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Radon exhalation and gamma radioactivity levels in soil and radiation hazard assessment in the surrounding area of National Thermal Power Corporation, Dadri (U.P.), India

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HIGHLIGHTS

- High resolution gamma ray spectroscopy with HPGe for ^{226}Ra, ^{232}Th & ^{40}K activity concentration in soil.
- Lungs damage risk from radon inhalation; Radon exhalation measurements using SSNTD's.
- External hazard index, gamma absorbed dose rates & annual effective dose rates estimation.
- Average dose rates and Ra_{eq}values, lower than world average.
- Positive correlation between radium activity and radon exhalation rate.

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ABSTRACT

In the present study soil samples were collected from the region around a National Thermal Power Corporation (NTPC) at Dadri (U.P.), India. Radon activity and radon exhalation rates were measured by using "sealed can technique" using LR 115-type II nuclear track detectors. Radon activities are found to vary from 177.5 ± 23.1 to 583.4 ± 4.9 Bq m^{-3} with an average value of 330.5 ± 30.4 Bq m^{-3}. Surface exhalation rates in these samples vary from 63.9 ± 8.3 to 210.2 ± 15.1 mBq m^{-2} h^{-1} with an average value of 119.1 ± 11.1 mBq m^{-2} h^{-1}, whereas mass exhalation rates vary from 2.5 ± 0.3 to 8.1 ± 0.6 mBq kg^{-1} h^{-1} with an average of 4.6 ± 0.4 mBq kg^{-1} h^{-1}.

Activity concentrations of naturally occurring radionuclides (^{226}Ra, ^{232}Th and ^{40}K) were also measured in these soil samples using high resolution γ−ray spectroscopic system. Activity concentrations of ^{226}Ra, ^{232}Th, and ^{40}K vary from 32.2 ± 6.0 to120.9 ± 4.5 Bq kg^{-1}, 19.3 ± 0.9 to 44.6 ± 1.5 Bq kg^{-1} and 195.4 ± 2.8 to 505.4 ± 6.3 Bq kg^{-1} with overall mean values of 70.0 ± 8.9 Bq kg^{-1}, 34.8 ± 1.2 Bq kg^{-1} and 436.1 ± 5.6 Bq kg^{-1} respectively. From the activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K, radium equivalent activity (Ra_{eq}) and the external hazard index (H_{ex}) were calculated and found to vary from 73.4 to 214.7 Bq kg^{-1} and from 0.2 to 0.6 respectively.

1. Introduction

Coal contains natural radionuclides ^{226}Ra, ^{232}Th and ^{40}K. These radionuclides may be concentrated in fly ash after combustion in a thermal power plant. Fly ash from a thermal power plant is spread and distributed in the surrounding area by air and may be deposited on the soil of the region surrounding the thermal power plant. Thus it is quite important to estimate the radon exhalation rate and natural radioactivity in the soil around the thermal power plant for the estimation of radiation risk to the habitants there. Soil, the main source of continuous radiation exposure to human beings is generally considered as the third (next to air and water) main environmental component. Natural radioactivity is wide spread in the earth's environment and it exists in soils, rocks, water and sand etc (UNSCEAR, 1993) and these natural radioactive material can

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reach hazardous radiological levels under certain conditions. Soil is widely used as construction material in India such as in the formation of bricks and as filling materials etc. Thus the measurement of natural radioactivity in soil which is the basic indicator of radiological contamination in the environment is important to know the health risks and to establish base line data for future radiation protection and exploration (Ramli et al., 2005).

In the coal fired power stations, coal produces large amount of fly ash after burning. This fly ash is spread and distributed in surrounding area by air and may be deposited on the soil surface. Since coal contains ^{226}Ra, ^{232}Th and ^{40}K radionuclide so almost all naturally existing radionuclides are present in fly ash and hence may increase in the soil of the surrounding area. The determination of radioactive pollutants in soil is of great importance owing to the fact that plant roots are one of the ways of incorporating them in the food chain.

Various studies concerning radioactivity bound to soil have been carried out such as: (Al-Hamarnch and Awadalhah, 2009; Mehra et al., 2010; Mahur et al., 2010; Gusain et al., 2009; Tzortzis and Tsertos, 2004) and many others. Most of these studies were concentrated on natural sources, as the natural radiation is the largest contributor to the external radiation dose of the world population. More specially, natural environmental radioactivity and the associated external exposure due to gamma-radiation depend primarily on the geological and geo-graphical conditions and appear at different levels in the soils of each region in the world (UNSCEAR, 2000).

Radiation doses vary depending upon the concentrations of the natural radionuclides like ^{238}U, ^{232}Th and their daughter products and ^{40}K, present in soil. These radionuclides pose exposure risks due to their gamma ray emission and internally due to radon and its progeny that emit alpha particles (UNSCEAR, 1988).

