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Baseline Studies of Terrestrial Outdoor Gamma Dose Rates of Ten Selected Markets in Port Harcourt Metropolis

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Authors' contributions

This work was carried out in collaboration between both authors. Author CPO designed the study, performed the statistical analysis, wrote the protocol, wrote the first draft of the manuscript and managed the analyses of the study. Author SO managed the literature searches. Both authors read and approved the final manuscript.

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ABSTRACT

In-situ measurement of background ionizing radiation of 10 markets in Port Harcourt metropolis of Rivers State, Nigeria was done using radiation meters and global positioning system. Two portable handheld nuclear radiation monitors (radalert100 and digilert200) to measure exposure dose rate at the various points and a GPS (Germin GPS map 76S for exact positions. The average exposure rates ranged from 0.011 mRh^{-1} (Mile 1 market) to 0.017 mRh^{-1} (Rukpokwu international market). The exposure dose rate measured at Rumuodomaya slaughter market (H). Rumuokoro market and Rukpokwu international market (J) were higher than the permissible value of 0.013 mRh^{-1}. The absorbed dose rate of all the ten markets exceeded the world average value of 84.0 $nGyh^{-1}$ while the annual effective dose calculated for all the markets were lower than the permissible value. The cancer risk parameter estimated (excess lifetime cancer risk) of all the markets exceeded the permissible value of 0.29×10^{-3}. The result of this work gives the baseline radiation status of those markets sampled.

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Keywords: Radalert; radiation; exposure; absorbed dose; excess lifetime cancer risk.

1. INTRODUCTION

Human beings are exposed to background ionizing radiation that stems both from natural and man- made sources [1]. In general, approximately 87% of the annual total radiation dose of any person comes from natural radionuclides of both terrestrial and cosmogenic origin [2,1]. The exposure from natural sources could be from radionuclides in the ground, building materials, air, food, food spices and even some elements in our bodies. Radionuclides are not distributed evenly throughout the environmental media, the knowledge of their presence, contamination, distribution, activity and interaction with materials (soil, food, food spices, air, tissues, etc.) plays a very pivotal and significant role in radiation protection [2]. Exposure to this form of outdoor natural terrestrial radiation originates predominantly from the upper 30cm of the soil [3,4]. According to United Nations Scientific Committee on the Effect of Atomic Radiation (UNSCEAR) [5], about 87% of the radiation dose received by mankind is due to natural radiation sources. Cosmic rays from space include energetic protons, gamma ray, electrons and so [6,7]. The exposure to cosmic radiation depends mostly on altitude, latitude and solar activity [7]. Human external exposure to radiation from all source types is mainly due to gamma rays because of its penetrative ability [8]. Chemical and physical changes which require the direct adsorption of energy from the incident radiation by the target represents the initial physical perturbations from which subsequent radiation effects evolve [9]. These effects starts with the initial changes at the molecular ,cellular, tissue and whole body levels that may lead to a wide range of health effects ranging from irritation, radiation-induced cancer, hereditary disorders to immediate death [10,11].

Exposure to natural radiation can come through inhalation, ingestion or otherwise enters the blood stream through wounds and also from irradiation from external sources such as linear accelerators. Radiation damage to tissues or organs of the body depends on the dose of radiation received or the absorbed dose which is expressed in a unit called gray (Gy) [9]. The potential damage from an absorbed dose depends on the type of radiation and sensitivity of different tissues and organs [5,3]. The effective dose is used to measure ionizing radiation in terms of the potential for causing harm. Sievert, the unit of effective dose takes into account the type of radiation and sensitivity of tissues and organs [12]. Exposure to ionizing radiation can cause injuries and clinical symptoms which may include a chromosomal transformation, cancer induction, free radical formation, and bone necrosis and radiation cataractogenesis [13]. Previous research works have shown that human activities have great potentials to elevate the level of environmental background ionizing radiation. Subsequently, some human activities have greatly led to the ozone layer depletion and consequently increased cosmic rays reaching the earth surface and affecting the background radiation [14,15].

Most markets in Port-Harcourt are not lockup shops but an open roof cover structures mostly where food spices area sold. The activities in such markets are regarded as outdoor activities and most traders spend more time in the market than homes. These traders are exposed to radiation from the products such as building materials, food and its spices, soil etc which has been established that their radionuclide contents are high and can be a source of radiation exposure [16]. It is then imperative to determine the outdoor terrestrial radiation levels in some selected markets where food spices are being sold in Port Harcourt Metropolis. The aim of this study therefore is to measure the terrestrial outdoor gamma dose rates in ten markets and determine the associated radiation risk to the general public that uses such markets. The result of this work serves as baseline radiological data of those markets future studies.

2. MATERIALS AND METHODS

An *in situ* approach of background ionizing radiation measurement was adopted and preferred to enable samples maintain their original environmental characteristics. A Radalert-200 nuclear radiation monitor (S.E international, inc. Summer town, USA), containing a Geiger Muller tube capable of detecting α-particles, β-particles, γ -rays and X-rays within the temperature range of -10^{o} to 50^{o}C, and a geographical positioning system (GPS) were used to measure the precise location of sampling. During measurement, the tube of the radiation monitoring meter was raised to a standard height of 1.0 m above the ground [17,18] with its window first facing vertically upward or the suspected source and then vertically downward while the GPS readings taken at that spot.

