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Measurement of radiological and lifetime excessive cancer risk due to naturally occurring radioisotopes in wastes dumpsites soils in Sagamu, Southwest, Nigeria

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ABSTRACT

The concentrations and spatial distribution of the natural gamma ray emitting radioisotopes ^{238}U, ^{232}Th and ^{40}K, in dumpsite soils were analyzed with the aim of evaluating the radiation hazards and cancer risk using NaI (TI) gamma ray spectrometry technique. The ranges of activity concentrations of ^{238}U, ^{232}Th and ^{40}K were 77.07 ± 16.52 – 237.08 ± 53.12 $Bqkg^{-1}$, below detection limit (BDL)-19.79 ± 1.62 $Bqkg^{-1}$ and BDL-1551.45 ± 108.51 Bq kg^{-1} respectively. Radiological parameters: absorbed dose rate, radium equivalent, annual effective dose equivalent, internal and external hazard indices, gamma level index, activity utilization index, annual genetic significant dose equivalent, exposure rate and excessive lifetime cancer risk, were calculated to know the complete radiological hazardous risk of the dumpsite soils to the dwellers of the selected sites. The radiological parameters estimated were higher than the world average value in most of the sample points. This results showed that the soil from these dumpsites were not suitable for building, construction and farming purposes; and human exposure to the ionizing γ-radiation through inhalation should be discouraged. Multivariate analyses were carried out to know the existing relations between the parameters. Therefore, the radiological risks to the general populations from waste- enhanced naturally occurring radioactive materials from the selected dumpsites soils are considered to be significant.

Keywords: ionizing γ-radiation, radiation hazards, radioisotopes, and Spatial distribution

INTRODUCTION

The contamination of soil, water and air with radioisotopes can be transferred to human through the soil via vegetable ingestion (^{40}K),through air inhalation (^{222}Rn and ^{220}Rn) and dermal uptake. These radioisotopes even at lower dosage can have potential impacts on human health and environmental quality and may pose a long term risk [1]. The indiscriminate disposal of wastes in non-engineered landfills posed greater health challenges to the populace [2]. The impact of this point source of contamination is not only in terms of obnoxious smell and pathogens, but from ionizing radiations emanating from such dumping sites [2, 3]. Our habitat is steadily bombarded with ionizing radiations from primordial, natural and man-made sources [4]. The most common radioisotopes in environmental compartments are the radioactive isotopes of the three natural decay series (^{235}U, ^{238}U, and ^{232}Th) and ^{40}K. This unregulated haphazard disposal of wastes has led to the pollution of soil and groundwater resources [5].

Studies have shown that vegetables and staple food stuffs contain traces of radioisotopes [6, 7] and as a result of this, waste dumpsites has been implicated as a liable reservoir of radioactive materials of environmental and health concern. Peasant farmers cultivate plant legumes and vegetables in the field around the dumpsites. Therefore, the transportation of radioisotopes and other emerging pollutants in soil from dumpsites are possible via root-uptake with higher possibility of human absorption through ingestion and inhalation.

In Sagamu municipality, solid wastes are mostly deposited in unregulated dumpsites. Studies have shown that dumpsites contain traces of radioactive materials comprised of domestic co-disposed with industrial, agricultural, building and hospital wastes and other wastes [2, 8, 9]. More so, solid wastes sites create local sites where natural radioisotopes are concentrated in the environment and due to the soil-solute interchange. These contaminants migrate to groundwater and as a result of soil-to-plant transfer mechanism, accumulation of radioisotopes in plants and animals might occur.

Humans are exposed to high doses of internal and external radiation from the dumpsites. Based on this, the objectives of this present study was to determine the concentrations of waste enhanced naturally occurring radioisotopes present in representative soil samples from dumpsites by γ-ray spectrometry in order to estimate the hazard indices from these dumpsites to the general public.

MATERIALS AND METHODS

Description of the Study area

Sagamu is a town located within latitude 6˚45'0" N and 6˚55'0" North of the Equator and longitude $3^0$35'0" E and $3^0$40'0" East of the Greenwich Meridian (Figure 1). The area stands on a low–lying gent undulating terrain with altitude ranging between 30 and 80 m above sea level. The soil type of Sagamu is Ferralitic [10] and Ferruginous [11]. The climate is classified as humid tropical climatic zone [12] and controlled by the tropical maritime and tropical continental air masses [11]. The mean annual rainfall of Sagamu for 2012 was 1100 mm [13]. The three major dumpsites selected for this present are Makun dumpsite along Sagamu-Benin Express way, Oba Erinmole road dumpsite and Mosimi dumpsite respectively.

