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Background Gamma Radiation in Nigerian Market Environment

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Abstract: Human exposure to ionizing radiation from natural sources is an unending and unpreventable phenomenon on earth. Radiation profile and exposure risks for some major markets in Port Harcourt metropolis have been ascertained using radiation exposure rate meter (Radalert-100). The exposure rate measured at mile 3 market and its environs ranged from 0.001±0.0001 to 0.022±0.003 mRh^{-1} with mean value of 0.014±0.002 mRh^{-1} while that measured at mile 1 ranged from 0.011±0.001 to 0.018±0.003 mRh^{-1} with mean value of 0.014±0.002 mRh^{-1}. The exposure rate measured at Rumu-Okoro market ranged from 0.010±0.0001 to 0.018±0.003 mRh^{-1}. The exposure rates measured at the three markets are relatively equal but slightly higher than the recommended safe value of 0.013 mRh^{-1}. The mean absorbed doses estimated from the exposure rates for Mile 3, Mile 1 and Rumu-Okoro are 119.2, 113.68 and 114.8 nGyh^{-1} respectively, while their mean equivalent doses are 1.15, 1.19 and 1.11 mSvy^{-1} respectively. The annual effective dose calculated gave mean values of 0.14, 0.16 and 0.168 mSvy^{-1}. These values are lower than the stipulated safe value of 1.0 mSvy^{-1}. The excess lifetime cancer risk estimated exceeded the recommended values in all the sampling points. From the radiation profile of the sampled markets, no immediate radiation risk is expected though there could be a long term effects on the sellers in those markets.

Keywords: Assessment, Equivalent Dose, Market Environment, Radiation Exposure

Introduction

Natural radioactivity from the environment has three components: Cosmic rays, terrestrial radiation and ingestion (eating, drinking and breathing). Cosmic rays from our Sun and our galaxy and terrestrial radiation from the Earth crust as well as incorporations of radioisotopes from the biosphere represent whole-body exposures. A special role is played by the inhalation of the radioactive noble gas radon which, in particular, represents an exposure for the lungs and the bronchi. In addition to these natural sources further exposures due to technical, scientific and medical installations developed by modern society occur. The existence of natural radioactive substances, however demonstrates that radioactivity and the development of life coexisted since the very earliest times on our planet, (Grupen, 2010).

Human exposure to ionizing radiation from natural sources is an unending and unpreventable phenomenon on earth (Sadiq and Agba, 2011). Human exposure to natural radiation exceeds that from all man-made sources (including: Medical, weapons testing and nuclear technologies) put together. The two main contributors to natural radiation exposures are: High-speed cosmic ray particles incidents in the earth's atmosphere and the primordial radionuclides present in the Earth's crust which are present everywhere, including the human body. Some exposure to natural radiation sources is modified by human activities. Examples are: Natural radionuclides released into the environment in mineral processing and phosphate fertilizer processing, fossil fuel combustion and quarrying activities, which enhances radiation exposures. Some people are exposed to enhanced levels of radiation at their places of work (Sadiq and Agba, 2011).

External exposure outdoors arises from terrestrial radionuclides present in trace levels in all soil types. Radiation emitted by these radionuclides within 15-30cm of the topsoil reach the earth surface (Farai and Vincent, 2006). Only those radionuclides with half-lives comparable to the age of the earth and their decay products, exist in significant quantities in these materials. The estimation of exposure to ionizing radiation is an important goal of regulatory authorities and radiation protection scientists. In public health management of radiation emergencies, one of the essential components of integrated assessment is to quickly and accurately assess and categorize the exposure.

