

Assessment of Ionizing Radiation Dose and Risk Levels associated with Radioactivity in Oraifite, Nigeria

Anekwe, U.L.

Department of Physics, Federal University Otuoke, Bayelsa State, Nigeria.

uzanekwe@yahoo.co.uk

ABSTRACT

Radioactivity has been natural occurrence in human environment and its adverse effects are highly undesirable. This study assessed radiation risk levels associated with radioactivity in Oraifite using gamma ray (γ -ray) spectrometry and radiation survey meter. The mean value of background ionizing radiation (BIR) exposure rate ranged from 0.011 to 0.014mRh⁻¹. The mean activities of ²²⁶Ra, ²³²Th, ⁴⁰K ranged from 23.54±4.89 to 41.03±4.28 BqKg⁻¹, 9.69±1.88 to 11.34±1.86 BqKg⁻¹, 419.22±3.41 to 737.91±4.78 BqKg⁻¹ respectively. Mean values of radium equivalent (Ra_{eq}), absorbed dose (D), Igamma (IX), internal hazard index (H_{in}), external hazard index (H_{ex}) and annual effective dose equivalent (AEDE), were 60.05Bqkg⁻¹, 55.75nGh⁻¹, 0.86, 0.41, 0.30 and 0.07mSvy⁻¹ respectively. Excess lifetime cancer risk (ELCR) which is estimation of the probability of cancer incidence in a population of individuals for a specific lifetime had a mean value of 0.25x10⁻³ and this is lower than the world permissible limit of 0.29x10⁻³. The average dose to human organs/tissues; lungs, ovaries, bone marrow, testes, kidney, liver and whole body were 0.033, 0.028, 0.033, 0.040, 0.028, 0.023, and 0.033 mSvy⁻¹ respectively, meaning that all the computed organ dose were far much lower than the maximum allowable standard value of 1.0 mSvy⁻¹. Virtually all hazard indices were below the ICRP recommended values and in general the residents of Oraifite are not under ionizing radiation threat.

Keywords: Spectrometry, Radiation Dose, Assessment, Health risk, Activity concentration

1 Introduction

Human beings are constantly exposed to radiations, basically to Ionizing and Non ionizing radiations. The health implications of radiation exposure have been of great public concern. These two major types of radiation are electromagnetic in nature. Ionizing radiation has high energy that can cause the atoms of the matter through which it passes to be electrically charge and ejects electrons from the atom it interacts with. This process actually results to gamma radioactivity. Radioactivity for so many decades has been known to be spontaneous emission of radiation in the form of particles or photon energy. It is a spontaneous disintegration of the nuclei of some isotopes with the emission of alpha (α) or beta (β) particles or gamma (γ) rays. This phenomenon occurs in all human-environment for which Oraifite community is not an exception. The earth and its atmosphere contain radioactive materials that are natural since the "Big Bang" era. In their natural state they are called naturally occurring radioactive materials, NORMs. Natural radioactivity is wide spread in the earth's environment and it exists in various geological formations in soil, rocks, plants, water and air [1]. Radionuclides include elements in the ²³⁸U, ²³⁵U, ²³²Th series and their respective decay daughters, as well as ⁴⁰K. A significant part of the total dose contribution in the form of natural sources comes from terrestrial gamma radionuclides. Only nuclides with half-lives comparable with the age of the earth or their corresponding decay products, existing in terrestrial materials, such as ⁴⁰K, ²³⁸U and ²³²Th

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radionuclides, are of great interest [2]. When these are concentrated by human activity, the naturally-occurring radioactive materials become technologically-enhanced NORMs or simply called TENORMs. Technologically occurring radioactive material represents the unintentional exposure to natural sources of radiation which would not exist without the technological activity [3].

Non-ionizing radiation has low energy that is not sufficient to knock off an orbital electron from the atom of matter through which it passes, though the electrons can be taken to higher energy level. Examples are radio frequency waves such as the third, fourth and fifth generation frequencies (3G, 4G, 5G), infrared and visible light radiations. The World Health Organization (WHO) and the International Telecommunication Union (ITU) recommended adoption of the radio-frequency exposure limits developed by the International Commission on Non-Ionizing Radiation Protection (ICNIRP) as reviewed and updated in 2018. Expert groups and public health agencies such as WHO and ICNIRP broadly agreed that no health risks have been established from exposure to low radio signals used for mobile communications [4]. Antenna Bureau in the Netherlands has refuted conspiracy theorist that 5G tests harmed birds [4]. However, according to [5], the laboratory tests performed provided the best scientific understanding of the effects of wireless radiation, but did not reflect the real-life environment in which wireless radiation systems operate, hence they reported that high frequency, radiofrequency spectrum from recent reviews can result in carcinogenicity. This assertion is not in agreement with WHO, ICNIRP, ITU, positions. In recent time many cancer related illnesses are being associated to all forms of non ionizing radiations but it has been speculations and without scientific proof.

