British Journal of Applied Science & Technology
5(2): 142-149, 2015, Article no.BJAST.2015.014
ISSN: 2231-0843

SCIENCEDOMAIN *international*
www.sciencedomain.org

Baseline Measurements of Natural Radioactivity in Soil Samples from the Federal University of Technology, Owerri, South-East, Nigeria

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Authors' contributions

This work was carried out in collaboration between all authors. Author BCE designed the study, collected and prepared the samples, participated in the laboratory procedures and wrote the first draft of the manuscript. Author NNJ supervised the laboratory procedures and the statistical analysis. Authors BCA, CEO and HUE performed the literature searches and participated in the statistical analysis. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/BJAST/2015/12171
Editor(s):
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Complete Peer review History: http://www.sciencedomain.org/review-history.php?iid=713&id=5&aid=6480

Original Research Article

Received 2nd June 2014
Accepted 30th July 2014
Published 10th October 2014

ABSTRACT

Aims: To determine the gamma dose rates and radionuclide concentration levels in soil samples from the Federal University of Technology, Owerri, Nigeria.
Study Design: Sixty (60) soil samples were collected at different locations in the Federal University of Technology, Owerri, Nigeria. Each prepared sample was placed symmetrically on top of a lead-shielded NaI (Tl) detector for measurement.
Place and Duration of Study: Federal University of Technology, Owerri, Nigeria, between April 2013 and October 2013.
Methodology: A γ-ray spectrometry in the Radiation and Health Physics Research Laboratory,

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University of Ibadan, Nigeria was employed to carry out the radioactivity measurement of the 60 soil samples. The activity concentrations, absorbed dose rate in air as well as annual effective dose equivalent were calculated.
Results: The activity concentrations of 40K, 226Ra and 232Th ranged from 21.90±1.62Bqkg^{-1} – 142.45±1.37Bqkg^{-1}, < 3.65Bqkg^{-1} - 36.01±2.25Bqkg^{-1} and
<4.43Bqkg^{-1} – 43.87±0.75Bqkg^{-1} respectively. The average absorbed dose rate was calculated as 25.99±8.35nGyh^{-1} while the annual effective dose equivalent ranged between 9.39μSvy^{-1} and 56.83μSvy^{-1} with an average of 31.89±10.25μSvy^{-1}. These values are less than the world average values of absorbed and effective doses which are 51nGyh^{-1} and 70μSvy^{-1} respectively.
Conclusion: Human activities and the presence of radioactive minerals on the campus of the Federal University of Technology, Owerri, Nigeria have not increased the radionuclide concentrations in the University environment beyond safety limit.

Keywords: Federal University of Technology; Owerri; Nigeria; gamma spectrometry; natural radioactivity; soil.

