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Measurements of Background Ionizing Radiation Levels in Selected Farms in Agbor, Delta State, Nigeria

***Egheneji, Anthony A. and Osuhor, Priscilla O.**

Department of Physics, University of Delta, Agbor, Delta State, Nigeria.

*Corresponding author's email: anthony.egheneji@unidel.edu.ng

ABSTRACT

Measurements of Background Ionizing radiation (BIR) levels were carried out in six farms with a calibrated Digilert-200 radiation meter positioned 1.0 m above the ground level. Geographical positioning system (GPS) was also used to find the coordinates of each studied farm. The measured overall average BIR exposure rate across the selected farms was 3.78 µR/h. Using radiological relations, the health risks parameters and the radiation effective doses to different organs/ tissues were determined as follow: Mean equivalent dose rate 0.03 µSv/h), Mean absorbed dose rate (33.09 nGy/h), mean annual effective dose equivalent (0.05 mSv/y), mean excess life cancer risk (0.14×10^{-3}. These values were lower than the recommended permissible limits of 13 µR/h, 0.1µSv/h, 84.0 nGy/h, 1.0 mSv/y and 0.29×10^{-3} respectively as recommended by (International Commission on Radiological Protection (ICRP) and United Nations Scientific Committee on the effects of Atomic Radiation (UNSCAER). Similarly, the effective dose delivered to different organs of the body within the recommended limits of 1.0 mSv/y. The results showed that the study area is safe from radiation exposure contamination.

Keywords:
Background Exposure Rate,
Ionizing,
Radiation,
Health Risk Parameters,
Farm.

INTRODUCTION

Background ionizing radiation (BIR) refers to the continuous, low-level ionizing radiation to which all living organisms are exposed from both natural and artificial sources. It represents the baseline exposure that contributes significantly to the cumulative radiation dose received by the general population annually. Globally, the average annual effective dose from all ionizing radiation sources is approximately 3 mSv/year, with natural background sources like cosmic rays, terrestrial radionuclides such as ^{238}U, ^{232}Th and ^{40}K and internal radionuclides constituting about 80 % of this exposure (Kovler *et al*., 2017; Thomas *et al*., 2022). The remaining portion arises mainly from human-made sources, notably medical diagnostic procedures and industrial activities (WHO, 2023).

Background ionizing radiation varies geographically due to factors such as local geology, altitude, and soil composition. Terrestrial sources depend on region and concentrations of primordial radionuclides in the Earth's crust, while cosmic radiation increases with altitude and varies with geomagnetic latitude (Restier-Verlet, 2025)

Nature itself possesses materials that are radioactive. Soil, air, water, rocks, vegetation, etc. contain some radioactive materials or radiation that can be inhaled or ingested into the body. These sources of exposure to radiation are natural (EPA, 2016). Human exposure to the sources of natural radiation has continued in everyday life. The earth has continued to receive constant bombardment from high-energy particles that emanate from outer space and produce other particles. Radon happens to be the largest source of natural radiation, which contributes to half the overall exposure of all sources. The Natural Background Radiation is illustrated in Figure 1 (Watson *et al.* 2000)

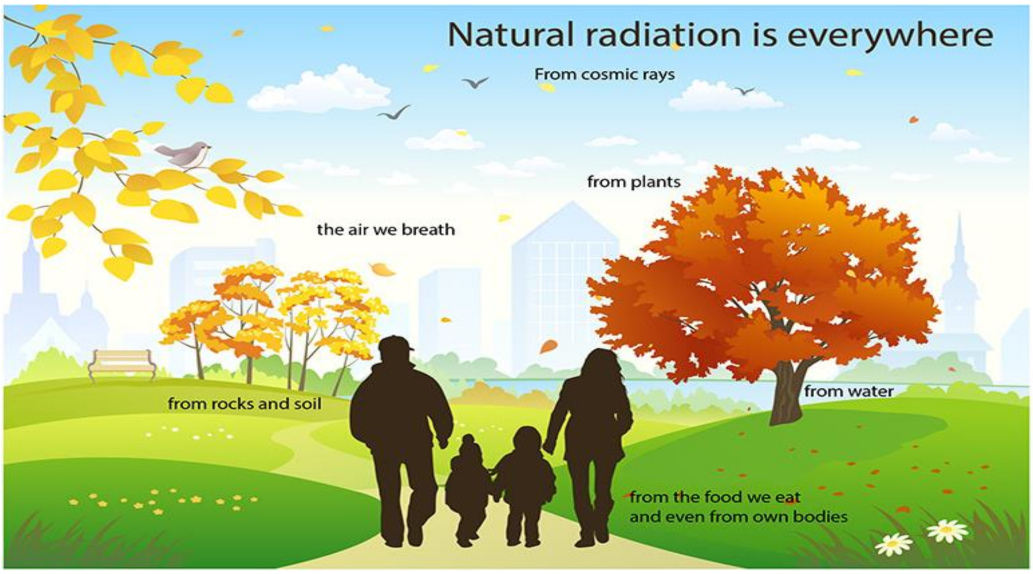

Figure 1: Shows the Natural Background Radiation (UNSCEAR 2008)

When these radiations enter the human body it causes excitation and ionization of the human cells causing the cell structure to change (Emelue *et al*., 2014).They can also lead to cancer formation, cataracts and gene mutation (Ogola *et al*., 2016).