It is only ionizing radiation that has the ability to penetrate a living cell and to damage the chemical compositions of the cells resulting in carcinogenicity. NORMs can be found in (1) Human bodies, (2) Living-places, (3) domestic products, and (4) in the food we eat. Soil, water and air, are the common media for naturally occurring radioactive materials transfer process. The primary sources of natural ionizing radiations are the cosmic rays and terrestrial radiation. Radon gas can find its way into human body through ingestion and inhalation. The Cosmic rays from the Sun and galaxy, terrestrial radiation from the Earth crust, and incorporation of radioisotopes from the biosphere summarize the undesirable exposure all over the world [6]. The exposure of human beings to ionizing radiation from natural sources is a continuing and inescapable feature of life on earth and it exceeds that from all man-made (artificial) sources combined [6]. Artificial sources include industrial, medical and nuclear fuel cycle. Scientists have conducted studies on exposures and activity concentrations at different locations and reports of such previous studies are found in [7], [8], [9], [10], [11]. The Assessment of Ionizing Radiation Risks associated with Gamma Radioactivity in Oraifite is an original research work and has not been previously conducted hence the primary aim of the study was to investigate certain health parameters. Hence the need to evaluate radiological indices in that locality to provide useful base line data through measurement of background ionizing radiation (BIR) and activity concentration in soil samples. Therefore in agreement with [12], measurement of natural radioactivity in soil is very important to determine the amount of change of the natural background activity with time as a result of any radioactivity release that may alter the natural ecosystem.

2 Materials and Methods.

2.1 Study Area

Oraifite is politically located in Anambra State of the South East of Nigeria. Geographically, it lies between Latitude 5.90° and 6.04° N to 6.00° and 6.87° E and geologically Oraifite is in Nanka Formation under Bende Ameki Group. The Ameki Group and the overlying Ogwashi-Asaba Formation in the

Southern Benue Trough and Anambra Basin are correlative with the Agbada Formation in the Niger Delta [13]. Ameki Group is in the Niger Delta and there are three principal lithostratigraphic units based on the dominant environment of deposition in ascending order of Akata, Agbada and Benin. The Agbada Formation mainly consists of sequence of sandstones and shales. The sandy unit constitutes the hydrocarbon reservoir in the Niger Delta oil fields while the shales form the seal [14]. This Formation consists of sand in which grain size increases upwards and the gamma radiation from natural radionuclides in the upper layer is often higher than in the underlying marine clays [15]. Oil exploration took place in Oraifite along the Unodu coastal area in the 1990s but there was no evidence of hydrocarbon deposit in commercial quantity. According to [16] the Niger Delta has the same geomorphology as the region of Bight of Biafra for which Oraifite is a part. The study area is made up of four quarters or districts for convenience namely; Unodu, Ezumeri, Irefi and Ifite with sample codes UNO, EZU, IRE and IFI respectively. Socio-politically, the ancient natives were mainly peasant farmers, wine tappers, fishermen and petty traders. At the moment, with high level of western education a lot of people have abandoned the traditional farming and other work practices and are involved in oil and gas activities and corporate business as they migrate to cities. Industrial and economic activities in the area include bottled and Sachet water packaging, saw-milling, wine tapping, ion welding and fabrication, etc. Figure i is the Google map showing the study area.

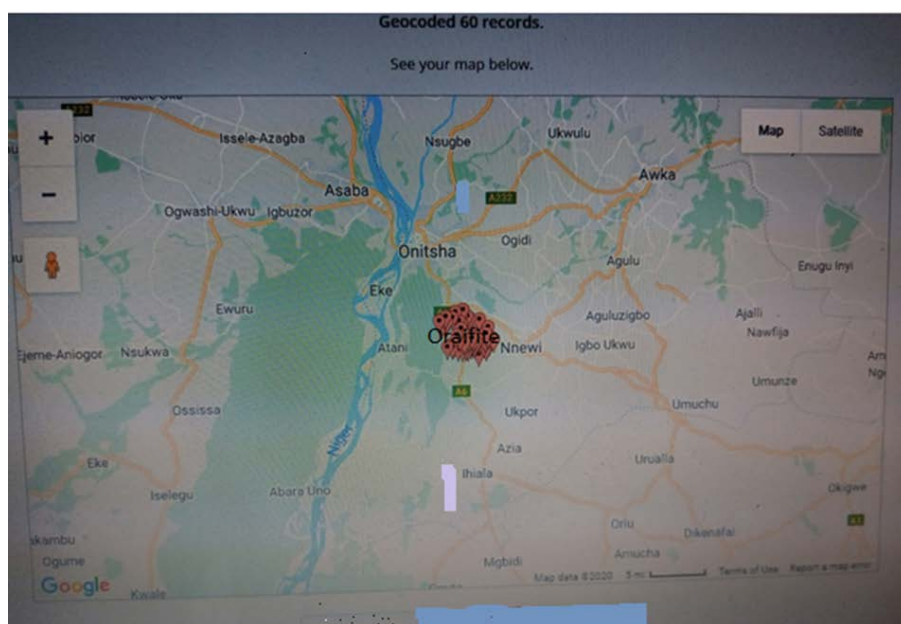


Figure-1: Google map of the study area

2.2 Background ionizing radiation measurement

The BIR exposure rate measurement was done *in situ* in accordance with the world best standard procedure as applied by [17]. A Radalert 100X radiation monitoring meter with Geiger counter was used. The meter detects alpha, beta, gamma and X-ray radiations. The meter detector is a halogen-quenched Geiger-Mueller tube with mica end window LND712 of density 1.5 - 2.0 mg/cm² and side wall of 0.012 inches #446 stainless steel. Its maximum alpha and beta efficiencies are 10% and 15% respectively and it operates within temperature range of -20° C to 50° C and -4° to 122°F. The radiation meter manufactured by S.E. International Incorporation, Summer Town, USA was calibrated with a ¹³⁷Cs source of specific energy with high accuracy display switchable to count per minute (CPM), milli Roentgen per hour (mR/hr) and micro Sievert per hour (μSv/hr). As a choice the meter was set to

