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Assessment of natural radionuclides in the soil samples from Marwar region of Rajasthan, India

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HIGHLIGHTS

- Natural radionuclides were studied in soil samples of Jodhpur and Nagaur districts.
- All the samples were characterized by using NaI(Tl) Gamma ray spectrometry.
- External and internal hazard for the studied soil samples were within safe limit.
- The soil of studied area can be used as a construction material.

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ABSTRACT

In the present investigation, ^{226}Ra, ^{232}Th and ^{40}K analysis has been carried out in the soil samples collected from different locations of Jodhpur and Nagaur districts of Northern Rajasthan, India using gamma ray spectroscopy. The measured activity concentration ranges from 13 ± 8 to 36 ± 9 Bq kg^{-1}, 40 ± 9 to 71 ± 11 Bq kg^{-1} and 294 ± 125 to 781 ± 159 Bq kg^{-1} with the mean value of 24 ± 9 Bq kg^{-1}, 55 ± 11 Bq kg^{-1}and 549 ± 141 Bq kg^{-1} for ^{226}Ra, ^{232}Th and ^{40}K, respectively. The radium equivalent activity of all the soil samples ranges from 114 to 157 Bq kg^{-1} with an average value of 141 Bq kg^{-1}, which is lower than the safe limit 370 Bq kg^{-1} as set by the Organization for Economic Cooperation and Development. The total absorbed dose of all the investigated samples varies from 56 to 77 nGy h^{-1} with an average value of 68 nGy h^{-1}. The overall annual effective dose ranges from 0.34 to 0.47 mSv with the average value of 0.41 mSv. The corresponding values of external and internal hazard index of all the soil samples ranges from 0.32 to 0.43 and 0.37 to 0.53 with an average value of 0.39 and 0.45 respectively. It was observed that the soil of Jodhpur and Nagaur districts is suitable for construction purpose without posing any health hazard.

1. Introduction

The natural radionuclides are usually found in soil, rocks, plants, water and air (Ibrahiem et al., 1993; Malanca et al., 1996). The information about these natural radionuclides concentration levels and their effect on the environment is of great importance in several fields of science and engineering. Therefore it is useful to know the distribution of source rock materials containing higher levels of natural radionuclides in soil. The naturally occurring radionuclides present in soil include ^{226}Ra, ^{232}Th and ^{40}K (Rani and Singh, 2005; Menon et al., 1982). Gamma radiation emitted from these naturally occurring radionuclides, represents the main source of irradiation on human body and contribute to the total absorbed dose via. Ingestion, inhalation and external irradiation (Steinhausler, 1992).

The presence of radionuclides above a certain permissible level in soil becomes a health hazard. Their exposure is associated with the risk of leukemia and certain other cancers such as melanoma, cancers of kidney and prostate (Henshaw et al., 1972). As a consequence the soil radioactivity is usually important for the purpose of establishing base line data for further radiation impact assessment, radiation protection and exploration (Ramli et al., 2005).

The concentration of natural radionuclides in soil varies from one region to another region in the World. Recently it has been

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reported that the activity concentration of natural radionuclides found in the soil samples of Hanumangarh, Sriganganagar, Churu and Sikar districts of Rajasthan was higher than the permissible limit (Duggal et al., 2013). Jodhpur and Nagaur are adjoining districts to the reported areas. Hence the study on the measurement of activity concentration of natural radionuclides in these adjoining districts assumes significance. Such a study will be helpful in determining whether the soil of these adjoining regions can be used for construction purpose without posing any health hazard. However literature survey shows that no attempt has been made towards the measurement of activity concentration of natural radionuclides in the Jodhpur and Nagaur districts. In the present study the activity concentration of natural radionuclides ^{226}Ra, ^{232}Th and ^{40}K in the soil samples from Jodhpur and Nagaur districts of Rajasthan, India has been investigated.

2. Geology of the area

Rajasthan is located in North West of India. It lies between 23 °30' and 30 °11' north latitude and 69 °29' and 78 °17' east longitude. Fig. 1 shows the geographic location of Rajasthan in India, as well as the location of the sampling sites.