Farai and Vincent (2006) measured the outdoor radiation levels in Abeokuta, Nigeria using Thermo luminescent dosimetry and reported that the equivalent dose due to outdoor exposure in the city ranged from 0.19 to 1.64 mSv/yr and a mean of 0.45 mSv/yr and the mean dose of extra-terrestrial radiation was estimated to be 0.18 mSv/yr in the city. A nationwide survey conducted by (Farai and Jibiri, 2000) of terrestrial radiation, using the technique of in-situ gamma spectrometry reported that the mean annual effective dose equivalent is 0.27 mSv/yr. The radiation can cause injuries and clinical symptoms; which may include a chromosomal transformation, cancer induction, free radical formation, bone necrosis and radiation catractogenesis (Norman, 2008). The injuries and clinical symptoms could be caused at both high doses and prolonged low dose exposure. Because of the lethal effects of ionizing radiation, the practice has been to monitor and assess the levels of exposure and keep one's exposure to ionizing radiation as low as reasonably achievable.

Previous researchers 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 (Foland *et al*., 1995; Bamidele, 2013). Most markets in Port Harcourt are not lockup shops but open-roof cover structures mostly where different products like food, building materials, fabrics, food spices, etcetera, are 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 it's spices, soil which has been established that their radionuclide content are high and can be a source of radiation exposure (Ajayi *et al*., 2012). It is then imperative to determine the outdoor terrestrial radiation levels in some major markets in Port Harcourt. The aim of this study therefore is to measure the terrestrial outdoor gamma dose rates in four major markets and determine the associated radiation risk to the general public that uses such markets and compare their radiation levels.

Materials and Methods

The Radalert 100X used in this study is a digital pocket Geiger counter designed for general purpose monitoring of radioactivity. It detects alpha, beta, gamma and X- radiation, visually shown on a highly accurate digital display with readings in your choice of both CPM (to 110,000 counts per minutes) and mR/hr (up to 110 mR/h) or switchable to the international standard of µSv/h (up to 1,100 µSv/h). The detector is a halogen-quenched Geiger-Mueller tube with mica end window (LND712 or equivalent). Mica window density of 1.5-2.0 mg/cm^2 with side wall of 0.012 inches #446 stainless steel. The energy sensitivity 1000 CPM /mR h^{-1} referenced to Cs-137 and its maximum alpha and beta efficiencies are 10 and 15% respectively. Temperature range of -20°C to 50°C and -4° to 122°F.

An in-situ approach of background ionizing radiation measurement was adopted to enable samples maintain their original environmental characteristics. A well calibrated Radiation monitor, Digilert-200 and Radalert –100 nuclear radiation monitoring meter (S.E. International Incorporation, Summer Town, USA), containing a Geiger-Muller tube capable of detecting alpha, beta, gamma and X-rays was used within the temperature range of -10°C to 50°C and a Geographical Positioning System (GPS) was used to measure the precise location of sampling. The Geiger-muller tube generates a pulse current each time radiation passes through the tube and causes ionization (Jibiri *et al*., 2011). Each pulse is electronically detected and registered as a count. The radiation meters were calibrated with a 137Cs source of specific energy and set to measure exposures rate in milli Roentgen per hour (mRhr^{-1}). The meter has an accuracy of ±15%. The tube of the radiation monitoring meter was raised to a standard height of 1.0 m above the ground (Ajayi and Laogun, 2006). With its window facing the suspected source, while the GPS reading was taken at that spot.

Measurements were taken within the hours of 10 am - 4.00 pm since exposure rate meter has a peak response to environmental radiation within these hours. In order to ensure quality assurance the provisions taken include: Two measuring instruments were deplored to field and standardization of the measuring instruments before use was done, multiplicity of measurement for each sample point (n = 4 for radiation measurements for each sample point). The switch (knob) was turned to return the meter to zero after each measurement. According to (Avwiri *et al*., 2013), the generated data were converted to absorbed dose rate nGy h^{-1} using the relation for the external exposure rate as follows:

$$1uR/h = 8.7\,nGy/h = 8.7\times10^{-3}uGy/\left(1/8760y\right) \tag{1}$$

Radiological Parameters

Equivalent Dose Rate

To estimate the whole body equivalent dose rate over a period of one year, we used the National Council on Radiation Protection and Measurement's recommendation (Ononugbo *et al*., 2011):

$$1mRh^{-1} = \frac{0.96 \times 24 \times 365}{100} mSvy^{-1} \qquad (2)$$

The results of the calculated whole body equivalent dose rate are presented in Table 1-3.