Measurements were repeated six times at each site on different days within the 1 months to take care of any fluctuation in the environmental temperature, and this was repeated for 6 months in which the monitoring was carried out. Readings were taken between the hours of 1300 and 1600 h, since the radiation meter has the maximum response to environmental radiation within these hours as recommend by National Council on Radiation Protection and Measurement (NCRP) [19]. The meter was set to read in milli-Roetgen per hour.

3. RESULTS AND DISCUSSION

The results of the *in-situ* ionizing radiation for the areas of study (ten selected markets) are therefore presented in the Tables 1-10 and Figs. 1, 2, 3 and 4 are comparison of average exposure dose rates, annual effective dose, excess lifetime cancer risk with their respective standards and radiation contour map of five of the markets sampled respectively.

3.1 Absorbed Dose Rate

The radiation dose to an organism is the total quantity of energy absorbed from ionizing radiation per unit mass of the tissue and the dose rate refers to the energy absorbed over time. The exposure dose rate measured in μRh^{-1} were converted unto absorbed dose rate using the conversion factor [20].

$$1\mu Rh^{-1} = 8.7\ nGyh^{-1} = \frac{8.7\times10^{-3}}{\frac{1}{8760\ y}}\ \mu Gyy^{-1} = 76.212\ \mu Gyy^{-1} \quad (1)$$

3.2 Annual Effective Dose Equivalent (AEDE)

The values of the absorbed dose calculated were used to estimate the annual effective dose equivalent received by residents in those coastal communities. Dose conversion factor of 0.7 Sv/Gy recommended by UNSCEAR [5] for the conversion coefficient from absorbed dose in air to effective dose received by adults and occupancy factor of 0.2 for outdoor. The annual effective dose equivalent was calculated using the equation [21]:

$$\text{AEDE (outdoor)} = D\ (nGyh^{-1}) \times 8760\ h \times 0.7\ Sv/Gy \times 0.2$$
$$= D\ (nGyh^{-1}) \times 1.2264 \times 10\text{-}3\ Sv/Gy \quad (2)$$

3.3 Excess Lifetime Cancer Risk (ELCR)

The estimated values of AEDE was used to calculate the excess lifetime cancer risk for the five communities using the equation [21]:

$$\text{ELCR} = \text{AEDE}\ (mSvy^{-1}) \times \text{average Duration of life (DL) in years} \times \text{Risk factor (RF } Sv^{-1}) \quad (3)$$

Where AEDE, DL and RF are the annual effective dose equivalent, duration of life (70 years) and the risk factor (Sv^{-1}), the fatal cancer risk per Sievert. For low dose background radiation which are considered to produce stochastic effects, ICRP 60 uses value of 0.05 Sv^{-1} for the public exposure.

Exposure dose rate of Fimie market (A) ranges from 0.008 to 0.016 mRh^{-1} while the absorbed dose rate ranges from 95.7 to 139.2 $nGyh^{-1}$. The annual effective dose calculated ranges from 0.11 to 0.21 $mSvy^{-1}$ while the excess lifetime cancer risk estimated ranges from 0.29× 10^{-3} to 0.58 × 10^{-3}. Exposure dose rate of Trans-Amadi slaughter market (B) ranges from 0.010 to 0.018 mRh^{-1} while the absorbed dose rate ranges from 87.0 to 156.6 $nGyh^{-1}$. The annual effective dose calculated ranges from 0.133 to 0.240 $mSvy^{-1}$ while the excess lifetime cancer risk estimated ranges from 0.36× 10^{-3} to 0.65 × 10^{-3}. Higher values of 0.016 mRh-1 and 0.018 mRh-1 was obtained food spices area and mixture of different products area respectively. Exposure dose rate of fruit garden market (C) ranges from 0.009 to 0.017 mRh^{-1} while the absorbed dose rate ranges from 78.3 to 147.9 $nGyh^{-1}$. The annual effective dose calculated ranges from 0.120 to 0.23 $mSvy^{-1}$ while the excess lifetime cancer risk estimated ranges from 0.33× 10^{-3} to 0.62 × 10^{-3}. Exposure dose rate of Mile 1 market (D) ranges from 0.0.10 to 0.016 mRh^{-1} while the absorbed dose rate ranges from 43.5 to 139.2 $nGyh^{-1}$. The annual effective dose calculated ranges from 0.067 to 0.21 $mSvy^{-1}$ while the excess lifetime cancer risk estimated ranges from 0.18× 10^{-3} to 0.58 × 10^{-3}.

