Natural radionuclide and radiological impact assessment of teak plantation, University of Ilorin, Kwara State

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Abstract. The amount of naturally occurring radionuclide in Teak plantation was measured using gamma ray spectrometer RS-125. This device gave an in-situ measurement of radioactivity concentration of $^{40}$K, $^{232}$Th, $^{238}$U and dose rate. The data was taken in 20 locations, the overall mean dose rate (DR) is 47.81 Gyh$^{-1}$. The overall mean activity concentrations for $^{40}$K, $^{232}$Th, $^{238}$U are 456.19 BqKg$^{-1}$, 29.02 BqKg$^{-1}$ and 26.21 BqKg$^{-1}$ respectively. It was also observed that only the estimated outdoor dose rate D of $^{40}$K at study location L1 exceeded the world limit of 57nGyh$^{-1}$. This could be due to its closeness to the university main gate with lots of possible interfering human activities around the gate area. However, further study on detailed geochemical investigation is required to reach at some conclusion. By comparing the mean values of the activity concentrations and their radiological risks with the several world standards, it can be concluded that the Teak plantation is highly rich in Potassium.

Keywords: Background Radiation, Conversion factors, Activity Concentration.
study evaluated the level of radionuclides in Western Ghats. The natural occurring isotopes activity concentration in soil samples was high, hence the elevated result obtained from the background radiation in Western Ghats area. The study aimed at assessing environmental radioactivity, and this was done with the use of gamma-ray spectrometry [6]. Here in Nigeria, Usikalu et al [7] studied background radiation in selected locations of Ota and its health inference on dwellers. The study concluded that there is no immediate radiological risk on dwellers. The studies of [8 - 15] on natural radionuclide, background radiation and its health burden emphasized the need to monitor our environment to ensure radiological safety of dwellers in an area. The current study therefore, focused on assessing the background radiation of teak plantation and the radiological impact of natural radionuclides measured in the area.

2. Materials and Method

2.1. The Study Area

The Teak plantation is located within the University of Ilorin, Ilorin, Kwara state. It lies entirely within the North Central region of Nigeria bounded within longitude 4° 38’ and 4° 39’E and latitudes 8° 28’ and 8° 29’N and an elevation ranging from 310 to 313 m. The study area has easy access such that car can drive through, that made the field work easy. The plantation is bounded to the south by the Date plantation and University of Ilorin senior staff quarters and to the North west by university of Ilorin junior staff quarters, to the west by the university of Ilorin Zoo and to the North by a vast area of plain land. The plantation consists of 530 hectares of Teak established since 2008 (Ilorin.info). Figure 1 is a map showing the Teak plantation in university of Ilorin, with P1 to P20 used as notation for sample location L1 to L20.

![Map of university of Ilorin showing the Teak Plantation and sample collection points](image)

2.2. Materials used for the survey

Material used to carry out the data survey includes: RS-125 spectrometer, GPS device and rechargeable batteries.

2.3. Field Survey

In situ measurement for activity concentration of 40K, 232Th, 238U, and the gamma dose rate was taken over the Teak plantation in the University. The data were taken in 20 location using a grid method with a portable gamma radiation hand detector device called the RS-125 gamma spectrometer, held 1 meter above the ground during measurement. The elevation and coordinate of each sampling point was taken using a global positioning system known as GPS (a hand held GPSmap 62s Garmin product). Sampling was done 2 meters apart. Each reading was taken 4 times and the mean was calculated to improve the accuracy of the results. The detector has high sensitivity with large 2.0 x 2.0 sodium iodide (NaI) crystal. Measurement was done by direct Assay readings. Automatic stabilizing on naturally radioactive elements was done for average of 5 minutes on each sampling point. Result presented in assay mode are % K, ppm of U and Th. Conversion factors were used to convert % and
ppm to Bq Kg⁻¹: 1ppm of 238U equals to 12.35 Bq Kg⁻¹; 1ppm of ²³²Th = 4.06 Bq Kg⁻¹, and 1% of ⁴⁰K = 313 Bq Kg⁻¹. For 40K in ppm, 1Bq Kg⁻¹ is 3.23 ppm and 1 ppm of ²³²Th equal to 11.1 Bq Kg⁻¹. The principal method of risk assessment and health effect evaluation is via the calculation of the radiation absorbed dose rate. Biological, clinical and radiological effects have direct association to the obtained absorbed dose rate [5, 11-18].