The knowledge of background radiation is important as it helps in knowing the possible source and its effect on man (Sadiq &Agba, 2011). According to some available data, the BIR levels in some areas are low and high in some other areas. The result of the study carried out by the Eket & Emelue, (2020) using well calibrated Digital Geiger Muller showed that the natural radiation levels are within the permissible level. According to Nwabuoku *et al*., 2025 the level of BIR in Ogwashi-Uku is below the world permissible limit. The report of Fedrick, (2019) showed higher BIR levels in Nkalagu-Ezillo rice farm of Ebonyi State.

Though BIR levels are generally low in many cases and therefore poses no serious threat to man, critical monitoring is essential to maintain the radiation within the safety limits (Al-Asadi, 2019). Moreover the residents of the study area are predominantly farmers and spend most of their time in the farms. Hence this study aim to measure the BIR level in some selected farms in Agbor.

MATERIALS AND METHODS

Agbor is a town situated in Ika South Local Government Area of Delta State, Nigeria; its coordinates are 6.20^0 N and 6.20^0 E. Its population is about 240,000 with an area of about 650 km^2 (Olabaniyi *et al*., 2007). This area is known for farming activities; cassava, yam cocoyam and corn are some of the major farm produce gotten from this study area. Figure 2 shows the map of Agbor town while the map of the study area showing the sampled farm locations are shown in Figure 3. The coordinates of the sampling farms are presented in Table 1

Table 1: Locations Studied and Their Geographical Locations

Locations	Latitude	Longitude
Farm 1	N6^{0}14’7.183	E6^{0}10’37.64
Farm 2	N6^{0}13’5.140	E6^{0}15‘39.44
Farm 3	N6^{0}14’6.28	E6^{0}10’25. 92
Farm 4	N6^{0}13’82.14	E6^{0}17’45.69
Farm 5	N6^{0}13’88.14	E6^{0}17’45.69
Farm 6	N6^{0}15’7.121	E6^{0}10’39.92

