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Radiation Measurements 39 (2005) 431–439
Radiation Measurements
www.elsevier.com/locate/radmeas

^{226}Ra, ^{232}Th and ^{40}K analysis in soil samples from some areas of Punjab and Himachal Pradesh, India using gamma ray spectrometry

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Received 7 July 2004; received in revised form 13 September 2004; accepted 16 September 2004

Abstract

The activity concentrations and the gamma-absorbed dose rates of the terrestrial naturally occurring radio nuclides viz. ^{226}Ra, ^{232}Th and ^{40}K were determined in soil samples collected from some areas of Punjab and Himachal Pradesh, using gamma ray spectrometry. The soil activity ranges from 18.22 to 90.30 Bq kg^{-1} for ^{226}Ra, 34.80 to 124.68 Bq kg^{-1} for ^{232}Th and 80.42 to 181.41 Bq kg^{-1} for ^{40}K with mean values of 57, 87 and 143 Bq kg^{-1}, respectively. The concentrations of these radionuclides are compared with the available data from other countries. The measured activity concentration of ^{226}Ra and ^{232}Th in soil is higher and for ^{40}K is lower than the world average. Radium equivalent activities are calculated for the analyzed samples to assess the radiation hazards arising due to the use of these soil samples in the construction of dwellings. All the soil samples have radium equivalent activities lower than the limit set in the OECD report (370 Bq kg^{-1}). The overall mean outdoor terrestrial gamma dose rate is 86.54 nGy h^{-1} and the corresponding outdoor annual effective dose is 0.11 mSv. The activity concentration of ^{238}U has also been determined using fission track technique and the values range from 1.18 to 5.12 ppm with mean value of 2.13 ppm. The content of radioactive elements in the soil of Palmpur area is found to be more compared with the samples from the other study areas of Punjab and Himachal Pradesh.

Keywords: Gamma ray spectrometry; Fission track technique; Soil samples; Ra_{eq} activities; Annual effective dose; External hazard index

1. Introduction

Human beings have always been exposed to natural radiations arising from within and outside the earth. The exposure to ionizing radiations from natural sources occurs because of the naturally occurring radioactive elements in the soil and rocks, cosmic rays entering the earth's atmosphere from outer space and the internal exposure from radioactive elements through food, water and air. Natural radioactivity is wide spread in the earth's environment and it exists in various geological formations in soil, rocks, plants, water and air (Ibrahiem et al., 1993; Aly Abdo et al., 1999; Malance et al., 1996; Myrick et al., 1983; Maul and Ohara, 1989; Pimpl et al., 1992). The natural radioactivity in soil comes from U and Th series and natural K. Artificial radionuclides can also be present such as ^{137}Cs, resulting from fallout from weapons testing. The radiological implication of these radionuclides is due to the gamma ray exposure of the body and irradiation of lung tissue from inhalation of radon and its daughters. Therefore, the assessment of gamma radiation dose from natural sources is of particular importance as natural radiation is the largest contributor to the external dose of the world population (UNSCEAR, 1988). The

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doi:10.1016/j.radmeas.2004.09.003

measurement of natural radioactivity due to gamma rays from the dose rate is needed to implement precautionary measures whenever the dose is found to be above the recommended limits. The growing worldwide interest in natural radiation exposure has lead to extensive surveys in many countries. External gamma dose estimation due to the terrestrial sources is essential not only because it contributes considerably ($0.46\,mSvy^{-1}$) to the collective dose but also because of the variations of the individual doses related to this pathway. These doses vary depending upon the concentrations of the natural radio nuclides, ^{238}U, ^{232}Th, their daughter products and ^{40}K, present in the soils and rocks, which in turn depend upon the local geology of each region in the world (Radhakrishna et al., 1993; Quindos et al., 1994). To evaluate the terrestrial gamma dose rate for outdoor occupation, it is very important to estimate the natural radioactivity level in soils. The natural radioactivity of soil samples is usually determined from the ^{226}Ra, ^{232}Th and ^{40}K contents (OECD, 79). Since 98.5% of the radiological effects of the uranium series are produced by radium and its daughter products, the contribution from the ^{238}U and the other ^{226}Ra precursors are normally ignored (Zastawny et al., 1979). Nationwide surveys have been carried out to determine the radium equivalent activity of soil samples in many countries (Singh et al., 2003; Al-Jundi et al., 2003; Mireles et al., 2003; Ibrahim, 1999; Sroor et al., 2001; Ibrahiem et al., 1993). Naturally occurring heaviest radioactive toxic element uranium is found in traces in almost all types of rocks, soils, sands and waters. Due to its property to get dissolved in aqueous solution in hexavalent (U^{6+}) form and to precipitate as a discrete mineral in tetravalent (U^{4+}) form, uranium forms deposits in the earths crust where the geological conditions become favorable.