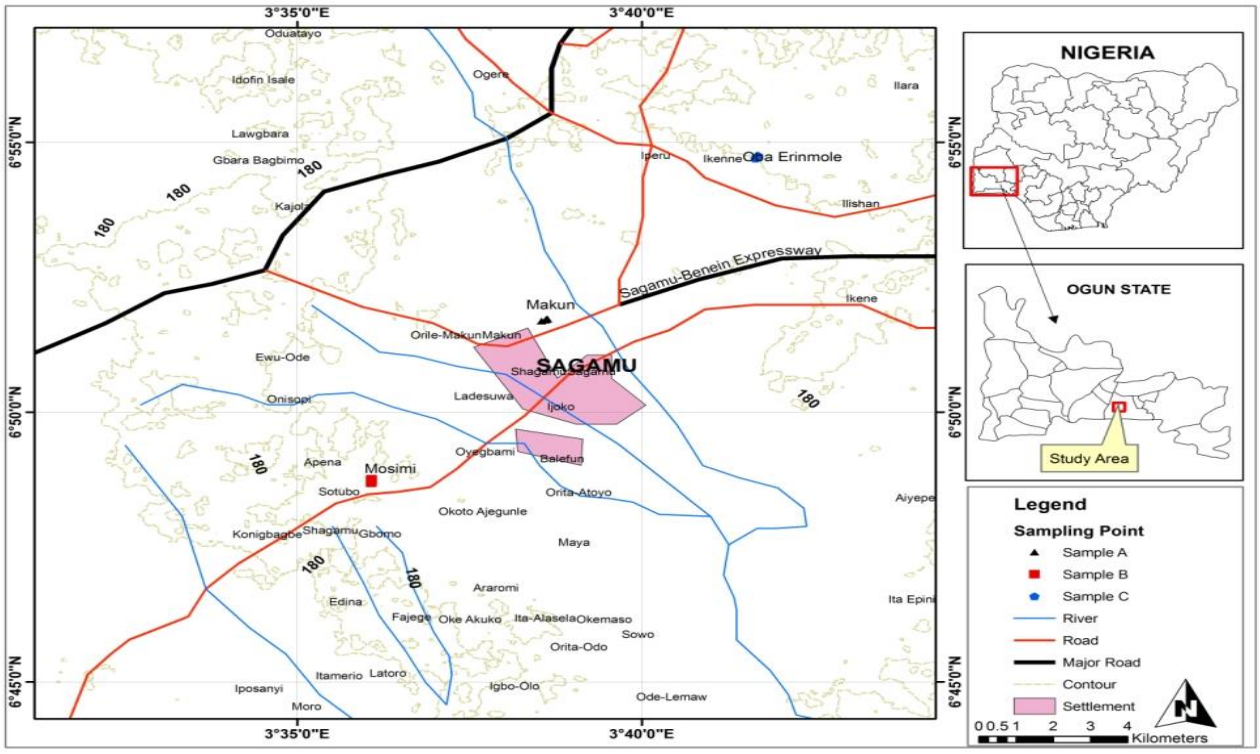

Fig. 1: Map of the study area showing the sampling locations

Sample collection and Preparation

A total of fifteen (15) soil samples were collected from the selected dumpsites using soil auger after careful removal of overlying wastes, thus exposing the underlying soil from where the soil samples were collected. The soil samples were taken at about 0 – 15 cm depth (using a meter rule) by the use of hand-driven auger, and taken to the laboratory in labeled polythene bags stored, and were air-dried at laboratory temperature in order to avoid cross contamination. The samples were then pulverized and filtered through a 2 mm mesh sieve. Five hundred grams (500 g) of pulverized soil samples was subsequently measured and packed into cylindrical containers (beaker). These samples were safely conveyed to National Institute of Radiation Protection and Research, University of Ibadan, Ibadan, South – West Nigeria. At the laboratory, the plastic were hermitically sealed with adhesive tape and kept for 30 days to ensure that the parent and daughter nuclides in the sample were at secular equilibrium between radium and its gaseous decay progenies. At the end of the four weeks in-growth period, the samples were subjected to gamma-ray spectroscopy counting.

Radioactivity measurements

System used for measurements

Activity concentrations of radioisotopes ^{238}U, ^{232}Th and ^{40}K were measured by γ-ray spectrometry using NaI (TI) detector. The counting system used in the determination of the natural radioisotopes contents of the soil consists of 7.6 cm x 7.6 cm NaI (TI) detector (Model Bicron, Canberra, USA) couple to Canberra 10 multi-channel analyzer with adequate lead shielding which reduced the background by a factor of about 95%. The spectrometer was tested for its linearity and calibrated for energy and efficiency using the well calibrated standard gamma source obtained from an International Atomic Energy Agency (IAEA), Laboratories, Vienna, Austria [14]. The 7.5 % resolution obtained at 0.662 MeV of ^{137}Cs was capable of distinguishing the gamma ray energies of interest in the study. All the samples were counted for 3600 sec in order to obtain good statistics for uranium, thorium daughter products and ^{40}K. The quality assurance was determined through repeated measurements and to ascertain the stability of the measuring system. The background radiation due to the naturally occurring radioisotopes in the environment around the detector was measured by using an empty plastic container. The empty plastic container was measured in the same manner as the soil samples for the same counting time of 3600 s (10 hours). The background spectrum was subtracted from the measure spectra to obtain the net radioisotope activities. The background, reference sample and the

