Radiological dose implications of the natural radioactivity contents of sediment of rivers and streams in the northern part of Ibadan city

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(Received 28 February 2007)

The concentrations of natural radionuclides namely ^{40}k, ^{238}U and ^{232}Th in the sediment of rivers and streams in the Northern part of Ibadan city, Nigeria was examined in this study. A highly sensitive γ – spectrometric system coupled to a computerized ACCUSPEC multichannel analyzer system (MCA) was employing in the investigation. 50 samples from different locations were analyzed and the mean radioactivity concentrations obtained were (0.0564 ± 0.0056), (0.0128 ± 0.0017) and (0.0175 ± 0.0037) KBqkg^{-1} for ^{40}K, ^{238}U and ^{232}Th respectively. The mean absorbed dose rate, the mean annual effective dose equivalent and the collective dose equivalent for sediment from Northern part of the city were measured to be (20.00 ± 0.035) nGyh^{-1}, 60.5 μSvy^{-1} and 1.21 × 10^2 manSvy^{-1} respectively. Exposure to these low doses can be significant over a long period of time and constitute health hazard, especially when inhabitants of the area consume water and ingest aquatic species.

I. INTRODUCTION

A Myriad percentage of exposure to surrounding back ground radiation is encountered in drinking water supplies and ingestion of sea foods such as fish, Cray fish, crabs and reptiles, because natural occurring radionuclides, especially ^{40}K, ^{238}U, ^{232}Th, are present in the sediment of rivers and streams [1,2].

Uses of radionuclides in medicine, industry and research are on the increase in Nigeria. There are a number of centres using radiation facilities in the city of Ibadan such as Nigeria Tobacco Company (NTC), University College Hospital (UCH), and Federal Radiation Protection Service (FRPS). The number is growing. Since sediment can contains pollutants discharge to the rivers and streams [3], therefore, it is possible for waste from these centres to find their ways into rivers and streams. This is due to the fact that inhabitants of the city have been noted for dumping all sort of waste into the streams. Knowledge of level of radiation concentration in sediment is essential to dose that may accrue to inhabitants. Hitherto there are no standards for level of natural radioactivity in sediments. The amount of radioactive nuclides found in sediments varies widely with different locations. No information is available on the variation of radionuclides concentrations in sediments in the area. The baseline study will form the basis for evaluating any future environmental pollution or radioactive contamination of the area [4].

Ibadan a city in South Western part of Nigeria can be located on latitude 3.52º East and Longitude 7.23º North [5]. It has a population of about 4 million people [5]. The most prominent rivers in Ibadan are Odo-Ona and Ogunpa. Other streams link to them at various joints. The cartography of the map of Ibadan North (Fig. 1) shows the streams and rivers [6].

II. EXPERIMENTAL PROCEDURE

The counting system employed in this work comprised of a 7.6 cm × 7.6 cm NaI(TI) detector (Model 802 by Canberra Inc. U.S.A) coupled to an ACCUSPEC installation (i.e. an Accuspec Display & Acquisition Software). The detector has a resolution of about 7.4% at the 662 KeV line for ^{137}Cs, which is good enough for distinguishing γ – energies for ^{40}K, ^{238}U and ^{232}Th. The system is connected to the computerized MCA through a coaxial cable. The detector has a 15 cm – thick lead shielding to guide against natural background radiation, with other background effects, which are intrinsic to the detector, corrected for the theoretically [7].

A total of 50 sediments samples each weighing 1.2 kg was collected in dry season at a depth of 35 cm from 50 different locations (Fig. 1). All samples were kept in plastic bags believed to be non-radioactive and returned to the laboratory where they were dried under a temperature condition of about 27^{o}C for 24 hours [8]. Each of the dry samples was pulverized and then passed through a 2 mm sieve, with the larger particles discarded. 200 g of each sieved sediment sample was placed in 100 cm^3 Aluminium container for γ – activity analysis.

