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Measurement Of Background Ionizing Radiation And Evaluation Of Lifetime Cancer Risk In Highly Populated Motor Parks In Enugu City, Nigeria.

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Abstract: *This study presents the background ionizing radiation (BIR) level of some populated motor parks in Enugu City. The parks are Holy Ghost, Old Park, Abakpa, New Market and Garriki. An In-situ measurement of BIR exposure rate in mR/h was done using a well calibrated portable Geiger Counter nuclear radiation detector (GQ GMC-320 Plus, manufactured by GQ Electronics LLC, USA). The exposure rates were used to evaluate the annual effective dose equivalent (AEDE) and excess lifetime cancer risk (ELCR) within the parks. The mean exposure rates recorded within the areas in order of magnitude are 0.0143±0.0019 mR/h, 0.0135±0.002 mR/h, 0.0114±0.0025 mR/h, 0.0112±0.0014 mR/h and 0.0112±0.0024 mR/h respectively for Abakpa, Gariki, New market, Old Park and Holy Ghost. The mean exposure rate for Holy Ghost, Old Park and New Market are below the world recorded average value of 0.013 mR/h while that of Abakpa and Garriki are slightly greater than the world average value. The corresponding absorbed doses as a result of BIR exposure in the locations are far higher than UNSCEAR recommended safe limit. The estimated mean AEDE at Holy Ghost, Abakpa, Old Park, New Market and Garriki are 0.119±0.025 mSv/yr, 0.153±0.022 mSv/yr, 0.120±0.015 mSv/yr, 0.122±0.027 mSv/yr and 0.144±0.023 mSv/yr respectively with Abakpa having the maximum value and Holy Ghost having the minimum value. All the mean AEDE are lower than the ICRP recommended permissible limits of 1.00 mSv/yr for the general public. The estimated mean ELCR are $(0.418\pm0.087)\times10^{-3}$, $(0.534\pm0.077)\times10^{-3}$, $(0.419\pm0.052)\times10^{-3}$ $(0.426\pm0.094)\times10^{-3}$ and $(0.504\pm0.079)\times10^{-3}$ respectively for Holy Ghost, Abakpa, Old Park, New Market and Garriki. These values are higher than the UNSCEAR reported world average value of 0.29×10^{-3}. The study revealed that the BIR levels within the areas are due to the presence of natural radionuclides which are enhanced by the various human activities carried out in the areas and also due to exhaust emission of hydrocarbon combustion. The study also revealed that Abakpa Park is on higher BIR level than the other Parks. Generally, the radiation level within the areas does not constitute any immediate radiological health effect on the general public but there exist a probability of one developing cancer over a life time of exposure within the studied environments.*

Keywords: *Exposure, Excess lifetime cancer risk, Enugu City, Motor Parks*

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I. Introduction

Radiation has been part of the environment since the creation of the earth and as such, humans are continually and unavoidably exposed daily to varying doses of ionizing radiation [1]. This radiation called background ionizing radiation (BIR) has become a huge public concern all over the world and it is an inevitable part of the natural environment. The main source of radiation in the environment are natural sources which includes cosmic rays which enter the earth from outer space and primordial radionuclides ^{40}K , ^{238}U and ^{232}Th that originated from the earth's crust and are present everywhere in the environment; in rocks, soil, water, sediments, foods and including the human body itself [2]. There is also radioactivity in air due mainly to the presence of radon (^{222}Rn) and thoron (^{220}Rn) gases formed as daughter products in ^{238}U and ^{232}Th decay series, respectively [3], which readily build up in air. In addition to the inevitable natural background radiation sources, man can be exposed to various man-made sources, or natural sources that are enhanced by man's activities. One of such is the burning of coal, petroleum and other fossil fuels.

Petroleum and other Fossil fuels, produced from underground reservoirs in the presence of geological formations contain trace quantities of the naturally occurring radionuclides ^{40}K, ^{238}U and ^{232}Th which are released during combustion [4]. During combustion of petroleum, the radionuclides as well as their decay products and other non-radioactive trace elements become concentrated in the resulting smoke, soot, ash and slag. In power generating plants, cars, trucks and other automobiles, these are released through the exhaust systems of the engines into the immediate environment. Consequent upon the volume of vehicular activities taking place daily at major roads and motor parks in some cities, the immediate environment of these areas is characterized of poor air quality and may as well high background radiation level and exposure as a result of the volume of exhaust emission of smoke and soot with associated radionuclides ^{226}Ra, ^{222}Rn, ^{210}Pb and ^{210}Po which are members of the decay chain of ^{238}U and ^{232}Th found in petroleum. The radionuclides which are released with the smoke, soot and ash into the environment, some been gases, readily mixed up with air particles and dissolve in nearby water body easily find their way into the human body. Radon gas for example is of particularly significant in this regard, this is because the immediate decay products of radon-222 are radionuclides with short half-lives, which attach themselves to fine particles in the air, and when inhaled, they irradiate the tissues of the lung with alpha particles, and increases the risk of lung cancer [5]. The same is true of radon-220 (thoron), but the degree of exposure of the lung is much less. Exposure to radiation and its negative health effects on biological tissues cannot be over emphasized. Radiation damage to DNA may result in gene mutation, chromosomal aberration or breakages and cell death [6] and some modifications that can affect the normal functioning of organs and tissues.