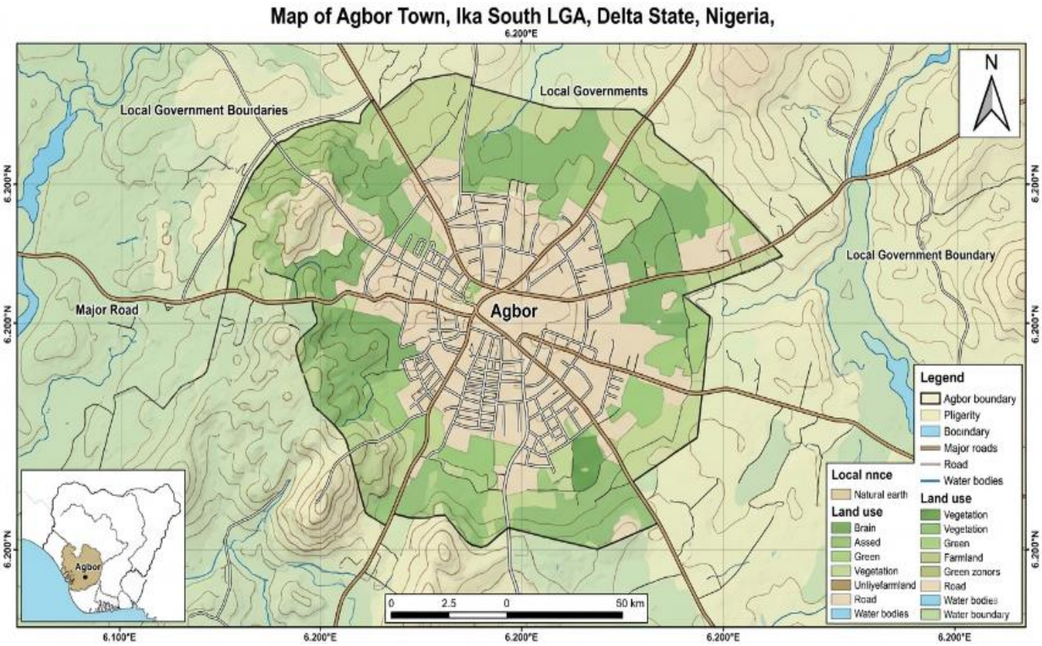

Figure 2: Map of Agbor Showing its Topography

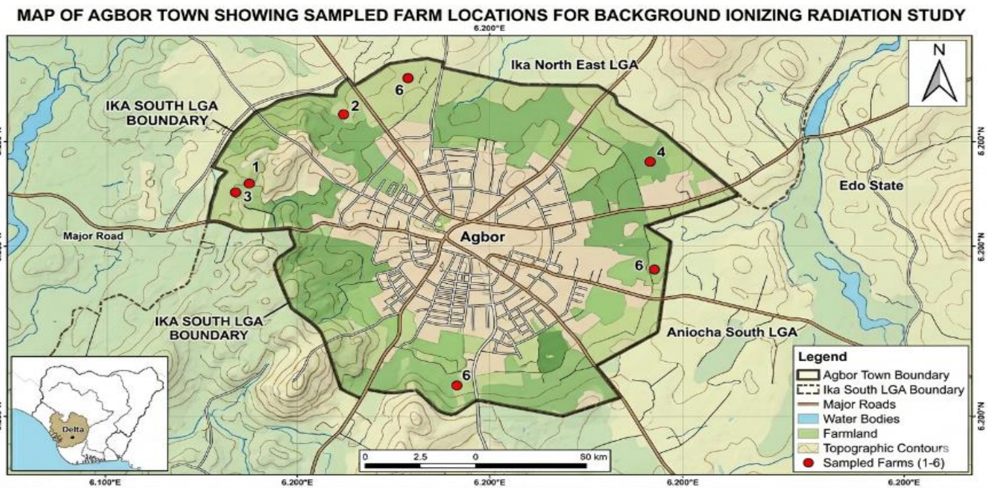

Figure 3: Locations Studied and their Geographical Locations

Materials

The major materials used for the work were global Positioning System (GPS) and Digilert Nuclear Radiation Monitor (Digilert, 2000)

Global Positioning System (GPS)

Global Positioning System (GPS) is an instrument used to estimate the geographical coordinates of the sample points. GPS Map76 Garmin product was used to estimate the geographical coordinate of the selected fertilized farms.

Digilert Nuclear Radiation Monitor: (Digert200)

The Digilert 200 is a health and safety instrument that measures alpha, beta, and gamma radiation. The Digilert detector records the ionizing procedure and shows the outcome on the liquid crystal display (LCD). The Digilert 200 was well calibrated for accurate readings of background ionizing radiation (BIR). The unit of measurement is controlled by using the mode switch. Its digital display shows readings in the choice of counts per minute (cpm), mRh-1, or accumulated counts. The reading display shows the current radiation level in milliroentgens per hour ($mRhr^{-1}$). Whenever Digilert 200 is operating, the red count light flashes each time a count (an ionizing event) is detected. Numerous indicators on the LCD show information about the mode setting. Digilert 200 uses a Geiger-Muller tube to detect radiation levels. Alpha and low-energy beta radiation doses do not pierce most solid subjects; the Geiger tube has one end, a thin disk of mica. The screen is open at the top of the Digilert 200; the open area is called the window. It permits alpha and beta at low energy and gamma radiation through it, so it can pierce the mica end of the tube.

Methods
Six farms were randomly selected from Agbor for the BIR exposure measurements. In each farm, ten sampling points were carefully marked out, P is a code assigned to each sampling point to ensure easy referencing. That is P 1 is the first sampling point, 1P1, the first sampling point in Farm 1.The device used for the measurement was held at about one meter above the ground level with its window facing the point under investigation. This ensures that sampling points maintain their original environmental characteristics (Agbalagba *et al.*, 2016). The generated data were converted to absorbed dose rate nGy/h using the relation (Centers for Disease Control and Prevention (CDC), 2021).

$$1\mu R h^{-1} = 8.7 \text{ nGy} h^{-1} \quad (1)$$

Radiological Health Risk Analysis
Equivalent Dose Rate
To estimate the whole body equivalent dose rate for an hour the National Council on Radiation Protection and Measurement's is used (Ononugbo *et al.*,2011) was used

$$\text{Equivalent dose rate} = \text{exposure rate} \times 0.0087 \quad (2)$$

Absorbed Dose
The absorbed dose was calculated using the relation

$$1\mu Sv/h = 81000 \text{ nGy/h} \quad (3)$$

Annual Effective Dose (AEDE)
This was computed from the absorbed dose rate and is given by the following equation (Ononugbo *et al.*, 2020)

$$AEDE\ (mSv/y) = ADR\ (nGy/h) \times 8760 \times 0.7 Sv/Gy \times 0.25 \quad (4)$$

Where ADR is the absorbed dose rate

Excess Life Cancer Risk (ELCR)
The ELCR was calculated according to the relation

$$ELCR = AEDE \times DL \times RF \quad (5)$$

Where AEDE is the annual effective dose equivalent, DL is the average duration of life and RF is the risk factor. RF is 0.05 for stochastic effect (Taskin *et al.*, 2009).

