Measurement of Radioactivity in Some Motor Oil Samples by Using (HPGe) Detector

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Abstract: In this work, we have measured specific activity in ten motor oil samples for ten origins taken from the local markets by using high purity germanium (HPGe) detector. The results obtained have shown that the highest values of specific activity of (U-238, Th-232 and K-40) which was equal to (22.520 Bq/l, 26.640 Bq/l and 221.340 Bq/l), for [(Rasheed) sample (Iraq origin), (Noblu) sample (Iran origin) and (Maas) sample (Netherland origin)], respectively, while the lowest values of specific activity for (238U, 232Th and 40K) was found in (Jopetrol) sample (Jourden origin) which was equal to (12.340 Bq/l, 11.450 Bq/l and 97.530 Bq/l), respectively, the paper considers the first study in Iraq to measured specific activity for motor oil samples.

Keywords: (HPGe) Detector, Motor Oil, Specific Activity, Hazards Indicies

1. Introduction

Natural environmental radioactivity and the associated external exposure due to gamma radiation depend mainly on the local geological and geographical conditions and appear at different levels in each region in the World. natural radionuclides in the ground, oil, air, food, the universe and even elements our own bodies. The assessment of these doses from natural materials is important as an external radiation exposures from natural materials which contribute to about 50% of the average annual dose to humans from all radiation sources [1].

Gamma radiation emitted from naturally occurring radioisotopes, such as K-40 and the radionuclides from the Th-232 and U-238 series and their decay products (also called terrestrial background radiation), which exist as trace levels in all ground formations, represents the main external source of irradiation to the human body [2].

Radioisotopes that are present in soil significantly affect terrestrial gamma radiation levels. In the last decade, several studies were carried out to assess the average outdoor terrestrial gamma dose rate in air [3]. Oil, motor oil, and gas are used in a number of different ways, containing: fuel for lubricants, electricity production, transport, and consumer products and numerous industrial. In terms of the raw materials, gas and oil originate from the breakdown of organic matter in a sedimentary formation (the source rock) and may become trapped in a suitable reservoir structure. Many types of reservoir structures are known, but all require that the vertical migration of oil and gas from the porous reservoir rock be prevented by an impervious covering known as the Caprock (often rock salt or clay) [4].

The radionuclides identified in the gas and oil streams belong to the decay chains of the naturally occurring primordial radionuclides U-238 and Th-232. These parent radionuclides have very long half-lives and are present in the earth’s crust with activity concentrations that depend on the type of the rock. Radioactive decay of U-238 and Th-232 produces several series of daughter radioisotopes of different physical characteristics and of different elements with respect to their half-lives, modes of decay, and types and energies of emitted radiation [5]. The major radioactive of elements that are enhanced by the oil and the gas industry and that have potentially hazardous effects on the environment and humans due to their radiotoxicity and long half-lives are Ra-226 belonging to U-238 decay series and Ra-228 that belongs to the Th-232 decay series.
[6]. The aim of the present work is to measured specific activity in different types for motor oil samples from different origins by using high purity germanium (HPGe) detector.

2. Experimental Setup

A. Collection and Preparation of the samples

Motor oil samples which were available in the local markets, some of them were Iraqi origins and the others from different foreign origins, then weighed and transferred to (1000 ml) labelled Marinelli beakers and stored. The sealed motor oil samples were then kept for about one month before measurements in order to achieve secular equilibrium for U-238 and Th-232 with their respective progenies [7].

B. Specific activity concentrations of radionuclides

The specific activity concentrations of radionuclides in motor oil samples were obtained by using the equation [8]:

\[
A = \frac{(Net\; Area-BG) \times M \times I_{\gamma}(E_{\gamma}) \times eff \times T}{...} \quad (1)
\]

where:

- B.G: Background activity.
- A: specific activity concentrations of the radionuclides measured in (Bq/l) units.
- eff: efficiency of the detectors at energy \( E_{\gamma} \).
- \( M \): mass motor oil samples (liter).
- \( I_{\gamma}(E_{\gamma}) \): the abundance at energy \( E_{\gamma} \).
- T: time of measurement which was equal to (7200 s).

C. Radiation Hazard indices Calculation

1. Radium Equivalent Activity (Ra\textsubscript{eq})

The distribution of U-238, Th-232 and K-40 in motor oil is not uniform. Uniformity in respect of exposure to radiation has been defined in terms of (Ra\textsubscript{eq}) in (Bq/l) units and is given by the expression [9]:

\[
Ra_{eq}(Bq/kg) = A_{U} + 1.434A_{Th} + 0.077A_{K} \quad ... (2)
\]

Where, \( A_{U} \), \( A_{Th} \) and \( A_{K} \) are the specific activity concentrations of U-238, Th-232 and K-40 in (Bq/l) units respectively.

