Assessment Of Natural Radioactivity Level And Radiation Hazard Parameters In The Terrestrial Environment Of Eloor Island, Kerala

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ABSTRACT

The present study is aimed at measuring the concentration of primordial radionuclides in the soil samples of Eloor Island, an industrial area in Ernakulam District and evaluating the radiation exposure to the local population. The ambient radiation exposure rate was measured using potable scintillometer survey meter and the activity concentration of ²³²Th, ²³⁸U and ⁴⁰K in the soil samples were analyzed using (5×4)³ NaI(Tl) gamma spectrometer. The exposure rate measured using survey meter varied from 63 nGy h⁻¹ to 374 nGy h⁻¹. The activity concentration of ²³²Th, ²³⁸U and ⁴⁰K in soil samples ranged from 44.8 Bq kg⁻¹ to 792.8 Bq kg⁻¹ for ²³²Th, 8 Bq kg⁻¹ to 445.5 Bq kg⁻¹ for ²³⁸U and 129 Bq kg⁻¹ to 1160.5 Bq kg⁻¹ for ⁴⁰K. Hence the absorbed gamma dose and radiation hazard indices due to natural environmental radiation was done. The study showed no significant impact due to the NORM Industries in the Eloor Industrial region.

Keywords: Natural radioactivity, Gamma spectrometer, Eloor Island, Radiation exposure

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INTRODUCTION

Terrestrial gamma radiation arising from the natural radionuclides present in the soil causes both external and internal exposure. According to (Charles, 2001) out of the total radiation exposure nearly 97.7% is from natural sources and only the remaining 2.3% is from manmade sources of radiation. The natural radionuclides of importance with respect to external gamma radiation are radioactive series headed by ²³⁸U and ²³²Th along with ⁴⁰K present in the soil. Soil acts as a medium for transferring radionuclides in air and vegetables. Uranium is radiotoxic as well as chemo toxic where as thorium is to be considered as only radiotoxic (Arogunjo et al., 2009). ⁴⁰K, secondary isotope of K present in many rock forms, be an important component of the total radioactivity to which humans are exposed (Arogunjo et al., 2009). Apart from the natural concentration these radionuclides, some of the NORM (Naturally occurring radioactive materials) processing industries can contribute to the environmental levels of these radionuclides. The present study was carried out in an industrial area Eloor...
are processing rock phosphate and the monazite Th by; U-nnel analyzer with computer software; K0rials; -; kg0

The present study was carried out in 125 selected locations of Eloor island. The external radiation exposure rates were measured by a portable Scintillometer based low level radiation survey meter of type UR705. Routine calibration was done for the survey meter with a 137Cs standard source. Cross calibration with a different radiation survey meter and radioactive sources at Health Physics Unit, Indian Rare Earth’s, Udjugamandal was done. Each measurement is the average of 10 observations taken from a given location. Surface soil samples from 125 selected locations of study area were collected as per the environmental radiation measurement protocols. From each location nine samples were taken and a composite was made. Extraneous materials like plant parts, pebbles, stones etc have been removed from the soil samples and oven dried at 110°C for 24 hours to remove the water content from soil. The dried samples were crushed in mortar and allowed to pass through 70mesh sieves to maintain uniformity in soil grain size. The dried, crushed and sieved samples were packed in a 500gm polythene container and weighed. The bottles were then sealed hermetically to trap 222Rn gas and its daughter products and were kept for one-month period so as to ensure secular equilibrium between 226Ra and its daughter products. Gamma spectrometric analysis of the soil samples were done using Na(Tl) gamma ray spectrometer with 5x4 inch planar detector with adequate lead shielding coupled to a 1K channel multichannel analyzer with computer software (NETSWIN) for data acquisition and analysis. The energy response and counting efficiency of this spectrometric system was done periodically using Cs and Co gamma standards and IAEA reference materials RGU-1, RGTh-1 and RGK-1. The spectra were collected for 20,000 s each. The activity concentration of 232Th, 238U and 40K were determined from the spectrum of the corresponding samples. The activity was determined from the integrated counts under the photo peak from the energy spectrum using gamma energies of 1461keV for 40K, 228Ac was evaluated from 1764 keV gamma line of 214Bi and for 232Th 2614keV gamma line of 208Tl was used. The Minimum Detectable Level chosen for 40K was 34Bqkg⁻¹, for 232Th, 8 Bqkg⁻¹ and for 238U, 9 Bqkg⁻¹. The radiation dose resulting from the primordial radionuclides in air (1 m above the ground surface) was estimated using the following formula given by (Charles, 2001)