Jodhpur district the study area in the present work is located in western part of Rajasthan and is bounded by 26 °00' to 27 °37' latitude and 72 °55' to 73 °55' longitude. It shares common border with five districts namely Bikaner, Jaisalmer in north and northwest, Banner and Pali in South West and South East and Nagaur in East-North East. The area is covered by Hillocks rocks, Luni-Jawa Plains, Sukri and Jojri rivers. The rocks of the area contain sandstone, limestone and granite. The major mineral occurrence of the district is Jasper, Dolomite and Ball clay. The geological configuration of Jodhpur district is represented by rocks ranging from Pre-Cambrian to recent in age. The lithounits consist of igneous, sedimentary and metamorphic units.

Nagaur district falls almost in the central part of Rajasthan. The district is bounded by the latitudes 26 °02'–27 °37' and longitudes 73 °05'–75 °24'. This area comprises a part of great Thar desert and a large part of it is covered by windblown sand. The boundary of this region is shared by seven districts of Rajasthan viz. -Jaipur, Ajmer, Pali, Jodhpur, Bikaner, Churu and Sikar. This district is well known over the world owing to the presence of Makrana marble.

Fig. 1. The map showing samples locations in Northern Rajasthan.

It is covered by the Delhi super group rocks, Erinpura granite, Malani igneous suite, Marwar super group rocks and Jogira fuller's Earth/Kuchera Khajuwana series rocks. The lake that contains the highest content of salt i.e. Sambhar lake is located in Nagaur District. The minerals which occur in this region are limestone, lignite, gypsum and marble. The type of soil found in these two districts is clay, clay loam, sandy loam and sandy soil.

3. Materials and methods

3.1. Sample collection and preparation

In order to measure the activity concentration of natural radionuclides the soil samples were collected from 20 different locations of Jodhpur and Nagaur districts of Marwar region of Rajasthan on random basis. The samples were collected at a depth equal to or greater than 0.75 m from the ground level so as to get the natural soil. The organic material, pebbles, roots and vegetables presented in the soil were removed manually. All these soil samples were crushed in to fine powder by using mortar pestle. Thereafter the samples were dried in an electric oven at 110 °C and sieved through 150 μm sieve. Each dried sample of 250 g was sealed in an airtight PVC container of 250 ml capacity and kept isolated for about 4 weeks, so as to ensure radioactive equilibrium among the daughter product of radon (^{226}Ra), thoron (^{232}Th) and their short lived decay products.

3.2. Gamma ray spectrometry

The activity concentration of natural radionuclides ^{226}Ra, ^{232}Th and ^{40}K were measured in soil samples by using a gamma ray spectrometer. The prepared samples were placed in a shielded gamma ray spectrometry unit for a counting time of 3 h in order to get accurate results. The measurement of natural radionuclides in soil samples was carried out by using NaI(Tl) gamma radiation detector of size 63 mm × 63 mm with a multichannel analyzer. The activity concentration of ^{40}K was determined from the 1460 keV photo peak; the activity of ^{226}Ra from the 1764 keV gamma line of ^{214}Bi; and that of ^{232}Th from the 2610 keV gamma line of ^{208}Tl (Henshaw et al., 1972). This spectral analysis was performed with the aid of computer software SPTR-ATC (AT-1315). The peak energies of gamma spectra were measured with respect to the 662 keV photo peak of ^{137}Cs. The detector was calibrated with standard sources of ^{238}U, ^{232}Th and ^{40}K; these sources have been selected as per IAEA (2003). The detection limits are 3, 3 and 30 Bq kg^{-1} for ^{226}Ra, ^{232}Th and ^{40}K respectively. The activity concentrations of the soil samples were calculated from the intensity of each line in the spectrum, taking in to consideration the mass, the geometry of the samples, the counting time and the efficiency of detector.

3.3. Radium equivalent activity

It is well known that natural radionuclides ^{226}Ra, ^{232}Th and ^{40}K are not uniformly distributed in soil. The non-uniform distribution of these naturally occurring radionuclides is due to non-equilibrium between ^{226}Ra and its decay products. For uniformity in exposure estimates, the concentration of radionuclides have been defined in terms of Radium equivalent activity (Ra_{eq}) having units Bq kg^{-1}. This permits the comparison of specific activity of materials containing different amounts of ^{226}Ra, ^{232}Th and ^{40}K by the following relation (Yu et al., 1992)

$$Ra_{eq} = C_{Ra} + 1.43C_{Th} + 0.07C_K, \quad (1)$$

where C_{Ra}, C_{Th} and C_K are activity concentrations of ^{226}Ra, ^{232}Th