Fundamental Journals
International Journal of Fundamental Physical Sciences (IJFPS)
IJFPS, Vol 5, No 2, pp 38-42, June , 2015
DOI:10.14331/ijfps.2015.330084

Original Research Papers
Open Access Journals
ISSN: 2231-8186
P. J. JoJo
http://fundamentaljournals.org/ijfps/index.html

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

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(*Received March 2015; Published June 2015*)

ABSTRACT

The present study is aimed at measuring the concentration of primordial radionuclides in the soil samples of Eloor Island, an industrial area in Ernakulum 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 ^{232}Th, ^{238}U and ^{40}K in the soil samples were analyzed using (5×4)" NaI(Tl) gamma spectrometer. The exposure rate measured using survey meter varied from 63 nGyh^{-1} to 374 nGyh^{-1}. The activity concentration of ^{232}Th, ^{238}U and ^{40}K in soil samples ranged from 44.8 Bq kg^{-1} to 792.8 Bqkg^{-1} for ^{232}Th, 8 Bqkg^{-1} to 445.5 Bqkg^{-1} for ^{238}U and 129 Bqkg^{-1} to 1160.5 Bqkg^{-1} for ^{40}K. 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

DOI:10.14331/ijfps.2015.330084

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 ^{238}U and ^{232}Th along with ^{40}K 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). ^{40}K, 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 (udyogmandal) located on the bank of Periyar river, one of the major river in this region, is a home for number of major and minor industries in operation. The major industries of these regions produce fertilizers, insecticides, zinc and rare earths majority of these discharge their treated effluents into the river Periyar and the surrounding neighborhood. Rock phosphate is known to contain elevated levels of ^{238}U ranging from 1.0 to 5.7 Bq g^{-1} (Barišić, Lulić, & Miletić, 1992; Guimond & Hardin, 1989; Van der Heijde, Klijn, & Passchier, 1988) and its daughter products. Studies in the Periyar river on radioactivity distributions were reported earlier with emphasis on effluent discharges from the monazite industry (Haridasan, 2000; Khan, Pillai, Maniyan, Sujatha, & Haridasan, 2001; Pillai, December 2002; Sujata, 2001). Data for surrounding island environs are limited. The present work investigated the environmental levels of natural radionuclides in the soil and the associated dose levels in the air in the Eloor Island, (Udyogamandal) and thereby evaluating the radiation hazards to the local population residing in the island.

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 10.0667^0 North and Longitude 76.3000^0 East and is at an elevation of 4.3 m above Mean Sea Level. The sketch of study area is given in fig 1.

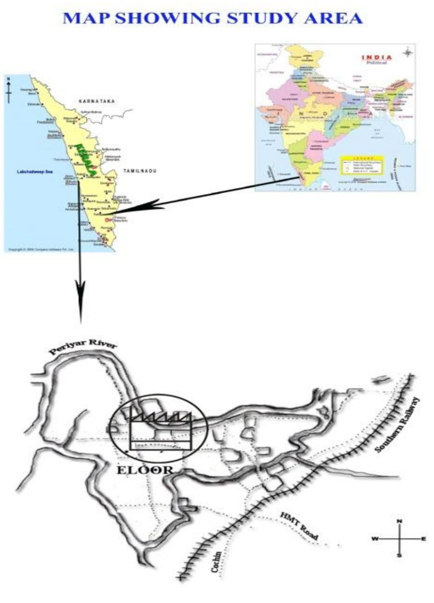

Fig 1. Sketch of the study area

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 ^{137}Cs standard source. Cross calibration with a different radiation survey meter and radioactive sources at Health Physics Unit, Indian Rare Earth's, Udyogamandal 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^{0}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 ^{222}Rn gas and its daughter products and were kept for one-month period so as to ensure secular equilibrium between ^{226}Ra and its daughter products. Gamma spectrometric analysis of the soil samples were done using NaI(Tl) gamma ray spectrometer with 5×4 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 ^{232}Th, ^{238}U and ^{40}K 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 ^{40}K, ^{238}U was evaluated from 1764 keV gamma line of ^{214}Bi and for ^{232}Th 2614keV gamma line of ^{208}Tl was used. The Minimum Detectable Level chosen for ^{40}K was 34Bqkg^{-1}, for ^{232}Th, 8 Bqkg^{-1} and for ^{238}U, 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)

$$D = (0.621C_{Th} + 0.462C_U + 0.0417C_K)\ nGy\ h^{-1} \quad (1)$$

Where, C_{Th}, C_U and C_K are the average activity concentrations of ^{232}Th, ^{238}U and ^{40}K in Bq kg^{-1}, respectively, in soil samples.