\[
D = (0.621C_{232Th} + 0.462C_{238U} + 0.0417C_{40K}) \text{ nGy h}^{-1}
\]

Where, \(C_{232Th}\), \(C_{238U}\) and \(C_{40K}\) are the average activity concentrations of 232Th, 238U and 40K in Bq kg⁻¹, respectively, in soil samples.

**STUDY AREA**

The study area namely Eloor (Udyogamandal) is an island of 14.2 Sq.km formed between two distributaries of river Periyar and is the largest industrial belt in Kerala. The place is located at a Latitude of 10.0667° North and Longitude 76.3000° East and is at an elevation of 4.3 m above Mean Sea Level. The sketch of study area is given in fig 1.

![Map showing study area](image_url)

**Fig 1. Sketch of the study area**

Twenty five percent industries of the state are located along the bank of river Periyar and the concentration of these industries is within a stretch of 5 Km in the Eloor-Edayar area. Eloor has more than 247 industries manufacturing a range of products like chemical-petrochemical, pesticides and insecticides, rare earth elements, rubber processing chemicals, fertilizers, zinc/chromium compounds and leather products. The two major industries of interest with respect to Naturally Occurring Radioactive Minerals (NORMs) are a fertilizer plant processing rock phosphate and the monazite processing plant, which has been in operation for the last 50 years. Apart from these industries, a zinc processing plant and a synthetic rutile production plant have been in operation for several years in the area.

**MATERIALS AND METHODS**

The present study was carried out in 125 selected locations of Eloor island. The external radiation exposure rates were measured by a portable Scintillometer based low level radiation survey meter of type UR705. Routine calibration was done for the survey meter with a 137Cs standard source. Cross calibration with a different radiation survey meter and radioactive sources at Health Physics Unit, Indian Rare Earth’s, Udjugamandal was done. Each measurement is the average of 10 observations taken from a given location. Surface soil samples from 125 selected locations of study area were collected as per the environmental radiation measurement protocols. From each location nine samples were taken and a composite was made. Extraneous materials like plant parts, pebbles, stones etc have been removed from the soil samples and oven dried at 110°C for 24 hours to remove the water content from soil. The dried samples were crushed in mortar and allowed to pass through 70mesh sieves to maintain uniformity in soil grain size. The dried, crushed and sieved samples were packed in a 500gm polythene container and weighed. The bottles were then sealed hermetically to trap 222Rn gas and its daughter products and were kept for one-month period so as to ensure secular equilibrium between 226Ra and its daughter products. Gamma spectrometric analysis of the soil samples were done using Na(Tl) gamma ray spectrometer with 5x4 inch planar detector with adequate lead shielding coupled to a 1K channel multichannel analyzer with computer software (NETSWIN) for data acquisition and analysis. The energy response and counting efficiency of this spectrometric system was done periodically using Cs and Co gamma standards and IAEA reference materials RGU-1, RGTh-1 and RGK-1. The spectra were collected for 20,000 s each. The activity concentration of 232Th, 238U and 40K were determined from the spectrum of the corresponding samples. The activity was determined from the integrated counts under the photo peak from the energy spectrum using gamma energies of 1461keV for 40K, 228Ac was evaluated from 1764 keV gamma line of 214Bi and for 232Th 2614keV gamma line of 208Tl was used. The Minimum Detectable Level chosen for 40K was 34Bqkg⁻¹, for 232Th, 8 Bqkg⁻¹ and for 238U, 9 Bqkg⁻¹. The radiation dose resulting from the primordial radionuclides in air (1 m above the ground surface) was estimated using the following formula given by (Charles, 2001)