Effective Dose Rate (D_{organ}) to Different Organs /Tissues

$$Dorgan\ (mSv h^{-1}) = O \times AEDE \times F \quad (6)$$

Where O is the occupancy factor, 0.8 and F is the conversion factor for organ dose. The conversion factor (F) values for lungs, ovaries, bone marrow, testes, kidney, liver, and whole body as given by ICRP (1996) are 0.64, 0.58, 0.69, 0.82, 0.62, 0.46, and 0.68, respectively. This estimates the amount of radiation intake by PERSON (James *et al.*, 2020).

RESULTS AND DISCUSSION

The results obtained from the BIR level measurements and their calculated radiological health hazards in six selected farms in Agbor, Ika South Local Government Area are presented in Tables 2 to 7. While Figures 4 – 8 show the illustrations that compare the exposure rates, equivalent dose rate, absorbed dose rate, annual effective dose equivalent and excess life cancer risk associated with the study area with ICRP, 2003. The effective dose rates to different organs is well presented in Table 8.

Exposure Rate and Associated Health Risk Parameters from Farm 1
Farm 1 recorded a mean exposure rate of 3.242 μR/h, with individual sampling point values ranging from 2.283 μR/h (1P6) to 4.224 μR/h (1P9). The corresponding mean absorbed dose rate was 28.4 nGy/h, the mean annual effective dose equivalent (AEDE) was 0.044 mSv/yr, and the mean excess lifetime cancer risk (ELCR) was 0.119 × 10^{-3}. All measured values are substantially below the ICRP permissible limits of 13 μR/h, 84 nGy/h, 1.0 mSv/yr, and 0.29 × 10^{-3} respectively, indicating that Farm 1 poses no radiological health threat to farm workers.

Exposure Rate and Associated Health Risk Parameters from Farm 2
Farm 2 recorded the lowest mean exposure rate among all six farms at 2.363 μR/h, ranging from 1.370 μR/h (2P10) to 3.425 μR/h (2P3). The mean absorbed dose of 20.7 nGy/h, AEDE of 0.032 mSv/yr, and ELCR of 0.087 × 10^{-3} were the lowest across all farms. These values confirm that Farm 2 represents the least radiologically impacted location within the study area, remaining well within all internationally recommended safety thresholds.

Table 2: Exposure Rate and the Associated Health Risk Parameters from FARM 1

Sampling Point	Exposure Dose (μR/h)	Equivalent Dose (μSv/h)	Absorbed Dose (nGy/h)	AEDE (mSv/y)	ELCR ×10^{-3}
1P1	2.8539	0.025	25	0.038325	0.105011
1P2	3.1963	0.028	28	0.042924	0.117612
1P3	3.6530	0.032	32	0.049056	0.134413
1P4	3.0822	0.027	27	0.041391	0.113411
1P5	3.4247	0.030	30	0.045990	0.126013
1P6	2.2831	0.020	20	0.030660	0.084008
1P7	3.1963	0.028	28	0.042924	0.117612
1P8	3.8813	0.034	34	0.052122	0.142814

1P9	4.2237	0.037	37	0.056721	0.155416
1P10	2.6256	0.023	23	0.035259	0.096610
Range	1.9406	0.017	17	0.026061	0.071408
SD	0.5826	0.0051	5.10	0.007823	0.021440
Mean	3.2420	0.0284	28.4	0.043537	0.119292
ICRP, 2003	13	0.1	84	1.00	0.29

Table 3: Exposure Rate and the Associated Health Risk Parameters from FARM 2

Sampling Point	Exposure Dose (µR/h)	Equivalent Dose (µSv/h)	Absorbed Dose (nGy/h)	AEDE (mSv/y)	ELCR $\times 10^{-3}$
2P1	1.7123	0.015	15	0.022995	0.063006
2P2	2.7397	0.024	24	0.036792	0.100810
2P3	3.4247	0.030	30	0.045990	0.126013
2P4	2.8539	0.025	25	0.038325	0.105011
2P5	2.0548	0.018	18	0.027594	0.075608
2P6	2.5114	0.022	22	0.033726	0.092409
2P7	2.7397	0.024	24	0.036792	0.100810
2P8	1.8265	0.016	16	0.024528	0.067207
2P9	2.3973	0.021	21	0.032193	0.088209
2P10	1.3699	0.012	12	0.018396	0.050405
Range	2.0548	0.018	18	0.027594	0.075608
SD	0.6207	0.0054	5.44	0.008335	0.022838
Mean	2.3630	0.0207	20.7	0.031733	0.086949
ICRP, 2003	13	0.1	84	1.00	0.29