mR/hr for this particular study. The Geiger-Mueller tube generates a pulse current each time radiation passes through the tube and causes ionization and each pulse is electronically detected and registered as a count. Measurements were taken within the hours of 10 am to 4.00 pm since exposure rate has a peak response to environmental radiation within these hours [18]. During measurement, the meter was raised to a standard height of 1.0 m above the ground [19], and multiplicity of measurements, $n = 6$ were taken and the average recorded in mR h^{-1} for each sampled point. A geographical positioning meter was used to take the coordinates and elevation /altitude of each sampled point.

2.3 Soil sample collection and preparation

Top soil samples were collected in black polythene bags using a steel hand geological auger at a depth between 0 and 15 cm. The use of black polythene bag was to avoid breaking down of the radioisotopes present in the samples. The samples were later dried each bag retaining its code given at the point of collection. The drying was by spreading samples on polyethylene sheets at ambient temperature for seven days in a controlled environment to prevent dust contamination. This was followed by another stage of oven drying for 24 hours at 60°C . Samples were then grounded into powdered form using pestle and mortar, and the powder was filtered using 100- mesh sieve. 250g of each dried homogeneously pulverized sample having a code number was filled in a skin-tight Marinelli beaker to prevent escape of gaseous ^{220}Rn and ^{222}Rn . The containers with their contents were kept for 28 days during which the daughter radionuclides were brought into secular radioactive equilibrium with their respective long-lived parents [20].

2.4 Spectrometry.

The samples were analyzed according to International Atomic Energy Agency procedure, [21] and [22], using gamma ray (γ -ray) spectrometer analysis. A $7.6\text{ cm} \times 7.6\text{ cm}$ geometry sodium iodide doped with thallium [Na(Tl)] was used as the detector. Each sample was placed on the detector coupled to an ORTEC 456 amplifier and a computer program MAESTRO window was connected to the detector to match gamma energies. Interference from ecological background radiation was eliminated by allowing the counting to be done in the Canberra lead castle of 100 mm thick. Several line spectra gathered yielding strong peaks corresponding to 1460 keV for ^{40}K , 1764.5 KeV (Bi-214) for ^{238}U and 2614.5 keV (Ti-208) for ^{232}Th . Finally activity concentrations (C) in Bq kg^{-1} of identified nuclides were computed after decay correction applying the equation below.

$$A_c = C_n / P_\gamma M \epsilon \quad (1)$$

Where A_c is the activity concentration of the radionuclide in the sample given in Bq kg^{-1} , C_n is the net count rate under the corresponding peak, P_γ is the absolute transition probability of the specific γ -ray, M is the mass of the sample (kg) and ϵ is the detector efficiency at the specific γ -ray energy

2.5 Hazard Indices Computation

2.5.1 Radium Equivalent Activity, Ra_{eq} (Bq kg^{-1})

Radium equivalent is a radiological index which takes into account the radiation hazards associated with the activity levels of ^{226}Ra , ^{232}Th and ^{40}K by a single quantity. [23]. Ra_{eq} is mathematically expressed by [3] as

$$\text{Ra}_{\text{eq}} = C_{\text{Ra}} + 1.43C_{\text{Th}} + 0.077C_{\text{K}} \quad (2)$$

where C_{Ra} , C_{Th} and C_{K} are the activity concentrations of ^{226}Ra , ^{232}Th and ^{40}K respectively. It is assumed in the above relation that 10 Bq kg^{-1} of ^{226}Ra , 7 Bq kg^{-1} of ^{232}Th and 130 Bq kg^{-1} of ^{40}K produce equal

gamma dose. It is recommended that the maximum value of Ra_{eq} in soil should be less than 370 Bqkg^{-1} [24] and this is regarded as standard limit.