The objective of this study was focused on determining the activity concentrations of ^{238}U, ^{226}Ra, ^{232}Th and ^{40}K in soil samples collected from different locations of Punjab and Himachal Pradesh and to see the trend in variation of these values from Punjab to Himachal Pradesh. The activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K in collected soil samples were estimated by gamma ray spectrometry and the fission track registration technique (Fleischer et al., 1975) was used for the analysis of uranium concentration in these samples.

1.1. Geology of the area

Fig. 1 shows the geographic location of the states of Punjab and Himachal Pradesh in the map of India, as well as the location of the sampling sites. The geographic location of the study area in Punjab (Amritsar to Pathankot) is between latitude 31.37 and 32.17N and longitude 74.55 and 75.42E. Punjab sediments are derived from Siwalik Himalayas and occur in the form of alluvium. The study area in Himachal Pradesh which falls in Kangra district lies between 32.05 and 32.18N latitude and 75.56 and 76.18E longitudes. The district is bounded on the SW by Una district; on the NW by district Gurdaspur of Punjab, on the North by Lahaul-Spiti and Chamba districts, on the East by Kullu and Mandi districts, while on South it touches Hamirpur district. The area is characterized by the occurrence of the following formations/Groups from north to south viz. Dhauladhar granites, Chail formation, Dharamshala traps, Dharamkot limestone, Sabathus, Dharamshala Group and Shivalik Group. The individual formation and groups are separated from one another by longitudinal thrust systems; significant among them are Main Boundary Thrust, Chail Thrust and the Drini Thrust. Apart from these tectonic planes, the rock units are crosscut by transverse faults/lineaments trending NE–SW. The southern extremity and parallel to the lesser Himalayas is the Shivalik group of rocks, which are succeeded by vast stretch of Quaternary alluvium of the state of Punjab.

2. Experimental procedure

2.1. Estimation of natural radioactivity levels by gamma spectrometry technique

In order to measure natural radioactivity in soil, surface soil samples were collected from undisturbed sites at each location. After removing the stones and organic materials, the samples were dried in an oven at about 100 °C for 1–2 h to remove the moisture content and then crushed to pass through a 150 μm mesh sieve to homogenize it. Then, a sample of $250 \pm 0.05\%$ was weighed and finally, a split of the prepared sample was packed in a standard plastic container (7.5 cm × 6.5 cm diam.) and after properly tightening the threatened lid, the containers were sealed with adhesive tape and left for at least 4 weeks (> 7 half-lives of ^{222}Rn and ^{224}Ra) before counting by gamma spectrometry in order to ensure that the daughter products of ^{226}Ra up to ^{210}Pb and of ^{228}Th up to ^{208}Pb achieve equilibrium with their respective parent radionuclides. The standard sources for ^{226}Ra and ^{232}Th (in secular equilibrium with ^{228}Th) have been prepared using known activity contents and mixing with the matrix material of phthalic acid powder. Analar grade potassium chloride (KCl) of a known amount in the same geometry has been used as the standard source for ^{40}K. The radionuclides ^{226}Ra, ^{232}Th and ^{40}K contents have been estimated using a low background gamma spectrometry system, which makes use of a $5'' \times 4''$ NaI (Tl) flat detector (M/s Harshaw low background integral assembly). The detector is enclosed in a massive 10 cm thick lead shielding lined with 1.5 mm thick cadmium followed by 0.8 mm thick copper on the inner surfaces to reduce the contribution due to fluorescence X-rays. The dimensions of the free surface within the shielding enclosure are 44 cm × 44 cm × 65 cm deep. Using different disc-type reference standard sources supplied by M/s ECIL, the gamma ray spectrometer is calibrated up to 3 MeV. The counting time for each sample was 12,000 s to get a statistically small error. With appropriate corrections for laboratory background, the activity of ^{226}Ra was evalu-