soil samples were measured under the same conditions [15]. Three regions of interest in the spectrum were identified. These were centered on the three characteristic photopeaks at approximately 1.460 MeV for (^{40}K), 1.760 MeV for (^{214}Bi) and 2.614 MeV for (^{208}TI) in the samples was obtained. These were used for evaluating the activity levels of ^{40}K, ^{238}U and ^{232}Th series respectively. The activity concentration (A_c) of ^{238}U, ^{232}Th and ^{40}K in Bqkg^{-1} were obtained using the relation in equation 1 below [16]:

$$\text{Sample activity } (A_C)\ (\text{Bq}kg^{-1}) = \frac{C_i}{\varepsilon(E)\ x\ t\ x\ m} \qquad (1)$$

Where C*i* is the net peak area after subtraction of background of the gamma-ray line at energy E, ε (E) is the detector efficiency of such gamma-ray line, t is the time of measurement in seconds and m is the mass of the sample in kg. The below detectable limit (BDL) of each radionuclide were determine from the background radiation spectrum for the same counting time for the dumpsites soil samples.

The detection limits (DL) which is required to estimate the minimum detectable activity in a sample and will be obtained using Equation 2

$$\text{LLD} = 4.65\left\lfloor {}^{C_b}/_{t_b} \right\rfloor^2 \times f \qquad (2)$$

where Cb is the net background count in the corresponding peak, tb is the background counting time (s), and f is the factor that converts cps (counts per second) to activity concentration (Bq kg^{-1}).

Radiation Hazard Parameters

In order to estimate the radiation hazards incurred by the population due to the activity levels radioisotopes in the selected dumpsite soils in Sagamu, some radiation hazard indices were calculated. The detailed formulas and units for the eleven radiological and health hazard parameters evaluated are presented in Table 2. Though the total activity concentrations of radioisotopes were calculated, this does not provide the exact indication about the total radiation hazards due to unequal distribution of the radioisotopes (^{40}K, ^{238}U and ^{232}Th) in the soil. Statistical summary of all the calculated radiological parameters and their recommended levels by UNSCEAR [4] are given in table 3.

Table 1: Summary of the radiological parameters of all the dumpsite soil samples

S/N	Radiological and Health hazard parameters	Mathematical formulas [a, b]	Units	World average value (UNSCEAR, 2000)
1.	Absorbed Dose Rate (D_R)	$D_R = 0.462A_U + 0.604A_{Th} + 0.0417A_K$	$nGyhr^{-1}$	57
2.	Radium equivalent (Ra_{eq})	$Ra_{eq} = A_U + 1.43A_{Th} + 0.077A_K$	$Bq\ kg^{-1}$	370
3.	Annual effective dose equivalent ($AEDE_{outdoor}$)	$AEDE_{(outdoor)} = D_R(nGyhr^{-1})\ x\ 8766\ hr\ x\ 0.7\ SvG^{-1}x\ 0.2x10^{-3}$	$(\mu Svyr^{-1})$	70
4.	Annual effective dose equivalent ($AEDE_{indoor}$)	$AEDE_{(indoor)} = D_R(nGyhr^{-1})\ x\ 8766\ hr\ x\ 0.7\ SvG^{-1}x\ 0.8x10^{-3}$	$(\mu Svyr^{-1})$	450
5.	External Hazard index (H_{ext})	$H_{ext} = \frac{A_U}{370} + \frac{A_{Th}}{259} + \frac{A_K}{4810} \leq 1$	-	≤ 1
6.	Internal Hazard index (H_{int})	$H_{int} = \frac{A_U}{185} + \frac{A_{Th}}{259} + \frac{A_K}{4810} \leq 1$	-	≤ 1
7.	External (γ-radioactivity) level index	$I_{\gamma r} = \frac{A_U}{300} + \frac{A_{Th}}{200} + \frac{A_K}{3000}$	-	≤ 0.5
8.	Activity Utilization Index (AUI)	$AUI = \left(\frac{A_U}{50Bqkg^{-1}}\right)f_U + \left(\frac{A_{Th}}{50Bqkg^{-1}}\right)f_{Th} + \left(\frac{A_K}{500Bqkg^{-1}}\right)f_K \leq 2$	-	≤ 2
9.	Exposure Rate (ER)	$ER = 1.90A_U + 2.82A_{Th} + 0.179A_K$	(μRhr^{-1})	600
10.	Annual gonadal dose equivalent (AGDE)	$AGDE = 3.09\ A_U + 4.18\ A_{Th} + 0.315\ A_K$	$(\mu Svyr^{-1})$	1000
11.	Excess Life time Cancer Risk (ELCR)outdoor	$ELCR_{(outdoor)} = AEDE_{outdoor}x\ DL\ x\ RF$	$(\mu Svyr^{-1})$	0.29

[a][4],[b][17].