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RADIATION HAZARD PARAMETERS

Mean Radium equivalent activity concentration index, Ra$_{eq}$. The specific activities of radium, thorium and potassium in different combinations in soil samples has been compared using a single index called the radium equivalent activity concentration index, Ra$_{eq}$, which is defined as (Beretka & Mathew, 1985)

$$ Ra_{eq} = C_{Ra} + 1.43 C_{Th} + 0.077 C_{K} $$

Where $C_{Ra}$, $C_{Th}$, and $C_{K}$ are the specific activities of $^{226}$Ra ($^{238}$U), $^{232}$Th and $^{40}$K (in Bq kg$^{-1}$) respectively. This equation is based on the estimate that 1Bq Kg$^{-1}$ of $^{226}$Ra ($^{238}$U), 0.7 Bq Kg$^{-1}$ of $^{232}$Th or 13 Bq Kg$^{-1}$ of $^{40}$K generate the same $\gamma$-ray dose rate.

Radiation Hazard Indices: In order to measure the radiation hazard to the dwellings using the soil for the construction of buildings, the external radiation hazard, $H_{ex}$ and internal radiation hazard, $H_{in}$, were calculated by the following equation (Ahmed, 2005).

$$ H_{ex} = \frac{A_{Ra}}{370} + \frac{A_{Th}}{258} + \frac{A_{K}}{4810} $$

$$ H_{in} = \frac{A_{Ra}}{185} + \frac{A_{Th}}{259} + \frac{A_{K}}{4810} $$

where $A_{Ra}$, $A_{Th}$ and $A_{K}$ are the activities of $^{226}$Ra, $^{232}$Th and $^{40}$K in Bq kg$^{-1}$. The values of the indices should be <1. (Krieger, 1981).

The gamma hazard index, $I_{\gamma}$: It is defined as

$$ I_{\gamma} = \frac{C_{Ra}}{150} + \frac{C_{Th}}{100} + \frac{C_{K}}{1500} $$

This index can be used to estimate the level of $\gamma$ radiation hazard associated with the natural radionuclides in specific materials (Harb, 2008).

Annual effective dose equivalent: The annual effective dose equivalent was estimated using the dose rate data obtained from the concentration values of natural radionuclides in soil samples, adopting the conversion factor from the absorbed dose in the air to the effective dose (0.7 Sv Gy$^{-1}$) and the outdoor occupancy factor (0.2) proposed by UNSCEAR, 2000 the annual effective dose rate was calculated from the formula,

$$ \text{Effective dose rate (mSv y}^{-1}) = D \times 8760 \times 0.2 \times 0.7 \times 10^{-6} $$

RESULT AND DISCUSSION

The results of dose rate measurements done using survey meter and the activity concentrations of $^{40}$K, $^{238}$U and $^{232}$Th in soil samples in the study area are presented in Table: 1. It can be observed that the maximum dose obtained in survey meter measurement was 374 nGy h$^{-1}$ and the minimum obtained was 63 nGy h$^{-1}$ with a mean value of 159.2 nGy h$^{-1}$. The activity concentration of $^{232}$Th in soil samples ranges from 44.8 Bq kg$^{-1}$ to 792.8 Bq kg$^{-1}$ with a mean value of 344.2 Bq kg$^{-1}$. The $^{238}$U is in the range of 8 Bq kg$^{-1}$ to 445.5 Bq kg$^{-1}$ with a mean value of 44.1 Bq kg$^{-1}$ and that of $^{40}$ K activity is in a range of 129.4 Bq kg$^{-1}$ to 1160.5 Bq kg$^{-1}$ with a mean value of 534.1 Bq kg$^{-1}$. The median values of concentration of $^{232}$Th, $^{238}$U and $^{40}$K in soils are 304, 27.1 and 459.1 Bq kg$^{-1}$ respectively. The world average concentration of $^{232}$Th, $^{238}$U and $^{40}$K are 45, 33 and 420 Bq kg$^{-1}$ respectively and the all India average values for $^{232}$Th, $^{238}$U and $^{40}$K are 64, 29 and 400 Bq kg$^{-1}$. The mean activity concentrations of $^{232}$Th, $^{238}$U and $^{40}$K obtained in the present study were 7.6, 1.3 and 1.3 times respectively higher than the world average values and 5.4, 1.5 and 1.3 times respectively higher than the Indian average values respectively (Ziqiang & Binglin, 2000).