Exposure dose rate of Mile 3 market (E) ranges from 0.008 to 0.021 mRh^{-1}. Food spices area of the market recorded the highest radiation exposure rate of 0.021 mRh^{-1} due to radiation emission from the natural and artificial food spices. The absorbed dose rate ranges from 69.6 to 182.7 $nGyh^{-1}$ while the annual effective dose calculated ranges from 0.11 to 0.28 $mSvy^{-1}$. The excess lifetime cancer risk estimated ranges from 0.29× 10^{-3} to 0.76 × 10^{-3}. Exposure dose rate of Creek Road market (F) ranges from 0.009 to 0.018 mRh^{-1} while the absorbed dose rate ranges from 78.3 to 156.6 $nGyh^{-1}$. The annual effective dose calculated ranges from 0.12 to 0.24 $mSvy^{-1}$ while the excess lifetime cancer risk estimated ranges from 0.33× 10^{-3} to 0.65 × 10^{-3}. Exposure dose rate of Rumuokoro market (G) ranges from 0.009 to 0.022 mRh^{-1} while the absorbed dose rate ranges from 78.3 to 191.4 $nGyh^{-1}$. The annual effective dose calculated ranges from 0.120 to 0.29 $mSvy^{-1}$ while the excess lifetime cancer risk estimated ranges from 0.33× 10^{-3} to 0.80 × 10^{-3}. Exposure dose rate of Rumuodumaya slaughter market (H) ranges from 0.009 to 0.019 mRh^{-1} while the absorbed dose rate ranges from 78.3 to 165.3 $nGyh^{-1}$. The annual effective dose calculated ranges from 0.12 to 0.25 $mSvy^{-1}$ while the excess lifetime cancer risk estimated ranges from 0.33× 10^{-3} to 0.69 × 10^{-3}.

Exposure dose rate of Akwaka market (I) ranges from 0.009 to 0.018 mRh^{-1} while the absorbed dose rate ranges from 78.3 to 156.6 $nGyh^{-1}$. The annual effective dose calculated ranges from 0.12 to 0.24 $mSvy^{-1}$ while the excess lifetime cancer risk estimated ranges from 0.33× 10^{-3} to 0.65 × 10^{-3}. Exposure dose rate of Rukpokwu international market (J) ranges from 0.011 to 0.023 mRh^{-1} while the absorbed dose rate ranges from 95.7 to 200.1 $nGyh^{-1}$. The annual effective dose calculated ranges from 0.147 to 0.307 $mSvy^{-1}$ while the excess lifetime cancer risk estimated ranges from 0.40× 10^{-3} to 0.836 × 10^{-3}. The lowest mean exposure rate of 0.011mRh^{-1} was at Mile 1 (D) market due to the type of product which is mainly clothes and the highest mean exposure dose rate of 0.017mR/h was measured at Rukpokwu international (J). Fig. 1 shows the comparison of the mean exposure rate of the ten markets with international commission radiological protection (ICRP) [22] standard. From Fig. 1, Rumuokoro (G) with an average exposure of 0.014±0.0043 mRh^{-1}, Rumuodomaya slaughter market (H) with an average exposure of 0.014±0.0029 mRh^{-1} and Rukpokwu international market (J) with an average exposure of 0.017±0.0037 mRh^{-1} were seen to be higher than the permissible value of 0.013 mRh^{-1} while the mean exposure of other markets are within the standard. Studies on radioactivity levels in food spices clearly reveals that some artificial and natural food spices has

Table 1. Exposure rates of Fimie market (A) and their radiological parameters

S/n	Sample area code	geographical position	Average exposure dose rate (mR/h)	Absorbed dose rate (D) (nGy/h)	Annual effective dose (mSv/yr)	Excess lifetime cancer risk (ELCR) X 10^{-3}
1	A_1	N04°47'14.4" E007°02'08.3"	0.016	139.20	0.213	0.581
2	A_2	N04°47'14.0" E007°02'08.9"	0.012	104.40	0.160	0.436
3	A_3	N04°47'12.1" E007°02'09.8"	0.012	104.40	0.160	0.436
4	A_4	N04°47'09.5" E007°02'12.0"	0.012	104.40	0.160	0.436
5	A_5	N04°47'12.7" E007°02'10.8"	0.011	95.70	0.147	0.400
6	A_6	N04°47'11.7" E007°02'11.5"	0.008	69.60	0.107	0.291
7	A_7	N04°47'11.9" E007°02'10.8"	0.013	113.10	0.173	0.472
8	A_8	N04°47'12.3" E007°02'11.3"	0.014	121.80	0.187	0.509
9	A_9	N04°47'12.5" E007°02'10.6"	0.010	87.00	0.133	0.363
10	A_{10}	N04°47'12.8" E007°02'10.3"	0.011	95.70	0.147	0.400
Mean			**0.012±0.002**	**103.50±18.9**	**0.159±0.03**	**0.432±0.08**

Table 2. Exposure rates of Trans Amadi slaughter market (B) and their radiological parameters

S/n	Sample area code	Geographical position	Average exposure dose rate (mR/h)	Absorbed dose rate D (nGy/h)	Annual effective dose (mSv/yr)	Excess lifetime cancer risk ELCR X 10^{-3}
1	B_1	N04°48'47.5" E007°02'40.5"	0.012	104.40	0.160	0.436
2	B_2	N04°48'49.4" E007°02'40.1"	0.011	95.70	0.147	0.400
3	B_3	N04°48'48.3" E007°02'39.6"	0.018	156.60	0.240	0.654
4	B_4	N04°48'49.4" E007°02'41.0"	0.011	95.70	0.147	0.400
5	B_5	N04°48'49.2" E007°02'40.3"	0.013	113.10	0.173	0.472
6	B_6	N04°48'50.1" E007°02'42.9"	0.014	121.80	0.187	0.509
7	B_7	N04°48'50.3" E007°02'43.1"	0.013	113.10	0.173	0.472
8	B_8	N04°48'49.6" E007°02'42.2"	0.011	95.70	0.147	0.400
9	B_9	N04°48'49.9" E007°02'43.3"	0.010	87.00	0.133	0.363
10	B_{10}	N04°48'48.5" E007°02'42.9"	0.016	139.20	0.213	0.581
Mean			0.013±0.003	112.20±22	0.172±0.03	0.47±0.09