Where A_U, A_{Th} and A_K are the activity concentrations of ^{238}U, ^{232}Th and ^{40}K in (Bq/kg) present in waste dumpsites soil respectively. f_U(0.462), f_{Th}(0.604) and f_K (0.0417) are the fractional contributions to the total dose rate due to γ-radiation from the actual radionuclide of ^{238}U, ^{232}Th and ^{40}K,

respectively. DL and RF is duration of life (70 years) and risk factor (Sv^{-1}), fatal cancer risk per sievert. For stochastic effects, ICRP 60 uses values of 0.05 for the public.

Multivariate statistical analysis

Multivariate statistical analysis was employed to assess the relationship and interdependency among the soil characteristics because of its usefulness as a tool to reduce and organize large data sets into groups with similar characteristics without losing much information. It is widely accepted and effectively used in radioactive analysis. In the present study, the naturally occurring radioisotopes characteristics and its associated radiological parameters in dumpsite soils were subjected to multivariate statistical analysis (i) pearson's correlation (ii) principal component analysis (PCA) using the commercial statistics software package SPSS (version 17.0). This statistical analysis was carried out in order to have a multivariate view and a good representation of the overall level of waste enhanced naturally occurring radioisotopes and its radiological indices in the dumpsite soils. Pearson correlation were carried out in order to clarify the relationship among the variables, especially the influence of soil radiological parameters on the distribution of radioisotopes while PCA was used to identify and summarize patterns among variables, highlight their similarities and differences [22].

Pearson's correlation coefficients analysis

Correlation analysis was carried out in order the strength of association and direction of the linear relationship between pairs of variables through the calculation of the linear Pearson product moment correlation coefficient (r). According to the to the values of pearson moment correlation coefficients (r) obtained, radioisotopes ^{238}U and ^{40}K shows a strong positive correlation with all the radiological parameters determined at 0.05 and 0.01 level of significant.

Principal component Analysis (PCA)

Principal component Analysis (PCA) was performed to establish the possible factors that contribute towards the radioisotopes concentrations with its radiological parameters and sources apportionment. PCA was applied between the studied variables on the basis varimax orthogonal rotation with Kaiser Normalization with eigenvalue greater than 1 after Kaiser-meyer Olkin (KMO) measuring of sampling adequacy and Bartlett's test of sphericity was adequate and significant for the variables. The rotated component matrix is given in Table 4, and illustrated in Fig. 2.

RESULTS AND DISCUSSION

Activity concentrations of radioisotopes

The measured specific activity concentrations of the radioisotopes (^{238}U, ^{232}Th and ^{40}K), radium equivalent, absorbed dose rate and other radiological parameters evaluated with their recommended worldwide average values are presented in Tables 2 and 3. The activity concentrations of the radioisotopes, ^{238}U, ^{232}Th and ^{40}K, range from 77.07 ± 16.52-237.08 ± 53.12 Bq kg^{-1}, BDL-19.79 ± 1.62 Bq kg^{-1} and BDL-1551.45 ± 108.51 Bq kg^{-1} with an average of 141.36 ± 31.68 Bq kg^{-1}, 6.30 ± 0.58 Bq kg^{-1} and 497.09 ± 34.64 Bq kg^{-1} respectively. The mean activity concentrations of the three radioisotopes are in the order: $^{232}Th < ^{238}U < ^{40}K$. The mean value 238U is about 5 times higher than the worldwide average value of 33 Bqkg^{-1} [4]. The mean value of ^{232}Th was below the world average value of 45 Bq kg^{-1} [4], while the mean value ^{40}K was higher than the worldwide average value of 420 Bq kg^{-1} [4]. The activity concentrations of the radioisotopes in the dumpsites differed widely because the activity levels in the dumpsites mainly depend on their combined physical, chemical and geochemical properties of the accumulated wastes at the dumpsites.

Table 2: Geological location and activity concentrations of radioisotopes (A_c) & absorbed dose rate value for different soil samples

