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Estimation of ^{222}Rn exhalation rate and assessment of radiological risk from activity concentration of ^{226}Ra, ^{232}Th and ^{40}K

Pargin Bangotra[a], Rohit Mehra[a,*], Rajan Jakhu[a], Kirandeep Kaur[a], Pragya Pandit[b], Sandeep Kanse[c]

[a] Radiation Physics Laboratory, Dr. B.R. Ambedkar National Institute of Technology, Punjab, India
[b] Atomic Minerals Directorate For Exploration and Research, New Delhi, India
[c] Radiological Physics & Advisory Division, Bhabha Atomic Research Centre, Mumbai, India

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ABSTRACT

The activity concentration of natural radionuclides and ^{222}Rn (Radon) exhalation rate in soil samples were determined using NaI gamma detector and Scintillation based Smart Radon Monitor (SRM). Soil samples were collected from different geological formations of the same area. The concentration of three radionuclides (^{226}Ra, ^{232}Th and ^{40}K) in the studied area has been varied from 25 Bq kg^{-1} to 48 Bq kg^{-1}, 28 Bq kg^{-1} to 47 Bq kg^{-1} and 356 Bq kg^{-1} to 598 Bq kg^{-1} respectively. The average value of ^{226}Ra (Radium) equivalent activity in soil samples of the studied area was 125 Bq kg^{-1}. The ^{226}Ra equivalent activities of soil samples have been calculated to assess the radiation hazards arising due to the use of these soils in the construction of dwellings. The exhalation of ^{222}Rn from the earth's crust and building material are the main source of ^{222}Rn in indoor environment. The ^{222}Rn exhalation rate in the studied area was varied from 16.9 ± 0.5 mBq Kg^{-1} h^{-1} to 38.2 ± 0.9 mBq Kg^{-1} h^{-1}. A weak correlation was obtained between the ^{226}Ra and ^{222}Rn exhalation rate. The annual effective doses for different organs and radiation hazards have been also calculated in the studied area. The overall average annual effective dose in the studied is lower than the world recommended value of 1.0 mSva^{-1}.

1. Introduction

Primordial radionuclides ^{238}U (Uranium), ^{232}Th (Thorium) and ^{40}K (Potassium) are existed since the creation of earth. Especially ^{40}K and the radionuclides of ^{238}U - ^{226}Ra and ^{232}Th series are relevant with respect to radiological dose to human beings (UNSCEAR, 1988, 2000). The worldwide average natural dose to human is 1.4–2.4 mSv y^{-1}. The distribution of natural radionuclides and its radiological effects is most important factor for affecting the human environment. The dose rate varies from place to place depending on concentration of natural radionuclides in the soil. Natural radioactivity concentration depends mainly on geological and geographical conditions and appears at different levels in soils from different geological regions (UNSCEAR, 2000). 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 cancer such as melanoma, cancers of kidney and prostate (Henshaw et al., 1972).

There are few regions in the world known to High Background Radiation Areas (HBRAs) due to local geology and geochemical effects that cause enhanced level of terrestrial radiation (UNSCEAR, 1993, 2000). Very high background radiation areas are found at Guarapari, the coastal region of Espirito Santo and the Morro Do Forro in Mines Gerais in Brazil (Veiga et al., 1999; Paschoa, 2000), Yangjiang in China (Wei and Sugahara, 2000), the southwest coast of India (Sunta et al., 1982; Sunta, 1993; Ghiassi-Nejad et al., 2012), in the United States and Canada and in some other countries (UNSCEAR, 2000).

The dwellings in India have been constructed with bricks mixed with nearly 80% of soil, which may contain highly occurred concentrations of natural radionuclides (Ferdoas et al., 2007). Every building construction material contains different quantities of natural radioactive nuclides. Radiation exposure due to building materials can be further divided into external and internal exposure. External gamma dose estimation due to the terrestrial sources is essential not only because it contributes considerably to the collective dose but also because of variations of the individual dose related to this pathway. The external exposure is caused by direct gamma radiation, whereas internal exposure is caused by inhalation of ^{222}Rn (Radon), ^{220}Rn (Thoron) and their decay products (Bangotra et al., 2015; Mehra et al.,

* Corresponding author.
E-mail address: mehrar@nitj.ac.in (R. Mehra).

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2015; Mehra et al., 2016; Evans et al., 1981). Higher values of uranium concentration in water samples and its radiological risk along with higher concentration of ^{222}Rn, ^{220}Rn and their decay products have been reported in neighbouring districts (Punjab) of studied area (Sharma and Singh, 2017; Bangotra et al., 2015; Mehra et al., 2014). So an initiative has been taken to study the radiation hazards and radiological risk from soil in Barnala and Sangrur districts for health risk assessment. The main objective of the present study was to study the level of radioactive element viz. ^{226}Ra, ^{232}Th, and ^{40}K in the Barnala and Sangrur region of Punjab (India). The doses of organs and tissues have been also calculated for health risk assessment. In this region, soil is main constituent of brick material used in construction of dwellings.