2.4. Absorbed dose rate

The outdoor absorbed dose rates in air at a height of 1 m above the ground surface to which the workers in the area and farmlands are exposed were estimated based on the formula provided by United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) [16]. The formula given in the calculation was used for the calculations

\[ D = 0.462C_u + 0.604C_{th} + 0.041C_k \] (1)

Where \( C_u \), \( C_{th} \), and \( C_k \) are radiation concentrations in Bq Kg⁻¹ and \( C_u \), \( C_{th} \), and \( C_k \) are the radioactivity concentration in Bq Kg⁻¹ and \( C_u \), \( C_{th} \), and \( C_k \) are the dose conversion factors which are 0.462, 0.604 and 0.0417 for ²³⁸U, ²³²Th and ⁴⁰K respectively. Average value is given as 57nGyh⁻¹ [7, 16].

2.5. Annual Effective Dose

The sternness of any radiological danger to humans is estimated based on the annual radiation dose that is absorbed by a person working/living in the ionizing radiation environment. To estimate the annual effective dose for outdoor, equation 2 was put into use. The conversion coefficient from absorbed dose in air to effective dose of 0.7 SvGy⁻¹ and the outdoor occupancy factor of 0.2 were used in the calculation. The dose rate D(nGy⁻¹) is the data obtained from the activity concentrations of natural radionuclides in Teak plantation, on the average, an adult spent ~ 20% of their time outdoor, and ~ 80% indoor in Nigeria, hence the 0.2 factor (20%) in equation 2 [8].

\[ AED = D(nGy⁻¹) \times 24 \times 365 \times 0.7 \times 10^{-2} \] (2)

2.6. Excess lifetime cancer risk (ELCR)

The Excess Life Cancer risk (ELCR) was calculated using the following equation:

\[ ELCR = AED \times DL \times RF \] (3)

Where, AED is the Annual Equivalent Dose, the average duration of life, DL, is estimated to 70 years, and Risk Factor (RF) with the unit Sv⁻¹ is taken as 0.05 as recommended by ICPR for stochastic effects on general public in calculations [8]. World average value of ELCR is given as 0.2 × 10⁻¹ [16].

3. Results and Discussion

The dose rate and activity concentrations of the three primordial radioisotopes ²³²Th, ²³⁸U and ⁴⁰K were measured and an average dose rate of 47.815 nGy⁻¹ was obtained for the twenty studied locations. The mean activity concentration for ⁴⁰K is 456.1975 Bq Kg⁻¹ and that of ²³⁸U and ²³²Th are 29.025 and 26.208 Bq Kg⁻¹ respectively as shown in table 1. Figure 3 shows the annual effective dose (AED) with study location L1 exceeding the world average of 0.07 mSv⁻¹. It was also observed that only the estimated outdoor dose rate D of ⁴⁰K at study location L1 exceeded the world limit of 57 nGyh⁻¹, as shown in figure 4. This could be due to its closeness to the university main gate with lots of possible interfering human activities around the gate area. However, further study on detailed geochemical investigation is required to reach at some conclusion. The Excess Life Cancer risk was calculated average ELCR is 0.206 × 10⁻¹ as shown in table 1. This value is just at the borderline of the world average of 0.2 × 10⁻¹. This ELCR value infers that the likelihood of developing cancer over a lifetime, assuming that an adult lives seventy years on the average on earth, is 50/50 (which is not high, nor low, but just on the border line).
### Figure 2. Annual Effective Dose (AED)

![Graph showing AED values for different sample locations.](image)

