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Background Radiation from ^{238}U, ^{232}Th, and ^{40}K in Bells Area and Canaan City, Ota, Nigeria

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Abstract

Natural radionuclides are present in every constituent of the environment. Monitoring of environmental radionuclides is very vital to avoid exposure above the threshold limit. Due to this, the background radiation from ^{238}U, ^{232}Th, and ^{40}K of Bell University of Technology and Canaan Land City was determined from 20 sample points each in the two areas using RS230 Gamma Spectrometer. The mean activity concentration of ^{40}K, ^{238}U, and ^{232}Th for Bells University of Technology was 442.66 Bq/kg, 41.98 Bq/kg, and 48.35 Bq/Kg, respectively. In Canaan City, mean activity concentration of ^{40}K, ^{238}U, and ^{232}Th was 373.65 Bq/kg, 18.85 Bq/kg, and 67.22 Bq/kg, respectively. The mean absorbed dose rates recorded by the spectrometer directly were 70.03 nGy/h and 66.65 nGy/h, while that estimated from the activity concentration were 67.06 and 64.89 nGy/h for Bells University and Canaan City, respectively. The measured and estimated absorbed dose rates were higher than the safe limit of 57 nGy/h. The mean values of other radiological parameters estimated, except that of the gamma index and excess lifetime cancer risk were lower when compared to the recommended limit. It could be concluded that the possibility of suffering any radiation risk is low in these two areas, but there is possibility of cancer risk for someone that has stayed in the area for 70 years and above.

Introduction

Humans are continually exposed to ionizing radiation of cosmic and terrestrial origin [1], [2], [3]. The principal component of radiation is terrestrial gamma radiation which originates chiefly from the radioactive decay of natural potassium, radium, and thorium [4], [5]. These elements are widely distributed in terrestrial materials including soil, rocks, and building material extracted from the earth crust [6], [7], [8]. Epidemiological studies have shown that exposure to enhanced degree of background radiation of terrestrial origin is associated with somatic and genetic health effects that are detrimental to vital organs of the human body which can occasionally lead to death overtime [9], [10]. Information on the level of radiation and distribution of radioelements such as ^{238}U, ^{234}Th, and their respective progenies together with the non-series ^{40}K in the environment gives very important radiological baseline submission. Such submission is crucial in the understanding of man's exposure to ionizing radiation and useful in instituting radiation protection laws [6], [7], [8]. Assessment of public rate of exposure to ionizing radiation possibly due to changes in environmental radioactivity due to anthropogenic activities [11], [12] or geogenic processes is important. Usikalu *et al.* [13] relied heavily on results from such studies that assess the activity concentration of primordial radionuclides such as ^{238}U, ^{234}Th, and their respective progenies together with the non-series ^{40}K.

In Nigeria, the activity concentrations of these radionuclides (^{238}U,^{234}Th, and their respective progenies together with the non-series ^{40}K) have been carried out by many researchers from different parts of the country [14], [15], [16], [17], [18]. This research work is intended to complement and broaden the existing data on the assessment environmental radioactivity in the country with specific interest in the residential areas around Bells University of Technology and Canaan City, Ota. Study on the level of ionizing radiation in these locations is essential to yield data that will provide information that may be used to assess the radiological health impacts on the residents of the study areas.

Study area

The two areas (Bells University of Technology and Canaan City) used for this study are located in Ota,

Ogun State, Nigeria (Figure 1). These two communities are within the proximity of Idiroko, one of the Nigerian land borders with the Benin Republic. The geology of Ota is generally made up of sedimentary rocks of the Dahomey Basin (Figure 2). The lithostratigraphy sequences underlying the study area are Abeokuta, Ewekoro, Oshosun, Ilaro, and Benin Formations. Recently, an Alluvium which are of sands and shales are considered as the youngest of all these sequences, while Abeokuta Formation is considered as the oldest [19], [20], [21], [22]. As revealed in Figure 2, the study area falls on the Benin Formation, which is known as Coastal Plain Sands. This sequence is of Pliocene age, which is majorly composed of continental sands and intercalations of clay and shale within these sands [23].