<table>
<thead>
<tr>
<th>Radionuclide</th>
<th>Minimum</th>
<th>Maximum</th>
<th>Median</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>$^{232}$Th (Bq kg$^{-1}$)</td>
<td>44.8</td>
<td>792.8</td>
<td>304</td>
<td>344.2</td>
</tr>
<tr>
<td>$^{238}$U (Bq kg$^{-1}$)</td>
<td>8</td>
<td>445.5</td>
<td>27.1</td>
<td>44.1</td>
</tr>
<tr>
<td>$^{40}$K (Bq kg$^{-1}$)</td>
<td>129</td>
<td>1160.5</td>
<td>459.1</td>
<td>534.1</td>
</tr>
</tbody>
</table>

The absorbed gamma dose rate in air 1m above ground due to $^{232}$Th, $^{238}$U, $^{40}$K was calculated from their mean activity concentration and is presented in table 1. It is found that the absorbed dose rate varied from 54.5 nGy h$^{-1}$ to 602.1 nGy h$^{-1}$ with a mean value of 256.4 nGy h$^{-1}$. A very good co-relation was observed between the calculated and measured dose rates ($R^2 =0.75$) (Fig 2).

The co-relational analysis between absorbed dose rate and the dose owing individual radionuclides indicates that absorbed dose rate and dose owing to $^{232}$Th (Fig 3) to be closer ($R^2 =0.9$) and this may be due to the fact that major portion of the dose is contributed due to thorium content in the soil, negligible activity due to uranium and Potassium. The contribution by $^{232}$Th to total absorbed gamma dose rate was 83.1%, whereas $^{238}$U and $^{40}$K contribute about 8.4% and 8.5% respectively in the study area.
The hazard indices, external hazard index ($H_{ex}$) calculated in the present study varies from 0.3 to 3.7 and the $H_{in}$ calculated in the present study varies from 0.4 to 4.3. The value of these indices must be kept less than unity for the radiation hazard to be negligible. The gamma representative level calculated varies from 0.9 to 9.5. The annual effective dose for the outdoor environment calculated from the absorbed dose rate in the study area was found to be varying from 0.1 to 0.7 with a mean value of 0.3 mSv y\(^{-1}\). This was found to be higher when compared to the natural background gamma level 0.07 mSv y\(^{-1}\) reported by (Ziqiang & Binglin, 2000) for normal background areas. The value of radiation hazard parameters in some locations in the study area exceeds the recommended limit, may be due to the presence of relatively higher activity concentration of natural radionuclides in the soil in that locations.

**CONCLUSION**

The activity level of \(^{232}\text{Th}\), \(^{238}\text{U}\) and \(^{40}\text{K}\) analyzed in the 125 soil samples in the Eloor island indicates the presence of relatively higher values in the activity levels in some locations as compared to levels from national and international references. The most significant was the presence of thorium which was five times higher as compared to national average. The result also shows a good co-relation between \(^{232}\text{Th}\) series activity and the gamma dose. The relatively higher concentration of natural radionuclides in the soil samples attributed to the higher values of radiation hazard parameters in some locations.

These relatively higher values in some locations may be due to some historic reasons such as either phosphogypsum landfills done earlier or natural presence of monazite patches. The findings of the study showed no significant impact due to the NORM Industries in the Eloor Industrial region. There is very scarce baseline information for radioactivity levels in this region and this study has made a significant contribution for setting up reference levels for studies pertaining to natural radioactivity in the soil samples of this region in future.