### Table 1. Dose Rate Activity Concentration and ELCR of Radionuclide Heads

| SAMPLE CODE | Latitude N | Longitude E | D.R (nGyh⁻¹) | ⁴⁰K (BqKg⁻¹) | ²³⁸U (BqKg⁻¹) | ²³²Th (BqKg⁻¹) | ELCR |
|-------------|------------|-------------|--------------|--------------|--------------|----------------|------|
| L1          | 8          | 28.867'N    | 38.511'E     | 29.100       | 203.450      | 60.520         | 38.370 | 0.255 |
| L2          | 8          | 28.867'N    | 38.525'E     | 26.900       | 281.700      | 34.580         | 34.510 | 0.208 |
| L3          | 8          | 28.880'N    | 38.525'E     | 28.600       | 438.200      | 18.530         | 30.450 | 0.193 |
| L4          | 8          | 28.886'N    | 38.531'E     | 13.900       | 328.650      | 23.470         | 42.020 | 0.213 |
| L5          | 8          | 28.899'N    | 38.523'E     | 58.000       | 438.200      | 18.530         | 43.040 | 0.225 |
| L6          | 8          | 28.914'N    | 38.526'E     | 23.800       | 266.050      | 53.110         | 34.710 | 0.242 |
| L7          | 8          | 28.899'N    | 38.538'E     | 24.300       | 532.100      | 25.320         | 35.530 | 0.236 |
| L8          | 8          | 28.886'N    | 38.550'E     | 54.800       | 500.800      | 35.200         | 22.130 | 0.215 |
| L9          | 8          | 28.869'N    | 38.552'E     | 80.700       | 297.350      | 27.790         | 36.540 | 0.202 |
| L10         | 8          | 28.865'N    | 38.565'E     | 59.600       | 328.650      | 27.790         | 14.410 | 0.150 |
| L11         | 8          | 28.883'N    | 38.568'E     | 44.400       | 485.150      | 43.840         | 21.520 | 0.228 |
| L12         | 8          | 28.902'N    | 38.570'E     | 59.000       | 516.450      | 24.700         | 30.040 | 0.218 |
| L13         | 8          | 28.904'N    | 38.589'E     | 54.800       | 516.450      | 21.610         | 20.710 | 0.187 |
| L14         | 8          | 28.888'N    | 38.588'E     | 77.500       | 406.900      | 21.000         | 24.560 | 0.177 |
| L15         | 8          | 28.867'N    | 38.584'E     | 63.800       | 422.550      | 15.440         | 27.410 | 0.176 |
| L16         | 8          | 28.865'N    | 38.603'E     | 58.900       | 547.750      | 20.380         | 18.880 | 0.186 |
| L17         | 8          | 28.889'N    | 38.612'E     | 49.100       | 626.000      | 34.580         | 18.680 | 0.227 |
| L18         | 8          | 28.900'N    | 38.615'E     | 54.000       | 485.150      | 26.550         | 11.370 | 0.168 |
| L19         | 8          | 28.902'N    | 38.626'E     | 56.500       | 735.550      | 22.850         | 11.570 | 0.205 |
| L20         | 8          | 28.884'N    | 38.628'E     | 38.600       | 766.850      | 24.700         | 7.710  | 0.204 |

|             | min        | max        | mean     |
|-------------|------------|------------|----------|
| D.R (nGyh⁻¹)| 13.900     | 80.700     | 47.815   |
| ⁴⁰K (BqKg⁻¹)| 203.450    | 766.850    | 456.196  |
| ²³⁸U (BqKg⁻¹)| 60.520    | 60.520     | 29.025   |
| ²³²Th (BqKg⁻¹)| 1.277     | 1.038      | 0.964    |
4. Conclusion
The use of the fertilizers that contains Potassium in the sampling sites may contribute to the higher values of $^{40}K$ activity high values of the radionuclide. The values obtained in the study are within the recommended safety limit, implying that the teak plantation does not pose any immediate significant radiation hazard and hence the location of the plantation close to different settlements is considered to be safe for the inhabitants in the neighboring settlements. The probability of developing cancer over a lifetime exist from the ELCR obtained results, using 70 years as an adult life time.

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