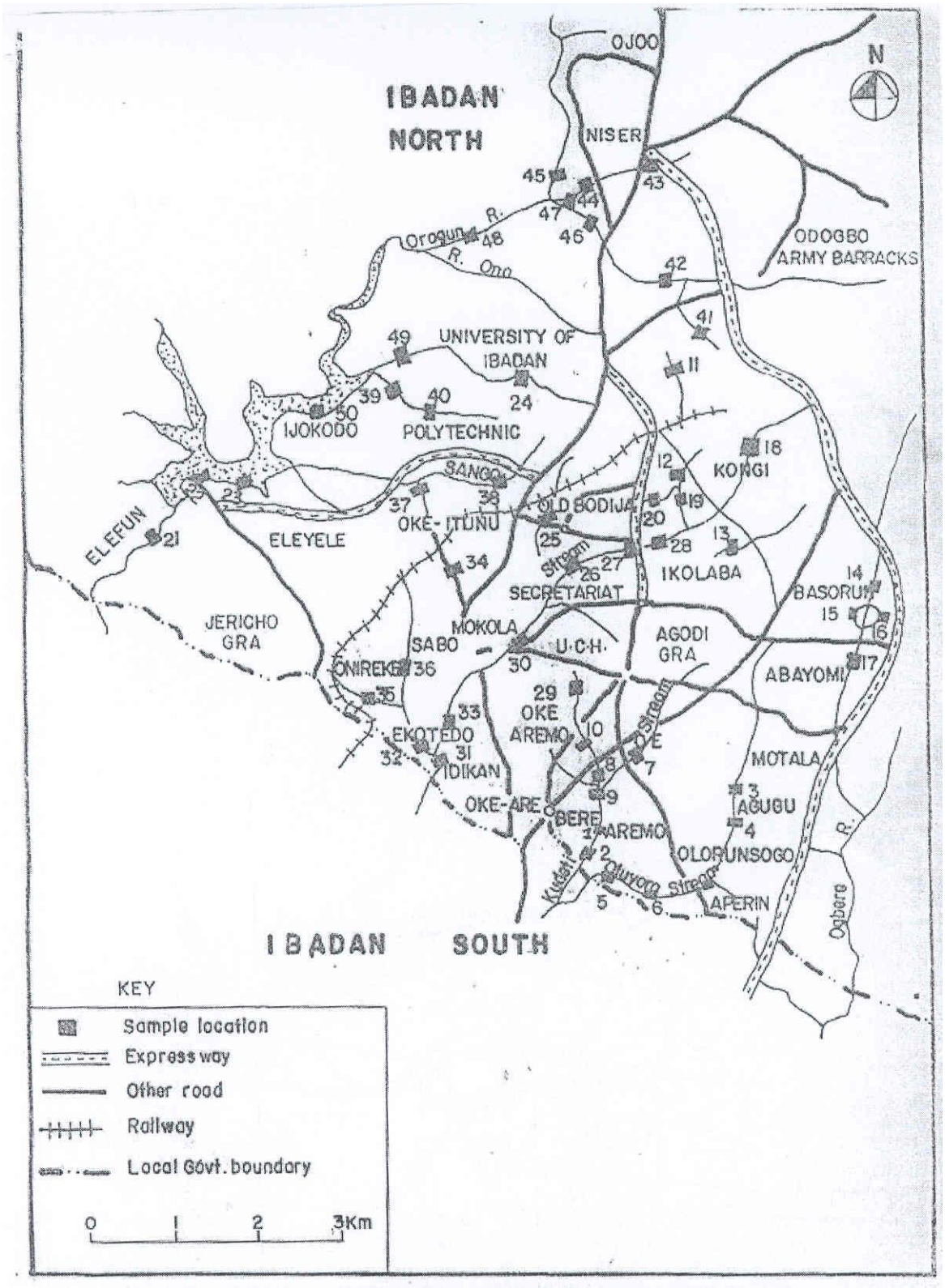

FIG. 1. The cartography of the map of Ibadan North showing streams and rivers.
Source: Geography Department, University of Ibadan.