Table 3. Exposure dose rate of fruit garden market (C) and their radiological parameters

S/n	Sample Area Code	Geographical Position	Average exposure dose rate (mR/h)	Absorbed Dose rate D (nGy/h)	Annual Effective Dose (mSv/yr)	Excess Lifetime Cancer Risk ELCR X 10^{-3}
1	C_1	N04°48'48.5" E007°00'02.9"	0.009	78.30	0.120	0.327
2	C_2	N04°47'57.3" E007°00'02.2"	0.012	104.40	0.160	0.436
3	C_3	N04°47'55.5" E007°00'03.7"	0.017	147.90	0.227	0.618
4	C_4	N04°47'54.0" E007°00'01.9"	0.013	113.10	0.173	0.472
5	C_5	N04°47'54.9" E007°00'00.6"	0.011	95.70	0.147	0.400
6	C_6	N04°47'55.2" E007°00'01.2"	0.012	104.40	0.160	0.436
7	C_7	N04°47'55.2" E007°00'01.3"	0.009	78.30	0.120	0.327
8	C_8	N04°47'56.0" E007°00'02.2"	0.010	87.00	0.133	0.363
9	C_9	N04°47'56.0" E007°00'03.0"	0.014	121.80	0.187	0.509
10	C_{10}	N04°47'57.0" E007°00'02.7"	0.013	113.10	0.173	0.472
Mean			0.012±0.002	104.40±21	0.160±0.03	0.436±0.09

relatively high radionuclide content [14]. This actually reflected in the result of this work which recorded higher background radiation levels within the market area where they sell food spices. Radiation emission from other products in the market and the environment could enhance the background radiation levels of some markets sampled.

Table 4. Exposure dose rate of mile 1 market (D) and their radiological parameters

S/n	Sample area code	Geographical position	Average exposure dose rate (mR/h)	Absorbed Dose rate D (nGy/h)	Annual effective dose (mSv/yr)	Excess lifetime cancer risk ELCR X 10^{-3}
1	D_1	N04°47'20.0" E007°00'07.4"	0.011	95.70	0.147	0.400
2	D_2	N04°47'24.0" E007°00'03.8"	0.014	121.80	0.187	0.509
3	D_3	N04°47'31.1" E006°59'57.0"	0.012	104.40	0.160	0.436
4	D_4	N04°47'33.1" E006°59'54.7"	0.013	113.10	0.173	0.472
5	D_5	N04°47'31.5" E006°59'53.2"	0.010	87.00	0.133	0.363
6	D_6	N04°47.555' E006°59.921'	0.013	113. 10	0.173	0.472
7	D_7	N04°47.497' E006°59.978'	0.016	139.20	0.213	0.581
8	D_8	N04°47'33.6" E006°59'51.2"	0.010	87.00	0.133	0.363
9	D_9	N04°47'37.1" E006°59'52.6"	0.005	43.50	0.067	0.182
10	D_{10}	N04°47'41.0" E006°59'51.5"	0.010	87.00	0.133	0.363
Mean			0.011±0.003	98.20±27.00	0.152±0.04	0.414±0.11

Table 5. Exposure dose rate of mile 3 market (E) and their radiological parameters

S/n	Sample Area Code	Geographical Position	Average Exposure dose Rate (mR/h)	Absorbed Dose rate D (nGy/h)	Annual Effective Dose (mSv/yr)	Excess lifetime cancer risk ELCR X 10^{-3}
1	E_1	N04°48.267' E006°59.429'	0.021	182.70	0.280	0.763
2	E_2	N04°48.260' E006°59.414'	0.014	121.80	0.187	0.509
3	E_3	N04°48.298' E006°59.458'	0.010	87.00	0.133	0.363
4	E_4	N04°48'18.1" E006°59'30.0"	0.018	156.60	0.240	0.654
5	E_5	N04°48.304' E006°59.481'	0.010	87.00	0.133	0.363
6	E_6	N04°48.284' E006°59.514'	0.014	121.80	0.187	0.509
7	E_7	N04°48.299' E006°59.536'	0.009	78.30	0.120	0.327
8	E_8	N04°48'19.7" E006°59'34.5"	0.019	165.30	0.253	0.691
9	E_9	N04°48.329' E006°59.588'	0.008	69.60	0.107	0.291
10	E_{10}	N04°48.269' E006°59.615'	0.010	87.00	0.133	0.363
Mean			0.013±0.003	115.20±40.00	0.177±0.06	0.48±0.07

The absorbed doses estimated are higher than the world permissible value of 84.0 $nGyh^{-1}$. Mean outdoor gamma dose rate measured for this study are higher than the values previously reported by Uosif et al. [23] and Rafique [19] (106 $nGyh^{-1}$ and 102 $nGyh^{-1}$) respectively. The measured outdoor gamma dose rates are also within the values reported in Turkey (78.3-135.7

nGyh-1) by Erees [8]. The highest outdoor gamma dose rate measured at Rukpokwu market (200.1 $nGyh^{-1}$) is higher than the values previously reported [23,19]. The measured outdoor gamma dose rates are also higher than the values reported in Turkey (78.3-135.7 $nGyh^{-1}$) [8]. This could be due to variations in the activities /products within the markets and also in geologic composition of the area.

