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ASSESSMENT OF NATURAL RADIOACTIVITY, ITS ASSOCIATED RADIOLOGICAL HAZARDS AND DOSE PARAMETERS IN ALABA INTERNATIONAL MARKET OJO, LAGOS STATE, NIGERIA

Isola, G.A.*, Ayanlola, P.S. and Fajuyigbe, A.

Department of Pure and Applied Physics, Ladoko Akintola University of Technology, Ogbomosho, Oyo State, Nigeria

Abstract

An in-situ measurement of dose rate using Radex RD1503 radiometer at Alaba International market had been undertaken in this study, the measurement took place at ninety (90) sampling points (representing 30 different spots). Gamma ray spectra of natural radioactivity for thirty soil samples from same sampling spots were also determined for ^{238}U , ^{234}Th series and ^{40}K . The activity concentrations obtained for the samples varied from 50.23 Bqkg^{-1} to 150.23 Bqkg^{-1} , 9.41 Bqkg^{-1} to 18.41 Bqkg^{-1} and 9.81 Bqkg^{-1} to 25.81 Bqkg^{-1} for ^{40}K , ^{238}Th and ^{226}Ra respectively. ^{137}Cs of artificial radionuclide was identified at five different spots but at a very minimal level. The dose parameters reported in the present study includes: Absorb dose rate in air, annual effective dose equivalent and exposure rate, which were obtained from the activity concentrations of the samples. The parameters have been presented to be below the international permissible maximum limits.

Keywords: Natural radioactivity, Dose parameters, Radiological hazard, Alaba market

*Corresponding author e-mail: gaisola@lautech.edu.ng

Introduction

Studies on radiation level and radionuclide distribution in the environment provide vital radiological baseline information. Such information is essentially in understanding human exposure from natural and man-made sources of radiation and necessary in establishing rules and regulations to radiation protection (Quindoset *et al.*, 2004 and Ibrahim *et al.*, 2006). Natural radioactivity in soil have been performed in many part of the world, mostly, assessment of the dose and risk resulting from them (Rudge *et al.*, 1993; Clouvas *et al.*,

2001; Copplestone *et al.*, 2001, Dowdall *et al.*, 2004, El-Bahi *et al.*, 2005, Akinloye *et al.*, 2012 and Isola *et al.*, 2015). The naturally occurring radionuclides present in soil includes Ra^{226} , Th^{232} and K^{40} (Khan *et al.* 1994).

Gamma radiation emitted from those naturally occurring radioisotopes, called terrestrial background radiation, represents the main source of irradiation of the human body and contributes to the total absorbed dose via ingestion, inhalation and external irradiation (Steinhausler, 1992). Studies revealed that 50-80% of the total gamma flux at the earth's surface arises from ^{40}K , ^{238}U and

²³²Th series in topsoil. Natural environmental radioactivity and the associated external exposure due to the gamma radiation depend primarily on the geological and geographical conditions and appear at different levels in the soils of each region in the world. Since the radionuclides are not uniformly distributed, the knowledge of their distribution in soils play an important role in radiation protection and measurement (Khan *et al.*, 1994), also the radioactivity of soils is essential for understanding changes in the natural background (Sroor *et al.*, 2001 and Chiozzi *et al.*, 2002).

This study takes a look into Alaba international market located in Ojo, Lagos State, Nigeria. The market is the largest electronics market in Nigeria founded in 1978 and occupies a land area of approximately 2 km² in the southwest of Lagos. The major activity involves the selling of electronic products and repairs of same. It is envisaged that these electronics releases electromagnetic radiation and the danger posed by this massive importation of e-waste to human health and environment cannot be overemphasized considering the level and the manufacture of these products. The level of daily business transactions has attracted new investors and dealers across Africa thereby expanding the market size and population on daily bases.

The paper presents the background radiation level and the gamma absorbed dose rate within the study area owing to the inevitable effects of radiations and health risk due to these exposures. It is therefore necessary to provide a baseline data to guide exposure to background gamma radiation that may result from human activities within the market that attracts more than two million populations on daily basis.

Materials and Methods

This study was carried out at Alaba International market Ojo, Lagos state, Southwestern part of Nigeria. Its coordinate lie on Latitude: **6°27'35.1"N** and Longitude: **3°13'42.37"E**. The market features more than 2,500 shops to house various electronics products most especially refurbishing and offering used electrical and electronic products for sale. The study area was sampled and a total of thirty (30) spots were identified so as to have adequate and comprehensive report of the area.