Exposure Rate and Associated Health Risk Parameters from Farm 3

Farm 3 exhibited a mean exposure rate of 4.886 µR/h, the second highest recorded, with a maximum point value of 7.078 µR/h at sampling point 3P8. The mean absorbed dose of 42.8 nGy/h, AEDE of 0.066 mSv/yr, and ELCR of 0.180×10^{-3} are notably elevated relative to Farms 1 and 2, though still below permissible limits. The higher readings may reflect localized variations in soil radionuclide composition within this farm's geological setting.

Table 4: Exposure Rate and the Associated Health Risk Parameters from FARM 3

Sampling Point	Exposure Dose (µR/h)	Equivalent Dose (µSv/h)	Absorbed Dose (nGy/h)	AEDE (mSv/y)	ELCR $\times 10^{-3}$
3P1	5.0228	0.044	44	0.067452	0.184818
3P2	3.9954	0.035	35	0.053655	0.147015
3P3	5.7078	0.050	50	0.076650	0.210021
3P4	5.1370	0.045	45	0.068985	0.189019
3P5	3.8813	0.034	34	0.052122	0.142814
3P6	5.4795	0.048	48	0.073584	0.201620
3P7	3.6530	0.032	32	0.049056	0.134413
3P8	7.0776	0.062	62	0.095046	0.260426
3P9	4.7945	0.042	42	0.064386	0.176418
3P10	4.1096	0.036	36	0.055188	0.151215
Range	3.4247	0.030	30	0.045990	0.126013
SD	1.0460	0.0092	9.16	0.014047	0.038487
Mean	4.8858	0.0428	42.8	0.065612	0.179778
ICRP, 2003	13	0.1	84	1.00	0.29

Exposure Rate and Associated Health Risk Parameters from Farm 4

Farm 4 recorded the highest mean exposure rate in the study at 5.674 µR/h, with a peak value of 8.562 µR/h at point 4P8 — the single highest individual reading across all farms. The corresponding mean absorbed dose of 49.7 nGy/h, AEDE of 0.076 mSv/yr, and ELCR of 0.209×10^{-3}, while the highest among all farms, remain below the ICRP-recommended limits. The elevated readings in Farm 4 could be attributed to higher concentrations of naturally occurring radionuclides such as ^{238}U, ^{232}Th, or ^{40}K in the underlying soil at this location.

Table 5: Exposure Rate and the Associated Health Risk Parameters from FARM 4

Sampling Point	Exposure Dose (µR/h)	Equivalent Dose (µSv/h)	Absorbed Dose (nGy/h)	AEDE (mSv/y)	ELCR $\times 10^{-3}$
4P1	6.3927	0.056	56	0.085848	0.235224
4P2	4.3379	0.038	38	0.058254	0.159616
4P3	5.1370	0.045	45	0.068985	0.189019
4P4	4.7945	0.042	42	0.064386	0.176418
4P5	4.3379	0.038	38	0.058254	0.159616
4P6	5.2511	0.046	46	0.070518	0.193219
4P7	5.4795	0.048	48	0.073584	0.201620
4P8	8.5616	0.075	75	0.114975	0.315032
4P9	6.5068	0.057	57	0.087381	0.239424
4P10	5.9361	0.052	52	0.079716	0.218422
Range	4.2237	0.037	37	0.056721	0.155416
SD	1.2678	0.0111	11.11	0.017025	0.046647
Mean	5.6735	0.0497	49.7	0.076190	0.208761
ICRP, 2003	13	0.1	84	1.00	0.29

Exposure Rate and Associated Health Risk Parameters from Farm 5

Farm 5 showed intermediate levels with a mean exposure rate of 3.836 µR/h, mean absorbed dose of 33.6 nGy/h, AEDE of 0.052 mSv/yr, and ELCR of 0.141×10^{-3}. All values fall comfortably within safe limits, confirming negligible radiological risk for workers in this farm.

