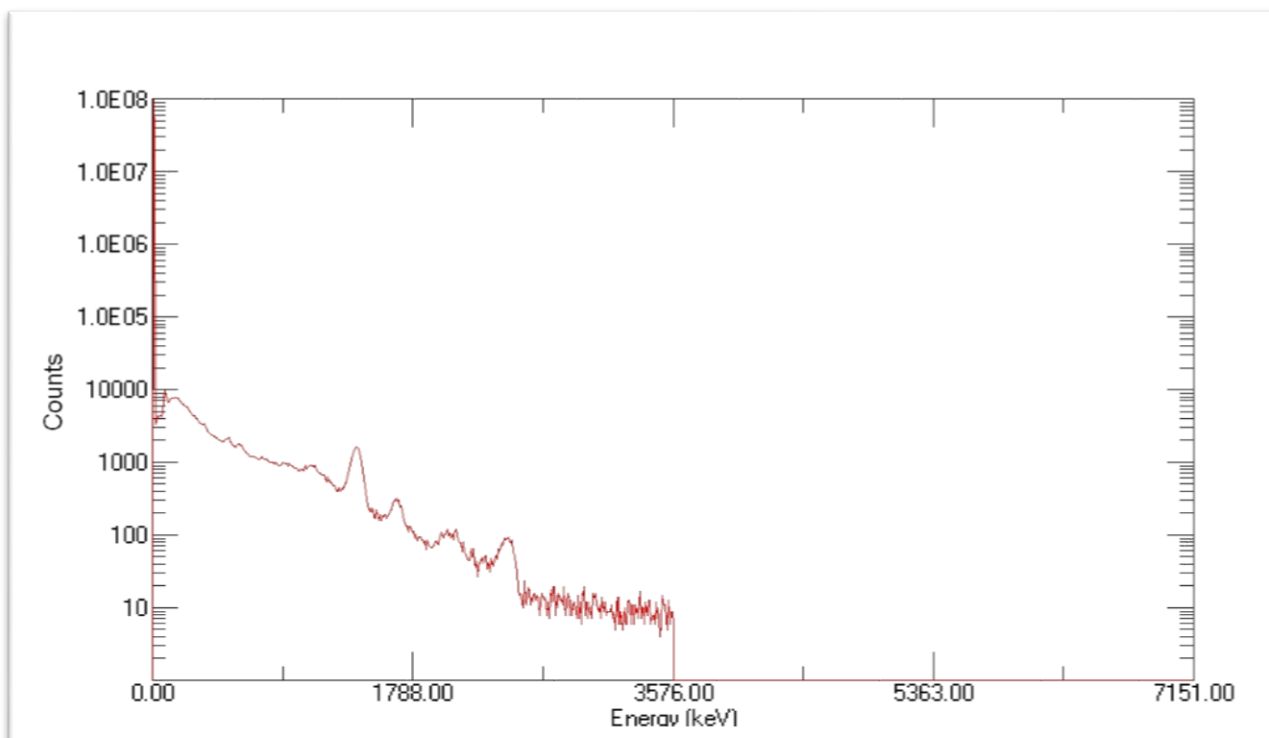


**Fig. 4.** Nuclear spectrum for rubber sample

## 6. CONCLUSIONS

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

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