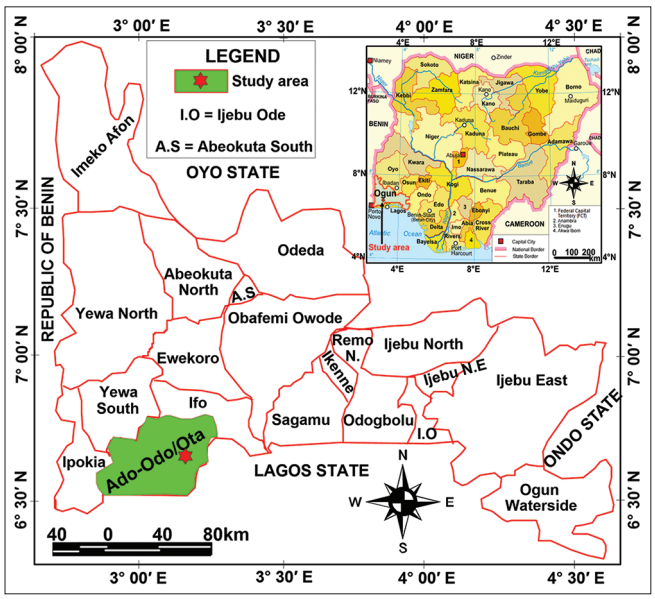

Figure 1: Map of Ogun State showing the study area

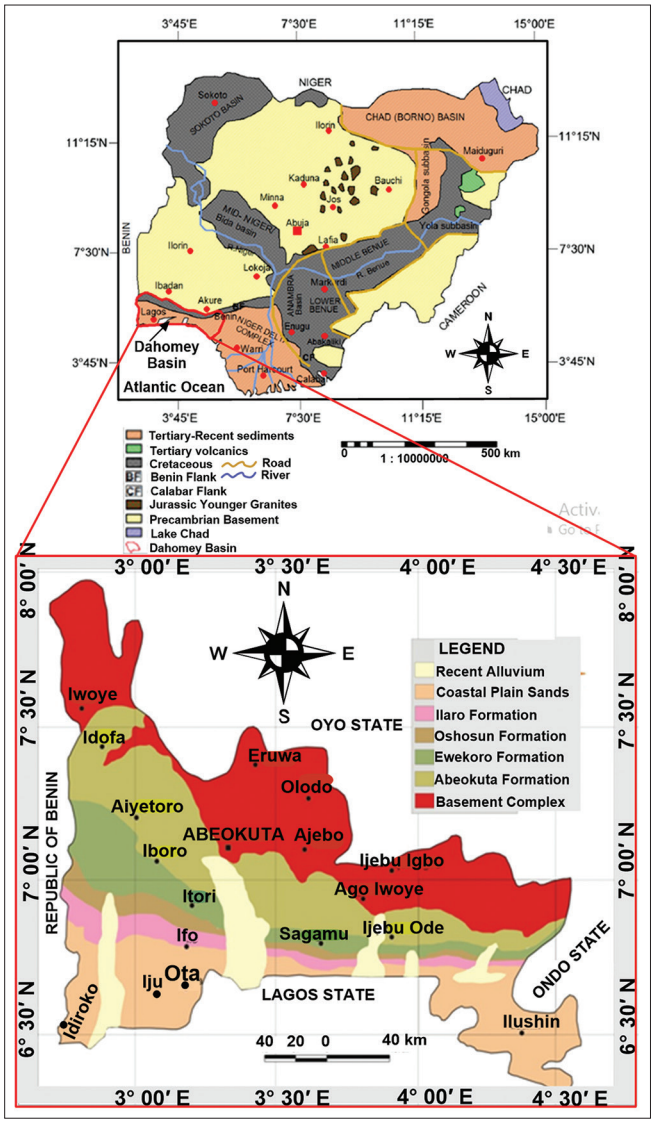

Figure 2: Geological map of Ogun state

Materials and Methods

Sampling location/instrumentation

Forty sample points comprising 20 locations from Bells University of Technology and 20 locations from Canaan City were chosen randomly within the study area (Figure 3). The selection points covered the whole area of study.