2.5.2 Absorbed Dose Rate

This is a measure of energy deposited in a medium by ionizing radiation. It is equal to the energy deposited per unit mass of the medium, and so has the unit J/kg , which is given by special name Gray (Gy). Absorbed dose rate therefore is absorbed dose divided by the time it takes to deliver that dose unit Gy/s . The absorbed dose rates in outdoor (D) due to gamma radiations in air at 1m above the ground surface for the uniform distribution of the naturally occurring radionuclides (^{226}Ra , ^{232}Th and ^{40}K) were computed as provided by [3]. Conversion factors used to calculate absorbed dose rate (D) in air per unit activity concentration in Bq/kg (dry weight) corresponds to

$$0.462 \text{ nGh}^{-1} \text{ for } ^{226}\text{Ra} \text{ (of U – series), } 0.621 \text{ nGh}^{-1} \text{ for } ^{232}\text{Th} \text{ and } 0.0417 \text{ nGh}^{-1} \text{ for } ^{40}\text{K} \text{ [25].} \quad (3)$$

2.5.3 Igamma

This is otherwise called representative level index, Igamma (IX) and it is the estimation of gamma radiation associated with the natural radionuclides in the soil. It is defined as

$$IX = C_{Ra}/150 + C_{Th}/100 + C_K/1500 \leq 1 \text{ [26].} \quad (4)$$

2.5.4 Annual Effective Dose Equivalent, AEDE (mSvy-1)

The annual effective dose rate (mSv.y^{-1}) was calculated by the formula provided by [3]. The conversion coefficient from absorbed dose in air to effective dose used is 0.7Sv.Gy^{-1} and outdoor occupancy factor of 0.2 as provided by [3], which stated that the worldwide annual effective dose from the natural sources of radiation in areas of normal background ionizing radiation is estimated to be 1 mSvy^{-1} .

The relation is as follows follows:

$$\text{Effective dose rate (mSvyr}^{-1}\text{)} = D (\text{nGh}^{-1}) \times 8760\text{h. y}^{-1} \times 0.7 \times (10^3 \text{ mSv}/10^9) \text{ nGh} \times 0.2$$

$$E_{ff} \text{ dose} = D \times 1.2264 \times 10^{-3} \quad (5)$$

2.5.5 Hazard Index

(a) Internal hazard Index

Radon and its short-lived products are also hazardous to the respiratory organs. The internal exposure to radon and its daughter progenies is quantified by the internal hazard index H_{in} , which is given by the equation below.

$$H_{in} = C_{Ra}/185 + C_{Th}/259 + C_K/4810 \quad (6)$$

(b) External Hazard index

This index represents the external exposure and it is defined by [3] as

$$H_{ex} = C_{Ra}/370 + C_{Th}/259 + C_K/4810 \quad (7)$$

2.5.6 Excess Lifetime Cancer Risk (ELCR).

ELCR is potential carcinogenic effects that are characterized by estimating the probability of cancer incidence in a population of individuals for a specific lifetime from projected intakes and exposures. According to [27], it is mathematically expressed as

$$\text{ELCR} = \text{AEDE} \times \text{DL} \times \text{RF} \quad (8)$$

where AEDE is the annual effective dose equivalent, DL is the average duration of life taken to be 52years in Nigeria [28] and RF is the fatal cancer risk factor of 0.05.

2.5.7 Organ/ Tissue dose

This is the effective dose delivered to a particular sensitive organ and can be calculated using the expression

$$D_{\text{organ}} (\text{mSv}^{-1}) = O \times AEDE \times F \quad (9)$$

where AEDE is annual effective dose equivalent, O is the occupancy factor 0.8 and F is the conversion factor of organ dose from incorporation. The values of F for

Lungs, Ovaries, Bone marrow, Testes, Kidneys, Liver and Whole body are

0.64, 0.58, 0.69, 0.82, 0.62, 0.46 and 0.68 respectively as provided by [29]

3 Results and Discussion

3.1 Results

The results of the Assessment of BIR and Activity concentrations are presented in Tables i, ii, iii, and iv. Table v showed the level of health risks together with the mean values of activity concentrations while Table vi represents the results of human Organ Doses. Results were compared with world permissible values in Figure ii, iii and iv.

Table 1. BIR and Activity concentration in Unodu

S/N	Sample code	Coordinates Lat & Lon. (°)	Alt. (m)	BIR rate (mRh ⁻¹)	Activity Concentration (Bqkg ⁻¹)		
					²²⁶ Ra	²³² Th	⁴⁰ K
1	UNO1	6.02694444 6.80611111	55.00	0.012±0.002	23.04±3.71	8.33±2.19	194.48±2.25
2	UNO2	6.01000000 6.82777778	75.00	0.010±0.004	42.65±4.28	9.27±2.14	484.85±3.76
3	UNO3	6.03305556 6.81472222	72.00	0.014±0.003	31.11±3.69	11.23±2.12	405.26±3.42
4	UNO4	6.02527778 6.81527778	63.00	0.010±0.006	20.16±4.00	11.49±3.50	327.49±3.04
5	UNO5	6.01833333 6.83416667	70.00	0.015±0.002	39.19±4.23	8.33±2.12	305.34±2.92
6	UNO6	6.02083333 6.80944444	60.00	0.025±0.004	48.99±3.41	11.23±3.20	302.44±2.91
7	UNO7	6.02250000 6.81444444	74.00	0.011±0.005	28.23±2.47	8.00±2.18	384.62±3.32
8	UNO8	5.99389999 6.81527778	65.00	0.010±0.001	63.98±2.71	8.65±2.15	282.35±2.80
9	UNO9	5.99500000 6.82194444	65.00	0.015±0.004	33.42±4.56	7.31±2.13	800.00±4.90
10	UNO10	5.99694444 6.82083333	66.00	0.013±0.006	16.70±3.54	15.80±2.18	744.19±4.72
11	UNO11	5.99897222 6.81555556	66.00	0.018±0.002	42.07±3.46	14.97±2.23	386.21±3.33
12	UNO12	6.00361111 6.83277778	67.00	0.014±0.003	12.09±5.35	8.96±2.15	521.48±3.91
13	UNO13	6.00055556	72.00	0.011±0.004	24.19±4.55	6.58±2.11	314.61±2.97