Absorbed Dose Rate (D)

The data obtained for the external exposure rate in μRh^{-1} were also converted into absorbed dose rates nGyh^{-1} using the conversion factor (Arogunjo *et al*., 2004; Avwiri *et al*., 2013):

$$1\mu Rh^{-1} = 8.7nGyh^{-1} = \frac{8.7 \times 10^{-3}}{\left(\frac{1}{8760y}\right)} = 76.212\,\mu Gyy^{-1} = 76.212\mu Gyy^{-1} \qquad (3)$$

Annual Effective Dose Equivalent (AEDE)

The computed absorbed dose rates were used to calculate the Annual Effective Dose Equivalent (AEDE) received by the market users. In calculating AEDE, dose conversion factor of 0.7 Sv/Gy and the occupancy factor for outdoor of 0.25 (6 h out of 24 h) was used. The occupancy factor for outdoor was calculated based upon interviews with traders. People of the study area spend almost 6 h outdoor due to the nature of their routine. The annual effective dose was estimated using the following relation:

$$AEDE(Outdoor)(mSvy^{-1}) = D(nGyh^{-1}) \times 8760h \times \frac{0.7Sv}{Gy} \times 0.25 \qquad (4)$$

Excess Life Cancer Risk (ELCR)

The annual effective dose calculated was used to estimate the Excess Lifetime Cancer Risk (ELCR) using Equation 5:

$$ELCR = AEDE \times Average\,duration\,of\ life \times Risk\ factor\ Rf \qquad (5)$$

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

Results

The in-situ measurement of radiation exposure rate of three major markets in Port Harcourt metropolis are presented in Table 1 to 3.

Table 1: Radiation exposure rate and their radiological parameters of mile 3 market area

Location	GPS Readings	Average exposure rate (mR/h)	Absorbed dose rate (nGy/h)	Equivalent dose rate (mSv/y)	AEDE (mSv/y)	ELCR ($\times 10^{-3}$)
M_1	N04°48'14.7'' E006°59'25.2''	0.010±0.001	87.000	0.841	0.013	0.046
M_2	N04°48'11.4'' E006°59'25.9''	0.013±0.002	113.100	1.090	0.173	0.606
M_3	N04°48'09.9'' E006°59'25.7''	0.018±0.003	156.600	1.512	0.240	0.840
M_4	N04°48'14.8'' E006°59'37.3''	0.022±0.004	191.400	1.851	0.293	1.026
M_5	N04°48'17.7'' E006°59'40.5''	0.010±0.001	87.000	0.841	0.013	0.046
M_6	N04°48'20.1'' E006°59'36.4''	0.001±0.001	8.700	0.080	0.001	0.005
M_7	N04°48'29.9'' E006°59'09.0''	0.019±0.003	165.300	1.602	0.253	0.886
M_8	N04°48'21.3'' E006°59'17.2''	0.011±0.001	95.700	0.931	0.015	0.053
M_9	N04°48'23.1'' E006°59'28.3''	0.016±0.003	139.200	1.350	0.213	0.746
M_{10}	N04°48'23.1'' E006°59'35.0''	0.014±0.002	121.800	1.183	0.187	0.655
M_{11}	N04°48'23.0'' E006°59'37.9''	0.016±0.003	139.200	1.350	0.213	0.746
M_{12}	N04°48'18.7'' E006°59'35.2''	0.010±0.001	87.000	0.841	0.013	0.046
M_{13}	N04°48'14.7'' E006°59'30.3''	0.010±0.001	87.000	0.841	0.013	0.046
M_{14}	N04°48'15.9'' E006°59'37.2''	0.011±0.001	95.700	0.931	0.015	0.053
M_{15}	N04°48'13.4'' E006°59'38.5''	0.019±0.003	165.300	1.602	0.253	0.886
M_{16}	N04°48'08.4'' E006°59'41.1''	0.015±0.002	130.500	1.260	0.200	0.700
M_{17}	N04°47'55.5'' E006°59'31.8''	0.018±0.003	156.600	11.52	0.240	0.840
	Average	0.014±0.002	119.240	1.154	0.138	0.484
	ICRP, 2003	0.013	84.00	1.000	0.480	0.290