Background radiation was measured with the use of RS230 super SPEC Handheld Gamma-Ray Spectrometer. The handheld gamma spectrometer was used to take the background radiation of Bells University of Technology and Canaan City, Ota. RS230 super SPEC Handheld Gamma-Ray Spectrometer is a useful instrument for measuring and assessing background radiation, suitable in geophysical field, for its easy operation and ruggedness. Potassium, uranium, and thorium decay series consist of radioisotopes that produce

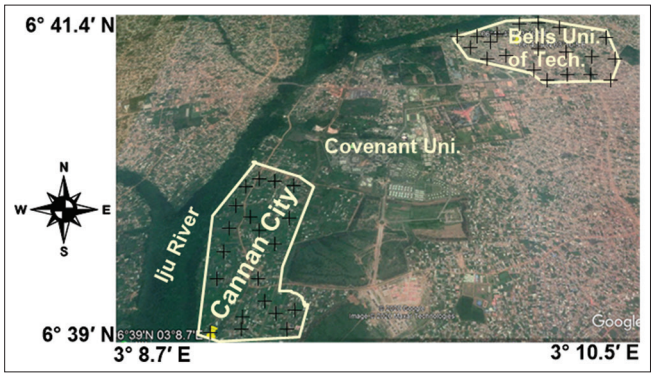

Figure 3: Base map of the study area

gamma rays of sufficient energy and intensity that can be measured by gamma ray spectrometer because they are much present in the natural environment. Natural sources of radiation come from radioisotopes build up during the formation of solar system. They are still in circulation because of their long half-lives. Among these natural sources of radiation are potassium (40-K), uranium (238-U, 235-U), and thorium (232-Th and its daughter

products or progeny). . Detector efficiency involves its absorption of gamma rays, its resolution, that is, ability to differentiate between two gamma rays of closed energy gap. The measurement of amount of potassium on the ground by gamma ray spectrometry is by the detection of 1416 keV gamma rays emitted by 40-K, which occur naturally at a fixed ratio, the assessment is direct and recorded in %. Uranium is assessed through detection of 1765 keV gamma rays of 214-Bi a progeny of U-238 and the result is recorded in ppm of equivalent uranium. Likewise, 232-Th is assessed through detection of 2615 keV gamma rays of 208-Ti, a daughter product of 232-Th decay series and the assessment is reported in ppm equivalent of thorium. The concentration of the source, the volume of the detector, efficiency, and the energy threshold of the equipment affect the total count gamma ray.

Activity concentration measurement

The spectrometer was held at about 1 m above the ground level for each measurement. The background reading of the activity concentration of ^{40}K, ^{238}U, and ^{232}Th with dose rate was first taken at each point for 5 times and the mean values were recorded. After which, 5 minute waiting time was observed at each point for the device to autostabilize with the natural radioelement of the study area. The activity concentration of ^{40}K, ^{238}U, and ^{232}Th was then retaken with the assay mode feature (Ass) of the spectrometer at sampling time of 90 second. The measurement was taken with the assay mode (Ass) for 5 times and the mean for each sample point was recorded. To minimize errors, the activity concentration values of ^{40}K, ^{238}U, and ^{232}Th use to estimate the radiological parameters values were the average of the assay mode reading (Ass) and the background reading recorded.

Radiological impacts estimation

The absorbed dose (D) is the dose received in an open air from the radionuclides present in the environmental media measured in nGy/h. The absorbed dose measurement was of two forms. The spectrometer used to record the absorbed dose directly and the other form was estimated from the activity concentration of the radionuclides present using Equation 1 [3], [24].

$$D\left(\frac{nGy}{h}\right) = 0.416A_u + 0.623A_{Th} + 0.414A_K \quad (1)$$

A_u, A_{Th}, and A_k are the activity concentration of ^{238}U, ^{232}Th, and ^{40}K, respectively

Annual effective dose (E) is the sum of the effective dose over a year. It is calculated for both outdoor (E_{out}) and indoor (E_{in}) using Equations 2 and 3, respectively [3], [24].

$$E_{out}\left(\frac{\mu Sv}{y}\right) = D\left(\frac{nGy}{h}\right) \times 24h * 365ays \times 0.2 \times 0.7 \times 0.001 \quad (2)$$

$$E_{in}\left(\frac{\mu Sv}{y}\right) = D\left(\frac{nGy}{h}\right) \times 24\,h \times 365\,days \times 0.8 \times 0.7 \times 0.001 \quad (3)$$

D is the absorbed dose rate in nGy/h

The annual gonadal dose equivalent (AGDE) is the dose received by the organs (gonads) bone marrow and bone cells. It was calculated using Equation 4 [25], [26].

$$AGDE\ (\mu Sv/y) = 3.09A_u + 4.18A_{Th} + 0.314A_k \quad (4)$$

The external hazard index (H_{ex}) is the hazard due to external exposure to radiation in the study area. It was calculated using Equation 5 [25], [26].