		6.83694444					
14	UNO14	6.00555556 6.84750000	95.00	0.010±0.003	11.51±5.00	14.55±2.20	459.77±3.66
15	UNO15	6.00361111 6.84305556	90.00	0.015±0.005	18.43±5.58	16.00±2.28	375.26±3.28
Mean			70.33	0.014±0.004	30.38±4.01	10.71±2.33	419.22±3.41

Table 2. BIR and Activity concentration in Ezumeri

S/N	Sample code	Coordinates (°)	Alt. (m)	BIR rate (mRh ⁻¹)	Activity Concentration (Bqkg ⁻¹)		
					²²⁶ Ra	²³² Th	⁴⁰ K
1	EZU1	5.99222222 6.82944444	58.00	0.014±0.006	25.92±4.66	10.97±1.90	432.94±3.54
2	EZU2	5.99666667 6.82416667	64.00	0.013±0.005	26.50±4.94	12.73±1.77	675.86±4.49
3	EZU3	5.99694444 6.83055556	95.00	0.011±0.002	20.73±2.49	12.97±1.74	687.85±4.53
4	EZU4	5.99138889 6.83444444	45.00	0.014±0.006	36.88±4.32	8.33±1.88	729.27±6.12
5	EZU5	5.99277778 6.83916667	42.00	0.012±0.003	10.93±6.64	11.75±1.86	679.45±4.50
6	EZU6	5.99222222 6.84166667	80.00	0.011±0.007	9.20±5.55	12.73±1.75	501.96±3.83
7	EZU7	5.99833333 6.84694444	97.00	0.010±0.005	38.61±3.86	10.42±1.81	888.89±5.17
8	EZU8	5.99388889 6.84583333	83.00	0.009±0.004	19.00±5.18	8.96±1.92	808.79±4.93
9	EZU9	5.99583333 6.85027778	92.00	0.010±0.006	36.88±4.38	10.70±1.84	536.71±3.97
10	EZU10	6.00005556 6.84500000	101.00	0.011±0.002	31.69±5.06	8.65±1.91	690.41±4.54
11	EZU11	6.00444444 6.84916667	111.00	0.012±0.002	12.09±5.93	8.65±1.90	800.00±4.90
12	EZU12	5.99833333 6.85305556	94.00	0.015±0.003	18.43±5.04	8.33±1.90	800.00±4.90
13	EZU13	6.00063611 6.84496944	94.00	0.011±0.005	12.09±4.88	10.97±1.82	885.11±5.16
14	EZU14	6.00233333 6.84669444	116.00	0.012±0.003	22.46±5.48	12.00±1.79	713.85±4.62
15	EZU15	6.00022222 6.83613889	96.00	0.011±0.003	31.69±4.92	8.96±1.89	760.66±4.77
Mean			84.53	0.012±0.004	23.54±4.89	10.47±5.99	706.12±4.66

Table 3. BIR and Activity concentration in Irefi

S/N	Sample code	Coordinates (°)	Alt. (m)	BIR rate (mRh ⁻¹)	Activity Concentration (Bqkg ⁻¹)		
					²²⁶ Ra	²³² Th	⁴⁰ K
1	IRE1	6.00302778 6.85583333	116.00	0.009±0.005	42.65±3.57	18.45±1.74	704.35±5.22
2	IRE2	6.01016667 6.86494444	126.00	0.010±0.001	40.34±3.62	18.45±1.70	581.82±4.15
3	IRE3	6.00677778 6.86738889	114.00	0.014±0.003	23.62±4.42	12.49±2.78	517.95±6.81
4	IRE4	6.00297222 6.87480556	108.00	0.009±0.003	21.31±4.98	10.70±1.77	847.06±5.05
5	IRE5	6.00591667 6.87225000	108.00	0.013±0.004	62.25±3.70	10.97±1.87	766.67±4.79
6	IRE6	6.00288889 6.86344444	103.00	0.010±0.005	29.38±4.35	7.31±1.89	825.00±5.57
7	IRE7	6.00097222 6.85783333	83.00	0.009±0.004	42.07±4.66	10.97±1.82	409.76±3.44
8	IRE8	5.99622222 6.86247222	91.00	0.010±0.002	38.03±2.56	10.14±1.88	721.57±4.64
9	IRE9	5.99216667 6.86463889	93.00	0.011±0.005	44.38±2.02	9.27±1.79	1004.26±5.51
10	IRE10	5.99647222 6.86638889	53.00	0.008±0.006	27.65±3.56	8.65±1.85	543.03±4.00
11	IRE11	5.99833333 6.86922222	86.00	0.012±0.003	47.84±4.33	9.27±1.85	544.83±6.88
12	IRE12	5.99855556 6.85672222	109.00	0.011±0.001	20.73±4.41	12.73±1.83	419.31±3.48
13	IRE13	5.98450000 6.85575000	30.00	0.012±0.002	30.54±4.95	12.49±1.86	526.03±3.93
14	IRE14	5.99097222 6.85555556	21.00	0.010±0.006	31.11±5.31	8.33±1.88	909.80±5.24
15	IRE15	6.00072222 6.85525000	113.00	0.010±0.005	38.61±2.23	9.86±1.33	432.94±3.54
Mean			87.71	0.011±0.004	36.03±3.91	11.34±1.86	650.29±4.82