Table 6: Exposure rate and the associated health risk parameters from FARM 5

Sampling Point	Exposure Dose (µR/h)	Equivalent Dose (µSv/h)	Absorbed Dose (nGy/h)	AEDE (mSv/y)	ELCR $\times 10^{-3}$
5P1	3.6530	0.032	32	0.049056	0.134413
5P2	2.9680	0.026	26	0.039858	0.109211
5P3	4.5662	0.040	40	0.061320	0.168017
5P4	4.7945	0.042	42	0.064386	0.176418
5P5	3.9954	0.035	35	0.053655	0.147015
5P6	3.3105	0.029	29	0.044457	0.121812
5P7	3.8813	0.034	34	0.052122	0.142814
5P8	4.3379	0.038	38	0.058254	0.159616
5P9	3.0822	0.027	27	0.041391	0.113411
5P10	3.7671	0.033	33	0.050589	0.138614
Range	1.8265	0.016	16	0.024528	0.067207
SD	0.6117	0.0054	5.36	0.008215	0.022508
Mean	3.8356	0.0336	33.6	0.051509	0.141134
ICRP, 2003	13	0.1	84	1.00	0.29

Exposure Rate and Associated Health Risk Parameters from Farm 6

Farm 6 recorded the second lowest mean exposure rate at 2.660 µR/h, with a mean absorbed dose of 23.3 nGy/h, AEDE of 0.036 mSv/yr, and ELCR of 0.098×10^{-3}. These values closely approximate those of Farm 2, confirming minimal radiological hazard.

Table 7: Exposure Rate and the Associated Health Risk Parameters from FARM 6

Sampling Point	Exposure Rate (µR/h)	Equivalent Dose (µSv/h)	Absorbed Dose (nGy/h)	AEDE (mSv/y)	ELCR $\times 10^{-3}$
6P1	2.1690	0.019	19	0.029127	0.079808
6P2	2.8539	0.025	25	0.038325	0.105011
6P3	2.0548	0.018	18	0.027594	0.075608
6P4	3.0822	0.027	27	0.041391	0.113411
6P5	2.2831	0.020	20	0.030660	0.084008
6P6	3.4247	0.030	30	0.045990	0.126013
6P7	3.1963	0.028	28	0.042924	0.117612
6P8	2.2831	0.020	20	0.030660	0.084008
6P9	2.5114	0.022	22	0.033726	0.092409
6P10	2.7397	0.024	24	0.036792	0.100810
Range	1.3699	0.012	12	0.018396	0.050405

SD	0.4724	0.0041	4.14	0.006343	0.017379
Mean	2.6598	0.0233	23.3	0.035719	0.097870
ICRP, 2003	13	0.1	84	1.00	0.29