$$H_{ex} = \frac{A_u}{370} + \frac{A_{Th}}{259} + \frac{A_k}{4810} \quad (5)$$

Similarly, the risk to respiratory organs from internal exposure to radon and its short-lived daughter nuclei was quantified in terms of the internal hazard index (H_{in}) using Equation 6. H_{in} and H_{ex} should be less than unity for the radiation hazard to be negligible [25], [26], [27].

$$H_{in} = \frac{A_u}{185} + \frac{A_{Th}}{259} + \frac{A_k}{4810} \quad (6)$$

The gamma index (Iγ) is used to estimate the gamma radiation hazard associated with the natural radionuclide in specific investigated samples. The representative gamma index is estimated using Equation 7 [17], [26]. It should be less than unity for the radiation hazard to be negligible [26], [27].

$$I_\gamma = \frac{A_u}{150} + \frac{A_{Th}}{100} + \frac{A_k}{1500} \quad (7)$$

The radium equivalent (Ra_{eq}) activity allows a single index or number to describe the gamma output from different mixtures of ^{238}U, ^{232}Th, and ^{40}K in a material. It was calculated using Equation 8 [25], [28].

$$Ra_{eq} = A_U + 1.43A_{Th} + 0.077A_k \quad (8)$$

The excess lifetime cancer risk (ELCR) was calculated using Equation 9 [18], [26].

$$ELCR = AED \times DL \times RF \quad (9)$$

AED is the annual equivalent dose equivalent, DL is the average duration of life (estimated to 70 years), and RF is the risk factor (S/v), for stochastic effects, ICRP uses RF as 0.05 for public [27]. The recommended limit for ELCR is 0.2×10^{-3} [24] below which there is no cancer risk to the populace.

Results and Discussion

The result of ^{238}U, ^{232}Th, and ^{40}K activity concentration and the absorbed dose rate recorded by the spectrometer due to the background radiation from the radionuclides in the sample sites at the residential areas around Bells University of Technology and Canaan City, Ota, Ogun State, Nigeria, is presented in Tables 1 and 2, respectively. Tables 3 and 4 also present the result of the radiological impacts from the two sites (Bells University of Technology and Canaan City). The gamma ray background radiation for Bells University of Technology due to ^{40}K activity concentration ranged from 250.10 to 657.30 Bq/kg with a mean of 442.66 Bq/kg of ^{40}K, while that of ^{238}U ranged from 28.04 to 62.99 Bq/kg with a mean of 41.98 Bq/kg and that of ^{232}Th ranged from 25.17 to 63.74 Bq/kg with a mean of 48.35 Bq/kg. In the Canaan Land City, the background radiation due to gamma ray from ^{40}K ranged from 31.30 to 563.40 Bq/kg with a mean of 373.65 Bq/kg while that of ^{238}U ranged from 0.00 to 43.33 Bq/kg with a mean of 18.85 Bq/kg and that of ^{232}Th ranged from 30.04 to 99.06 Bq/kg with a mean of 67.22 Bq/kg. The mean activity concentrations for ^{40}K and ^{238}U in Bells University of Technology with values 442.66 Bq/kg and 41.98 Bq/kg, respectively, are higher than that of Canaan City with mean values 373.65 Bq/kg and 18.85 Bq/kg, for ^{40}K and ^{238}U, respectively. Only ^{232}Th concentration in Canaan City with mean value 67.22 Bq/kg is higher than that of the Bells University of Technology with mean value 48.35 Bq/kg. The variation in activity concentrations might be as a result of the materials and human activities in the area. It was noticed that the values were high in asphalt tarred road and interlock paved road compared to untarred roads. Bells University of Technology has more of this asphalt tarred and interlock paved roads compared to the untarred roads and this might be the reason for the increase in its activity value. It is to be noted that the background radiation measured may not be from the soil alone as other human activities done within the school area can also be contributors. The mean values of ^{238}U and ^{232}Th obtained for the two sites (except for ^{238}U in Canaan City) were above the recommended limit of 35.0 and 30.0, respectively [3]. The level of ^{40}K in the two sites was below the recommended limit of 500.0 Bq/kg. The absorbed dose rate recorded by the spectrometer directly ranged from 54.90 to 87.50 nGy/h with a mean of 70.03 nGy/h and 27.50 to 94.80 nGy/h with a mean of 66.65 nGy/h, for Bells University and Canaan City, respectively. The value is higher than the recommended limit of 57 nGy/h and this may pose serious health risk. Nevertheless, it is not to be surprising as the values of ^{238}U and ^{232}Th were high compared to the recommended limit. Although activity concentration of ^{40}K is about 5 times higher than other radionuclides present, it is still within acceptable limit. Its concentration in human body is under close metabolic (homeostatic) control [29]. Hence, its concentration variation in dietary composition does not influence significantly the radiation dose received in human body [4], [30].