Table 4. BIR and Activity concentration in Ifite

S/N	Sample code	Coordinates (°)	Alt. (m)	BIR rate (mRh ⁻¹)	Activity Concentration (Bqkg ⁻¹)		
					²²⁶ Ra	²³² Th	⁴⁰ K
1	IFI1	6.03177778 6.82255556	65.00	0.013±0.004	54.18±3.55	10.97±1.87	675.86±4.49
2	IFI2	6.03813889 6.82619444	57.00	0.016±0.006	39.19±5.67	8.00±1.91	687.85±4.53
3	IFI3	6.02719444 6.83019444	80.00	0.010±0.003	57.06±3.90	10.70±1.90	729.27±6.12
4	IFI4	6.02300000 6.83511111	81.00	0.009±0.001	53.60±3.68	8.65±1.87	679.45±4.50
5	IFI5	6.04036111 6.83613889	61.00	0.012±0.002	49.57±4.19	4.94±1.88	501.96±3.83
6	IFI6	6.03397222 6.83541667	88.00	0.018±0.005	31.69±4.32	8.65±1.90	888.89±5.17
7	IFI7	6.03294444 6.84169444	111.00	0.014±0.004	63.98±3.45	11.75±1.85	808.79±4.93
8	IFI8	6.02686111 6.83700000	95.00	0.009±0.007	52.45±2.31	8.96±1.86	536.71±3.97
9	IFI9	6.02233333 6.83741667	84.00	0.009±0.003	38.61±2.23	7.31±1.90	690.41±4.54
10	IFI10	6.02980556 6.84491667	123.00	0.018±0.002	14.97±5.09	11.23±1.87	800.00±4.90
11	IFI11	6.02841667 6.85677778	97.00	0.016±0.004	26.50±5.26	9.27±1.85	800.00±4.90
12	IFI12	6.01883333 6.86786111	99.00	0.011±0.006	27.08±4.00	8.96±1.90	885.11±5.16
13	IFI13	6.00833333 6.85677778	136.00	0.009±0.003	55.91±4.00	12.25±1.85	713.85±4.62
14	IFI14	6.00880556 6.85155556	128.00	0.020±0.002	21.89±7.42	10.97±1.87	760.66±4.77
15	IFI15	6.01301667 6.84966667	117.00	0.014±0.002	28.81±5.18	12.73±1.90	909.80±5.24
	Mean		94.80	0.013±0.004	41.03±4.28	9.69±1.88	737.91±4.78

Table 5. Mean Activity Concentrations and Health Risk Indices

S/N	Location	^{226}Ra Mean	^{232}Th Mean	^{40}K Mean	Raeq	Dose	γ	AEDE	Hazard index		ELCR
		(Bqkg ⁻¹)	(Bqkg ⁻¹)	(Bqkg ⁻¹)	(Bqkg ⁻¹)	(nGh ⁻¹)		(mSvy ⁻¹)	H _{in}	H _{ex}	(x 10 ⁻³)
1	Unodu	30.38±4.01	10.71±2.33	419.22±3.41	48.63	38.17	0.78	0.05	0.29	0.21	0.18
2	Ezumeri	23.54±4.89	10.47±5.99	706.12±4.66	43.45	46.82	0.73	0.06	0.34	0.25	0.21
3	Irefi	36.03±3.91	11.34±1.86	650.29±4.82	56.80	44.80	0.79	0.06	0.37	0.28	0.21
4	Ifite	41.03±4.28	9.69±1.88	737.91±4.78	60.05	55.74	0.86	0.07	0.41	0.30	0.25
Mean											0.21
ICPR (2003)		35	30	400	370	84	1	0.48	1	1	0.29

Table 6. Dose Exposure to Human Organs or tissues

Location	Human Organ and Tissue Dose (mSvy ⁻¹)						
	Lungs	Ovaries	Bone Marrow	Testes	Kidney	Liver	Whole body
Unodu	0.030	0.020	0.030	0.030	0.02	0.02	0.03
Ezumeri	0.030	0.030	0.030	0.040	0.03	0.02	0.03
Irefi	0.030	0.030	0.030	0.040	0.03	0.02	0.03
Ifite	0.040	0.030	0.040	0.050	0.03	0.03	0.04
Average	0.033	0.028	0.033	0.040	0.028	0.023	0.033
Standard Limit	1	1	1	1	1	1	1