The detector was calibrated using a reference soil sample traceable to Department of Energy, Environmental Measurement Laboratory, New York (USA). This standard reference sample contained certified concentrations of the radionuclides of interest i.e. ^{40}K, ^{238}U and ^{232}Th. The gamma energies and lower limit of detection (LLD) used in estimation is presented in Table I. The counting was done at a preset time of 10 hours with the container sealed at a high geometry on the NaI(TI) detector. The gamma spectrum of each sediment samples was determined by counting for the same time (10 hrs). The count for all the samples was obtained. This value was related to the sediment concentration and exposure dose rate using the calibration carried out for the standard reference sample.

The exposure dose rate for each of the locations was estimated using the Beck *et al.* [9] relationship, which is given as

$$D = 0.042S_k + 0.429S_u + 0.666S_{Th}$$

where D in Gyh^{-1} due to the specific activity concentrations S_k, S_u and S_{Th} of ^{40}K, ^{238}U and ^{232}Th, in $KBqkg^{-1}$ respectively.

III. RESULTS AND DISCUSSION

Table II gives the summary of the investigation samples number and locations. The arithmetic mean and standard deviation values for each radionuclide are also contained in this table. The calculated absorbed dose rates in (μGyh^{-1}) are also given in the Table II.

For ^{40}K, the radioactivity concentration ranged between 0.0026 $KBqkg^{-1}$ at Oke-Igbala and 0.1940 $KBqkg^{-1}$ at Ijokodo. For ^{238}U, the value of concentration was between 0.0014 $KBqkg^{-1}$ at Adenuga and 0.0495 $KBqkg^{-1}$ at Ajibode 3. Also for ^{232}Th, the ranged was between 0.0017 $KBqkg^{-1}$ at Adenuga and 0.688 $KBqkg^{-1}$ at Eleyele Dam 2. The absorbed dose rate ranged between (0.0028 ± 0.0002) μGyh^{-1} at Alaadorin and (0.0494 ± 0.0049) μGyh^{-1} at Ajibode 3.

The mean concentrations of the radionuclides 40 K, ^{238}U and ^{232}Th were calculated to be (0.0564 ± 0.0056), (0.0128 ± 0.0017) and (0.0175 ± 0.0037) $KBqkg^{-1}$ respectively. The mean absorbed dose rate was estimated to be 20.00 ± 0.035 $nGyh^{-1}$ in air at a distance of 1 m above the ground level. The variation of absorbed dose rates with locations is illustrated in Fig. 2. A conversion factor of 0.7 $SvGy^{-1}$, assuming an outdoor occupancy of 50% [10] was used to obtain the annual effective dose equivalent in the area to be 60.5 μSvy^{-1}.

The collective effective dose equivalent can be calculated using the ICRP relationship given as

$$S_E = H_E\, N(H_E) \text{ [11]}$$

where S_E is the collective effective dose equivalent; H_E is the annual effective dose equivalent to an individual and $N(H_E)$ represents the population of the study area.

Based on the $N(H_E)$ put at 2,000,000 [5,12] the value of collective effective dose equivalent obtained from the expression was 1.21×10^2 $manSvy^{-1}$.

IV. CONCLUSION

The results obtained for absorbed dose rate in air, that is 60.50 μSvy^{-1} represents 86% of the world average of (70.0 μSvy^{-1}) [13]. This is 94% of (64.055 μSvy^{-1}) obtained from a similar study in coastal areas of Lagos [14] and 20% greater than (50.0 μSvy^{-1}) obtained within city of Lagos [15].

From the results, the dose is low, but may be significant over a period of time. It should also be noted that accumulation of low-doses over the years could bring about diseases such erythema, pigmentation, epilation, blistering, necrosis and ulceration to mention but few on the inhabitants of the area. This is due to the fact that radiation ranks among the most thoroughly investigated etiologic agents associated with diseases [16].