Table 1: Absorbed dose rate and activity concentration measurement from Handheld Gamma-Ray Spectrometer in Bell University area

Sample site	Coordinates	D*(nGy/h)	K(B/kg)	U(B/kg)	Th(B/kg)
B1	6.687954,3.170237	74.60	474.20	33.72	61.45
B2	6.684056,3.172043	85.55	574.36	59.90	52.52
B3	6.683114,3.171341	78.15	641.65	46.32	46.84
B4	6.687481,3.169991	74.69	496.11	40.14	52.99
B5	6.684253,3.171392	75.35	485.15	51.44	47.71
B6	6.688228,3.171288	73.02	511.76	44.46	42.69
B7	6.686223,3.169733	70.19	489.85	33.78	51.22
B8	6.684235,3169238	64.77	500.80	41.56	32.75
B9	6.687431,3.160240	73.82	485.15	55.76	41.21
B10	6.685734,3.167573	62.92	406.90	33.16	42.84
B11	6.689604,3.166755	56.00	344.00	32.30	42.83
B12	6.688654,3.167032	61.42	265.90	40.58	48.11
B13	6.688424,3.168595	70.50	364.65	44.28	55.42
B14	6.690503,3.168235	61.15	297.35	39.34	47.16
B15	6.689639,3.169031	57.20	323.96	32.30	49.68
B16	6.688025,3.169203	70.09	463.28	32.55	46.49
B17	6.686887,3.168646	65.09	391.25	37.49	47.87
B18	6.688177,3.168649	70.20	438.20	40.57	51.02
B19	6.686904,3.168926	73.72	424.51	45.08	53.11
B20	6.688155,3.168050	82.22	474.20	54.96	53.11
MIN		54.90	250.10	28.04	25.17
MAX		87.50	657.30	62.99	63.74
MEAN		70.03	442.66	41.98	48.35

Table 2: Absorbed dose rate and activity concentration measurement from Handheld Gamma-Ray Spectrometer in Canaan City

Sample site	Coordinates	D*(nGy/h)	K(B/kg)	U(B/kg)	Th(B/kg)
C1	6.655450,3.160591	63.45	406.90	30.64	56.03
C2	6.654780,3.161259	79.40	406.90	17.33	89.42
C3	6.654657,3.160951	74.40	469.50	10.22	75.31
C4	6.653455,3.160680	73.23	492.98	16.41	67.10
C5	6.653443,3.160643	70.40	422.55	27.24	77.60
C6	6.653395,3.160177	72.70	446.03	7.74	78.56
C7	6.653395,3.161966	73.20	375.60	7.74	77.96
C8	6.652491,3.160431	72.88	500.80	23.30	64.15
C9	6.652491,3.160054	74.38	391.35	30.03	64.15
C10	6.651887,3.160291	89.50	532.10	5.88	96.02
C11	6.651561,3.159673	74.25	438.20	30.95	83.55
C12	6.651018,3.159245	83.08	461.68	21.05	76.64
C13	6.652661,3.161707	80.70	446.03	5.89	81.00
C14	6.653365,3.162299	33.33	86.08	15.17	44.25
C15	6.654265,3.161871	31.50	93.90	22.29	33.90
C16	6.655682,3.162036	31.28	46.95	17.65	39.49
C17	6.654628,3.160939	41.05	133.03	18.88	46.80
C18	6.650807,3.160973	64.45	422.55	15.78	55.32
C19	6.653489,3.158741	79.18	469.50	30.34	65.88
C20	6.652836,3.145694	70.68	430.38	22.59	71.26
MIN		27.50	31.30	0.00	30.04
MAX		94.80	563.40	43.33	99.06
MEAN		66.65	373.65	18.85	67.22