Two methods were employed for the analysis, in-situ and laboratory measurement. The former employed a portable environmental radiometer model Radex RD1503 manufactured in Russia. The device estimates radiation level in magnitude of ambient equivalent power of gamma radiation dose rate, taking into account pollution of objects by beta sources. The dosimeter was switched on and held at one meter above the ground to absorb background radiation. The reading was displayed on the dosimeter screen after which the most reliable result is displayed after 40 seconds at thirty (30) identified spots. Equally, three soil samples were collected in each of the thirty identified spots, and the mean represent a sample from each spot.

The radionuclide activity concentrations of the samples assayed were determined at Radiation laboratory located in Ladoke Akintola University of Technology, Ogbomoso, Nigeria, after the laboratory procedures have been properly observed. Such as removing of the samples foreign bodies, drying at 60°C for 48h, grained then passed through 2mm sieves and placed in Marinelli type beakers. The samples were then kept for a period of twenty-eight days before the analysis at air tight condition to allow secular equilibrium between thorium,

radium and their decay products. The gamma spectrometry system was calibrated using standard mixtures of gamma emitting isotopes in Marinelli beakers, traceable to Analytical Quality Control Services (AQCS, U.S.A).

Each sample was counted for 36000s using a NaI (TI) detector. The detector is connected to the computerized MCA2100R through a coaxial cable. The activities of the samples were determined using the total net counts under the selected photo-peaks, the measured photo-peak efficiency, gamma intensity and weight of the samples. After correcting for background and Compton contribution, the activity concentrations of ^{238}U , ^{232}Th , ^{226}Ra , ^{40}K and ^{137}Cs were determined after assuming secular equilibrium with their decay products (^{238}U series: ^{226}Ra (186.0keV), ^{214}Pb (351.9keV) and ^{214}Bi (609.2keV): ^{232}Th series: ^{228}Ac (911keV), ^{208}Tl (583.1keV).

Calculations of Activity Concentration and Dose Parameters

In the calculations carried out in this section, we used the symbol: A_{Ra} , A_{Th} and A_{K} to represent the activity concentrations of ^{226}Ra for (^{238}U), ^{232}Th and ^{40}K radionuclides respectively.

Activity Concentration (A_i) in (Bqkg^{-1})

The activity concentration A_i of any γ -ray line taken to represent this parameter for the ^{226}Ra , ^{232}Th and ^{40}K radionuclides was calculated using the relation in Equation (1) (Amrani and Tahtat, 2001):

$$A_i \left(\frac{\text{Bq}}{\text{kg}} \right) = \frac{C_i}{\varepsilon(E) \times t \times m} \quad (1)$$

Where C_i is the net peak area after subtracting of background of the γ -ray line at energy E , $\varepsilon(E)$ is the detector efficiency of such γ -ray line, t is the time of measurement in seconds and m is the mass of sample in kg.

Absorbed Gamma Dose Rate in Air (D_{air})

The absorbed gamma dose rate in air at 1 m above the ground surface for the uniform distribution of radionuclides (^{226}Ra , ^{232}Th , and ^{40}K) was computed on the basis of provided guide lines (Hewamanna *et al.*, 2001; Oktay *et al.*, 2011). The conversion factors used to compute absorbed gamma dose rate in the air (D_{air}) per unit activity concentration in (1 Bq kg^{-1}) are 0.462 for ^{226}Ra , 0.621 for ^{232}Th , and 0.0417 for ^{40}K . Such dose parameter was calculated applying the relation in Equation (2) (Arafa, 2004):

$$D_{\text{air}} (\text{nGy h}^{-1}) = 0.462 A_{\text{Ra}} + 0.621 A_{\text{Th}} + 0.0417 A_{\text{K}} \quad (2)$$

Annual Effect Dose Equivalent (AEDE)

To estimate the AEDE, the conversion factor (0.7 Sv Gy^{-1}) from absorbed dose rate in the air in nGy h^{-1} to effective dose rate in $\mu\text{Sv y}^{-1}$ is used, with outdoor occupancy factor of 0.2. The AEDE was calculated using Equation (3) (UNSCEAR, 2000):

$$\text{AEDE} (\mu\text{Sv y}^{-1}) = D_{\text{air}} (\text{nGy h}^{-1}) \times 8766 \times 0.2 \times 0.7 \text{ Sv Gy}^{-1} \quad (3)$$

These indices measure the risk of stochastic and deterministic effects in the irradiated individuals. The recommended value of the annual effective dose equivalent is 0.48 mSv y^{-1} and the criterion of the total annual effective dose equivalent should be less than 1 mSv y^{-1} (UNSCEAR, 2000).