In this manuscript, the ^{222}Rn exhalation from the soil samples has been also taken into consideration for the health hazard studies. The rate at which ^{222}Rn escapes or emanates from the solid into surrounding air is known as ^{222}Rn emanation or ^{222}Rn exhalation. Many previous studies for ^{222}Rn exhalation rate have been conducted using Can technique (Saad et al., 2013; Sharma and Virk, 2001; Kumar et al., 2005; Menon et al., 2015). Can technique was discarded due interference of ^{220}Rn and tiny leaks from the can. Since the 'cans' are closed with gaskets (not hermetically sealed), it cannot guarantee the zero leakage of the ^{222}Rn during the course of its equilibrium and build– up over a period of 90 days in the can (Menon et al., 2015). In this paper, a Smart Radon Monitor (SRM) has been used for the estimation of ^{222}Rn exhalation rate (Gaware et al., 2011). This method refer to as dynamic method in which the ^{222}Rn monitor, placed in a re-circulating closed loop connected to the soil chamber and inbuilt pump, monitors the ^{222}Rn concentration at regular intervals. The present investigation will be helpful to determine whether the soil of the studied area can be used for construction purpose without posing any health hazard. The obtained data may be the baseline for future research and useful for radiation protection and radiological mapping in Northern India.

2. Geology

The state of Punjab is a vast alluvial plain which is composed of Quaternary Alluvium deposits- Older alluvium, Newer Alluvium and the Aeolian deposits. The scattered outcrops of the Aravali- Delhi Subgroup occur at Tosham (Haryana) just south of the study area i.e. Barnala and Sangrur Districts of Punjab, India (Fig. 1). The soil in the study area falls in the arid and moisture regime. The soils associated with alluvial planes shows better indurations and mature development of soil profile. They are composed of different layers of clay, sticky clay and fine to coarse grained micaceous sandstone (Kochhar et al., 2006).

3. Material and methodology

3.1. Sampling

The soil samples were collected from the different locations of Barnala and Sangrur districts of Punjab, India. In order to collect the natural soil, the soil samples have been collected from an auger hole at a depth of 0.75 m from the ground. The collected samples were crushed into fine powder using pestle and then soil passed through a scientific sieve of 150 μ mesh to obtain sample for measurement. The samples were then dried in an oven at a temperature of 383 K for 24 h. Before measurement each sample was packed in airtight PVC container and kept for a period of four weeks in order to obtain a radioactive equilibrium.

3.2. Measurement of natural radioactivity

Gamma spectroscopy has been used for the measurement of activity concentration of the soil samples due to its salient feature of less time consuming and non- destructive method. The ^{226}Ra, ^{232}Th and ^{40}K has been estimated in studied area using NaI (Tl) gamma detection detector of size 63 mm × 63 mm with a multichannel analyzer. The samples were counted for a period of 10,800 s and analyzed the photo peak of gamma ray of energy 1764 keV, 2610 keV and 1460 keV emitted from ^{226}Ra, ^{232}Th and ^{40}K respectively. The spectral analysis was done with the help of Gamma radiation computer software SPTR – ATC (AT–1315). The peak energies of the gamma ray spectra were measured in reference to the 661-keV photo peak of ^{137}Cs. The activity concentrations of these soil samples were calculated from the intensity of each line in the spectrum, taking into account the mass, geometry of the samples, counting time and efficiency of the detector. The detection limits of the radionuclides, ^{226}Ra, ^{232}Th and ^{40}K are 3 Bq kg^{-1}, 3 Bq kg^{-1} and 30 Bq kg^{-1} respectively. The air absorbed dose rate

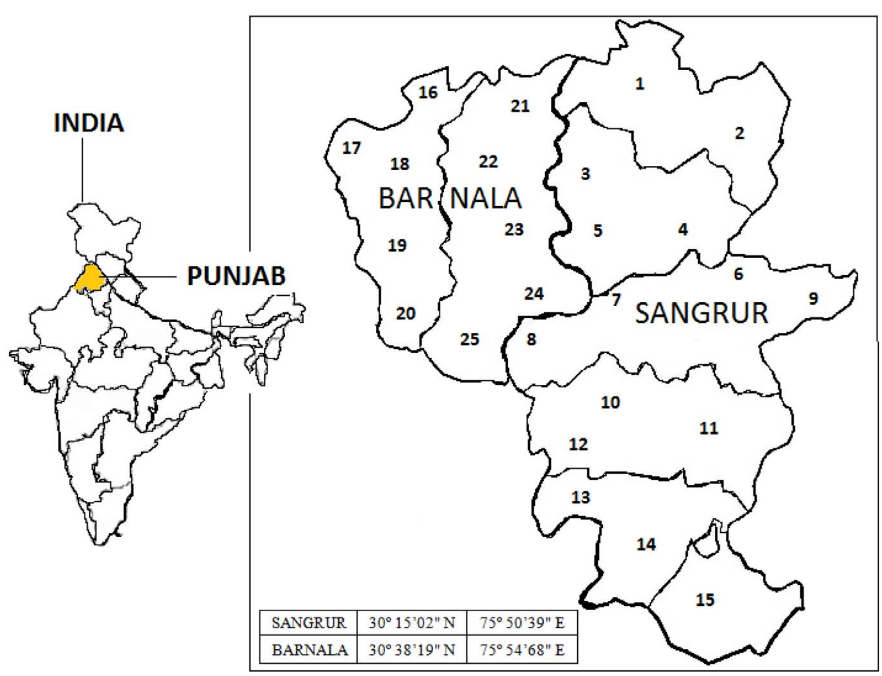

Fig. 1. Map of the investigated area (Barnala and Sangrur) of Punjab (India).