Table 2: Radiation exposure rate and their radiological parameters of mile 1 market area

Location	GPS readings	Average exposure rate (mR/h)	Absorbed dose rate (nGy/h)	Equivalent dose rate (mSv/y)	AEDE (mSv/y)	ELCR ($\times10^{-3}$)
A1	N04°47'37.5'' E006°59'42.2''	0.014±0.002	121.800	1.183	0.187	0.655
A2	N04°47'36.4'' E006°59'53.1''	0.015±0.002	130.500	1.260	0.200	0.700
A3	N04°47'35.4'' E006°59'52.0''	0.016±0.003	139.200	1.350	0.213	0.746
A4	N04°47'33.4'' E006°59'53.3''	0.011±0.001	95.700	0.931	0.015	0.053
A5	N04°47'34.5'' E006°59'52.5''	0.015±0.002	130.500	1.260	0.200	0.700
A6	N04°47'30.6'' E006°59'52.1''	0.016±0.003	139.200	1.350	0.213	0.746
A7	N04°47'21.9'' E006°59'48.9''	0.013±0.002	113.100	1.090	0.173	0.606
A8	N04°47'27.3'' E006°59'52.7''	0.015±0.002	130.500	1.260	0.200	0.700
A9	N04°47'27.6'' E006°59'55.5''	0.014±0.002	121.800	1.183	0.187	0.655
A10	N04°47'24.8'' E006°59'59.2''	0.015±0.002	130.500	1.260	0.200	0.700
A11	N04°47'19.5'' E007°00'07.3''	0.011±0.001	95.700	0.931	0.015	0.053
A12	N04°47'21.6'' E007°00'09.4''	0.011±0.001	95.700	0.931	0.015	0.053
A13	N04°47'18.0'' E007°00'11.0''	0.014±0.002	121.800	1.183	0.187	0.655
A14	N04°47'14.25'' E007°00'09.1''	0.018±0.003	156.600	1.512	0.240	0.840
A15	N04°47'19.3'' E007°00'02.5''	0.014±0.002	121.800	1.183	0.187	0.655
	Average	0.014±0.002	113.68	1.190	0.162	0.568
	ICRP, 2003	0.013	84.00	1.000	0.480	0.290

Table 3: Radiation exposure rate and their radiological parameters of rumuokoro market area

Location	GPS readings	Average exposure rate (mR/h)	Absorbed dose rate (nGy/h)	Equivalent dose rate (mSv/y)	AEDE (mSv/y)	ELCR ($\times10^{-3}$)
B1	N04°52'02.5'' E006°59'41.6''	0.012±0.001	104.400	1.009	0.160	0.560
B2	N04°52'00.8'' E006°59'50.2''	0.015±0.002	130.500	1.260	0.200	0.700
B3	N04°51'58.3'' E006°59'48.5''	0.010±0.001	87.000	0.841	0.013	0.046
B4	N04°51'53.7'' E006°59'46.4''	0.018±0.003	156.600	1.512	0.240	0.840
B5	N04°51'53.2'' E006°59'42.0''	0.013±0.002	113.100	1.090	0.173	0.606
B6	N04°51'43.3'' E006°59'39.2''	0.012±0.001	104.400	1.009	0.160	0.560
B7	N04°52'05.0'' E006°59'46.1''	0.014±0.002	121.800	1.183	0.187	0.655
B8	N04°52'07.3'' E006°59'54.0''	0.014±0.002	121.800	1.183	0.187	0.655
B9	N04°52'08.2'' E006°59'59.1''	0.013±0.002	113.100	1.090	0.173	0.606
B10	N04°52'10.9'' E006°59'55.9''	0.012±0.001	104.400	1.009	0.160	0.560
B11	N04°52'12.4'' E006°59'56.1''	0.013±0.002	113.100	1.090	0.173	0.606
B12	N04°52'01.7'' E006°59'57.6''	0.012±0.001	104.400	1.009	0.160	0.560
B13	N04°51'59.8'' E006°59'56.2''	0.013±0.002	113.100	1.090	0.173	0.606
B14	N04°51'59.9'' E006°59'57.1''	0.013±0.002	113.100	1.090	0.173	0.606
B15	N04°52'05.7'' E006°59'25.6''	0.014±0.002	121.800	1.183	0.187	0.655
	Average	0.0137±0.002	114.840	1.110	0.168	0.589
	ICRP, 2003	0.013	84.000	1.093	0.480	0.290