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)

$$Ra_{eq} = C_{Ra} + 1.43C_{Th} + 0.077C_K \quad (2)$$

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 γ- 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).

$$H_{ex} = \frac{A_{Ra}}{370} + \frac{A_{Th}}{258} + \frac{A_K}{4810} \quad (3)$$

$$H_{in} = \frac{A_{Ra}}{185} + \frac{A_{Th}}{259} + \frac{A_K}{4810} \quad (4)$$

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, Iγ: It is defined as

$$I_\gamma = \frac{C_{Ra}}{150} + \frac{C_{Th}}{100} + \frac{C_K}{1500} \quad (5)$$

This index can be used to estimate the level of γ 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,

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

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 792.8Bq 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 higher than the Indian average values respectively (Ziqiang & Binglin, 2000).

Table 1. Activity concentration of natural radionuclides, their corresponding absorbed dose rate and measured dose rate in the study area

Parameters	Minimum	Maximum	Median	Mean
^{232}Th (Bq kg^{-1})	44.8	792.8	304	344.2
^{238}U (Bq kg^{-1})	8	445.5	27.1	44.1
^{40}K (Bq kg^{-1})	129	1160.5	459.1	534.1
Absorbed gamma dose rate (nGy h^{-1})	54.5	602	232.4	256.4
Measured gamma dose rate (nGy h^{-1})	63.1	374.1	159.2	176.2

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).

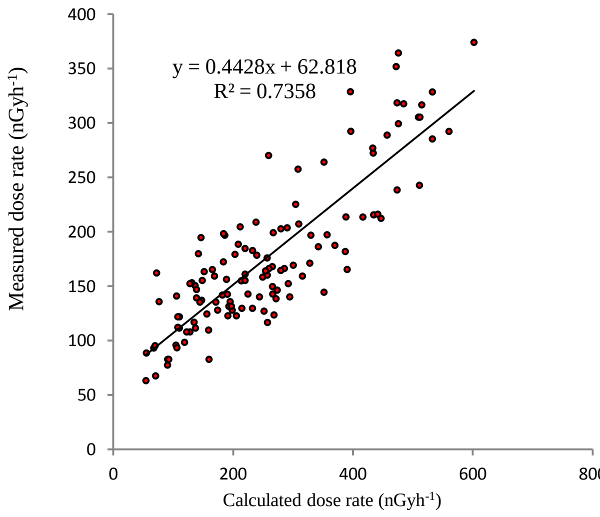

Fig2. Calculated dose rate versus measured dose rate

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.

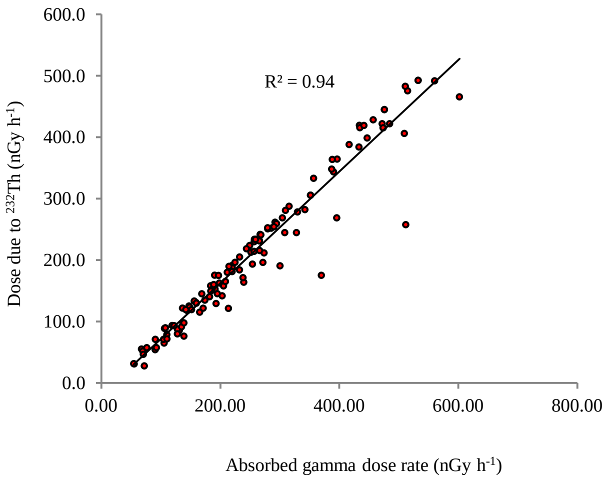

Fig 3. Correlation between the ^{232}Th dose rate and total dose rate

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).

	^{40}K (Bq kg^{-1})	^{238}U (Bq kg^{-1})	^{232}Th (Bq kg^{-1})	Absorbed γ dose rate (nGy h^{-1})
World average	420	33	45	59
China	440	84	41	62
Japan	310	29	28	53
Indian average	400	29	64	56
Coastal Karnataka	122	36	31.1	41.7
Ullal	268	546	2971	2212
Present study	534.1	44.1	344.2	256.4

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 Ra_{eq}, external hazard indices and internal hazard indices evaluated were given in table 3. It can be seen that the average value of Ra_{eq} 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 Ra_{eq} 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).

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

Parameter	**Range**	**Mean**
Annual effective dose	0.1 – 0.7	0.3
Ra_{eq}	117.5 – 1352.6	577.4
H_{ex}	0.3 – 3.7	1.6
H_{in}	0.4 – 4.3	1.7
Radiation hazard index, Iγ	0.9 – 9.5	4.1

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 keep 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}Th, ^{238}U and ^{40}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}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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