1. INTRODUCTION

There are two kinds of radiation according to their origin: natural and artificial radiation. Natural radiation comes from cosmic rays from outer space and naturally occurring radioactive materials (NORMs) that exist in food, air and our natural habitat while exposure in medical practice mostly due to diagnostic X-rays, contributes the largest fraction of human's exposure to artificial radiation. About 90% of human radiation exposures arise from natural sources [1]. Significant naturally occurring radionuclides present in the soil are ^{238}U, ^{232}Th and ^{40}K [2]. These radionuclides are not uniformly distributed hence, the knowledge of their distribution in soil plays an important role in radiation protection. Soil not only acts as a source of continuous radiation exposure to humans but also as a medium of migration for transfer of radionuclides to biological systems [3]. Hence, the basic indicator of radiological contamination in the environment is the soil [4]. The understanding of the decay chain where series of stepwise decay in terms of half-lives of nuclei of unstable radionuclides lead to stable states in form of other nuclides is very paramount. Alpha (α) and beta (β) particles are given off while gamma (γ) radiation is emitted. High levels of uranium and thorium and their decay products in rock and soil are the main sources of high natural background radiation. There is a continuous bombardment of human and his environment by these (radionuclides) ionizing radiations [5]. The long term exposure to uranium and radium through inhalation has several health effects such as chronic lung diseases, acute leucopoenia, anaemia and necrosis of the mouth. Radium causes bone, cranial and nasal tumours. Thorium exposure can cause lung, pancreas, hepatic, bone, kidney cancers and leukaemia [6]. Therefore, gamma dose rates and radionuclides activity concentrations should be monitored because of their health implications. The Federal University of Technology, Owerri (FUTO) Nigeria was one of the four federal universities of technology established by the Federal Government of Nigeria (FGN) in 1980. It is located in the South-Eastern, Nigeria. The University is surrounded by a number of autonomous communities and homesteads all of which had contributed land acquired for the development of the University. These communities are Ihiagwa, Obinze, Umuoma Nekede, Eziobodo, Avu, Okolochi, Obibiezena and Emeabiam. The University is situated 25km south of Owerri, the Imo State capital and between the western external tangent (Owerri-Portharcourt Road) and the eastern external tangent (Owerri-Aba Road). It is bisected by a new road between Obinze and Naze which connects the two mentioned major roads. The Otamiri River traverses FUTO from North to South and the University has the land area of $4.05\times10^{7}m^{2}$ and the staff/students' strength of about 16,000. Candidly, no radiological measurements have been carried out on and around the campus of FUTO. Baseline measurement of activity concentration levels in a natural environment like that of FUTO offers the opportunity to document present conditions in order to scientifically assess future effects due to other external factors such as human activities. Besides, since radiation cannot be felt by the human sense organs, it is important that the total amount of radiation emitting-NORMs in an area is known and kept to a very low level in order to safeguard the live of the people and ensure radiation-pollution free environment. The purpose of this work is essentially, therefore, to: (1)

determine the gamma dose rates and radionuclide concentration levels in the soil samples from FUTO.(2) obtain radiometric data for future reference and research in the area.

2. MATERIALS AND METHODS

2.1 Sample Collection and Preparation

Sixty soil samples were collected at different locations in the Federal University of Technology, Owerri, Nigeria. The samples were air-dried, crushed and homogenized. The homogenized samples were packed and sealed in plastic containers. A time of four weeks was allowed after packing and sealing to attain secular radioactive equilibrium between Uranium and Thorium series and their short-lived daughter products [7]. Each container accommodated 0.2kg of the sample.

2.2 Experimental Set-up

The detector used for the radioactivity measurements was a lead-shielded 76mm×76mm NaI(Tl) detector crystal (802 Series, Canberra Inc.) coupled to a Canberra Series 10+ multichannel analyser (MCA) (model no. 1104) through a preamplifier. It had a modest resolution of about 8% at 662 keV. It was due to the poor resolution of the detector that high and clean peaks with less continuum were used. Certified reference materials used were IAEA/RGK-1 (K_2SO_4), IAEA/RGU-1 (U-Ore) and IAEA/RGTh-1 (Th-Ore). The activity concentration of ^{214}Bi (determined from its 1.760MeV gamma-ray peak) was chosen to provide an estimate of ^{226}Ra (^{238}U) in the samples, while that of the daughter radionuclide ^{208}Tl (determined from its 2.615MeV gamma-ray peak) was chosen as an indicator of ^{232}Th. Potassium-40 was determined by measuring the 1.460MeV gamma rays emitted during its decay. All the obtained raw data were converted to conventional units using calibration factors. Each sample was placed symmetrically on top of the detector and measured for a period of 8h (28,800s).The net area under the corresponding peaks in the energy spectrum was computed by subtracting counts due to Compton scattering of higher peaks and other background sources from the total area of the peaks. From the net area, the activity concentrations in the samples were obtained using [8].