2. Absorbed Gamma Dose Rate (\( D_{\gamma} \))

Absorbed dose rate (\( D_{\gamma} \)) in (nGy/h) units can be calculated using the following formula [10]:

\[
D_{\gamma}(nGy/h) = 0.462A_{U} + 0.604A_{Th} + 0.0417A_{K} \quad ... (3)
\]

3. Annual Effective Dose Equivalent (AEDE)

The (AEDE) received by a member is calculated from the absorbed dose rate by applying dose conversion factor of (0.7 Sv/Gy) and the occupancy factor for outdoor and indoor was 0.2 and 0.8 respectively (AEDE) is determined using the following equations [11]:

\[
(AED)_{o}(mSv/y) = D_{\gamma}(nGy/h) \times 10^{6} \times 8760/y \times 0.80 \times 0.7Sv/Gy \quad (4)
\]

\[
(AED)_{i}(mSv/y) = D_{\gamma}(nGy/h) \times 10^{6} \times 8760/y \times 0.20 \times 0.7Sv/Gy \quad (5)
\]

4. Gamma Index (\( I_{\gamma} \))

The gamma index (\( I_{\gamma} \)) was determined by using the following relation [12]:

\[
I_{\gamma} = \frac{A_{U}}{150} + \frac{A_{Th}}{100} + \frac{A_{K}}{1500} \quad ... (6)
\]

5. External (\( H_{ex} \)) and Internal (\( H_{in} \)) Hazard Indices

To estimate radiation dose expected to be delivered externally if a building is constructed, (\( H_{ex} \)), due to the emitted \( \gamma \)-rays, can be calculated using the following equation [13]:

\[
H_{ex} = \frac{A_{U}}{370} + \frac{A_{Th}}{4810} + \frac{A_{K}}{4810} \quad \leq 1 \quad ... (7)
\]

In addition to the external irradiation, radon and its daughter products are also hazardous to the respiratory organs. The internal exposure to radon and its short-lived products is proscribed by (\( H_{in} \)). The internal hazard index is calculated by the following formula [13]:

\[
H_{in} = \frac{A_{U}}{185} + \frac{A_{Th}}{259} + \frac{A_{K}}{4810} \quad \leq 1 \quad ... (8)
\]

3. Results and Discussions

Our present investigation is based on the study of ten motor oil samples from different origins taken from the local markets, table 1 it can be noticed that:

Table 1. Kinds, Origins, specific activities of radionuclides and some other parameters hazards indices in motor oil samples.

<table>
<thead>
<tr>
<th>No.</th>
<th>Kinds</th>
<th>Origins</th>
<th>U-238 (Bq/l)</th>
<th>Th-232 (Bq/l)</th>
<th>K-40 (Bq/l)</th>
<th>Ra\textsubscript{eq} (Bq/kg)</th>
<th>D\textsubscript{\gamma} (nGy/h)</th>
<th>(A.E.D) (mSv/y)</th>
<th>I\textsubscript{\gamma}</th>
<th>Hazard index</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Jopetrol</td>
<td>Jourden</td>
<td>12.340</td>
<td>11.450</td>
<td>97.530</td>
<td>36.223</td>
<td>16.684</td>
<td>0.082</td>
<td>0.020</td>
<td>0.262</td>
</tr>
<tr>
<td>2</td>
<td>Lexus</td>
<td>Japan</td>
<td>21.220</td>
<td>17.540</td>
<td>103.640</td>
<td>54.282</td>
<td>24.720</td>
<td>0.121</td>
<td>0.030</td>
<td>0.386</td>
</tr>
<tr>
<td>3</td>
<td>Maas</td>
<td>Netherland</td>
<td>14.340</td>
<td>13.870</td>
<td>221.340</td>
<td>51.217</td>
<td>24.232</td>
<td>0.119</td>
<td>0.030</td>
<td>0.382</td>
</tr>
<tr>
<td>4</td>
<td>Craflf</td>
<td>KSA</td>
<td>20.440</td>
<td>20.460</td>
<td>201.740</td>
<td>65.232</td>
<td>30.214</td>
<td>0.148</td>
<td>0.037</td>
<td>0.475</td>
</tr>
<tr>
<td>5</td>
<td>Fury</td>
<td>Kuwait</td>
<td>18.340</td>
<td>13.530</td>
<td>143.760</td>
<td>48.757</td>
<td>22.640</td>
<td>0.111</td>
<td>0.028</td>
<td>0.353</td>
</tr>
<tr>
<td>6</td>
<td>Nobla</td>
<td>Iran</td>
<td>22.510</td>
<td>26.640</td>
<td>165.550</td>
<td>73.355</td>
<td>33.394</td>
<td>0.164</td>
<td>0.041</td>
<td>0.527</td>
</tr>
<tr>
<td>7</td>
<td>Liqui Moli</td>
<td>Germany</td>
<td>16.680</td>
<td>17.750</td>
<td>213.230</td>
<td>58.481</td>
<td>27.319</td>
<td>0.134</td>
<td>0.034</td>
<td>0.431</td>
</tr>
<tr>
<td>8</td>
<td>Mobil 1</td>
<td>Farance</td>
<td>19.870</td>
<td>21.850</td>
<td>200.750</td>
<td>66.573</td>
<td>30.749</td>
<td>0.151</td>
<td>0.038</td>
<td>0.485</td>
</tr>
<tr>
<td>9</td>
<td>Furtcs</td>
<td>U.A.E</td>
<td>20.450</td>
<td>15.620</td>
<td>176.520</td>
<td>56.379</td>
<td>26.243</td>
<td>0.129</td>
<td>0.032</td>
<td>0.410</td>
</tr>
<tr>
<td>10</td>
<td>Rasheed</td>
<td>Iraq</td>
<td>22.520</td>
<td>20.080</td>
<td>189.610</td>
<td>65.834</td>
<td>30.439</td>
<td>0.149</td>
<td>0.037</td>
<td>0.477</td>
</tr>
<tr>
<td>Ave.</td>
<td></td>
<td></td>
<td>18.871</td>
<td>17.879</td>
<td>171.367</td>
<td>57.633</td>
<td>26.663</td>
<td>0.131</td>
<td>0.033</td>
<td>0.419</td>
</tr>
</tbody>
</table>
The highest value of specific activity of $^{238}\text{U}$ was found in (Rasheed) sample (Iraq origin) which was equal to (22.520 Bq/l), while the lowest value of specific activity of ($^{238}\text{U}$) was found in (Jopetrol) sample (Jourden origin) which was equal to (12.340 Bq/l), see Figure 1, with an average value of (18.871±2.7 Bq/l).