TABLE I. Gamma energies and lower limit of detection (LLD).

Radionuclides	Radionuclides corresponding to full-energy peak	Energy (MeV)	LLD ($KBqkg^{-1}$)
$^{137}C_s$	$^{137}C_s$	0.662	–
^{40}K	^{40}K	1.460	0.0020
^{226}Ra	^{214}Bi	1.760	1.0003
^{232}Th	^{208}Ti	2.650	0.0015

TABLE II. Radioactivity concentrations in $KBqkg^{-1}$ (BLD represents Below Lower Limit of Detection).

No of Samples and Location	^{40}K	^{238}U	^{232}Th	Calculated absorbed rates in μGyh^{-1}
1. Oluyoro	0.1481 ± 0.0063	0.0117 ± 0.0020	0.0083 ± 0.0045	0.0168 ± 0.0041
2. Ajegede	0.0899 ±0.0059	0.0015 ± 0.0021	BLD	0.0044 ± 0.0012
3. Ode-Aje	0.0748 ± 0.0058	BLD	BLD	0.0031 ± 0.0002
4. Agugu	0.0863 ± 0.0058	BLD	BLD	0.0036 ± 0.0002
5. Alaadorin	0.0667 ±0.0058	BLD	BLD	0.0028 ± 0.0002
6. Oke-Offa	0.0246 ± 0.0055	0.0067 ± 0.0030	0.0135 ± 0.0046	0.0129 ± 0.0046
7. Isale Oje	0.0720 ± 0.0058	0.0039 ± 0.0021	0.0040 ± 0.0045	0.0074 ± 0.0041
8. Yemetu	0.0403 ± 0.0056	BLD	0.0031 ± 0.0045	0.0038 ± 0.0032
9. Temidire	0.0177 ± 0.0055	0.0052 ± 0.0022	BLD	0.0031 ± 0.0012
10. Alawada	0.0291 ± 0.0056	BLD	0.0049 ± 0.0045	0.0045 ± 0.0032
11. Bodija	0.0828 ± 0.0059	BLD	0.0023 ± 0.0045	0.0050 ± 0.0033
12. Arowosope	0.0252 ± 0.0055	0.0066 ± 0.0022	0.0121 ± 0.0046	0.0120 ± 0.0042
13. Ashi	0.0723 ± 0.0058	BLD	BLD	0.0030 ± 0.0002
14. Bashorun	0.0168 ± 0.0055	0.0310 ± 0.0026	BLD	0.0140 ± 0.0014
15. Oja	0.0545 ± 0.0057	BLD	BLD	0.0023 ± 0.0025
16. Bernard	0.0378 ± 0.0056	0.0379 ± 0.0027	0.0043 ± 0.0046	0.0207 ± 0.0045
17. Amuda	0.0662 ± 0.0058	0.0101 ± 0.0023	0.0169 ± 0.0046	0.0184 ± 0.0043
18. Adenuga	0.0941 ± 0.0060	0.0014 ± 0.0021	0.0017 ± 0.0045	0.0057 ± 0.0042
19. Are	0.0434 ± 0.0057	0.0055 ± 0.0022	0.0250 ± 0.0047	0.0208 ± 0.0043
20. Are Ogunpa	0.0434 ± 0.0057	0.0226 ± 0.0025	0.0042 ± 0.0045	0.0143 ± 0.0043
21. Eleyele	0.0482 ± 0.0057	0.0415 ± 0.0028	0.0295 ± 0.0047	0.0395 ± 0.0046
22. Eleyele Dam 1	0.0802 ± 0.0059	0.0162 ± 0.0024	0.0337 ± 0.0047	0.0328 ± 0.0044
23. Eleyele Dam 2	0.1081 ± 0.0059	0.0256 ± 0.0025	0.0688 ± 0.0063	0.0613 ± 0.0055
24. Zik Hall	0.0251 ± 0.0055	0.0174 ± 0.0024	0.0332 ± 0.0047	0.0306 ± 0.0044