$$C\ (\mathrm{Bqkg^{-1}}) = k\, C_n \qquad (1)$$

where $k = \dfrac{1}{\varepsilon\, P_{\gamma} M_S}$,*C* is the activity concentration of the radionuclide in the sample given in Bqkg^{-1}, C_n is the count rate under the corresponding peak, ε is the detector efficiency at the specific gamma-ray energy, P_γ is the absolute transition probability of the specific gamma ray and M_s is the mass of the sample (kg). The detection limit (DL) of a measuring system describes its operating capability without the influence of the sample. The DL given in Bqkg^{-1}, which is required to estimate the minimum detectable activity in a sample, was obtained using [9].

$$\mathrm{DL}\ (\mathrm{Bqkg^{-1}}) = 4.65\,\frac{(C_b)^{1/2}}{t_b}\,k \qquad (2)$$

Where C_b is the net background count in the corresponding peak, t_b is the background counting time (s) and *k* is the factor that converts counts per second (cps) to activity concentration (Bqkg^{-1}) as given in Equation (1). The detection limits obtained in this study were 16.96Bqkg^{-1}, 3.65Bqkg^{-1} and 4.43Bqkg^{-1} for ^{40}K, ^{226}Ra and ^{232}Th respectively. All activity concentrations below these computed values are taken in this study as being below the detection limit (BDL) of the detector and are presented as <16.96Bqkg^{-1}, <3.65Bqkg^{-1} and <4.43Bqkg^{-1} for ^{40}K, ^{226}Ra and ^{232}Th respectively.

3. RESULTS AND DISCUSSION

The locations of samples are shown in (Fig. 1) and the activity concentrations of natural radionuclides (^{40}K, ^{226}Ra and ^{232}Th) at different locations are listed in (Table 1). From (Table 1), the activity concentration of 40K was highest at FUTO Microfinance Bank (142.45±1.37Bqkg^{-1}). This high value could be due to the presence of the radioactive mineral such as feldspar and the presence of loamy and clay sediments [10]. The least activity concentration of 40K was found at FUTO Business Premises (21.90±1.62Bqkg^{-1}). The highest activity concentration of 226Ra was found at the Pre-degree Unit (36.01±2.25Bqkg^{-1}). This high value could be due to the high presence of the radioactive minerals such as zircon and monazite [1]. However, the concentrations of 226Ra at FUTO Back Gate, Hostel A and FUTO Consult Ltd were below detection limit. The highest activity concentration of 232Th was found at Main Library (43.87±0.75Bqkg^{-1}) and this high value could be due to the presence of zircon and monazite [11].

Th-232 was not detectable at 750 Capacity Building. Furthermore, the mean activity concentrations of 40K, 226Ra and 232Th which were 90.18Bqkg^{-1}, 17.88Bqkg^{-1} and 22.82Bqkg^{-1} respectively compared well with other studies in Nigeria {South-South: 34.80Bqkg^{-1}, 16.20Bqkg^{-1} and 24.40Bqkg^{-1} for 40K, 226Ra and 232Th [12]; North-Central: 229.40Bqkg^{-1}, 7.80Bqkg^{-1} and 29.40Bqkg^{-1} for 40K, 226Ra and 232Th [13]}. Besides, the mean activity concentrations in this study were less than the world average values of 420Bqkg^{-1}, 50Bqkg^{-1} and 50Bqkg^{-1} for 40K, 226Ra and 232Threspectively [14].

3.1 Absorbed Dose Rates (D)

The absorbed dose rate, D (nGyh^{-1}), in air at 1m above the ground level is calculated using the equation [14]:

$$D = aC_{Ra} + bC_{Th} + cC_K + dC_{Cs} \quad (3)$$

Where a is the dose rate per unit ^{226}Ra activity concentration (4.27×10^{-10}Gyh^{-1}/Bqkg^{-1}), C_{Ra} is the concentration of ^{226}Ra in the sample (Bqkg^{-1}), b is the dose rate per unit ^{232}Th activity concentration (6.62×10^{-10}Gyh^{-1}/Bqkg^{-1}), C_{Th} is the concentration of ^{232}Th in the sample (Bqkg^{-1}), c is the dose rate per unit ^{40}K activity concentration (0.43×10^{-10}Gyh^{-1}/Bqkg^{-1}), C_K is the concentration of ^{40}K in the sample (Bqkg^{-1}), d is the dose rate per unit ^{137}Cs activity concentration (0.30×10^{-10}Gyh^{-1}/Bqkg^{-1}) and C_{Cs} is the concentration of ^{137}Cs in the sample (Bqkg^{-1}). Since Caesium-137 was not detected in any of the samples, the last term in Equation (3) was taken as zero. Using Equation (3) and the activity concentrations of the radionuclides in (Table 1), absorbed dose rates ranged between 7.65nGyh^{-1} and 46.31nGyh^{-1} whereas the average absorbed dose rate was calculated as 25.99±8.35nGyh^{-1} which is less than the world average value (51nGyh^{-1}) [14]. Absorbed dose rate values are presented in (Table 2).

3.2 Annual Effective Dose Equivalent (AEDE)

The absorbed gamma dose rates in air are usually related to human absorbed gamma dose in order to assess radiological implications. In assessing the outdoor effective dose equivalent to members of the population, two important factors were considered. The first was a factor that converted the absorbed dose rates (Gyh^{-1}) in air to human outdoor effective dose rates (Svy^{-1}) while the second factor gave the proportions of the total time for which a typical individual was exposed to outdoor or indoor radiation. The United Nations Scientific Committee on the Effects of Atomic Radiation [14] has recommended 0.7SvGy^{-1} as the value of the first factor and 0.2 and 0.8 as for outdoor and indoor occupancy factors respectively. This second factor implies that the average individual spends about 5h per day outdoors. In this study, only outdoor exposure from gamma-ray sources due to the concentrations of NORMs in the soil was considered. The annual effective dose equivalent resulting from the absorbed dose rate values was calculated using the equation as recommended by [14].

$$\text{AEDE} = T\,f\,Q\,D\,\mathcal{E} \quad (4)$$

where AEDE is the annual effective dose equivalent (μSvy^{-1}), T is time (being 8766hy^{-1}) f is the outdoor occupancy factor that corrects for the average time spent outdoors (0.2), Q is the quotient of the effective dose rate and absorbed dose rate in air (0.7SvGy^{-1}), $\mathcal{E}$ is a factor converting nano (10^{-9}) into micro (10^{-6}) and D is the absorbed dose rate in air (nGyh^{-1}). The values obtained are presented in (Table 2).

The annual effective dose equivalent based on the soil samples from FUTO ranged between 9.39μSvy^{-1} and 56.83μSvy^{-1} whereas the average AEDE was calculated as 31.89±10.25μSvy^{-1}. This average compares well with the result obtained by [12] in the South-South region of Nigeria (31.60μSvy^{-1}) however, it is less than the world average value (70μSvy^{-1}) [14].

4. CONCLUSION

The method of gamma spectrometry had been used to measure the activity concentrations of 60 soil samples collected from the Federal University of Technology, Owerri, Nigeria. It was observed that human activities and the presence of radioactive minerals have not sky-rocketed the radionuclide concentrations in the environment. The average absorbed dose rate and the average annual effective dose equivalent obtained in FUTO premises are less than the world average values. From these analyses, the general distribution of activity concentration in the University premises is within tolerable levels which imply that the University community is free from radiological contamination. The measurements in this study represent baseline information for future reference and research.