Figs. 2 and 3 shows the comparison of annual effective dose rate and excess lifetime cancer risk with their world standards. The annual effective dose rate estimated from absorbed dose of the markets sampled were within the world acceptable value while in all the markets, the excess lifetime cancer risk were higher than the world standard. The values are found to be higher than average world standard of 0.29 x 10^{-3} as shown in Fig. 3. The implication of this is

Table 6. Exposure dose rate of creek road market (F) and their radiological parameters

S/n	Sample area code	Geographical Position	Average exposure dose rate (mR/h)	Absorbed dose rate D (nGy/h)	Annual effective dose (mSv/yr)	Excess lifetime cancer risk ELCR X 10^{-3}
1	F_1	N04°45'31.4" E007°01'26.0"	0.009	78.30	0.120	0.327
2	F_2	N04°45'30.9" E007°01'23.6"	0.011	95.70	0.147	0.400
3	F_3	N04°45'31.0" E007°01'24.6"	0.014	121.80	0.187	0.509
4	F_4	N04°45'31.1" E007°01'27.1"	0.014	121.80	0.187	0.509
5	F_5	N04°45'29.2" E007°02'28.9"	0.011	95.70	0.147	0.400
6	F_6	N04°45'28.9" E007°01'30.1"	0.018	156.60	0.240	0.654
7	F_7	N04°45'31.9" E007°01'29.8"	0.014	121.80	0.187	0.509
8	F_8	N04°45'31.4" E007°01'35.3"	0.009	78.30	0.120	0.327
9	F_9	N04°45.522' E007°01.503'	0.011	95.70	0.147	0.400
10	F_{10}	N04°45.506' E007°01.480'	0.012	104.40	0.160	0.436
Mean			0.012±0.003	107.00±23.90	0.164±0.04	0.447±0.10

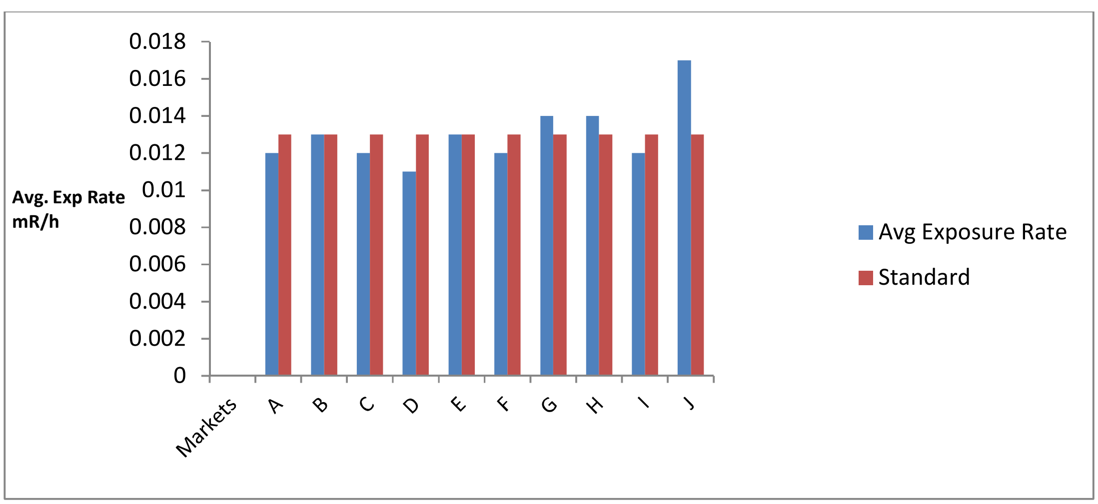


Fig. 1. Comparison of average exposure dose rate for each market with world average

Table 7. Exposure dose rate in Rumuokoro Market (G) and their Radiological Parameters

S/n	Sample area code	Geographical position	Average exposure dose rate (mR/h)	Absorbed Dose rate D (nGy/h)	Annual Effective Dose (mSv/yr)	Excess lifetime cancer risk ELCR X 10^{-3}
1	G_1	N04°51’59.4” E006°59’57.6”	0.013	113.10	0.173	0.472
2	G_2	N04°51’58.9” E006°59’57.7”	0.014	121.80	0.187	0.509
3	G_3	N04°51’59.1” E006°59’58.1”	0.018	156.60	0.240	0.654
4	G_4	N04°51’58.5” E006°59’59.4”	0.010	87.00	0.133	0.363
5	G_5	N04°51’59.1”’ E006°59’59.8”	0.012	104.40	0.160	0.436
6	G_6	N04°51’58.8” E007°00’00.7”	0.020	174.00	0.267	0.727
7	G_7	N04°51’58.9” E006°59’59.6”	0.009	78.30	0.120	0.327
8	G_8	N04°51’59.1” E006°59’58.8”	0.022	191.40	0.293	0.800
9	G_9	N04°51’58.9” E006°59’58.9”	0.012	104.40	0.160	0.436
10	G_{10}	N04°51’59.1” E006°59’58.2”	0.012	104.40	0.160	0.436
Mean			0.014±0.004	123.50±37.00	0.189±0.06	0.516±0.16