			Activity Concentrations ($Bqkg^{-1}$)				
Sample ID	Longitude	Latitude	^{238}U	^{232}Th	^{40}K	Raeq ($Bq.kg^{-1}$)	D_R ($nGyhr^{-1}$)
SATS 1	3°38.632′E	6°51.721′N	164.59 ± 39.98	8.19 ± 0.79	247.66 ± 18.21	195.37 ± 42.51	91.31 ± 19.71
SATS 2	3°38.622′E	6°51.713′N	186.79 ± 42.43	4.99 ± 0.47	265.23 ± 21.99	214.35 ± 44.80	100.37 ± 20.80
SASS 1	3°38.618′E	6°51.716′N	139.77 ± 31.49	5.47 ± 0.53	276.06 ± 21.96	168.85 ± 33.94	79.39 ± 15.78
SASS 2	3°38.600′E	6°51.699′N	161.98 ± 35.34	6.38 ± 0.55	1551.45 ± 108.51	290.57 ±44.48	143.38 ± 21.18
SASS 3	3°38.547′E	6°51.684′N	84.25 ± 20.31	7.41 ± 0.66	86.28 ± 6.56	101.49 ± 21.76	47.00 ± 10.06
SBTS 1	3°36.081′E	6°48.723′N	105.15 ± 25.09	4.19 ± 0.42	BDL	111.14 ± 25.69	51.11 ± 11.85
SBTS 2	3°36.076′E	6°48.729′N	144.99 ± 30.25	6.62 ± 0.64	362.69 ± 28.13	182.38 ± 33.33	86.11 ± 15.54
SBSS 1	3°36.080′E	6°48.735′N	179.61 ± 37.31	2.71 ± 0.27	664.68 ± 49.68	234.67 ± 41.52	112.33 ± 19.47
SBSS 2	3°36.080′E	6°48.754′N	79.03 ± 17.85	5.66 ± 0.54	385.07 ± 28.35	116.77 ± 20.81	55.99 ± 9.76
SBSS 3	3°36.077′E	6°48.684′N	186.14 ± 39.74	13.33 ± 1.19	774.93 ± 58.87	264.87 ±45.97	126.36 ± 21.53
SCTS 1	3°41.650′E	6°54.700′N	237.08 ± 53.12	3.19 ± 0.31	1292.61 ± 91.69	341.17 ± 60.62	165. 36 ± 28.55
SCTS 2	3°41.671′E	6°54.721′N	170.47 ± 37.92	19.79 ± 1.62	870.79 ± 64.66	265.82 ± 45.22	127.02 ± 21.19
SCSS 1	3°41.688′E	6°54.754′N	77.07 ± 16.52	BDL	BDL	77.07 ± 16.52	35.61 ± 7.63
SCSS 2	3°41.667′E	6°54.718′N	105.81 ± 24.50	0.57 ± 0.06	1062.53 ± 76.89	188.44 ± 30.51	93.54 ± 14.56
SCSS 3	3°41.676′E	6°54.742′N	118.22 ± 25.48	3.85 ± 0.38	BDL	123.73 ± 26.02	56.94 ± 12.00
Control	3°56.879′E	6°47.965′N	120.83 ± 29.61	8.38 ± 0.81	113.44 ±8.73	141.55 ± 31.44	65.62 ± 14.53
Min.			77.07 ± 16.52	BDL	BDL	77.07 ± 16.52	35.61 ± 7.63
Max.			237.08 ± 53.12	19.79 ± 1.62	1551.45 ± 108.51	341.17 ± 60.62	165.36 ± 28.55
Range			109.72 ± 25.91	13.33 ± 1.19	1551.45 ± 108.51	264.10 ± 44.10	129.75 ± 20.92
Mean			141.36 ± 31.68	6.30 ± 0.58	497.09 ± 34.64	188.64 ± 35.32	89.84 ± 16.51
World average [a]			33 [a]	45 [a]	420 [a]	370 [a, b]	57 [a]

[a][4], [b][17]

Absorbed Dose Rate (D_R)

Absorbed dose rate represents the dose received in the open air from γ-rays dose absorbed from radioisotopes concentrations environmental media. The calculated absorbed dose rate ranged from 35.61 ± 7.63 $nGyhr^{-1}$ to 165.36 ± 28.55 $nGyhr^{-1}$ with an average value of 89.84 ± 16.51 $nGyhr^{-1}$. The average absorbed dose rate is about 2 times higher than the world average value (57 $nGyhr^{-1}$) [4] (Table 2). The absorbed dose rate was higher than the recommended level in about 67 % of sampling points (10 locations) (Table 2).

Radium equivalent activities (Ra_{eq})

Radium equivalent is one of the most widely used hazard indices to describe the gamma output from different mixtures of ^{238}U, ^{232}Th and ^{40}K in the soils sampled from different dumpsites. Radium equivalent activity is a weighted sum ^{238}U, ^{232}Th and ^{40}K activity concentration based on the assumption that 370 $Bqkg^{-1}$ of ^{238}U, 259 $Bqkg^{-1}$ of ^{232}Th and 4810 $Bqkg^{-1}$ of ^{40}K produce the same γ-ray dose rate [18]. The calculated valued varied from 77.07 ± 16.52 (SCSS1) to 341.17 ± 60.62 (SCTS1) $Bqkg^{-1}$ with a mean value of 188.64 ± 35.32 $Bqkg^{-1}$ (Table 2). The estimated mean value of Ra_{eq} in this study is lower than the recommended maximum value of 370 $Bqkg^{-1}$ [4]. All the values obtained in this study were low, which implies that the soil of these dumpsites could be used without any restriction if the dumpsites are reclaimed through proper soil remediation procedure for building construction purposes in the nearest future.