The following parameters were estimated, the absorbed dose (D), annual effective dose (E_{in} and E_{out}), annual gonadal equivalent (AGDE) dose, hazard indices (H_{in} and H_{ex}), gamma index ($I\gamma$), Ra_{eq} activity index, and ELCR to assess any possible radiological hazard to the populace of these areas, as shown in Tables 3 and 4. The absorbed dose rate recorded by the spectrometer was compared with the dose estimated from the activity concentration of the radionuclides to assure its credibility, it was found that the measured and estimated doses are in total agreement. This means error was minimized and signifies the accuracy of the instrument used. The absorbed dose rate due to the background gamma radiation from ^{238}U, ^{232}Th, and ^{40}K ranged from 55.14 to 83.35 nGy/h with a mean of 67.06 nGy/h and 33.96 to 83.03 nGy/h with a mean of 64.89 nGy/h for Bells University of Technology and Canaan City,

Table 3: Estimated radiological impacts for Bells University area

Sample site	D* (nGy/h)	D (nGy/h)	E_{out} (μSv/yr)	E_{in} (μSv/yr)	AGDE (μSv/yr)	H_{ex}	H_{in}	Iγ	Ra_{eq}	ELCR (10^{-6})
B 1	74.6	72.47	88.93	355.49	510.18	0.43	0.52	1.16	158.1	0.32
B 2	85.55	83.35	102.29	408.85	585.16	0.48	0.65	1.31	179.22	0.36
B 3	78.15	76.45	93.82	375	540.55	0.44	0.57	1.20	162.7	0.33
B 4	74.69	71.24	87.43	349.45	501.5	0.42	0.53	1.13	154.11	0.31
B 5	75.35	72.81	89.36	357.18	510.89	0.43	0.57	1.14	157.02	0.32
B 6	73.02	67.67	83.04	331.94	476.69	0.39	0.51	1.06	144.91	0.29
B 7	70.19	66.97	82.19	328.51	472.48	0.4	0.49	1.06	144.74	0.29
B 8	64.77	59.87	73.47	293.66	422.68	0.34	0.46	0.94	126.95	0.26
B 9	73.82	70.88	86.99	347.72	497.06	0.41	0.57	1.11	152.05	0.31
B 10	62.92	58.16	71.38	285.3	409.44	0.34	0.43	0.92	125.74	0.25
B 11	56	55.14	67.67	270.47	387.01	0.33	0.41	0.87	120.03	0.24
B 12	61.42	58.9	72.28	288.9	410.17	0.35	0.47	0.93	129.85	0.26
B 13	70.5	69.13	84.85	339.15	483.19	0.41	0.53	1.09	151.61	0.3
B 14	61.15	59.06	72.48	289.69	412.21	0.35	0.46	0.93	129.67	0.26
B 15	57.2	58.44	71.71	286.65	409.36	0.35	0.43	0.93	128.28	0.25
B 16	70.09	62.44	76.62	306.28	440.55	0.37	0.45	0.99	134.7	0.27
B 17	65.09	62.55	76.76	306.83	438.97	0.37	0.47	0.99	136.07	0.27
B 18	70.2	67.83	83.25	332.74	476.41	0.4	0.51	1.07	147.26	0.29
B 19	73.72	70.61	86.65	346.36	494.78	0.42	0.54	1.11	153.71	0.31
B 20	82.22	77.24	94.8	378.92	540.92	0.45	0.61	1.21	167.42	0.33
MIN	56	55.14	67.67	270.47	387.01	0.33	0.41	0.87	120.03	0.24
MAX	85.55	83.35	102.29	408.85	585.16	0.48	0.65	1.31	179.22	0.36
MEAN	70.03	67.06	82.29	328.95	471.01	0.39	0.51	1.06	145.2	0.29

D* absorbed dose rate measurement recorded by the spectrometer. D is the estimated absorbed dose rate from radionuclides activity concentrations. AGDE: Annual gonadal equivalent

