ELEVATED NATURAL RADIOACTIVITY IN SOIL SAMPLES OF COASTAL KERALA, INDIA

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ABSTRACT

A systematic investigation on the radiation level and distribution of natural radionuclide's in the soils was carried out along coastal Kerala, India. A detailed external background gamma radiation level was carried out using a sensitive plastic scintillometer. The soil samples were collected following the standard procedure and analyzed for the concentration of natural radionuclides. Exceptionally high levels of gamma dose rates in air were observed in some sampling locations. The gamma spectrometry measurements indicate that the activity concentrations of $^{226}$Ra and $^{232}$Th in surface soil was found to be greater than the world average values reported by the United Nations Scientific Committee on the Effects of Atomic Radiation. A good correlation was observed between the activity concentrations of $^{226}$Ra and $^{232}$Th with organic matter content in soil. The results of these investigations are presented and discussed in this paper.

Key Words: Environmental radioactivity, Soil, Gamma spectrometry, Thorium, Atomic Radiation

INTRODUCTION

The exposure of human beings to ionizing radiation from natural sources is a continuous and inescapable feature of life on earth. For most individuals, this exposure exceeds that from all man-made sources combined. Exceptions that apply are some exposures caused by medical radiation procedures, through mishandling of radiation sources in accidents allowing radionuclides to be released to the environment and at some workplaces. In all cases, however the natural background source forms the baseline upon which all other exposures are added and it is a common level against which other exposures may be compared. There are two main contributors to natural radiation exposures high-energy cosmic ray particles incident on the earth's atmosphere and radioactive nuclides that originated in the earth's crust and are present everywhere in the environment with half-lives comparable to the age of the earth and their decay products. External exposure to human is mostly due to the presence of terrestrial radionuclides such as $^{238}$U and $^{232}$Th series and singly occurring $^{40}$K in soils sand at trace levels. The specific levels are related to the types of rock from which the soils originate. The high radiation levels have been observed in many countries due the enrichment of radioactive minerals in soil and sand leading to the formation of what are known as high background radiation areas. It should be noted that exposures in high background areas can vary in times as deposits are replenished by springs or environmental conditions. Urbanization of these areas may also lead to moderate change in the background levels. It is felt necessary to determine the background levels of radionuclides in soils of coastal regions of Kerala, India to provide an even more extensive evaluation of the exposure levels in high background radiation areas.

MATERIAL AND METHODS

Study area

The coastal region of Kerala extends to a length of 580 km. The pockets of monazite bearing regions of Kerala, India which has a significant resident population living for generations at comparatively higher background radiation levels appear suitable for natural radioactive level studies.
Gamma radiation survey
A detailed external gamma radiation survey was carried out along inlands and beach areas using a sensitive plastic scintillometer. The scintillometer was fabricated and calibrated at Health Safety and Environment Group, Bhabha Atomic Research Centre, Mumbai, India. It consists of a plastic scintillator of 5.5 cm diameter and height of 15 cm. The scintillator is covered with a thin coating of ZnS (Ag) to improve energy response below 60 keV\(^2\). The readings were recorded at a height of 1m above the ground level.

![Map of the study area showing sampling stations](image)

**Fig. 1 :** Map of the study area showing sampling stations

Sample collection and preparation
The top soils were collected from selected nine sampling stations (Fig. 1) along coastal Kerala. Standard techniques were followed in the collection of samples. While plant residues and stones were removed and samples were dried in an oven at 110°C till a constant dry weight is obtained. Dried samples were sieved and a soil of less than 250 micron particle size was used. About 250-300 g of each dried samples were filled in an air tight cylindrical polyethylene containers and sealed for minimum period of 30 days in order to attain secular equilibrium\(^3\). After equilibrium is attained the containers were placed on the detector and the activity was counted.