Table 8. Exposure dose rate of rumuodomaya slaughter market (H) and their radiological parameters

S/n	Sample Area Code	Geographical Position	Average Exposure dose Rate (mR/h)	Absorbed Dose rate D (nGy/h)	Annual Effective Dose (mSv/yr)	Excess Lifetime Cancer Risk ELCR X 10^{-3}
1	H_1	N04°52’09.2” E006°59’56.0”	0.014	121.80	0.187	0.509
2	H_2	N04°52’10.4” E006°59’56.3”	0.018	156.60	0.240	0.654
3	H_3	N04°52’11.1” E006°59’56.2”	0.013	113.10	0.173	0.472
4	H_4	N04°52’12.2” E006°59’56.7”	0.019	165.30	0.253	0.691
5	H_5	N04°52’11.9” E006°59’57.6”	0.012	104.40	0.160	0.436
6	H_6	N04°52’11.1” E006°59’57.7”	0.013	113.10	0.173	0.472
7	H_7	N04°52’13.9” E006°59’56.5”	0.014	121.80	0.187	0.509
8	H_8	N04°52’13.0” E006°59’56.1”	0.009	78.30	0.120	0.327
9	H_9	N04°52’11.1” E006°59’56.8”	0.014	121.80	0.187	0.509
10	H_{10}	N04°52’12.0” E006°59’56.6”	0.012	104.40	0.160	0.436
Mean			0.014±0.003	120.00±25.00	0.184±0.04	0.50±0.012

that there probability that individuals exposed to this radiation may likely develop cancer within their lifetime. Fig. 4 shows the radiation contour of five of the sampled markets showing the distribution pattern of the terrestrial radiation within the market places. In some markets, they are sparsely distributed while in some, they are evenly distributed. In Rukpokwu international market almost every sample point recorded higher background radiation and are more concentrated within the building material and food spices section of the market. This implies that there are high emission of radiation from those building materials and food spices. The emission from the nearby waste dump might have contributed to the enhanced radiation level of the market.

Table 9. Exposure Dose rate in Akwaka Market (I) and their Radiological Parameters

S/n	Sample Area Code	Geographical Position	Average Exposure dose Rate (mR/h)	Absorbed Dose rate D (nGy/h)	Annual Effective Dose (mSv/yr)	Excess Lifetime Cancer Risk ELCR X 10^{-3}
1	I_1	N04°52'58.3" E007°00'03.7"	0.015	130.50	0.200	0.545
2	I_2	N04°52'58.8" E007°00'03.8"	0.014	121.80	0.187	0.509
3	I_3	N04°52'59.3" E007°00'02.9"	0.008	69.60	0.107	0.291
4	I_4	N04°52'58.8" E007°00'02.9"	0.009	78.30	0.120	0.327
5	I_5	N04°52'58.7" E007°00'03.7"	0.012	104.40	0.160	0.436
6	I_6	N04°52'59.1" E007°00'03.6"	0.010	87.00	0.133	0.363
7	I_7	N04°52'59.2" E007°00'03.9"	0.009	78.30	0.120	0.327
8	I_8	N04°52'59.0" E007°00'03.1"	0.018	156.60	0.240	0.654
9	I_9	N04°52'58.6" E007°00'03.3"	0.011	95.70	0.147	0.400
10	I_{10}	N04°52'58.7" E007°00'02.9"	0.017	147.90	0.227	0.618
Mean			0.012±0.004	107.00±30.70	0.164±0.05	0.447±0.13

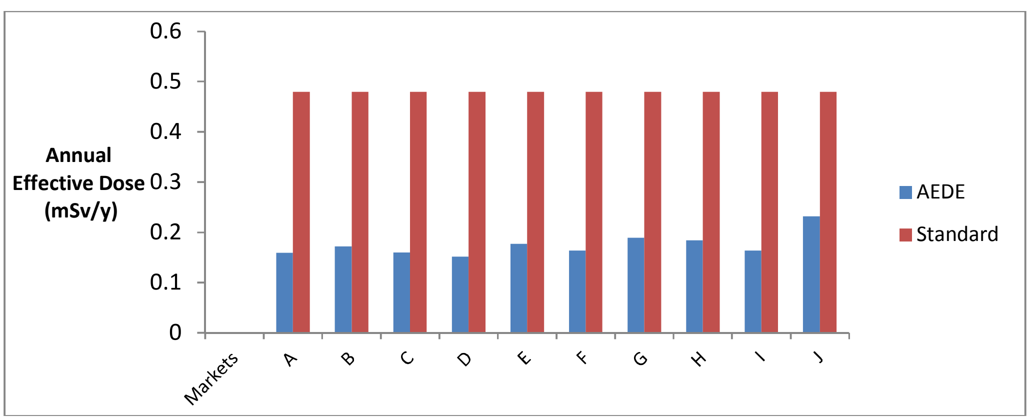


Fig. 2. Comparison of annual effective dose and world average

Table 10. Exposure Dose rate in Rukpokwu International Market (J) and their Radiological Parameters