Discussion

Assessment of radiation profile and exposure risk from some major markets in Port Harcourt metropolis have been carried out using well calibrated exposure rate meters and the results are as presented in Table 1 to 3. The exposure rate measured in mile 3 market and its environs ranged from 0.001±0.0001 to 0.022±0.003 mRh^{-1} with mean value of 0.014±0.002 mRh^{-1}. The highest radiation level of 0.022±0.002 mRh^{-1} was recorded at M4. The high radiation levels associated with this area might be a function of the geology and geographical altitude of the area. It could also be due to the presence of building materials in the area. Lower values of 0.010±0.0001 mRh^{-1} were recorded at M_1, M_{12} and M_{13} which may be due to type of products being sold in the area of the market.

The exposure rate measured in mile 1 market and its environs ranges from 0.011±0.001 to 0.018±0.003 mRh^{-1} with mean value of 0.014±0.002 mRh^{-1}. The highest radiation level of 0.018±0.003 mRh^{-1} was recorded at A_{14}. The high radiation levels associated with this area might be a function of the products or consumer goods and food spices being sold within the area. The lowest radiation level was recorded at A_4, A_{11} and A_{12}. The exposure rate measured at Rumu-Okoro market ranged from 0.010±0.0001 to 0.018±0.002 mRh^{-1} with mean value of 0.014±0.001 mRh^{-1}. The highest radiation level of 0.018±0.003 mRh^{-1} was recorded at B_4 which could be due to ceramic concentration within the area. The lowest value of 0.010±0.001 mRh^{-1} was recorded at B_3 which is just open area leading to residential houses.

Comparison of the radiation profile of these markets showed that the mean radiation levels of the three markets are relatively equal. The exposure rates measured in these major markets compared well with the result of (Termizi *et al*., 2014) carried out in Akwanga market areas. The results obtained also compared well with the results obtained by (Avwiri *et al*., 2013) from the measurement of the terrestrial radioactivity of the Aluu land fill in Rivers State. The radiation exposure rates measured in this study are relatively higher than the safe limit of 0.013 mRh^{-1}. Figures 1-3 show the radiation contour map of the markets. The relative spacing of the contour lines indicates the relative slope of the surface and the distribution of radiation exposure rates of high values and low values.