25. Sango	0.0556 ± 0.0057	BLD	0.0049 ± 0.0045	0.0056 ± 0.0032
26. Oshunkunle	0.0342 ± 0.0056	0.0078 ± 0.0022	0.0051 ± 0.0045	0.0082 ± 0.0042
27. Secretariat	0.0711 ± 0.0058	BLD	0.0017 ± 0.0045	0.0041 ± 0.0032
28. Ikolaba	0.0647 ± 0.0058	BLD	0.0308 ± 0.0047	0.0232 ± 0.0034
29. Agodi	0.0509 ± 0.0057	0.0312± 0.0026	0.0304 ± 0.0047	0.0358 ± 0.0045
30. Dandaru	0.0223 ± 0.0055	0.0086± 0.0022	0.0401 ± 0.0048	0.0313 ± 0.0044
31. Oke-Igbala	0.0026 ± 0.0053	0.0058± 0.0022	0.0032 ± 0.0045	0.0047 ± 0.0042
32. Idikan	0.0219 ± 0.0055	0.0157 ± 0.0024	0.0400 ± 0.0048	0.0343 ± 0.0045
33. Ekotedo	0.0045 ± 0.0054	0.0251 ± 0.0025	0.0421 ± 0.0048	0.0390 ± 0.0045
34. Dugbe	0.0043 ± 0.0054	0.0190 ± 0.0024	0.0566 ± 0.0049	0.0460 ± 0.0045
35. Onireke	0.0107 ± 0.0054	0.0378± 0.0023	0.0300 ± 0.0047	0.0367 ± 0.0043
36. Sabo	BLD	0.0286± 0.0026	BLD	0.0123 ± 0.0011
37. Barrack	0.0398 ± 0.0056	0.0095± 0.0022	0.0159± 0.0046	0.0163 ± 0.0042
38. Polytechnics	0.0607 ± 0.0058	0.0111± 0.0023	0.0055 ± 0.0045	0.0110 ± 0.0042
39. Apete	0.0286 ± 0.0056	0.0033 ± 0.0021	0.0464 ± 0.0048	0.0335 ± 0.0043
40. Poly Entrance	0.0104 + 0.0054	0.0300+ 0.0026	0.0019 + 0.0045	0.0146 + 0.0044
41. Agbowo	0.0349 + 0.0056	BLD	0.0455 + 0.0048	0.0318 + 0.0034
42. Apata	0.0697 + 0.0058	0.0128+ 0.0023	0.0473+ 0.0048	0.0399 + 0.0044
43. Saw mill	0.0124 + 0.0055	0.0261+ 0.0025	0.0356 + 0.0047	0.0354 + 0.0044
44. Niser	0.1661 + 0.0064	BLD	0.0146 + 0.0046	0.0216 + 0.0033
45. Ajibode 3	0.0212 + 0.0055	0.0495 + 0.0029	0.0409 + 0.0052	0.0494 + 0.0049
46. Ajibode 1	0.0986 + 0.0060	0.0288 + 0.0026	0.0260 + 0.0047	0.0338 + 0.0045
47. Ajibode 2	0.1172 + 0.0061	0.0082 + 0.0022	BLD	0.0085 + 0.0012
48 Botanical garden	0.0792 + 0.0059	0.0065+ 0.0022	0.0042 + 0.0045	0.0089 + 0.0042
49. Oba Dam	0.1292 + 0.0062	0.0129+ 0.0023	BLD	0.0110 + 0.0013
50. Ijokodo	0.1940 + 0.0065	0.0212+ 0.0025	0.0391+ 0.0048	0.0433 + 0.0045
Average	0.0564 + 0.0056	0.0128+ 0.0017	0.0175 + 0.0037	0.0200 + 0.0035
Standard Deviation	0.0428 + 0.0008	0.0130 + 0.0011	0.0186+ 0.0020	0.0151 + 0.0014