Table 1. Activity concentrations of the radionuclides at different locations

Sample ID	Sample locations	^{40}K (Bqkg^{-1})	^{226}Ra (Bqkg^{-1})	^{232}Th (Bqkg^{-1})
1	PG school lecture theatre	134.25±1.38	11.21±4.85	34.42±0.78
2	Pre-degree unit building	113.58±1.41	36.01±2.25	35.42±0.77
3	SAAT building	140.45±1.37	18.08±3.61	23.51±0.81
4	Main library	125.96±1.39	22.71±3.15	43.87±0.75
5	Potluck fast food	113.23±1.41	22.92±3.11	33.98±0.77
6	FUTO microfinance bank	142.45±1.37	30.37±2.57	41.11±0.76
7	Afrihub building	125.44±1.39	32.03±2.47	37.03±0.76
8	SOHT building	87.23±1.45	25.81±2.83	18.41±0.83
9	ETF biological sciences building	142.02±1.37	26.90±2.76	30.86±0.78
10	Endowment lecture theatre hall	103.55±1.42	26.54±2.76	5.07±0.95
11	SMAT building	125.96±1.39	24.66±2.96	33.03±0.77
12	SOSC extension building	125.44±1.39	24.51±2.97	29.06±0.78
13	FUTO main gate	100.67±1.42	13.74±2.93	30.86±0.76
14	Senate building	50.60±1.51	15.69±3.21	6.32±0.87
15	University staff primary school	88.45±1.43	15.40±3.28	19.58±0.78
16	Management technology building	68.65±1.47	22.85±2.55	26.19±0.77
17	FUTO business premises	21.90±1.62	19.81±2.85	14.18±0.82
18	ASUU secretariat	134.51±1.38	19.89±2.95	27.77±0.77
19	SAAT academic staff offices	68.13±1.48	20.97±2.75	22.15±0.78
20	Junior staff quarters	77.03±1.46	16.34±3.16	28.18±0.76
21	Professorial quarters	63.68±1.49	10.99±4.08	29.50±0.76
22	BCH building	76.07±1.46	6.36±2.25	25.72±0.77
23	SOSC new lecture theatre	88.80±1.44	10.92±4.81	5.58±0.90
24	FUTO bus park	88.28±1.43	21.62±2.69	18.81±0.79
25	FUTO cafeterias	86.45±1.44	20.39±2.82	18.81±0.80
26	Diamond bank building	75.54±1.47	4.70±2.19	8.85±0.88
27	Chemical engineering building	72.23±1.47	14.32±3.51	21.60±0.78
28	Hostel C	92.21±1.43	6.44±2.24	15.91±0.81
29	STACC	94.30±1.43	17.14±3.16	27.04±0.77
30	FUTO back gate	55.39±1.52	<3.65	15.21±0.83
31	Senior staff quarters	98.49±1.42	16.70±3.21	24.73±0.78
32	SOSC building	70.40±1.47	29.07±2.22	21.82±0.78
33	Convocation square	72.84±1.48	4.77±2.90	25.61±0.78
34	Hostel A	77.81±1.47	<3.65	6.50±0.91
35	Mechanical engineering building	98.75±1.42	18.66±2.97	24.17±0.78
36	Hostel D	96.65±1.43	6.94±2.22	22.81±0.79
37	National maritime building	95.96±1.42	8.60±4.61	19.66±0.80
38	Lecture hall II	76.15±1.46	16.41±3.20	21.12±0.79
39	ECOBANK building	73.45±1.47	20.83±2.77	21.57±0.78
40	Old registry block	80.34±1.46	22.85±2.67	29.72±0.76
41	Medical centre	56.96±1.51	10.63±4.14	14.62±0.83
42	Hall of mercy	93.43±1.43	22.42±2.69	20.65±0.80
43	500 capacity building	89.85±1.44	15.40±3.35	17.63±0.80
44	Scholarship residential Building	88.54±1.44	11.06±4.00	21.90±0.78
45	Sunic fast food	107.82±1.40	6.51±2.23	18.88±0.80
46	FUTO ICT	90.64±1.43	26.83±2.35	20.94±0.79
47	Pilot library	94.47±1.43	9.40±4.43	29.72±0.76
48	Directorate of general studies Building	90.20±1.44	19.67±2.93	27.92±0.77
49	SEET lecture theatre	37.77±1.57	20.25±2.84	21.90±0.78
50	Hostel B	80.78±1.45	13.38±3.66	21.53±0.78
51	Hostel E	120.56±1.38	20.54±2.76	20.79±0.78
52	Workshop III	74.76±1.46	20.39±2.80	14.36±0.81
53	CCE Unit	99.27±1.42	19.96±2.82	25.13±0.77
54	Department of computer Sci Lab II	85.75±1.44	23.28±2.56	27.11±0.76
55	Works department building	59.06±1.50	4.05±2.15	16.31±0.81
56	FUTO consult LTD	104.33±1.41	<3.65	18.26±0.81
57	FISO building	81.30±1.44	11.14±3.95	15.06±0.81
58	Workshop II	103.55±1.41	20.17±2.80	20.39±0.79
59	SEET building	93.16±1.43	15.11±3.36	27.52±0.77
60	750 capacity building	35.50±1.56	24.95±2.46	<4.43