S/n	Sample Area Code	Geographical Position	Average Exposure dose Rate (mR/h)	Absorbed Dose rate (D) (nGy/h)	Annual Effective Dose (mSv/yr)	Excess Lifetime Cancer Risk ELCR X 10^{-3}
1	J_1	N04°53'42.7" E006°59'22.5"	0.019	165.30	0.253	0.691
2	J_2	N04°53'44.2" E006°59'21.0"	0.019	165.30	0.253	0.691
3	J_3	N04°53'42.1" E006°59'21.9"	0.017	147.90	0.227	0.618
4	J_4	N04°53'43.7" E006°59'19.9"	0.018	156.60	0.240	0.654
5	J_5	N04°53'43.8" E006°59'17.9"	0.017	147.90	0.227	0.618
6	J_6	N04°53'42.9" E006°59'15.6"	0.011	95.70	0.147	0.400
7	J_7	N04°53'41.2" E006°59'15.9"	0.012	104.40	0.160	0.436
8	J_8	N04°53'41.6" E006°59'17.5"	0.014	121.80	0.187	0.509
9	J_9	N04°53'42.0" E006°59'20.4"	0.020	174.00	0.267	0.727
10	J_{10}	N04°53'43.4" E006°59'16.7"	0.023	200.10	0.307	0.836
Mean			0.017±0.003	147.90±32.00	0.232±0.05	0.618±0.14

Table 11. Mean Exposure dose rate and their Radiological parameters of the various markets

S/n	Sample Area (markets)	Geographical Position	Average Exposure dose Rate (mR/h)	Absorbed Dose rate D (nGy/h)	Annual Effective Dose (mSv/yr)	Excess Lifetime Cancer Risk ELCR X 10^{-3}
1	Fimie (A)	N04°47'13.5" E007°02'0.4"	0.012±0.0022	103.5±18.99	0.159±0.029	0.432±0.079
2	Trans Amadi slaughter (B)	N04°48'49.2" E007°02'41.6"	0.013±0.0025	112.2±21.88	0.172±0.033	0.467±0.091
3	Fruit garden (C)	N04°47'56.0" E007°00'02.2"	0.012±0.0024	104±21.31	0.160±0.033	0.436±0.086
4	Mile 1 (D)	N04°47'32.3" E007°00'52.1"	0.011±0.0030	98.2±27.9	0.152±0.40	0.414±0.108
5	Mile 3 (E)	N04°48'26.9" E006°59'46.8"	0.013±0.0046	115.7±40.40	0.177±0.062	0.483±0.169
6	Creek road (F)	N04°45'34.9" E007°01'32.4"	0.012±0.0028	107.0±23.93	0.164±0.037	0.447±0.100
7	Rumuokoro (G)	N04°51'59.0" E006°59'52.9"	0.014±0.0043	123.5±37.77	0.189±0.058	0.516±0.158
8	Rumuodomaya slaughter (H)	N04°52'11.6" E006°59'56.7"	0.014±0.0029	120.0±25.22	0.184±0.039	0.502±0.105
9	Akwaka (I)	N04°52'58.9" E007°00'03.4"	0.012±0.0035	107.0±30.70	0.164±0.047	0.447±0.128
10	Rukpokwu international J)	N04°53'42.8" E006°59'18.9"	0.017±0.0037	147.9±32.29	0.232±0.049	0.618±0.135

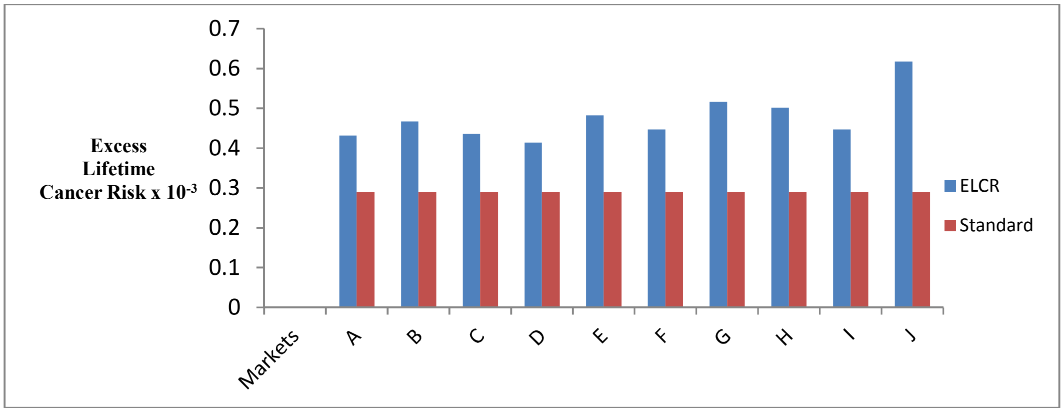
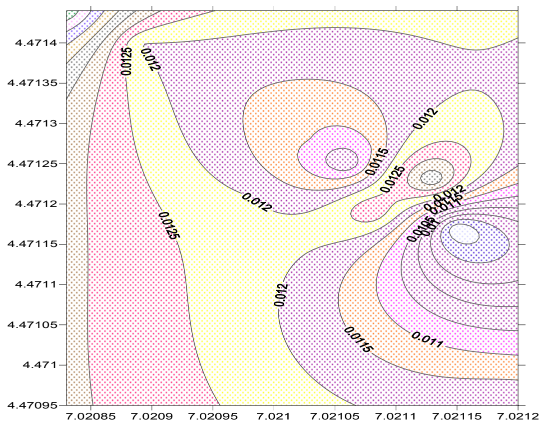
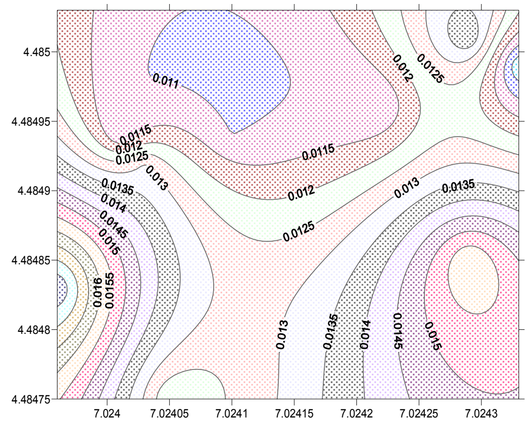