Table 4: Estimated radiological impact for Canaan City

Sample site	D* (nGy/h)	D (nGy/h)	E_{out} (μSv/yr)	E_{in} (μSv/yr)	AGDE (μSv/yr)	H_{ex}	H_{in}	Iγ	Raeq	ELCR (10^{-6})
C 1	63.45	64.97	79.73	318.68	456.86	0.39	0.47	1.04	142.09	0.28
C 2	79.4	78.98	96.94	387.46	555.45	0.48	0.53	1.28	176.54	0.34
C 3	74.4	69.79	85.64	342.34	494.09	0.42	0.45	1.13	154.06	0.3
C 4	73.23	68.66	84.27	336.83	486.21	0.41	0.46	1.11	150.31	0.3
C 5	70.4	77.08	94.59	378.1	541.53	0.46	0.54	1.24	170.75	0.33
C 6	72.7	69.63	85.45	341.56	492.66	0.42	0.44	1.13	154.42	0.3
C 7	73.2	66.33	81.4	325.36	468.02	0.4	0.42	1.08	148.14	0.28
C 8	72.88	70.39	86.39	345.3	497.62	0.42	0.48	1.13	153.59	0.3
C 9	74.38	68.93	84.6	338.17	484.04	0.41	0.5	1.10	151.89	0.3
C 10	89.5	82.9	101.74	406.67	586.98	0.5	0.52	1.35	184.15	0.36
C 11	74.25	83.03	101.9	407.33	582.79	0.5	0.59	1.33	184.16	0.36
C 12	83.08	75.26	92.37	369.21	530.64	0.45	0.51	1.21	166.18	0.33
C 13	80.7	70.24	86.2	344.57	497.12	0.42	0.44	1.15	156.05	0.31
C 14	33.33	37.33	45.81	183.1	259.05	0.23	0.28	0.60	85.08	0.16
C 15	31.5	34.69	42.57	170.16	240.19	0.21	0.27	0.55	78	0.15
C 16	31.28	33.96	41.68	166.59	234.47	0.21	0.26	0.54	77.73	0.15
C 17	41.05	42.54	52.2	208.66	295.9	0.26	0.31	0.68	96.04	0.18
C 18	64.45	58.33	71.58	286.1	412.88	0.35	0.39	0.94	127.42	0.25
C 19	79.18	73.38	90.06	359.98	516.78	0.44	0.52	1.17	160.69	0.32
C 20	70.68	71.43	87.65	350.37	503.07	0.43	0.49	1.15	157.63	0.31
MIN	31.28	33.96	41.68	166.59	234.47	0.21	0.26	0.54	77.73	0.15
MAX	89.5	83.03	101.9	407.33	586.98	0.5	0.59	1.35	184.16	0.36
MEAN	66.65	64.89	79.64	318.32	456.82	0.39	0.44	1.05	143.74	0.28

D* absorbed dose rate measurement recorded by the spectrometer. D is the estimated absorbed dose rate from radionuclides activity concentrations

respectively. The mean values for both sites are higher than the recommended limit of 57 nGy/h [3]. The values for outdoor annual effective dose ranged from 67.67 to 102.29 μSv/y with a mean of 82.29 μSv/y and 41.68 to 101.90 with a mean of 79.64 μSv/y for Bell University of Technology and Canaan City, respectively, while that of indoor annual effective dose ranged from 270.47 to 408.85 μSv/y with a mean of 328.95 μSv/y and 166.59 to 407.33 μSv/y with a mean of 318.32 μSv/y for Bell University of Technology and Canaan City, respectively. The annual effective dose received outdoor and indoor by a member of the public is very important in determining the radiation risk due to the background radiation exposed to from the gamma rays from ^{238}U, ^{232}Th, and ^{40}K activity concentrations. The outdoor occurs outside a building and the indoor is exposed to within a house. However, the mean values calculated for the outdoor and indoor annual effective doses in the study areas were below the recommended limit of 1000 μSv/y, and therefore, the populace in the area are safe.

To assess the effect of the background radiation to the gonads, bone marrow, and bone surface which are part of the sensitive organs generally targeted by radiation, the AGDE dose was calculated. The values recommended to be safe limit are values ≤ 1000 μSv/y beyond which there will be destruction of the red blood cells produced by the bone marrow and these red blood cells will be eventually replaced by white blood cells [3]. However, the values obtained for both locations are within the recommended limit. The values of the hazard indices for the study area are less than unity which is the safe limit, and no radiation injury can occur with hazard indices less than 1 [27]. The value of the representative gamma index (Iγ) ranged from 0.87 to 1.31 with a mean of 1.06 and 0.54 to 1.35 with a mean of 1.05 for Bell University of Technology and Canaan City, respectively. Although some of the values in the two sites were lower than unity below which no serious radiation risk can occur, the mean values for these two sites were higher than the recommended limit of unity [3]. Representative gamma index (Iγ) is correlated with the annual dose rate due to the excess external gamma radiation caused by superficial material. Iγ is mostly estimated for materials that might be used as construction