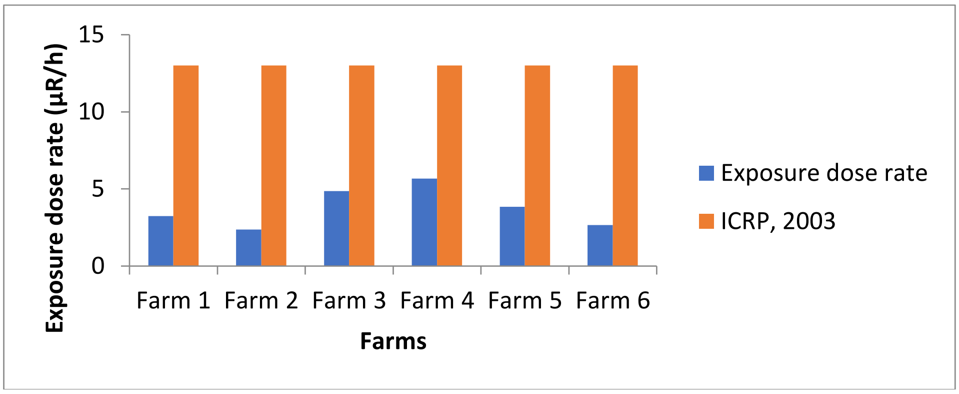

Figure 4: Comparison of Exposure Rate with ICRP. 2003

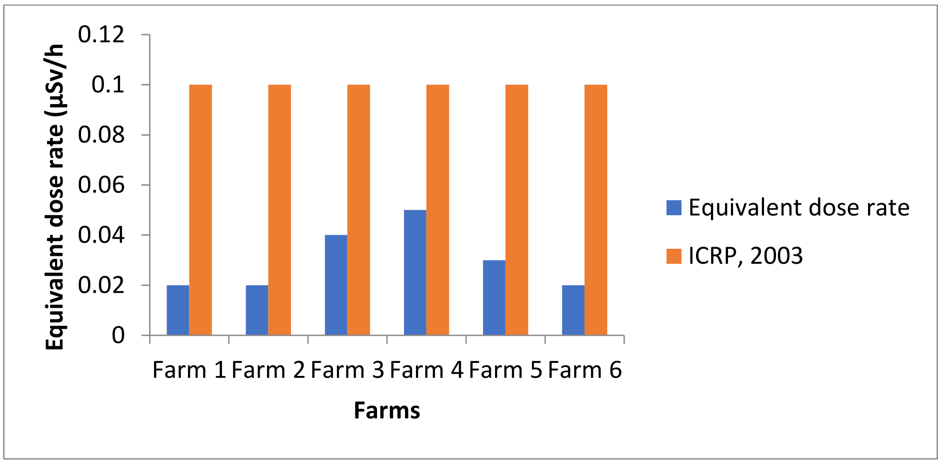

Figure 5: Comparison of Equivalent dose Rate with ICRP, 2003

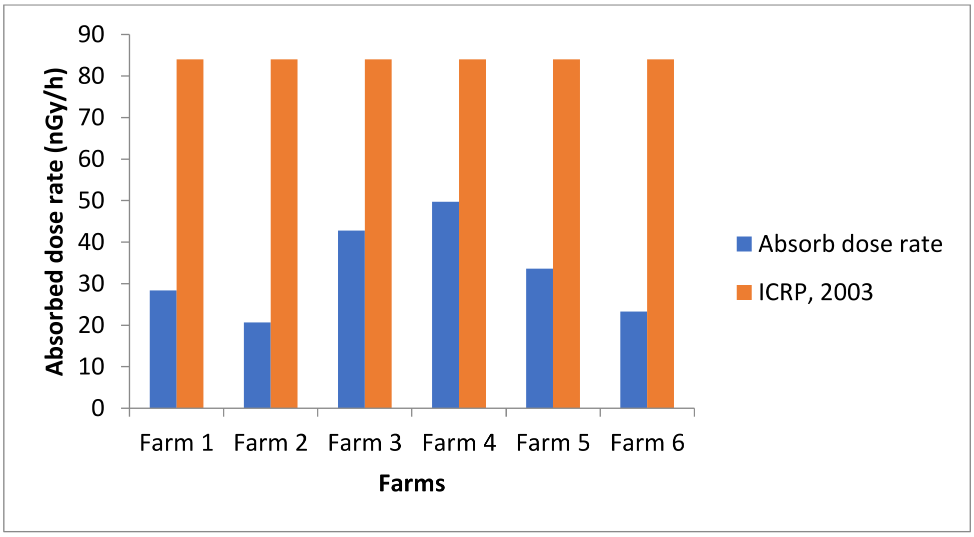

Figure 6: Comparison of Absorbed dose Rate with ICRP, 2003

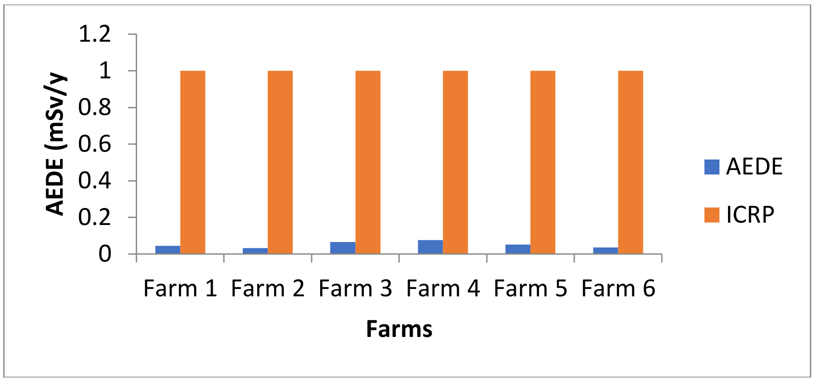

Figure 7: Comparison of AEDE with ICRP, 2003

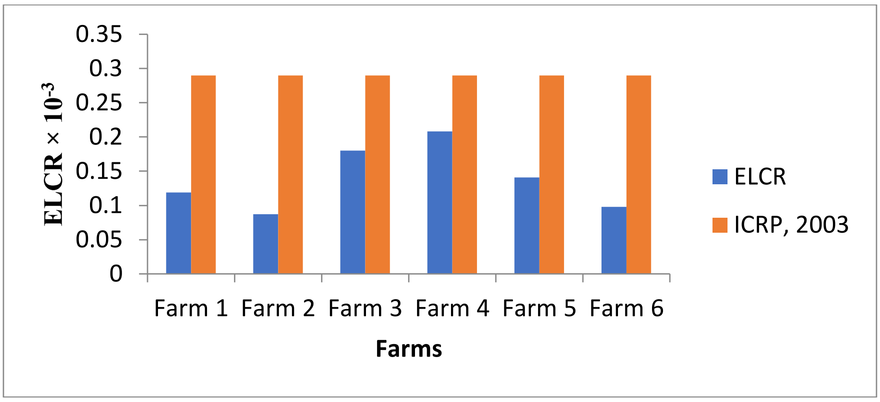

Figure 8: Comparison of ELCR with ICRP, 2003

Mean Dose to Different Body Organs across All Farms

Table 7 show the effective dose rates delivered to the different organs in the adult body. The testes received the highest dose of 0.029 mSv/yr in Farm 1 while the least dose of 0.016 mSv/yr was recorded in liver. Absorption rate of food nutrient by different organs may have accounted for the higher dose intake in testes compare to liver (Ovuomarie-kelvin *et al*., 2018). These estimated values are well below the globally acceptable limit of 1.0 mSv/yr. BIR levels from these farms have no significant to the radiation dose intake to these organs.