**ACKNOWLEDGEMENT**

The authors are thankful to Principal, The Cochin College, Kochi for providing necessary laboratory facilities and officials and staffs for their kind co-operation and support. This work has been done as a part of the research project granted by Board of Research in Nuclear Sciences (BRNS), Department of Atomic Energy, Government of India. (Sanction No. 2007/36/57-BRNS/2416 dated 18-1-08).

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**Table 3. Radiation Hazard parameters measured in the Eloor island.**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Range</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annual effective dose</td>
<td>0.1 – 0.7</td>
<td>0.3</td>
</tr>
<tr>
<td>$R_{an}$</td>
<td>117.5 – 1532.6</td>
<td>577.4</td>
</tr>
<tr>
<td>$H_{ex}$</td>
<td>0.3 – 3.7</td>
<td>1.6</td>
</tr>
<tr>
<td>$H_{in}$</td>
<td>0.4 – 4.3</td>
<td>1.7</td>
</tr>
<tr>
<td>Radiation hazard index, $I_H$</td>
<td>0.9 – 9.5</td>
<td>4.1</td>
</tr>
</tbody>
</table>

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**Fig 3.** Correlation between the \(^{232}\text{Th}\) dose rate and total dose rate

The relatively higher level of activity concentration of radionuclides in some locations of study area may be due to some historic reasons such as phosphogypsum landfills or natural presence of monazite patches. The comparison of mean value of activity concentration of natural radionuclides in the studied area with those of other literatures is presented in the Table 2.

**Table 2.** Comparison of activity concentration of natural radionuclides obtained in the present study and other parts of the world (Charles, 2001).

<table>
<thead>
<tr>
<th>Parameter</th>
<th>$^{40}\text{K}$ (Bq kg(^{-1}))</th>
<th>$^{238}\text{U}$ (Bq kg(^{-1}))</th>
<th>$^{232}\text{Th}$ (Bq kg(^{-1}))</th>
<th>Absorbed $\gamma$ dose rate (nGy h(^{-1}))</th>
</tr>
</thead>
<tbody>
<tr>
<td>World average</td>
<td>420</td>
<td>33</td>
<td>45</td>
<td>59</td>
</tr>
<tr>
<td>China</td>
<td>440</td>
<td>84</td>
<td>41</td>
<td>62</td>
</tr>
<tr>
<td>Japan</td>
<td>310</td>
<td>29</td>
<td>28</td>
<td>53</td>
</tr>
<tr>
<td>Indian average</td>
<td>400</td>
<td>29</td>
<td>64</td>
<td>56</td>
</tr>
<tr>
<td>Coastal Karnataka</td>
<td>122</td>
<td>36</td>
<td>31.1</td>
<td>41.7</td>
</tr>
<tr>
<td>Ullal</td>
<td>268</td>
<td>546</td>
<td>2971</td>
<td>2212</td>
</tr>
<tr>
<td>Present study</td>
<td>534.1</td>
<td>44.1</td>
<td>344.2</td>
<td>256.4</td>
</tr>
</tbody>
</table>

**Radiation hazard parameters:** In order to evaluate the radiation hazards to the local population living in the island due to the presence of natural radionuclides in soil the radium equivalent activity, external hazard index, internal hazard index, annual effective dose equivalent, representative level index etc were calculated from the activity concentration of natural radionuclides in the soil samples. The results of radiation hazard parameters $R_{an}$, $H_{in}$, external hazard indices and internal hazard indices evaluated were given in table 3. It can be seen that the average value of $R_{an}$ for the soil in the study area is 577.4 Bq kg\(^{-1}\), which is five times higher than the world average value of 89Bq kg\(^{-1}\) and also the value exceeds the safe limit of 370 Bq kg\(^{-1}\) given by It can be seen that the average value of $R_{an}$ for the soil in the study area is 577.4 Bq kg\(^{-1}\), which is five times higher than the world average value of 89Bq kg\(^{-1}\) and also the value exceeds the safe limit of 370 Bq kg\(^{-1}\) given by (Charles, 2001).
REFERENCES