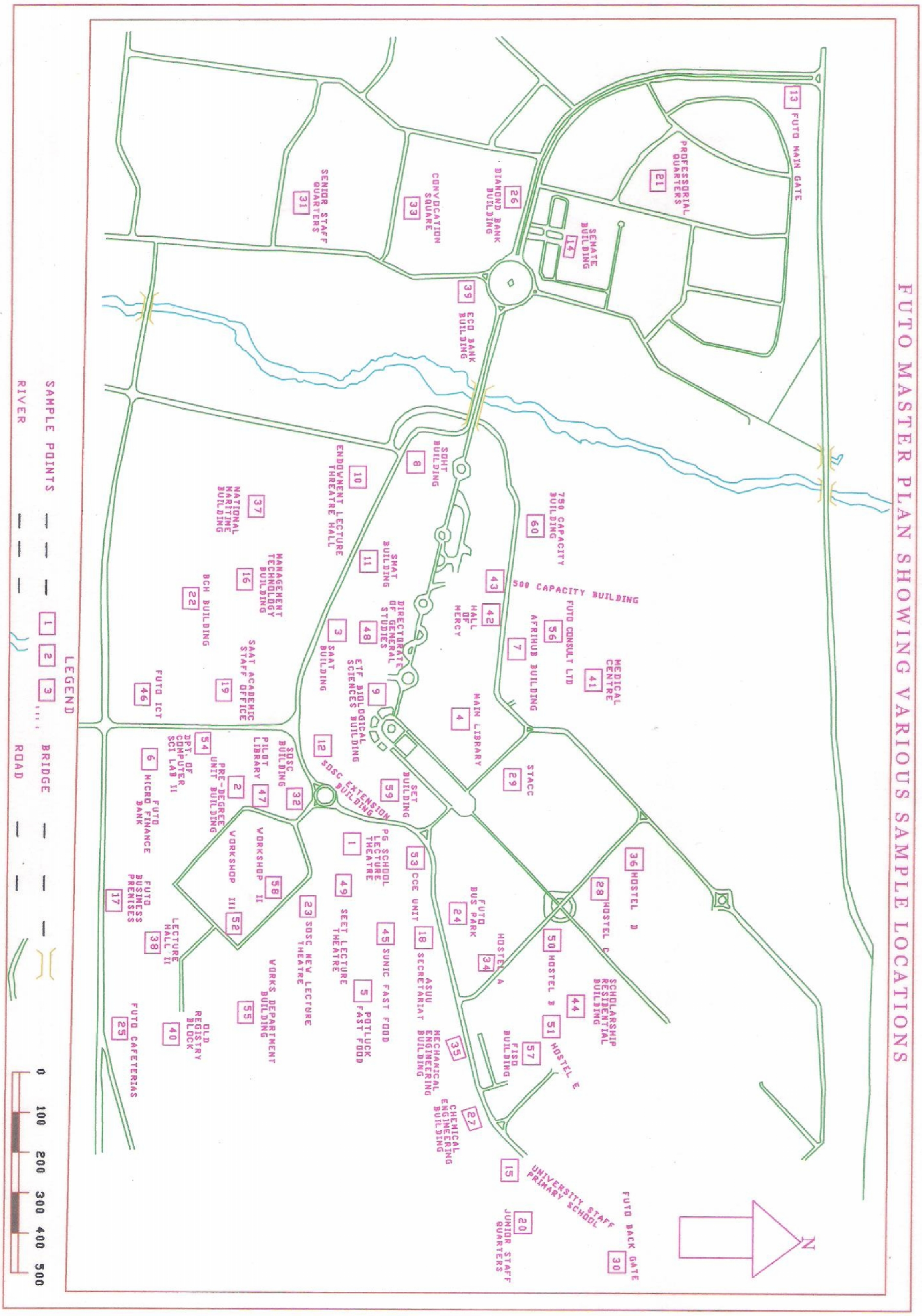

Fig. 1. Map of the study area

Table 2. Absorbed dose rates and outdoor effective dose rates at different locations

Sample ID	Sample locations	Absorbed dose rates ($nGyh^{-1}$)	Effective dose rates (μSvy^{-1})
1	PG school lecture theatre	33.35	40.92
2	Pre-degree unit building	43.71	53.64
3	SAAT building	29.32	35.99
4	Main library	44.16	54.19
5	Potluck fast food	37.15	45.59
6	FUTO microfinance bank	46.31	56.83
7	Afrihub building	43.58	53.49
8	SOHT building	26.96	33.09
9	ETF biological sciences building	38.02	46.66
10	Endowment lecture theatre hall	19.14	23.49
11	SMAT building	37.81	46.40
12	SOSC extension building	35.10	43.07
13	FUTO main gate	30.63	37.58
14	Senate building	13.06	16.03
15	University staff primary school	23.34	28.65
16	Management technology building	30.05	36.87
17	FUTO business premises	18.79	23.06
18	ASUU secretariat	32.66	40.08
19	SAAT academic staff offices	26.55	32.58
20	Junior staff quarters	28.94	35.52
21	Professorial quarters	26.96	33.09
22	BCH building	23.01	28.24
23	SOSC new lecture theatre	12.18	14.94
24	FUTO bus park	25.48	31.27
25	FUTO cafeterias	24.88	30.53
26	Diamond bank building	11.11	13.64
27	Chemical engineering building	23.52	28.86
28	Hostel C	17.25	21.17
29	STACC	29.27	35.93
