Radiological hazards from construction materials in the vicinity of thermal power station

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***Abstract-* The natural radionuclides activity concentration of ^{232}Th, ^{40}K and ^{226}Ra were measured in soils around the thermal power station in Udupi using NaI(Tl) gamma ray spectrometer. ^{232}Th, ^{40}K and ^{226}Ra mean activity in soils were found to be 17.72 Bq/kg, 54.23 Bq/kg and 32.82 Bq/kg respectively. The soil is commonly used construction material in the region. Soil is used to make bricks to construct houses and dwellings. In view of this, the radiological hazard due to natural radioactivity in soil such as Radium equivalent activity, Absorbed gamma dose rate (D), Internal hazard index (H_{in}), External hazard index (H_{ex})were assessed.**

Key words –Radioactivity, soil, coal-based power plant, Internal hazard index (H_{in}), External hazard index (H_{ex}).

I. INTRODUCTION

The fly-ash from coal-based thermal power plant is one of the major sources of radiation exposure to human beings. The combustion of coal in thermal power stations result in the production of fly-ash. The natural radionuclide like thorium, potassium and uranium present in the bulk of the coal get concentrated in fly-ash. The re-distribution of fly-ash into the environment or use of soil contaminated with fly-ash in the manufacturing of bricks to construct houses, is a potential source of radiation exposure. In view of this, a detailed study has been carried out to determine the radionuclide concentration in soils around the thermal power plant, Udupi Power Corporation Limited (UPCL), in Udupi district. From different locations surrounding thermal power plant, twenty-two soil samples were collected. In order to assess the radiological hazards, absorbed gamma dose rate in air, external hazard index, internal hazard index, radium equivalent activity and representative level index were assessed. The results of this systematic investigations are presented in the paper.

II. MATERIALS AND METHODS

Around the UPCL coal based thermal power plant, from 22 different locations, the soil samples were collected. The samples were collected from undisturbed areas away from buildings, vegetation and human activities. The top layer of the soil is cleaned by removing grass, its root mats and stones. About 1 m^2 area has been marked and top layer about up to 20cm of soil were collected. Soil samples were collected 6 km around the UPCL. First at a distance of 1km soils were collected from seven different villages round UPCL. Again, seven samples were collected in the 3 km radius zone. Finally, eight samples were collected in the 6 km zone. The sample were collected in polythene bags. The collected soil samples were taken into laboratory and were transferred to porcelain tray and dried in an oven at 100°C for constant dry weight. Moisture percentage of the sample was estimated by weight loss method. The dried sample was then sieved through 250-μ sieve. About 300gms of soil samples were taken in a plastic container, carefully sealed and kept for a period of one month to allow ^{222}Rn to attain equilibrium with its progeny (Shetty et al, 2006).

A. Measurement of radioactivity

The concentration of, ^{232}Th, ^{40}Kand ^{226}Ra in soil samples were analyzed using NaI(Tl) scintillation spectrometer. A flat type NaI(Tl) crystal of size 5" × 5" with multichannel analyzer was used. Spectrum was analyzed using GSPEC software (Para Electronics-Manufacturing Division of Electronic Enterprises, Mumbai, India). The spectrometer was calibrated both in terms of energy response and counting efficiency using the standard sources (Shetty et al., 2006). The standard sources were procured from the International Atomic Energy Agency, Vienna. The Standard sources were RG-U, RG-Th and RG-K respectively for uranium, thorium and potassium. The detector efficiency for different gamma lines of various radionuclides was calculated using the following relation,

$$E(\%) = N \times \frac{100}{c} \times \frac{100}{a}$$

Where E is the efficiency of the system, N is the net count rate under photo peak, c is the strength of the source (Bq/kg), a is the percentage of abundance of the gamma ray. The ^{226}Ra in the sample were estimated using ^{214}Bi having gamma peaks at 1764 keV (15.9%), while that of the daughter radionuclide ^{208}Tl having an energy 2614 keV (35.8%) was used to estimate ^{232}Th because the secular equilibrium was achieved between the daughter nuclides and their parent nuclides. The concentration ^{40}K was estimated from ^{40}K itself having energy 1460.8 keV (10.7%). The activity of a radionuclide in soil sample is then determined using the relation,

$$A = N \times \frac{100}{E} \times \frac{100}{a} \times \frac{1000}{W}$$

Where A is the activity of a radionuclide in Bq/kg, N is the net count rate, E is the efficiency of the detector, a is the abundance of the gamma ray, W is the weight of the sample.

III. RESULTS AND DISCUSSION

A. Activity of radionuclides in soil

The range and mean activity of ^{232}Th^{40}K, and ^{226}Ra are reported in Table 1. The ^{40}Kactivity varies from 27.82-74.40 Bq/kg with a mean value of 54.23 Bq/kg, the ^{226}Ra activity varies from 17.68-53.14 Bq/kg with a mean value of 32.82 Bq/kg and that of ^{222}Th activity varies from 10.14-33.66 Bq/kg with a mean value of 17.72 Bq/kg. The ^{232}Th and ^{40}K activity vary within the study area but ^{226}Ra activity is almost constant. The radionuclides^{226}Ra does not migrate in soil unless it is deposited on the ground. The ^{232}Th, ^{40}K and ^{226}Ra activities in soil samples were comparable with the values reported from other parts of the world (UNSCEAR, 2010).