Internal, External Hazard and Gamma Indices (H_{int}, H_{ext} & γ-indices)

These indices represent the internal and external radiation hazard and the prime objective of these indices is to limit the radiation dose equivalent limit of 1 mSv/y [19]. The index value must be less than unity in order to keep the radiation hazard to be negligible. The calculated external hazard value is between 0.21 ± 0.04 to 0.92 ± 0.16 with a mean value of 0.51 ± 0.10 (Table 3). The mean value of external hazard index (H_{ext}) is less than unity. Hence, there is no radiological risk emanating from external exposure of the inhabitant or people working/living around the dumpsites to these deleterious natural radioisotopes except in one location with H_{ext} value of 0.92 ± 0.16. The calculated values of internal hazard index ranged from 0.42 ± 0.09 to 1.56 ± 0.31 with an average value of 0.89 ± 0.18. This is higher than the recommended limit. However, 60% of the sampling locations have the H_{int}

value exceeding the permissible value. Therefore these soils in this area pose an internal radiological risk to the inhabitants and people working or living around the study locations owing to the harmful effects of the ionizing radiation from the natural radioisotopes in the wastes soils.

The annual effective dose equivalent outdoor ($AEDE_{outdoor}$)

The calculated values of $AEDE_{outdoor}$ ranged from 43.62 ± 9.36 to 202.80 ± 35.01 $\mu Svyr^{-1}$ with a mean value of 110.18 ± 20.25 $\mu Svyr^{-1}$ respectively. This mean $AEDE_{outdoor}$ value is about 2 times higher than the world average value of 70 $\mu Svyr^{-1}$ [4] (Table 3). In about 87 % of the sampling points, the AEDE values obtained were higher than the world average value and the highest value was observed at SCTS1 (202.80 ± 35.01 $\mu Svyr^{-1}$), which is about 3 times higher than the recommended limit.

Annual genetically significant dose equivalent (AGSDE)

The annual genetically significant dose equivalent is also referred to as annual gonadal dose equivalent (AGDE) is used to assess the annual genetic significance of dose equivalent received by the population's reproductive organs (gonads) [20, 21]. A direct interaction of radiation with reproducible cells could result in the death or genetic mutation of the cell, whereas a direct interaction with the DNA of a dormant cell could have been less effect [19]. The gonads, bone marrow and bone surface are considered to be the organs of importance since they are active [4]. Hence, the AGSDE due to the activities of ^{238}U, ^{232}Th and ^{40}K was calculated and is ranged from 238.15 ± 51.05 to 1151.79 ± 194.23 $\mu Svyr^{-1}$, with a mean value of 619.21 ± 111.78 $\mu Svyr^{-1}$ (Table 3). This mean value is less than the recommended level (1000 $\mu Svyr^{-1}$) [4]. However, three sampling points have higher AGSDE value than the recommended limit (Table 3). In these three points, the fractional contribution from ^{238}U and ^{40}K to the total AGSDE were higher than the others.

Exposure rate

The calculated rate of exposure (ER) of an individual and scavengers to this naturally occurring radioisotopes in the selected dumpsites was higher than the maximum limit (600 μRhr^{-1}) in four sampling point (SCTS1, SASS2, SCTS2 and SBSS3) with a value of 714.09 ± 119.87 μRhr^{-1}, 631.39 ± 90.07 μRhr^{-1}, 551.25 ± 89.35 μRhr^{-1} and 543.92 ± 90.46 μRhr^{-1} respectively (Table 3). Therefore, the people living near these dumpsites should be aware of the inherent effects of exposure to this harmful ionizing radiation emanating from these dumpsites on a daily basis.

Activity Utilization Index (AUI)

Activity utilization index are calculated to examine whether the present study soils can be used for building construction or not. The calculated AUI value ranged from $0.71 \pm 0.15 \leftrightarrow 2.34 \pm 0.50$ with a mean value of 1.42 ± 0.30 (Table 3). The mean value of is lower than the permissible level. Six sampling points have higher AUI value than permissible level [4]. This shows that the present soil cannot be used for safety construction of buildings.

Excessive lifetime cancer risk (ELCR)

The potential carcinogenic and mutagenic effects are characterized by evaluating the probability of cancer incidence in a population of individuals for a specific lifetime from projected intakes cum exposure and chemical-specific dose response data (i.e. slope factors) [1]. The additional or extra risk of developing cancer due to exposure to a toxic and deleterious substances incurred by the inhabitants or the people working/living around the dumpsites over the lifetime of an individual. Excessive Lifetime Cancer Risk is calculated using the equation presented on the Table 1 and the calculated values ranged from $0.15 \pm 0.03 \times 10^{-3}$ to $0.71 \pm 0.12 \times 10^{-3}$ with an average value of $0.39 \pm 0.07 \times 10^{-3}$ (Table 3). The present average value is 1.6 times higher than the world average value of 0.29×10^{-3} [4] (Table 3). Ten of the sampling locations (67 %) have the ELCR values higher than the world average value and it ranged from 1.5-3 times higher than the world average value. This results show that the lifetime cancer risk due to exposure through the use of this dumpsite soils for a maximum duration of 70 years is high in at least 10 locations. Hence, the use of this dumpsite soil for building, construction, agriculture or for soil remediation studies and other purpose should be discouraged. More so, people working or living around the dumpsite should avoid the use of these soils for any of the aforementioned purposes.