Table 8: Mean of the Dose to Different Body Organ of the Study Area

Farm	Lungs ($mSvy^{-1}$)	Ovaries ($mSvy^{-1}$)	Bone Marrow ($mSvy^{-1}$)	Testes ($mSvy^{-1}$)	Kidney ($mSvy^{-1}$)	Liver ($mSvy^{-1}$)	Whole Body ($mSvy^{-1}$)
1	0.022291	0.020201	0.024032	0.028560	0.016736	0.016022	0.022639
2	0.016247	0.014724	0.017517	0.020817	0.012198	0.011678	0.016501
3	0.033593	0.030444	0.036218	0.043041	0.025221	0.024145	0.034118
4	0.039009	0.035352	0.042057	0.049981	0.029287	0.028038	0.039619
5	0.026373	0.023900	0.028433	0.033790	0.019800	0.018955	0.026785
6	0.018288	0.016574	0.019717	0.023432	0.013730	0.013145	0.018574
Range	0.022762	0.020628	0.024540	0.029164	0.017089	0.016360	0.023118
SD	0.008893	0.008059	0.009587	0.011394	0.006676	0.006391	0.009031
Corrected Mean†	0.025967	0.023533	0.027996	0.033270	0.019495	0.018664	0.026373
ICRP Limit	1.0	1.0	1.0	1.0	1.0	1.0	1.0

Discussion

Tables 1 to 6 show the mean exposure rate, absorbed dose rate, annual effective dose equivalent and the excess life cancer risk obtained from the BIR measurement of the six farms. The estimated absorbed dose ranged from 20.7 in Farm 1 to 49.7 nGy/h in Farm 4 with mean value of 33.08 nGy/h. This value is significantly lower than permissible mean value of 84.0 nGy/h (Taskin *et al*., 2009). The results shows that the environment is not contaminated by radiation. The mean absorbed dose from this work is much lower than126 and 185.39 nGy/h earlier reported by Ugbedi & Benson (2018) in Emene Industrial Layout of Enugu State , Nigeria and Mbeokwere *et al*., (2023) in Ikwo, Ebonyi State respectively. The calculated value of the annual effective dose AEDE varied from 0.031 to 0.076 $mSvy^{-1}$with observed average value of 0.061 $mSvy^{-1}$. This value is far lower than the safe limit of

1.00 mSvy^{-1}. (Taskin *et al*., 2009). The AEDE from this study is lower than the reported value of Ugbedi & Benson, (2018). The values of ELCR that were estimated was between 0.098 × 10^{-3} and 0.20 × $10^{-3}$with mean value of 0.14 × 10^{-3}. The mean value obtained from this work is quite lower than the average value of 0.29 × 10^{-3}. Farmers working in these farms are safe from developing cancer. The average value reported from this work is lower than the reported value of Mbeokwere *et al*., (2023).
Table 7 show the effective dose rates delivered to the different organs in the adult body. The testes received the highest dose of 0.029 mSv/yr in Farm 1 while the least dose of 0.016 mSv/yr was recorded in liver. Absorption rate of food nutrient by different organs may have accounted for the higher dose intake in testes compare to liver (Ovuomarie-kelvin *et al*., 2018). These estimated values are well below the globally acceptable limit of 1.0 mSv/yr. BIR levels from these farms have no significant to the radiation dose in take to these organs.

CONCLUSION

The health impacts of background ionizing radiation esposure dose rate from selected farms in Agbor was investigated using Digilert-200 Meter. The results obtained showed that the exposure rate 3.78 µR/h is lower than the acceptable limit of 13 µR/h. The mean absorbed dose of 33.08 nGy/h is less than the recommended safe limit of 84 nGy/h. This is an indication that the farms are not radiologically contaminated. The result of the calculated excess life cancer risk of 0.14 × 10^{-3} shows that the farmers in the study area are free from cancer related issues. The dose intake in the various organs in the body is significantly lower than the permissible limit.However, it is worthy to recommend periodic monitoring of soil background radiation with calibrated meters to detect any changes overtime. Spectrometry analysis of soil radionuclide in Agbor should be carried out to ascertain when the natural radionuclide in the soil will be higher than normal. Farmers in the area should be given proper education on basic radiation safety.

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