Experimental set-up
Natural radioactivity in soil samples was counted using a high resolution HPGe gamma spectrometry system. The HPGe detector was a co-axial n-type high purity germanium detector (model GR 4021 Canberra USA)
having an active volume of 41.1 cm³. The detector has a resolution (FWHM) of 2.01 keV at 1332 keV for gamma energy of Co-60 and has a relative efficiency of 42%. The output of the detector was analyzed using a 16K MCA system connected to PC. MCA functions were controlled by Genie 2000 software. The detector was mounted on a cryostat of type 7500 SL/ RDC/ ULB. The detector was shielded using 10 cm thick lead to reduce the background interface effects. The efficiency calibration for the system was carried out using RG U-238, RG Th-232, RG K-1 and SOIL-6 obtained from the International Atomic Energy Agency. The activity of ⁴⁰K was evaluated from the 1461 keV photopeak, the activity ²²⁶Ra from weighted mean of the activities of three photopeaks of ²¹⁴Bi (609.3, 1129.3 and 1764.5 keV) after subtracting the background counts and applying the Compton correction. In case of ²³²Th two photopeaks of ²⁰⁸Tl (583.1 and 2614.5 keV) were used in the same way. The Minimum Detection Levels (MDL) for the gamma spectrometry system used in the present study was 0.9, 1.2 and 4.06 Bq kg⁻¹ for ²²⁶Ra, ²³²Th and ⁴⁰K respectively. The samples were counted for a period of 30,000s.

**Organic matter measurement**

The organic matter present in the soil enhances the adsorption of radionuclides, although the amount adsorbed commonly comprises only a small fraction of the total¹. In the present study organic matter content of the soil was determined by the weight loss-on-ignition method⁵,⁶ at an ignition temperature of 550°C for 24 hours.

**RESULTS AND DISCUSSION**

**The natural radioactivity level in soil**

The ²²⁶Ra activity concentrations in top soils of study area were found to vary from 16.8 Bq kg⁻¹ to 304.8 Bq kg⁻¹. The ²³²Th activity concentrations vary from 40.5 Bq kg⁻¹ to 1342.3 Bq kg⁻¹ and that of ⁴⁰K was observed from 55.3 Bq kg⁻¹ to 333.0 Bq kg⁻¹. The highest value of 194.2 Bq kg⁻¹ of ²²⁶Ra was found in Trivandrum soil which is higher than world average values of 32 Bq kg⁻¹ for ²²⁶Ra given by UNSCEAR⁷. The Kollam region showed a greater value of 1342.3 Bq kg⁻¹ for ²³²Th activity concentration which is 30 times higher than the world average⁷ value 45 Bq kg⁻¹. The ⁴⁰K activity concentrations in all samples were below the world average⁷ value 420 Bq kg⁻¹. The **Fig. 2** clearly indicates the activity concentration of ²²⁶Ra, ²³²Th and ⁴⁰K in top soils of study area.

**Correlation study**

A good correlation was observed between of ²²⁶Ra, ²³²Th with organic matter content in soil samples. The correlation coefficients are 0.90 for ²²⁶Ra versus organic matter content and 0.86 for ²³²Th versus organic matter content in the soil as shown in **Fig. 3**, and **Fig. 4**. A poor negative correlation of - 0.26 was observed between ⁴⁰K and organic matter. This indicates that low dependence of ⁴⁰K in organic fraction of soil than ²²⁶Ra and ²³²Th. The elevated value of radioactivity in the samples can also attribute to the monazite mineral content in the soil samples.

**Gamma dose rate in air**

The biological effect, radiological, and clinical effects are directly related to the absorbed dose rate. The absorbed dose rates in air ‘D’ (nGy h⁻¹), at about 1.0 m above the surface were calculated based on the guidelines provide by the UNSCEAR⁷ using equation 1.

\[
D(\text{nGy h}^{-1}) = 0.604 C_{\text{Tb}} + 0.462 C_{\text{U}} + 0.0417 C_{\text{K}}
\]

Where \(C_{\text{Tb}}\), \(C_{\text{U}}\) and \(C_{\text{K}}\) are the activity concentrations (Bq kg⁻¹) of ²³²Th, ²²⁶Ra and ⁴⁰K respectively in the soil samples. Other than Kannur, Malappuram and Thrissur regions all the other sampling stations showed higher absorbed dose rate in air. The highest value of 958.7 nGy h⁻¹ found in Kollam which is much higher than the world average value 60 nGy h⁻¹. It may be noted that the major contribution to the gamma dose rates in air comes from the radionuclides of thorium series.
Fig 2: $^{226}$Ra, $^{232}$Th and $^{40}$K activity concentrations (Bq kg$^{-1}$) in soil along the sampling stations

Fig. 3: Correlation graph of $^{226}$Ra and organic matter content

Fig. 4: Correlation graph of $^{232}$Th and organic matter content


CONCLUSION

The external gamma dose rates in air in certain locations of coastal Kerala, India is exceptionally high from the normal variability ranges. The concentration of radionuclides in soil has dependence on organic matter content and also on the mineral composition of the soil. The values obtained from the present study indicates that the radioactivity in soil samples were much higher than the world average value in most of the locations along coastal Kerala, India.

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