Table 3: Radiological parameters of Dumpsites Soils in Ijebu-Ode

Sample ID	ER (μRhr^{-1})	AGDE($\mu Svyr^{-1}$)	H_{ext}	H_{int}	$I_{\gamma r}$	AUI	AEDEout ($\mu Svyr^{-1}$)	ELCR $x10^{-3}$
SATS1	384.6 ± 81.8	620.6 ± 132.6	0.53 ± 0.11	0.97 ± 0.22	0.67 ± 0.14	1.64 ± 0.38	120 ± 24.2	0.39 ± 0.08
SATS2	421.2 ± 86.3	681.3 ± 140	0.58 ± 0.12	1.08 ± 0.24	0.74 ± 0.15	1.81 ± 0.40	123.1 ± 25.5	0.43 ± 0.09
SASS1	335.4 ± 65.7	541.4 ± 106.4	0.46 ± 0.09	0.83 ± 0.18	0.59 ± 0.11	1.38 ± 0.30	97.4 ± 19.4	0.34 ± 0.07
SASS2	631.4 ± 90.1	1014.3 ± 145.6	0.78 ± 0.12	1.22 ± 0.22	1.09 ± 0.16	1.70 ± 0.34	175.8 ± 26	0.62 ± 0.09
SASS3	198.0 ± 41.7	318.4 ± 67.6	0.27 ± 0.06	0.50 ± 0.11	0.35 ± 0.07	0.88 ± 0.20	57.6 ± 12.3	0.20 ± 0.04
SBTS1	211.6 ± 48.9	342.4 ± 79.3	0.30 ± 0.07	0.58 ± 0.14	0.37 ± 0.09	1.02 ± 0.24	62.7 ± 14.5	0.22 ± 0.05
SBTS2	365.6 ± 64.8	589.6 ± 105	0.49 ± 0.09	0.88 ± 0.17	0.64 ± 0.11	1.45 ± 0.29	105.6 ± 19.1	0.37 ± 0.07
SBSS1	479.8 ± 81.4	775 ± 132	0.63 ± 0.11	1.12 ± 0.21	0.83 ± 0.14	1.75 ± 0.35	137.6 ± 23.9	0.48 ± 0.08
SBSS2	242.0 ± 41.0	388.8 ± 66.3	0.32 ± 0.06	0.53 ± 0.10	0.42 ± 0.07	0.83 ± 0.17	68.7 ± 12	0.24 ± 0.04
SBSS3	543.9 ± 90.5	874.2 ± 146.3	0.72 ± 0.12	1.22 ± 0.23	0.95 ± 0.16	1.95 ± 0.39	155 ± 26.4	0.54 ± 0.09
SCTS1	714.1±119.9	1151.8 ± 194	0.92 ± 0.16	1.56 ± 0.31	1.24 ± 0.21	2.34 ± 0.50	202.8 ± 35	0.71 ± 0.12
SCTS2	551.3 ± 89.4	882.9 ± 144.3	0.72 ± 0.12	1.18 ± 0.22	0.96 ± 0.16	1.89 ± 0.38	155.8 ± 26	0.55 ± 0.09
SCSS1	146.4 ± 31.4	238.2 ± 51.1	0.21 ± 0.04	0.42 ± 0.09	0.26 ± 0.06	0.71 ± 0.15	43.7 ± 9.36	0.15 ± 0.03
SCSS2	412 ± 61.9	663 ± 100.1	0.51 ± 0.08	0.80 ± 0.15	0.71 ± 0.11	1.07 ± 0.23	114.7 ± 17.9	0.40 ± 0.06
SCSS3	235.5 ± 49.5	381.4 ± 80.3	0.33 ± 0.07	0.65 ± 0.14	0.41 ± 0.09	1.14 ± 0.24	69.8 ± 14.7	0.24 ± 0.05
Control	275.6 ± 60.3	444 ± 97.6	0.38 ± 0.08	0.71 ± 0.16	0.48 ± 0.11	1.23 ± 0.28	80.5 ± 17.8	0.28 ± 0.06
Min.	146.4 ± 31.4	238.2 ± 51.1	0.21 ± 0.04	0.42 ± 0.09	0.26 ± 0.06	0.71±0.15	43.7±9.36	0.15 ± 0.03
Max.	714.1 ± 119.9	1151.8 ± 194	0.92 ± 0.16	1.56 ± 0.31	1.24 ± 0.21	2.34±0.50	202.8 ± 35	0.71 ± 0.12
Range	567.7 ± 88.5	913.6 ± 143	0.71 ± 0.12	1.14 ± 0.22	0.98 ± 0.15	1.63±0.35	159.1±25.6	0.56 ± 0.09
Mean	384.3 ± 69.0	619.2 ± 111.8	0.51 ± 0.10	0.89 ± 0.18	0.67 ± 0.12	1.42±0.30	110.18±20.25	0.39 ± 0.07
World average [a]	600	1000	≤ 1	≤ 1	≤ 0.5	≤ 2	70	0.29