TABLE 1. RADIONUCLIDE ACTIVITY OF ^{232}Th, ^{40}K AND ^{226}Ra IN SOILS

	Activity of ^{232}Th (Bq/Kg)	Activity of ^{40}K (Bq/Kg)	Activity of ^{226}Ra (Bq/Kg)
Mean	17.72	54.23	32.82
Median	21.86	54.30	31.53
Range	10.14-33.66	27.82-74.40	17.68-53.14

B. Absorbed gamma-ray dose rate (D)

The gamma dose rate of ^{40}K, ^{232}Th and ^{226}Ra in air above the ground surface and are reported in table 2 and calculated using following equation.

$$D(nGyh^{-1}) = 0.462\ A_{Ra} + 0.604\ A_{Th} + 0.042\ A_K$$

The absorbed gamma dose rate ^{40}K, ^{226}Ra and ^{232}Th in air varies in the range from 20.0-37.6 nGy h^{-1} with a mean value of 28.1 nGy h^{-1} and median 28.2 nGy h^{-1}. The cumulative absorbed dose rate in air due to these radionuclides varies in range 66-110 nGy h^{-1} with a mean dose rate of 83 nGy h^{-1}.

C. Radium equivalent activity (Ra_{eq})

The radium equivalent activity is the single quantity represent the specific activates of radionuclide ^{40}K, ^{232}Th and ^{226}Ra was estimated from the activity of the naturally occurring radionuclides which is reported in Table 2 by the following equation.

$$Ra_{eq}(Bq/kg) = A_{Ra} + (1.43\ A_{Th}) + (0.077\ A_K)$$

Where A_{Th} is ^{232}Th activity in Bq/kg, A_{Ra} is ^{226}Ra activity in Bq/kg, and A_K is ^{40}K activity in Bq/kg. The radium equivalent activity varies in the range 44.5-83.5 Bq/kg with a mean value of 62.3 Bq/kg.

D. External hazard index(H_{ex})

External hazard index (H_{ex}) is the external exposure to natural occurring radionuclide in soil is calculated by the equation.

$$H_{ex}(Bq/kg) = \frac{ARa}{370} + \frac{ATh}{259} + \frac{AK}{4810}$$

Where A_{Ra} is activity of ^{226}Ra in Bq/kg, A_{Th} is activity of ^{232}Th in Bq/kg and A_K is activity of ^{40}K in Bq/kg. The H_{ex} values vary from 0.12-0.23 with a mean value of 0.17. In all the sampling stations the H_{ex} values were less than unity.

E. Internal hazard index(H_{in})

Internal hazard index (H_{in}) is the internal exposure through daughter products of radon to the natural occurring radionuclides in soil is calculated by the equation.

$$H_{in}(Bq/kg) = \frac{ARa}{185} + \frac{ATh}{259} + \frac{AK}{4810}$$

Where A_{Ra} is activity of ^{226}Ra in Bq/kg, A_{Th} is activity of ^{232}Th in Bq/kg and A_K is activity of ^{40}K in Bq/kg. The H_{in} values vary from 0.17 - 0.37 with a mean value of 0.26. In all the sampling stations the H_{in} values were less than unity.

F. Representative level index($I\gamma r$)

Representative level index ($I\gamma r$) is used to estimate the level of gamma radiation hazards associated with natural occurring radionuclide concentration which is calculated using the following formula.

$$I\gamma r(Bq/kg) = \frac{ARa}{150} + \frac{ATh}{100} + \frac{AK}{1500}$$

Where $I\gamma r$ is activity of ^{226}Ra in Bq/kg, A_{Th} is activity of ^{232}Th in Bq/kg and A_K is activity of ^{40}K in Bq/kg. The H_{in} values vary from 0.16 - 0.29 with a mean value of 0.22. For the radiation hazard to be negligible Representative level index value must be less than unity.

TABLE 2. RADIOLOGICAL HAZARDOUS PARAMETERS

	D ($nGyh^{-1}$)	Ra_{eq} (Bq/kg)	H_{ex} (Bq/kg)	H_{in} (Bq/kg)	$I\gamma r$ (Bq/kg)
Mean	28.1	62.3	0.17	0.26	0.22
Median	28.2	62.5	0.17	0.25	0.22
Range	20.0-37.6	44.5-83.5	0.12-0.23	0.17-0.37	0.16-0.29

IV. CONCLUSIONS

The absorbed gamma dose rates in air due to natural radionuclides around power plant (UPCL) is within the permissible level. The mean activity of ^{232}Th, ^{40}K and ^{226}Ra in soils around UPCL was measured using NaI(Tl) gamma ray spectrometer and the values are comparable with the those reported from other environs of the world. The activity of ^{40}K and ^{232}Th were found to be higher than ^{226}Ra in some locations. The hazard index parameters are within the recommended level. Therefore soils around the thermal power station is free from radiological hazards and can be used to prepare bricks for the construction of dwellings.

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