Exposure rate (ER)

The exposure rate was calculated using the following relation (Akhtar *et al.*, 2005):

$$\text{ER} (\mu\text{Rh}^{-1}) = 1.00 A_{\text{Ra}} + 2.82 A_{\text{Th}} + 0.179 A_{\text{K}} \quad (4)$$

Dose Rate

The dose rate was calculated using the following relation (Darwish *et al.*, 2015):

$$\text{DR} (\mu\text{Sv y}^{-1}) = 0.0833 \text{ ER} \quad (5)$$

Results and Discussion

The in-situ measured dose rate is presented in Table 1. The results in Table 1 show that the dose rate obtained range from $0.09 \mu\text{Sv h}^{-1}$ to $0.23 \mu\text{Sv h}^{-1}$. The results of the identified radionuclides and the activity concentrations obtained from the analysis of samples are presented in Table 2. The results in Table 2

show that three radionuclides namely: ^{40}K , ^{226}Ra and ^{238}Th were obtained from the analyzed samples. The activity concentration obtained for the identified radionuclide vary from 50.23 Bq kg^{-1} to $150.23 \text{ Bq kg}^{-1}$ with the mean value of $117.34 \text{ Bq kg}^{-1}$ for ^{40}K , 9.81 Bq kg^{-1} to 25.81 Bq kg^{-1} and mean value of 12.15 Bq kg^{-1} for ^{226}Ra

Table 1: Absorbed dose rate (in-situ) obtained from different spots within Alaba Market

Sample ID	1 st Trial	2 nd Trial ($\mu\text{Sv/h}$)	3 rd Trial ($\mu\text{Sv/h}$)	4 th Trial ($\mu\text{Sv/h}$)	Average ($\mu\text{Sv/h}$)
AS1	0.20	0.18	0.18	0.19	0.19
AS2	0.11	0.18	0.14	0.15	0.15
AS3	0.24	0.14	0.13	0.15	0.17
AS4	0.12	0.16	0.14	0.19	0.15
AS5	0.16	0.14	0.12	0.12	0.14
AS6	0.19	0.12	0.15	0.18	0.16
AS7	0.14	0.13	0.14	0.14	0.14
AS8	0.12	0.08	0.12	0.13	0.11
AS9	0.09	0.09	0.13	0.13	0.11
AS10	0.05	0.10	0.17	0.16	0.12
AS11	0.12	0.20	0.19	0.21	0.18
AS12	0.04	0.08	0.13	0.15	0.10
AS13	0.08	0.08	0.13	0.13	0.11
AS14	0.12	0.14	0.13	0.16	0.14
AS15	0.19	0.16	0.12	0.15	0.16
Sample ID	1 st Trial	2 nd Trial ($\mu\text{Sv/h}$)	3 rd Trial ($\mu\text{Sv/h}$)	4 th Trial ($\mu\text{Sv/h}$)	Average ($\mu\text{Sv/h}$)
AS17	0.20	0.16	0.14	0.11	0.15
AS18	0.12	0.12	0.13	0.13	0.15
AS19	0.14	0.14	0.13	0.15	0.14
AS20	0.14	0.12	0.15	0.17	0.15
AS21	0.10	0.10	0.08	0.09	0.09
AS22	0.18	0.20	0.19	0.21	0.19
AS23	0.18	0.17	0.19	0.18	0.18
AS24	0.11	0.12	0.11	0.12	0.12
AS25	0.08	0.11	0.11	0.11	0.10
AS26	0.18	0.19	0.18	0.20	0.19
AS27	0.11	0.15	0.13	0.15	0.14
AS28	0.12	0.16	0.14	0.18	0.15
AS29	0.19	0.16	0.12	0.15	0.16
AS30	0.25	0.23	0.20	0.24	0.23

Table 2: Activity concentration (Bqkg^{-1}) of the radionuclide identified in the samples

