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

Narayana Yerol1, Sandesh Achari1, Vinutha P R2, Kaliprasad C S3, Prafulla1 and Shrinidhi Kini1

1Department of Physics, Mangalore University, Mangalore, India-574 199
2Beary’s Institute of Technology, Bollyar, Mangalore, India-574 153
3BMS College of Engineering, Basavanagudi, Bengaluru, India-560 019

Abstract- The natural radionuclides activity concentration of 232Th, 40K and 226Ra were measured in soils around the thermal power station in Udupi using NaI(Tl) gamma ray spectrometer. 232Th, 40K and 226Ra 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 (H10), External hazard index (H10) were assessed.

Key words – Radioactivity, soil, coal-based power plant, Internal hazard index (H10), External hazard index (H10).

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 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 m² area has been marked and top layer about up to 20 cm of soil was collected. Soil samples were collected 6 km around the UPCL. First at a distance of 1 km 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 222Rn to attain equilibrium with its progeny (Shetty et al., 2006).

A. Measurement of radioactivity

The concentration of, 232Th, 40K and 226Ra 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 226Ra in the sample were estimated using 214Bi having gamma peaks at 1764 keV (15.9%), while that of the daughter radionuclide 208Tl having an energy 2614 keV (35.8%) was used to estimate 232Th because the secular equilibrium was achieved between the daughter nuclides and their parent nuclides. The concentration 40K was estimated from 40K 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 232Th, 40K, and 226Ra are reported in Table 1. The 40K activity varies from 27.82-74.40 Bq/kg with a mean value of 54.23 Bq/kg, the 226Ra activity varies from 17.68-53.14 Bq/kg with a mean value of 32.82 Bq/kg and that of 232Th activity varies from 10.14-33.66 Bq/kg with a mean value 17.72 Bq/kg. The 232Th and 40K activity vary within the study area but 226Ra activity is almost constant. The radionuclides 226Ra does not migrate in soil unless it is deposited on the ground. The 232Th, 40K and 226Ra activities in soil samples were comparable with the values reported from other parts of the world (UNSCEAR, 2010).
TABLE 1. RADIONUCLIDE ACTIVITY OF 232Th, 40K AND 226Ra IN SOILS

<table>
<thead>
<tr>
<th>Activity of 232Th (Bq/kg)</th>
<th>Activity of 40K (Bq/kg)</th>
<th>Activity of 226Ra (Bq/kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>17.72</td>
<td>54.23</td>
</tr>
<tr>
<td>Median</td>
<td>21.86</td>
<td>54.30</td>
</tr>
<tr>
<td>Range</td>
<td>10.14-33.66</td>
<td>27.82-74.40</td>
</tr>
</tbody>
</table>

B. Absorbed gamma-ray dose rate (D)

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

\[ D(nGy^{-1}) = 0.462 A_{40K} + 0.604 A_{232Th} + 0.042 A_{226Ra} \]

The absorbed gamma dose rate 40K, 232Th and 226Ra in air varies in the range of 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 that represents the specific activities of radionuclide 40K, 232Th and 226Ra was estimated from the activity of the naturally occurring radionuclides which is reported in Table 2 by the following equation.

\[ Ra_{eq}(Bq/kg) = A_{40K}(1.43 A_{232Th}) + (0.077 A_{226Ra}) \]

Where A_th is 232Th activity in Bq/kg, A_{40K} is 226Ra activity in Bq/kg, and A_K is 40K 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 radionuclides in soil is calculated by the equation.

\[ H_{ex}(Bq/kg) = \frac{A_{226Ra}}{370} + \frac{A_{232Th}}{259} + \frac{A_{40K}}{4810} \]

Where A_{226Ra} is activity of 226Ra in Bq/kg, A_{232Th} is activity of 232Th in Bq/kg and A_K is activity of 40K 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.

\[ H_{in}(Bq/kg) = \frac{A_{226Ra}}{185} + \frac{A_{232Th}}{259} + \frac{A_{40K}}{4810} \]

Where A_{226Ra} is activity of 226Ra in Bq/kg, A_{232Th} is activity of 232Th in Bq/kg and A_K is activity of 40K 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_{yr})

Representative level index (I_{yr}) is used to estimate the level of gamma radiation hazards associated with natural occurring radionuclide concentration which is calculated using the following formula.

\[ I_{yr}(Bq/kg) = \frac{A_{226Ra}}{150} + \frac{A_{232Th}}{100} + \frac{A_{40K}}{1500} \]

Where I_{yr} is activity of 226Ra in Bq/kg, A_{232Th} is activity of 232Th in Bq/kg and A_K is activity of 40K 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

<table>
<thead>
<tr>
<th>D (nGy⁻¹)</th>
<th>Ra_{eq} (Bq/kg)</th>
<th>H_{ex} (Bq/kg)</th>
<th>H_{in} (Bq/kg)</th>
<th>I_{yr} (Bq/kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>28.1</td>
<td>62.3</td>
<td>0.17</td>
<td>0.26</td>
</tr>
<tr>
<td>Median</td>
<td>28.2</td>
<td>62.5</td>
<td>0.17</td>
<td>0.25</td>
</tr>
<tr>
<td>Range</td>
<td>20.0-37.6</td>
<td>44.5-83.5</td>
<td>0.12-0.23</td>
<td>0.17-0.37</td>
</tr>
</tbody>
</table>

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 232Th, 40K and 226Ra in soils around UPCL, was measured using NaI(Tl) gamma ray spectrometer and the values are comparable with the those reported from other environments of the world. The activity of 40K and 232Th were found to be higher than 226Ra 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.

REFERENCES