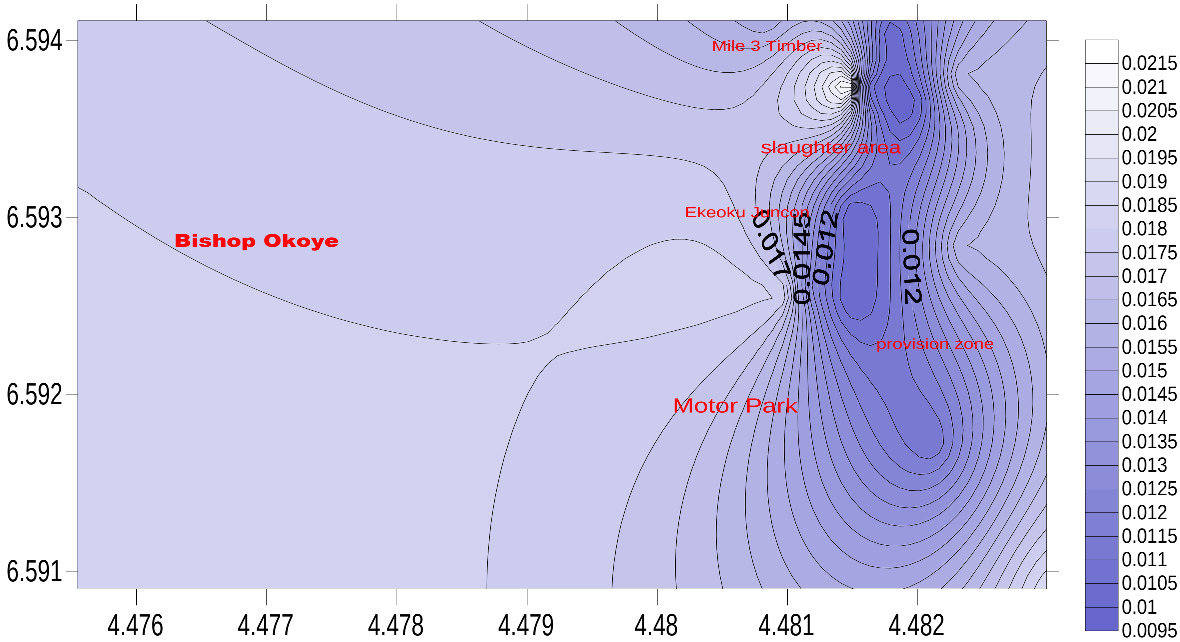

Fig. 1: Radiation contour of Mile 3 market and its environs (x,y axes in deg.) 0.0215 in mR/h