[a][4]

Table 4: Factor analysis (after varimax rotation) showing contribution of statistically dominant variables measures in this study

Variables	Component matrix	
	PC1	PC2
Iγr	**0.984**	0.143
AGDE($\mu Svyr^{-1}$)	**0.982**	0.180
D_R ($nGyhr^{-1}$)	**0.981**	0.182
ER (μRhr^{-1})	**0.980**	0.183
ELCR x 10^{-3}	**0.979**	0.197
$AEDE_{out}$ ($\mu Svyr^{-1}$)	**0.979**	0.199
Ra_{eq} ($Bqkg^{-1}$)	**0.976**	0.218
H_{ext}	**0.975**	0.223
H_{int}	**0.960**	0.238
AUI	**0.891**	0.355
^{238}U	**0.885**	0.270
^{40}K	**0.867**	0.083
^{232}Th	0.151	**0.959**
Eigenvalue	11.506	1.400
% of variance explained	84.231	11.396
Cumulative (%)	84.231	95.627

Significant value are given in bold

From the rotated component matrix, the eigen values and eigen vectors are extracted to explain the number of significant factors and the percent of variance explained by that factors. Table 7, shows the results of the factor loadings with a varimax rotation, as well as the eigen-values and communalities. The results showed that there were two eigen-values higher than one and that these two factors could explain over 95.627 % of the total variance. The first component (PC1) explained 84.231 % of the total variance and loaded heavily on ^{238}U, ^{40}K and all the radiological parameters (Ra_{eq}, ELCR, AGDE, ER, AUI, AEDEout D_R, Iγr, H_{ext}, and H_{int}). The second component (PC2) which account for 11.396% of the total variance was correlated very strongly with ^{232}Th only with a high loading value of 0.959 respectively. From the total component analysis, it is seen that ^{238}U and ^{40}K increase the radioactivity in the dumpsite soils and which leads to an increase in all the radiological parameters. Fig 2 gives a graphical representation of factor component 1 (84.231%) and component 2 (11.396%).

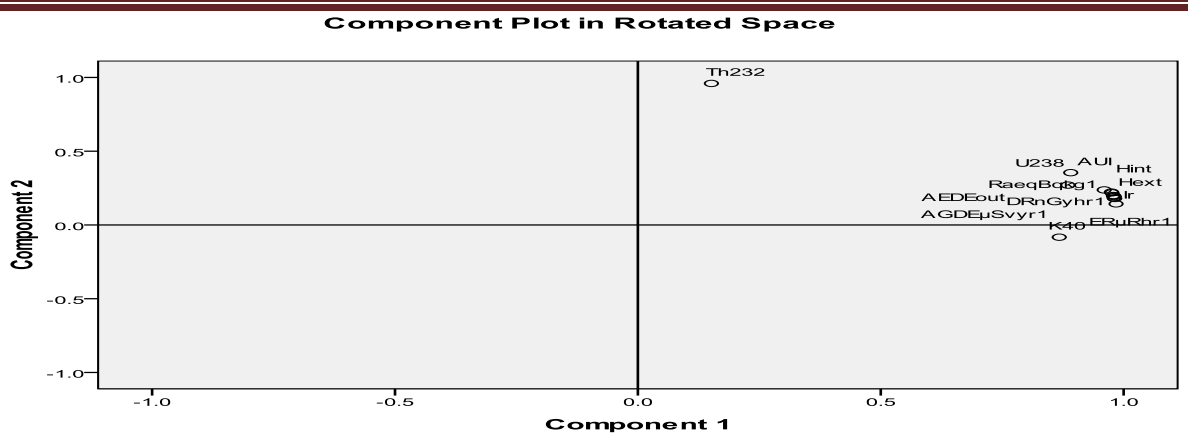

Fig. 2: Graphical representation of components PC-1 (84.231 %) and PC-2 (11.396 %)

CONCLUSIONS

The activity concentration of the radioisotopes and its associated radiological parameters from the selected dumpsites in Sagamu were estimated. The following conclusions were reached. The mean activity concentrations of all soil samples are of this order: $^{40}K > ^{238}U > ^{232}Th$. The total and average activity concentrations of the radioisotopes (^{40}K and ^{238}U) were higher than the reported worldwide average values. Radiological parameters like Absorbed dose rate, $I_{\gamma r}$, H_{int}, $AEDE_{outdoor}$ and $ELCR_{outdoor}$ were higher than the recommended level while others fell below the worldwide average value. This implies that the inhabitants of the study area are exposed to radiation exposure which was significantly higher than the corresponding exposure levels reported in some related studies. Statistically, there is a strong positive significant relationship between ^{40}K and ^{238}U series with all the calculated radiological parameters. The implication of this is that the soil of the selected dumpsites cannot be used for building construction or for agricultural purposes and the dwellers of the dumpsites should be aware of the effects of the harmful ionizing radiation emanating from the dumpsites.

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