Sample ID	^{40}K	^{226}Ra	^{232}Th
AS1		11.21 ± 4.85	14.42 ± 0.12
AS2	113.21 ± 1.41	12.92 ± 3.11	13.98 ± 0.77
AS3	125.96 ± 1.39	10.66 ± 2.96	BDL
AS4	140.45 ± 1.37	10.08 ± 3.61	11.51 ± 0.81
AS5	142.02 ± 1.37	12.30 ± 2.76	10.46 ± 0.18
AS6	113.58 ± 1.41	13.01 ± 2.25	11.42 ± 0.17
AS7	87.23 ± 1.45	10.81 ± 2.03	9.41 ± 0.83
AS8	124.25 ± 1.30	11.21 ± 4.15	13.42 ± 0.78
AS9	125.44 ± 1.39	12.03 ± 2.47	17.03 ± 0.76
AS10	86.65 ± 1.47	12.85 ± 2.55	16.19 ± 0.77
AS11	50.23 ± 1.41	9.92 ± 3.11	12.98 ± 0.77
AS12	103.55 ± 1.42	11.54 ± 2.76	12.07 ± 0.95
AS13	134.25 ± 1.38	11.21 ± 4.85	10.42 ± 0.78
AS14	98.75 ± 1.42	11.66 ± 2.97	13.17 ± 0.78
AS15	99.27 ± 1.42	11.96 ± 2.82	13.13 ± 0.77
AS16	113.23 ± 1.41	12.92 ± 3.11	13.19 ± 0.17
AS17	87.23 ± 1.45	12.81 ± 2.83	12.41 ± 0.83
AS18	134.25 ± 1.38	11.21 ± 4.85	14.42 ± 0.78
AS19	98.75 ± 1.42	11.26 ± 2.97	14.13 ± 0.72
AS20	142.25 ± 1.37	10.37 ± 2.57	11.11 ± 0.76
AS21	113.58 ± 1.46	10.01 ± 2.20	11.42 ± 0.77
AS22	122.46 ± 1.37	10.37 ± 2.57	11.11 ± 0.76
AS23	122.02 ± 1.07	12.90 ± 2.16	10.86 ± 0.76
AS24	125.44 ± 1.39	11.31 ± 2.17	10.06 ± 0.78
AS25	87.23 ± 1.45	25.81 ± 2.83	18.41 ± 0.83
AS26	125.96 ± 1.39	10.66 ± 2.96	13.03 ± 0.77
AS27	100.17 ± 1.42	11.74 ± 2.93	13.86 ± 0.76
AS28	141.45 ± 1.37	10.07 ± 2.57	11.21 ± 0.76
AS29	87.23 ± 1.45	9.81 ± 2.83	10.21 ± 0.83
AS30	150.23 ± 1.41	12.92 ± 3.11	13.98 ± 0.77
Average		12.15 ± 2.98	12.72 ± 0.70

and 9.41 Bqkg^{-1} to 18.41 Bqkg^{-1} with the mean value of 12.72 Bqkg^{-1} . With this report, all the investigated samples have values below the recommended criteria of 400 Bqkg^{-1} , 30 Bqkg^{-1} and 35 Bqkg^{-1} respectively (UNSCEAR, 2000). Meanwhile, Man-made radionuclide ^{137}Cs was detected at five sampled areas at very low values varying between 3.10 and 9.23 Bq/kg . It was however discovered that these spots are where the bulky of the so called e-waste are deposited before further distribution to their vendors.

The absorbed dose rate in air (D_{air}), annual effective dose equivalent (AEDE) and exposure rate (ER) obtained from the activity concentration of the analyzed samples are presented in Table 3. The value obtained for the D_{air} range from 9.97 nGyh^{-1} to 26.96 nGyh^{-1} with an average value of 18.16 nGyh^{-1} . The AEDE values obtained range from $12.24 \mu\text{Svy}^{-1}$ to $33.09 \mu\text{Svy}^{-1}$ with an average value of 22.28 nGyh^{-1} . The in-situ measured dose rate and the calculated dose rates are graphed on the histograms shown in Figure 1 (a) and (b). Both charts show that spot AS30 recorded highest dose rate. This can be attributed to large junks of electronic gadget within the vicinity of the spots. Spending lesser time is advisable within the identified spots. This is in a bid to avoid inhalation of radioactive gas which may be harmful to the lung.

Conclusion

This study has presented the results of the assessment of natural radioactivity, its associated radiological hazards and dose parameters in Alaba International Market Ojo, Lagos State, Nigeria. The analysis employed the use of in-situ measurement and gamma ray spectrometry. The natural radionuclide identified includes ^{40}K , ^{238}Th and ^{226}Ra while man-made radionuclide ^{137}Cs was also identified at five spots: AS1, AS9, AS17, AS21 and AS30 at a very low value. The activity concentrations obtained varied from 50.23 Bqkg^{-1} to 150.23 Bqkg^{-1} , 9.41 Bqkg^{-1} to 18.41 Bqkg^{-1} and 9.81 Bqkg^{-1} to 25.81 Bqkg^{-1} for ^{40}K , ^{238}Th and ^{226}Ra respectively. The findings in this work has revealed that Alaba International market and environs which has hosted the use of electronic gadgets of different sources, has not contributed adversely to the radioactivity levels of natural radionuclides and thus pose no radiological health risk.