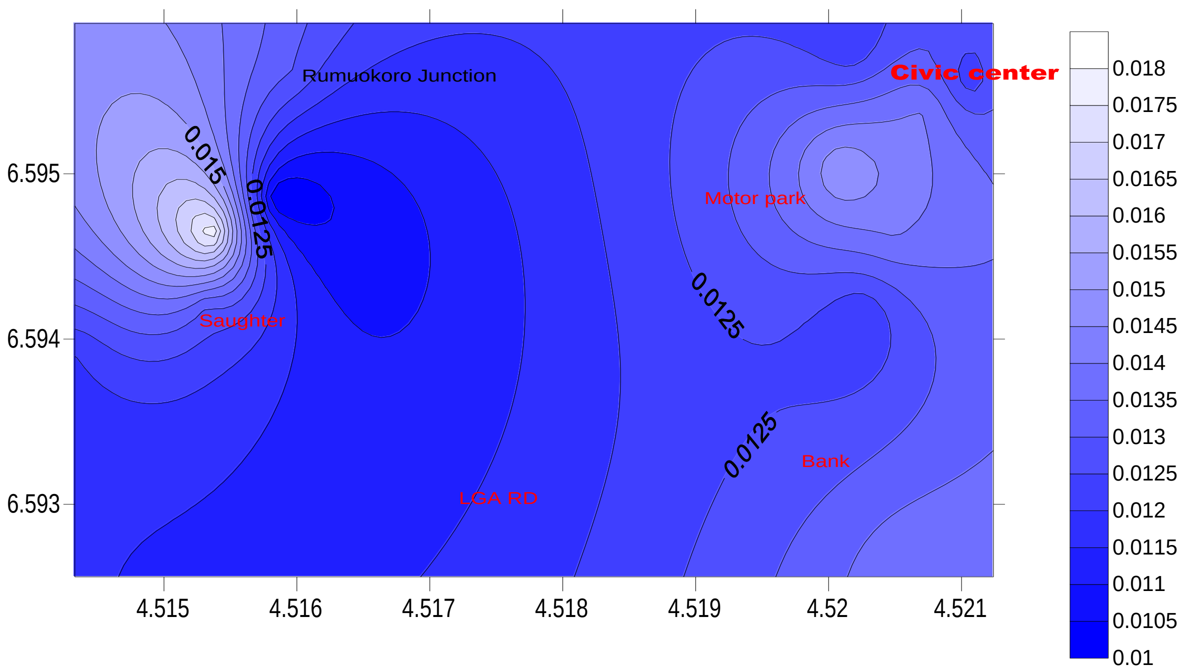

Fig. 2: Radiation contour of Rumuokoro Market and its environs (x,y axes in deg.), 0.018 in mR/h

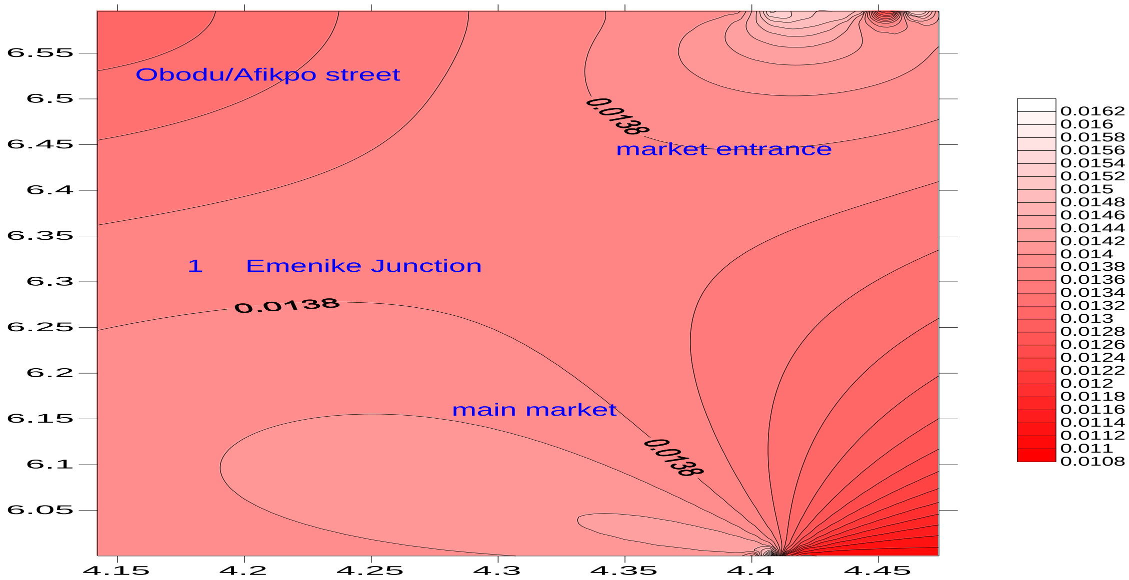

Fig. 3: Radiation contour of mile one Market and its environs (x,y axes in deg.), 0.0162 in mR/h

The mean absorbed dose rate estimated in mile 3, mile 2 and Rumu-Okoro markets and its environs are 119.24, 113.68 and 114.84 nGyh^{-1} respectively. These values are relatively higher than the recommended safe value of 84.0 nGyh^{-1} (ICRP, 2010). The estimated mean equivalent dose mile 3, mile 2 and Rumu-Okoro markets and its environs are 1.15, 1.19 and 1.11 mSvy^{-1} respectively which are within the recommended safe value of 1.0 mSvy^{-1}. The annual effective dose estimated in this study is lower than the recommended safe value and also lower that the value recorded in Akwanga by (Termizi *et al*., 2014) but excess lifetime cancer risk estimated exceeded the recommended value of $0.029\times10^{-3.}$ The result of this work showed generally a low radiation profile and will not cause any immediate radiation health risk.