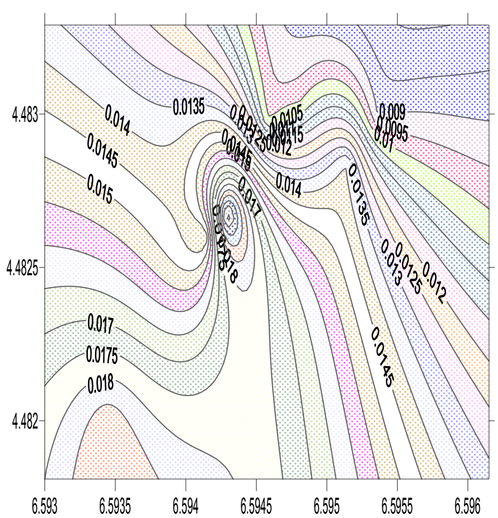
Fig. 3. Comparison of excess lifetime cancer risk with world average



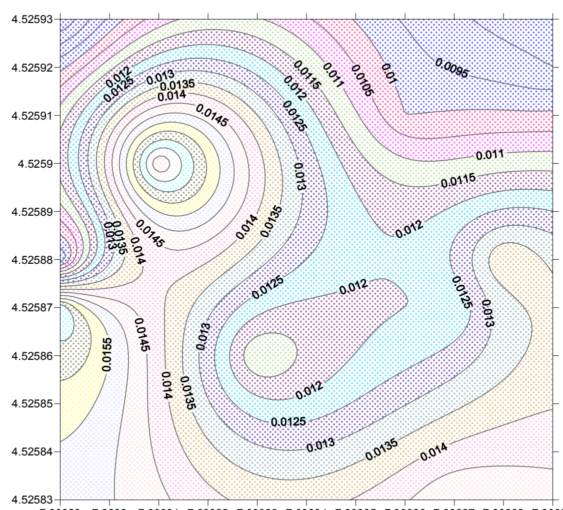
Fimie Market



Trans –Amadi Slaughter Market



Mile 3 Market



Akwaka Market

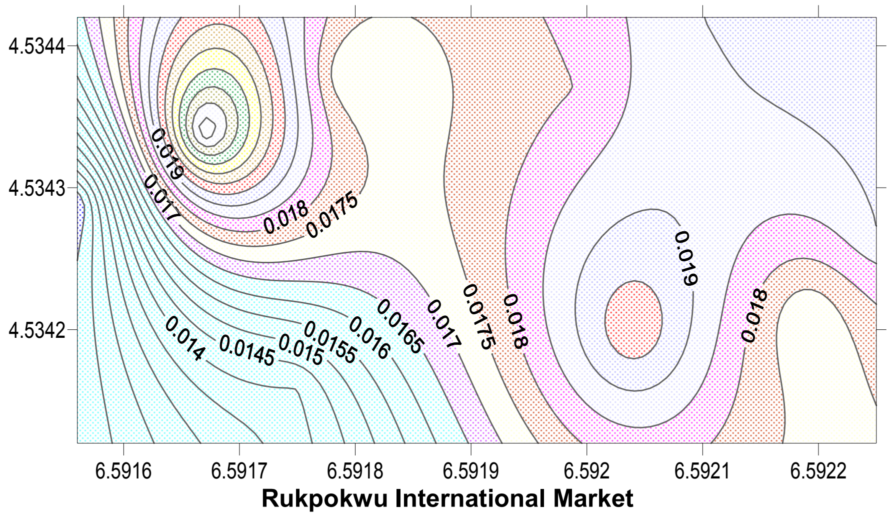


Fig. 4. Contour map of some of the markets sampled

4. CONCLUSION

The background radiation level of ten markets in in Port Harcourt metropolis have been studied using radiation meter (Radalert-100 and Digilert-200). The result revealed that the background ionizing radiation of three markets (Rukpokwu , Rumuokoro and Rumuodumaya markets) were above ICRP permissible level, but however no immediate health effects are expected. Absorbed doses in all the markets sampled exceeded the world permissible value of 84 $nGyh^{-1}$and excess lifetime cancer risk exceeded the safe value of $0.29 \times 10^{-3.}$ There is no immediate health implication of this exposure. Notwithstanding it is recommended that awareness and radiation protection mechanisms should be put in place in public commercial places.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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