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Figure 1: Chart showing the distribution of dose rate in the investigated spot.

Table 3: Estimated radiological parameters obtained from the activity concentration of the samples assessed

Sample ID	D _{air} (nGyh ⁻¹)	AEDE (μSvy ⁻¹)	ER (μRh ⁻¹)	DR (μSvh ⁻¹)
AS1		24.15 ± 2.71	84.35 ± 9.80	0.80 ± 0.10
AS2	19.64 ± 1.90	24.10 ± 2.33	84.38 ± 8.34	0.80 ± 0.08
AS3	9.97 ± 1.32	12.24 ± 1.62	42.80 ± 5.87	0.41 ± 0.06
AS4	17.96 ± 2.14	22.04 ± 2.63	76.87 ± 9.40	0.73 ± 0.09
AS5	18.28 ± 1.36	22.43 ± 1.67	78.40 ± 5.99	0.75 ± 0.06
AS6	18.00 ± 1.13	22.09 ± 1.39	77.37 ± 5.01	0.74 ± 0.05
AS7	14.60 ± 1.48	17.92 ± 1.82	62.78 ± 6.47	0.60 ± 0.06
AS8	19.01 ± 2.34	23.33 ± 2.87	81.52 ± 10.33	0.78 ± 0.10
AS9	21.80 ± 1.62	26.75 ± 1.99	93.51 ± 7.10	0.89 ± 0.07
AS10	19.93 ± 1.66	24.46 ± 2.04	85.74 ± 7.29	0.82 ± 0.07
AS11	14.99 ± 1.90	18.40 ± 2.33	64.57 ± 8.34	0.61 ± 0.08
AS12	17.37 ± 1.87	21.32 ± 2.29	74.62 ± 8.19	0.71 ± 0.08
AS13	17.46 ± 2.65	21.43 ± 3.25	74.82 ± 11.67	0.71 ± 0.01
AS14	17.94 ± 1.85	22.02 ± 2.27	77.10 ± 8.10	0.73 ± 0.08
AS15	18.07 ± 1.75	22.18 ± 2.15	77.65 ± 7.79	0.74 ± 0.07
AS16	19.11 ± 1.50	23.45 ± 1.84	82.14 ± 6.64	0.78 ± 0.06
AS17	18.10 ± 1.82	22.21 ± 2.23	75.07 ± 7.99	0.71 ± 0.08
AS18	20.11 ± 2.65	24.68 ± 3.25	86.14 ± 11.67	0.82 ± 0.01
AS19	18.41 ± 1.81	22.59 ± 2.22	79.06 ± 7.93	0.75 ± 0.08
AS20	17.90 ± 1.66	21.97 ± 2.04	76.61 ± 7.28	0.73 ± 0.07
AS21	16.72 ± 1.51	20.52 ± 1.85	71.67 ± 6.62	0.68 ± 0.06
AS22	17.05 ± 1.66	20.92 ± 2.04	73.06 ± 7.28	0.69 ± 0.07
AS23	17.94 ± 1.49	22.02 ± 1.83	77.09 ± 6.44	0.73 ± 0.06
AS24	16.88 ± 1.50	20.72 ± 1.84	72.41 ± 6.58	0.69 ± 0.06
AS25	26.96 ± 1.82	33.09 ± 2.23	116.75 ± 7.99	0.11 ± 0.08
AS26	18.59 ± 1.83	22.81 ± 2.25	79.68 ± 8.05	0.76 ± 0.08
AS27	18.50 ± 1.82	22.70 ± 2.23	79.46 ± 7.97	0.76 ± 0.08
AS28	17.80 ± 1.66	21.84 ± 2.04	76.18 ± 7.28	0.72 ± 0.07
AS29	14.70 ± 1.82	18.04 ± 2.23	63.15 ± 7.99	0.60 ± 0.08
AS30	21.23 ± 1.90	26.05 ± 2.23	91.00 ± 8.34	0.87 ± 0.08
Average		22.28 ± 2.26	77.87 ± 7.89	0.68 ± 0.07

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