A comprehensive study was conducted to determine radon activity, radon exhalation rate, uranium, thorium and potassium elemental concentration in surface soils samples in the surrounding area of a thermal power plant (NTPC) at Dadri, (U.P.) India.

Samples were collected from different locations around the thermal power plant of NTPC, Dadri toward Ghaziabad, India. Correlations among measured radionuclides were made to investigate the secular equilibrium in their decay chain as this condition is essential to make correct assumptions for the dose assessments. In order to control the radiation hazards, it is necessary to know the rate at which radiation is received. Since excess of radiation levels can produce two effects: somatic effect and genetic effect. Somatic effects include the production of cancers and various forms of tissue damages i.e. affecting the body. Genetic effects are due to damage of the parent germ cells (sperms and ovum) i.e. affecting the future generations (Mehra et al., 2010). Thus calculations of the external and internal hazard indices, absorbed gamma dose rate in air out doors and annual effective dose equivalent are presented and discussed. Also the radium equivalent activity has been calculated and compared with the results in literature.

2. Materials and methods

2.1. Sample collection

A total of 11 surface soil samples have been collected from eleven different locations of the surrounding area of NTPC, Dadri (U.P) India, in which first five samples were collected from the distance at the interval of 500 m and then next six samples were collected from a distance interval of 1000 m from NTPC Dadri toward Ghaziabad. The samples were collected from different distances as the amount of spread and distributed fly ash deposited on the soil may depend on the distance from the thermal power plant. All samples were collected in the month of June 2009 in summer. After collection the samples were dried at about 100 °C to remove moisture, were crushed to fine powder and then homogenized by passing through a 100 mesh sieve.

2.2. Radon exhalation rate

For the measurement of radon exhalation rate, "sealed can technique" was used. Equal amount of samples (100 g) were placed in the cans (diameter 7.0 cm and height 7.5 cm) similar to those used in the calibration experiment (Singh et al., 1997). LR-115 type II solid state nuclear track detector (2 cm × 2 cm) was fixed on the top inside the cylindrical can. The cans are sealed for 95 days and thus the sensitive lower surface of the detector is freely exposed to the emergent radon so that it could record the tracks of alpha particles resulting from the decay of radon in the remaining volume of can. Radon and its daughters reach an equilibrium concentration after 4 h and hence the equilibrium activity of emergent radon can be obtained from the geometry of can and the time of exposure. After the exposure for 95 days the detectors were taken out and etched in 2.5 N NaOH at 60 °C for a period of 90 min in a constant temperature water bath. The resultant alpha-particle tracks were counted using an optical microscope at a magnification of 400 × . From the track density the radon activity was calculated using a calibration factor of 0.056 track cm^{-2} d^{-1} (Bq m^{-3})$^{-1}$, obtained from an earlier calibration experiment (Singh et al., 1997) and recalibration afterward.

Surface exhalation rate is obtained from the following expression (Mahur et al., 2008a,b,c)

$$E_A = \frac{\mathrm{CV}\,\lambda}{A\left[T + \frac{1}{\lambda}\left\{e^{-\lambda T} - 1\right\}\right]} \quad (1)$$

This formula is also modified to calculate the mass exhalation rate

$$E_M = \frac{\mathrm{CV}\lambda}{M\left[T + \frac{1}{\lambda}\left\{e^{-\lambda T} - 1\right\}\right]} \quad (2)$$

where, E_A is radon surface exhalation rate (Bq m^{-2} h^{-1}); E_M is radon mass exhalation rate (Bq kg^{-1} h^{-1}); C is a radon exposure as measured by LR-115 type II solid state nuclear track detector (Bq m^{-3} h); V is the effective volume of can (m^3); λ is the decay constant for radon (h^{-1}); T is the exposure time (h); A is the area of the can (m^2) and M is mass of the sample.

2.3. Estimation of ^{222}Ra, ^{232}Th and ^{40}K

Soil samples (250 g) were sealed in air tight plastic container and left for more than one month to allow radioactive equilibrium among uranium and thorium and their short lived decay products. After this, the samples were subjected to high resolution gamma spectroscopy analysis. The measurements were carried out at Inter-University Accelerator Centre, New Delhi using a coaxial n-type HPGe detector (EG & G, ORTEC, Oak Ridge USA). The detector having a resolution of 2.0 keV and a relative efficiency of 20% was placed in 4 inch shield of lead bricks on all sides to reduce the background radiation from building materials and cosmic rays (Kumar et al., 2001). The detector was coupled to a PC based 4 K multi channel analyzer and an Analog to Digital Convertor (ADC) for data acquisition. The samples were counted for a period of 72,000 s for activity measurements.