30	FUTO back gate	12.45	15.28
31	Senior staff quarters	27.74	34.04
32	SOSC building	29.88	36.68
33	Convocation square	22.12	27.15
34	Hostel A	7.65	9.39
35	Mechanical engineering building	28.21	34.63
36	Hostel D	22.22	27.27
37	National maritime building	20.81	25.54
38	Lecture hall II	24.26	29.78
39	Eco bank building	26.33	32.32
40	Old registry block	32.89	40.36
41	Medical centre	16.67	20.45
42	Hall of mercy	27.26	33.46
43	500 capacity building	22.11	27.13
44	Scholarship residential building	23.03	28.26
45	Sunic fast food	19.91	24.44
46	FUTO ICT	29.22	35.86
47	Pilot library	27.75	34.06
48	Directorate of gen studies building	30.76	37.75
49	SEET lecture theatre	24.77	30.40
50	Hostel B	23.44	28.77
51	Hostel E	27.72	34.02
52	Workshop III	21.43	26.30
53	CCE unit	29.43	36.11
54	Department of computer Sci Lab II	31.57	38.75
55	Works department building	15.07	18.49
56	FUTO consult LTD	16.57	20.34
57	FISO building	18.22	22.36
58	Workshop II	26.56	32.60
59	SEET building	28.68	35.19
60	750 capacity building	12.18	14.95

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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Peer-review history:
The peer review history for this paper can be accessed here:
http://www.sciencedomain.org/review-history.php?iid=713&id=5&aid=6480