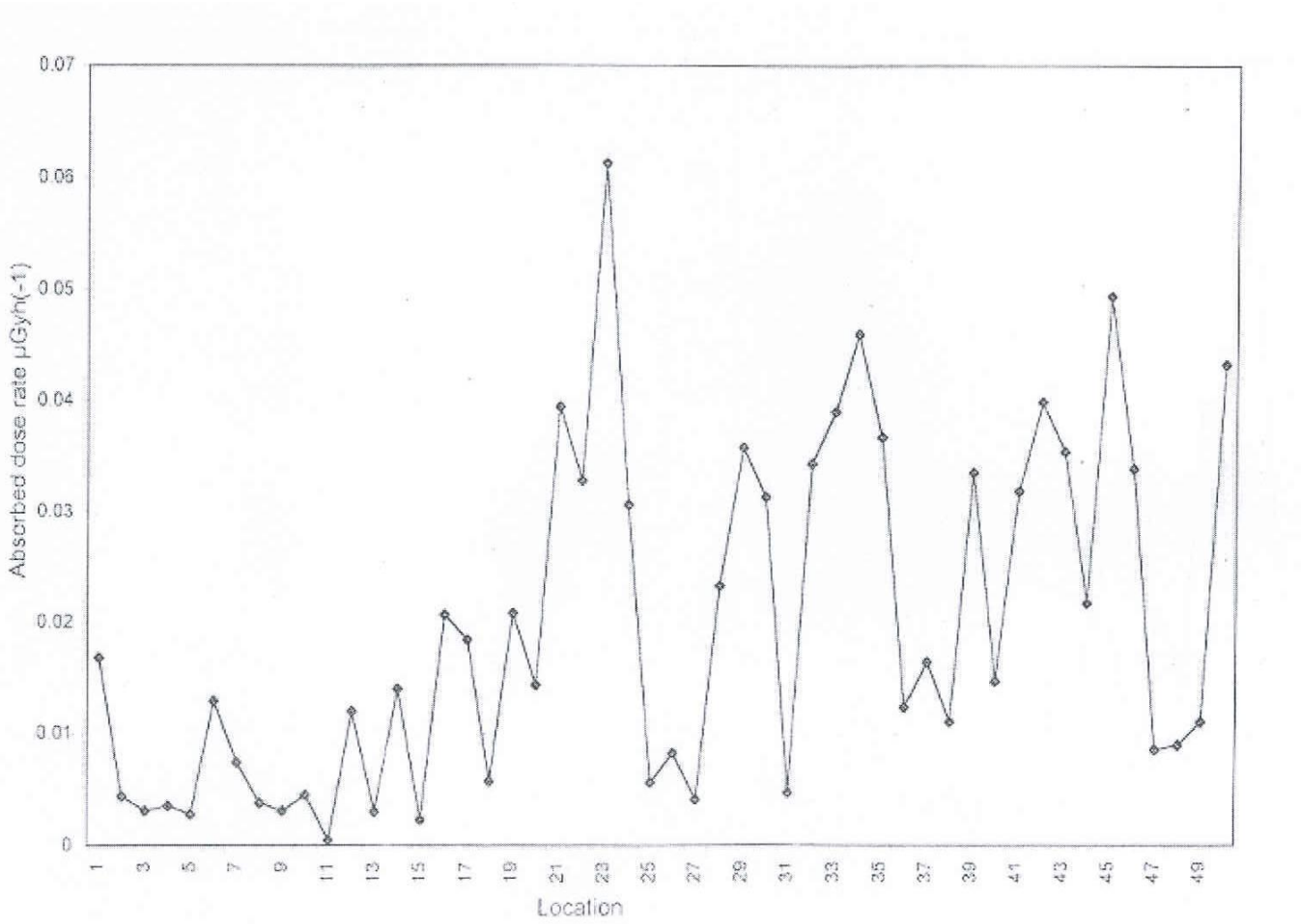

FIG. 2. Absorbed dose rates in 50 locations in Ibadan North.

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