Table 5: Recommended limit of the radiological impact parameters estimated in this study

World Limit	D (nGy/h)	Eout (μSv/yr)	Ein (μSv/yr)	AGDE (μSv/yr)	H_{ex}	H_{in}	Raeq (Bq/kg)	ELCR (10^{-6})
RL	57	1000	1000	1000	1	1	370	0.2

Table 6: Comparison table of radiological impact parameters at Bells University and Canaan City

Location	D* (nGy/h)	D (nGya/h)	Eout (μSv/yr)	Ein (μSv/yr)	AGDE (μSv/yr)	H_{ex}	H_{in}	I_γ	Raeq	ELCR (10^{-6})
Bell	70.03	67.06	82.29	328.95	471.01	0.39	0.51	1.06	145.2	0.29
Canaan land	66.65	64.89	79.64	318.32	456.82	0.39	0.44	1.05	143.74	0.28

materials and values greater than 1 should be avoided [25], [26]. Therefore, materials in these areas are not suitable for construction purposes to minimize radiation risk.

The estimated mean radium activity index (Ra_{eq}) Bells University of Technology is 145.2 Bq/kg and 143.74 Bq/kg for Canaan City. This parameter allows a single index to describe the gamma output in the background radiation from the radionuclides present (^{238}U, ^{232}Th, and ^{40}K) and must be <370 Bq/kg for it to be safe for the populace [3]. The values obtained for the two study area are within the safe limit and pose no radiation risk. The ELCR values ranged from 0.24×10^{-6} to 0.36×10^{-6} with a mean value of 0.29×10^{-6} for Bells University of Technology and ranged between 0.15×10^{-6} and 0.36×10^{-6} with a mean value of 0.28×10^{-6} for Canaan City. The mean values for both study areas are slightly higher than the recommended limit of 0.2×10^{-6}. This high value implies that the probability of developing cancer over a lifetime considering seventy years as the average life span of humans is high. The mean values of all the radiological parameters estimated (except that of the absorbed dose rate, representative gamma index, and the ELCR) were lower when compared to the recommended limit, as shown in Table 5, therefore, the possibility of suffering any radiation risk is very low in these two areas. Nevertheless, care must be taken to monitor the human activities in the area as the possibility of having cancer for populace residing in the area for 70 years is high. Figure 4 displays the recorded values for the study areas and Table 6 shows similar results for both the activity concentrations and the radiological impact parameters. It was observed that Bells University of Technology results are slightly higher in most of the parameters compared to those of Canaan City which may be due to the contribution of human activities in the area.

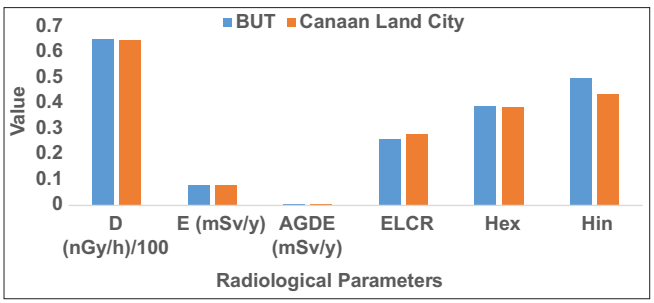

Figure 4: Comparison of the results obtained at Bells and Canaan City areas

Conclusion

Background radiation due to gamma ray emitted from ^{238}U, ^{232}Th, and ^{40}K in Bells University of Technology and Canaan City areas, Ota, Nigeria, was studied to know the radiation risk that populace in the area can be exposed to due to intense human activities common in the areas. The mean activity concentration of ^{40}K, ^{238}U, and ^{232}Th for Bells University of Technology area was 442.66 Bq/kg, 41.98 Bq/kg, and 48.35 Bq/kg, respectively, and that of Canaan City was 373.65 Bq/kg, 18.85 Bq/kg, and 67.22 Bq/kg for ^{40}K, ^{238}U, and ^{232}Th, respectively. The mean absorbed dose rate recorded by the spectrometer directly was 70.03 nGy/h and 66.65 nGy/h, for Bells University and Canaan City, respectively. The mean values of all the radiological parameters estimated except that of the absorbed dose, representative gamma index, and the ELCR were lower when compared to the recommended limit, therefore, the possibility of low radiation risk in these two areas.

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