Conclusion

The natural background radiations of three major markets in Port-Harcourt metropolis have been measured and the results are in good agreement with those determined in previous studies. The radiation profile of the markets are relatively low, therefore the sellers and buyers in these markets are within the internationally accepted safe limit for members of the public. The absorbed dose and excess lifetime cancer risk which was higher than the safe values may not lead to immediate health problem but should be checked for long term exposures. The obtained results should serve as baseline upon which other exposures could be assessed and in the unforeseeable future, serve as bench mark for dosimetric analyses.

Author's Contributions

Chinyere Ononugbo: Designed the study, managed the literature searches and wrote the first draft.

Uzochukwu Anekwe: Performed the statistical data analyses, managed protocols of critical review for significant intellectual content.

Ethics

This article is original and as such has not been previously published. All the authors read and approved the manuscript without ethical issues.

References

Ajayi, J.O., Adedokun, O., & Balogun, B. B. (2012). Levels of Radionuclide contents in stream waters of some selected Rivers sin Ogbomoso land, south west Nigeria. Research Journal of Environmental and Earth Science, 4(9): 835 – 837.

Ajayi, N. O., & Laogun (2006). Variation of environmental gamma radiation in Benin with vertical height. Nig. J .space Res. 2:47-54.

Arogunjo, M. A., Farai, I. P., & Fuwape, I. A. (2004). Impact of Oil and Gas Industry to the Natural Radioactivity Distribution in the Delta Region of Nigeria. Nig. Journal. Phys., 16, 131-136.

Avwiri, G. O. Egieye, J. F., & Ononugbo, C. P. (2013). Radiometric survey of Aluu landfill in Rivers state, Nigeria. Advan. Phys. Theory Appl. 22:24-30.

Bamidele, L. (2013). Measurement of ionizing radiation in high altitude town of Imesi-Ile, Osun State, Southwestern Nigeria. Environmental Research Journal. 7 (4-6): 79-82. ISSN: 1994-5396.

Farai, I. P., & Jibri, N. N. (2000). baseline studies of terrestrial outdoor gamma dose rate levels in Nigeria. Radiat. Prot. Dosim. 88(3): 247-254.

Farai, I. P., & Vincent, U. E. (2006). Outdoor radiation level measurement in Abeakuta Nigeria, by Thermoluminescent Dosimetry. Nig. Journ. Phys. 18(1): 121-123.

Foland, C. K., Kirland, T. K., & Vinnikoov, K. (1995). Observed Climatic Variations and Changes (IPCC scientific Assessment). New York: Cambridge University Press. pp: 101-105.

Grupen, C., 2010. Introduction to Radiation Protection. ISBN:978-3-642-02586-0, Springer Heidelberg Dordrecht, London, New York. 1-2.

ICRP, 2010. Publication 115: Lung cancer risk from radon and progeny and statement on radon. 40(1) 1-64.

Jibiri, N. O., Alausa, S. K., Owofolaju, A. E., & Adeniran, A. (2011). A terrestrial gamma dose rates and physical-chemical properties of farm soils from ex- tin mining locations in Jos-Plateau, Nigeria. African Journal of Environmental Science and Technology; 5(12):1039-1049.

Norman, E. B. (2008) Review of common occupational hazards and safely concerns for nuclear medicine technologist. Journal of Nuclear Med Tech, 36: 11-17.

Ononugbo, C. P., Avwiri, G. O., & Chad-Umoren, Y. E. (2011). Impact of Gas Exploitation on the Environmental Radioactivity of Ogba/Egbema/Ndoni Area, Nigeria. Energy and Environment, 22(8), 1017-1028.

Sadiq, A. A., & Agba, E. H. (2011). Background Radiation in Akwanga, Nigeria. Facta University: Working and Livi ng Environmental Protection 8(1):7-11.

Termizi, Ramli A., Aliyu, A. S., Agba, E. H., & Saleh, M. A. (2014). Effective dose from natural background radiation in Keffi and Akwanga Towns, cenrtral Nigeria. International Journal of Radiation Research, 12(1):1-6.