The highest value of specific activity of $^{232}\text{Th}$ was found in (Noblu) sample (Iran origin) which was equal to (26.640 Bq/l), while the lowest value of specific activity of ($^{232}\text{Th}$) was found in (Jopetrol) sample (Jourden origin) which was equal to (11.450 Bq/l), see Figure 3, with an average value of (17.879±3.5 Bq/l).

The highest value of specific activity of $^{40}\text{K}$ was found in (Maas) sample (Netherland origin) which was equal to (221.340 Bq/l), while the lowest value of specific activity of ($^{40}\text{K}$) was found in (Jopetrol) sample (Jourden origin) which was equal to (97.530 Bq/l), see Figure 3, with an average value of (171.367±34.9 Bq/l).
The highest value of (Ra_{eq}) was found in (Noblu) sample (Iran origin) which was equal to (73.353 Bq/l), while the lowest value of (Ra_{eq}) was found in (Jopetrol) sample (Jourden origin) which was equal to (36.223 Bq/l), with an average value of (57.633±8.2 Bq/l).

The highest value of (D_{Y}) was found in (Noblu) sample (Iran origin) which was equal to (33.394 nGy/h), while the lowest value of (D_{Y}) was found in (Jopetrol) sample (Jourden origin) which was equal to (16.684 nGy/h), with an average value of (26.663±3.7 nGy/h).

The highest value of (AED) was found in (Noblu) sample (Iran origin) which was equal to (0.164 mSv/y), while the lowest value of (AED) was found in (Jopetrol) sample (Jourden origin) which was equal to (0.082 mSv/y), with an average value of (0.131±0.01 mSv/y).

The highest value of (AEDE) was found in (Noblu) sample (Iran origin) which was equal to (0.041 mSv/y), while the lowest value of (AEDE) was found in (Jopetrol) sample (Jourden origin) which was equal to (0.020 mSv/y), with an average value of (0.033±0.005 mSv/y).

The highest value of (I_{\gamma}) was found in (Noblu) sample (Iran origin) which was equal to (0.527), while the lowest value of (I_{\gamma}) was found in (Jopetrol) sample (Jourden origin) which was equal to (0.262), with an average value of (0.419±0.06).

The highest value of (H_{in}) was found in (Noblu) sample (Iran origin) which was equal to (0.259), while the lowest value of specific activity of (H_{in}) was found in (Jopetrol) sample (Jourden origin) which was equal to (0.131), with an average value of (0.207±0.02).

The highest value of (H_{ex}) was found in (Noblu) sample (Iran origin) which was equal to (0.198), while the lowest value of specific activity of (H_{ex}) was found in (Jopetrol) sample (Jourden origin) which was equal to (0.098), with an average value of (0.156±0.02). This paper considers the first study in Iraq to measure specific activity for motor oil samples of different available kinds of motor oil which were available in the local markets by using high purity germanium (HPGe) detector, finally, we would like to mention that the present study is considered to be very important and vital because it is concerned with people health and safety in the first place.

4. Conclusions

In this paper we can be concluded that:

1. The lowest values of specific activity for (^{238}U, ^{232}Th and ^{40}K) and the parameters hazards indices [Ra_{eq}, D_{Y}, (AEDE)_{in}, I_{\gamma}, H_{in} and H_{ex}] was found in (Jopetrol) sample (Jourden origin).
2. The highest value of specific activity of (^{238}U) was found in (Rasheed) sample (Iraq origin).
3. The highest value of specific activity of (^{232}Th) was found in (Noblu) sample (Iran origin).
4. The highest value of specific activity of (^{40}K) was found in (Maas) sample (Netherland origin).
5. The highest value of all the parameters hazards indices [Ra_{eq}, D_{Y}, (AEDE)_{in}, (AEDE)_{out}, I_{\gamma}, H_{in} and H_{ex}] was found in (Noblu) sample (Iran origin).

References