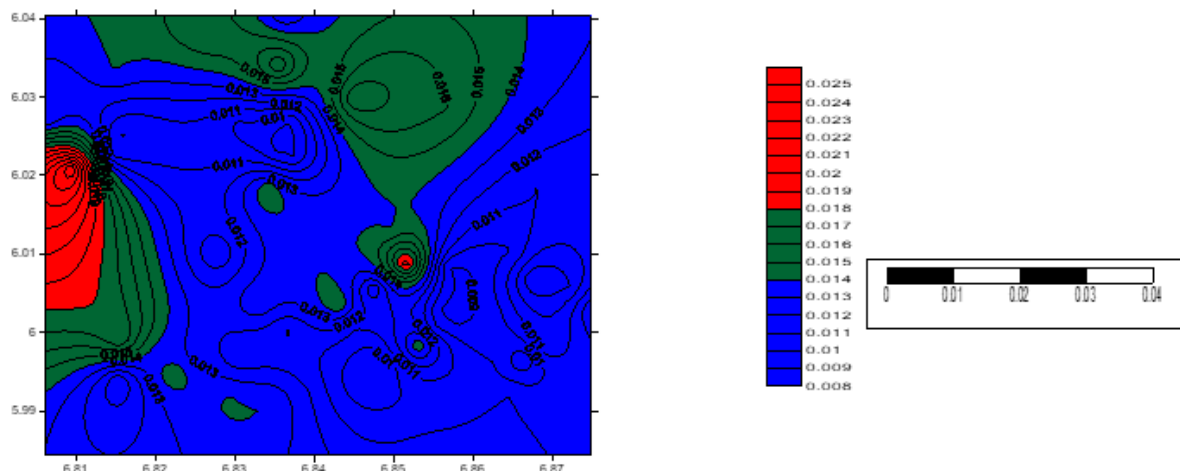


Figure. 2: Contour map of the community showing BIR distribution

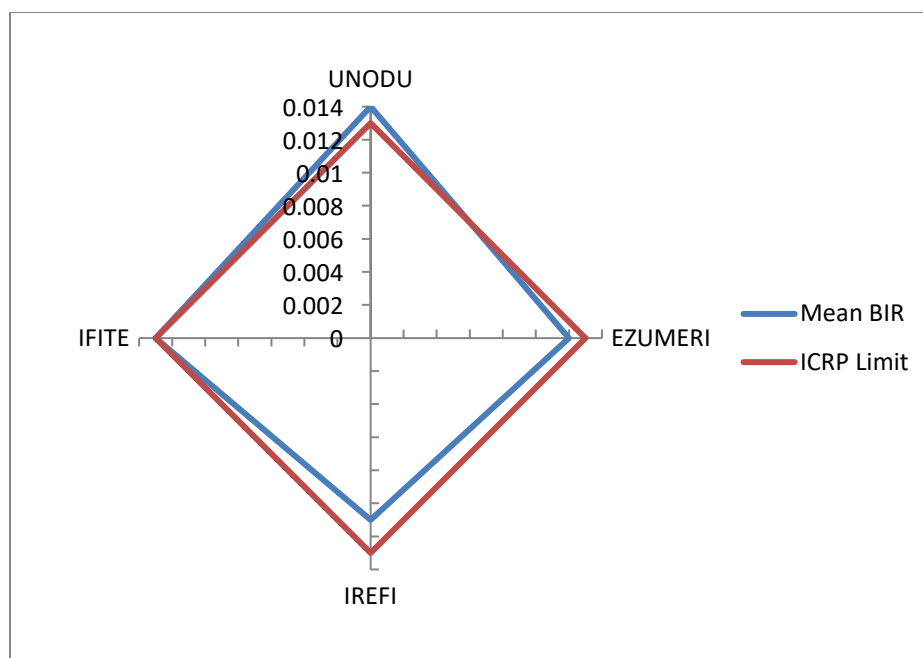


Figure 3: Comparison of mean value BIR with the ICRP world standard value

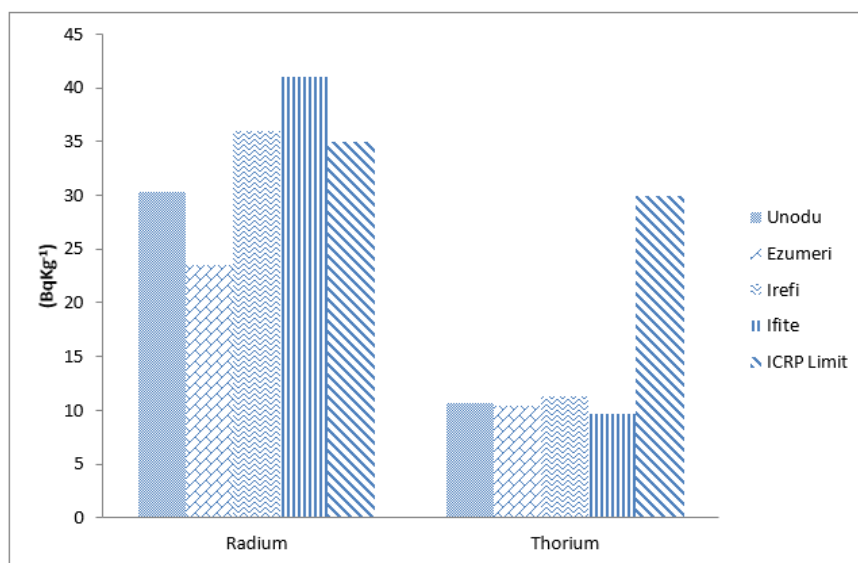


Figure 4: Comparison of mean activity concentration of nuclides of ^{226}Ra and ^{232}Th at the four quarters or districts

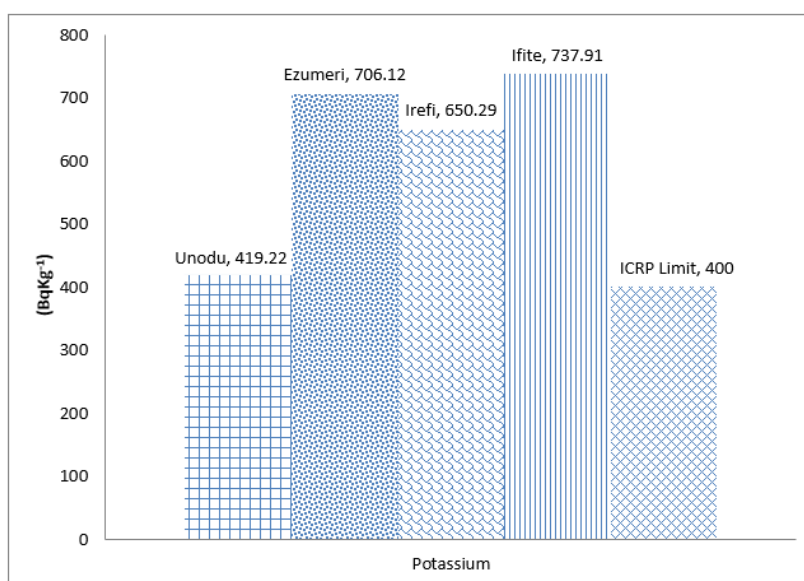


Figure 5: Comparison of mean activity concentration of nuclide of ^{40}K at the four quarters or districts

3.2 Discussion

The assessment of ionizing radiation dose and health risk levels was successfully carried out after laboratory analysis according to set aim and objectives. It was also in accordance with the best international known procedures and standards in BIR measurement and gamma spectrometry as used in previous studies [30], [31]. At the quarters or districts of Unodu and Ezumeri, the BIR exposure rate ranged from 0.010 to 0.025 mRh⁻¹ and 0.009 to 0.015 mRh⁻¹ respectively. At Irefi and Ifite quarters or districts BIR ranged from 0.008 to 0.014 mRh⁻¹ and 0.009 to 0.020 mRh⁻¹ respectively. Most of the measurements at the sampled points showed values less than the permissible value of 0.013 mRh⁻¹ which resulted in low

mean values at three of the districts. The values recorded were lower than values usually obtained in the Niger Delta area such as in [32]. Mean value ^{226}Ra in Unodu and Ezumeri quarters were below the standard value of 35Bqkg^{-1} . At Irefi and Ifite quarters it was higher than 35Bqkg^{-1} . The mean values of ^{232}Th were all lower than 30Bqkg^{-1} world limit. Figure ii is the contour map showing the distribution of BIR. Figure iii showed the comparison of measured BIR with the [29] world standard value while comparison of mean activity concentration of nuclides of ^{226}Ra and ^{232}Th at the four quarters or districts was represented in Figure iv. Mean values of ^{40}K ranged from 419.22 to 737.91Bqkg^{-1} which exceeded the recommended value of 400Bqkg^{-1} and lower than that recorded in Turkey sand [33]. Radium equivalents were found to be quite lower than the permissible value of 370Bqkg^{-1} . Figure v showed the comparison of mean activity concentration of nuclide of ^{40}K at the four quarters or districts. The average absorbed Dose rate recorded at the four quarters ranged from 38.17 to 55.74Gh^{-1} and these are quite lower than world standard value of 84nGh^{-1} . I_{gamma} , H_{in} , H_{ex} were all found to be lower than unity signifying conformity with the permissible limit. Average AEDE is lower than 0.48mSvy^{-1} and ELCR at the four quarters showed low values not exceeding the world permissible value of 0.29×10^{-3} . All Doses to human tissues or organs were very low.

4 Conclusion

Assessment of Ionizing Radiation Risk Levels associated with Radioactivity in Oraifite, Nigeria was carried out using X-ray spectrometry and radiation monitoring meter. Mean values of BIR conform to international permissible limit. The mean values of ^{226}Ra and ^{232}Th were within the recommended values but ^{40}K values were above 400Bqkg^{-1} . All the hazard indices computed were low and within normal range when compared with literature values. $D_{\text{organ/tissue}}$ were all within permissible limit meaning that natural radiation levels in this environment have no short-term adverse effect on human Lungs, Ovaries, Bone marrow, Testes, Kidney and Liver. Also the probability of carcinogenicity resulting from NORMs and or any anthropogenic radioisotopes in this study area is very slim as evident in ELCR values. However, regular monitoring is required in case of illegal radioactive waste dump that can cause sudden elevation of radiation parameters. Use of germanium detector technique for nuclides activity analysis is recommended as the town grows industrially.

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