The practice of radiation protection ensures that exposure to radiation should be kept to as low as reasonably achievable, called the ALARA principle. The estimation of exposure to ionizing radiation is therefore an important goal of regulatory authorities and radiation protection scientists [7]. Because of the lethal effect of ionizing radiation, any area with perceived high radiation level is subjected to accurate assessment of the exposure level and quantification and categorization of the radiation dose in order to ensure that the ALARA principle is maintained. With the frequent vehicular exhaust emission in and around major motor parks and garages and in line with the above discussion, the present study is thus aimed at assessing the BIR level in highly populated motor parks in Enugu City, Nigeria and also to estimate the radiological impact on the populace and environment. Background radiation levels in these areas are not yet established; hence the need to have a proper documentation of the radiation level that will serve as a base-line data of essential importance to public health agencies and the government in planning and monitoring of radiation protection programs and for future research purposes.

II. Materials And Methods

The study was carried out in Enugu city, Enugu State of south eastern Nigeria. Enugu city is located between longitudes 7º6′E and 7º54′E and latitudes 5º56′N and 6º52′N [8]. The state shares borders with Abia State and Imo State to the south, Ebonyi State to the east, Benue State to the north-east, Kogi State to the northwest and Anambra State to the west. It is 2545m above the mean sea level, with an area of about 79.25 square kilometers. The soil characteristically consists of hydro-orphic soil which is mineral rich soil and whose morphology is influenced by seasonal water logging caused by underlying impervious shale [8]. The study was carried out between January and March, 2018 in five (5) major motor parks/garages areas in Enugu town namely; Holy Ghost (GH), Old Park (OP), Abakpa (ABP), New market (NM) and Garriki Park (GP).

Measurement of background ionizing radiation (BIR) exposure rate in mR/h was done using a portable GQ GMC-320 Plus Geiger Counter nuclear radiation detector, manufactured by GQ Electronics LLC, USA. The detector can detect β-particles, γ- rays and x-rays. Whenever radiation passes through the Geiger tube, it triggers an electrical pulse for the CPU to register as a count. A total of ten (10) points for each of the location were marked out for measurement. The points were uniformly chosen to cover the area under study. An in-situ approach of measurement at 1.0 m above the ground level, with the window of the detector facing the point under investigation, was adopted to enable sampling points maintain their original environmental characteristics. Three measurements of exposure rate in mR/h were taken at each point at an interval of 3 minutes and these were then averaged to a single value as average exposure rate in air. The average exposure rates were then converted to absorbed dose (AD) rate in nGy/h using (1) according to [9, 10]:

$$1\,\mu R/h = 8.7\,nGy/h = \frac{8.7\times 10^{-3}}{(1/8760y)}\,\mu Gy/y \qquad (1)$$

The absorbed dose rates were then used to estimate the annual effective dose equivalent (AEDE) in μSv/yr and the excess lifetime cancer risk (ELCR) using the relations (2) and (3) respectively [9] and [10]:

$$AEDE\,(mSv/y) = AD\,(nGy/h)\times 8760\,h \times 0.7\,Sv/Gy \times 0.2 \qquad (2)$$

Where AD is the absorbed dose rate, 8760h is the total hours per year, 0.7Sv/Gy is the dose conversion factor from absorbed dose in air to the effective dose with an occupancy factor of 0.2 for outdoor exposure as recommended by [2].

$$ELCR = AEDE\,(mSv/y)\times DL \times RF \qquad (3)$$

Where AEDE is the annual effective dose equivalent, DL is average duration of life (70 years) and RF is the fatal cancer risk factor per sievert (Sv^{-1}). For low-dose background radiation, which is considered to produce stochastic effects, ICRP 103 uses a fatal cancer risk factor value of 0.05 for public exposure [11].

III. Results And Discussion

The results for the BIR exposure rate, absorbed dose, AEDE and ELCR for Holy Ghost, Abakpa, Old Park, New Market and Garriki are shown in Tables 1 to 5 respectively. The readings vary slightly in different locations. In all the locations, the exposure rate ranged from 0.007±0.001mR/h to 0.019±0.001mR/H with Abakpa having the highest value and Holy Ghost the lowest. The absorbed dose ranged from 60.90 nGy/h to 165.30 nGy/h. The values for AEDE ranged from 0.075 mSv/yr to 0.203 mSv/yr and that for ELCR ranged from 0.263×10^{-3} to 0.711×10^{-3}.

Table 1: Measured BIR Exposure rate and associated radiological indices in Holy Ghost pack

Location Code	Exposure rate (mR/h)	Absorbed dose rate (nGy/h)	AEDE (mSv/yr)	ELCR×10^{-3}
HG1	0.014±0.002	121.80	0.149	0.522
HG2	0.014±0.001	121.80	0.149	0.522
HG3	0.009±0.001	78.30	0.096	0.336
HG4	0.010±0.002	87.00	0.107	0.375
HG5	0.011±0.001	95.70	0.117	0.410
HG6	0.012±0.000	104.40	0.128	0.448
HG7	0.014±0.002	121.80	0.149	0.522
HG8	0.007±0.001	60.90	0.075	0.263
HG9	0.011±0.002	95.70	0.117	0.410
HG10	0.010±0.000	87.00	0.107	0.375
Mean±SEM	0.0112±0.0024	97.44±20.420	0.1194±0.025	0.4183±0.087

Table 2: Measured BIR Exposure rate and associated radiological indices in Abakpa pack

Location Code	Exposure rate (mR/h)	Absorbed dose rate (nGy/h)	AEDE (mSv/yr)	ELCR×10^{-3}
ABP1	0.014±0.002	121.80	0.149	0.522
ABP2	0.014±0.003	121.80	0.149	0.522
ABP3	0.012±0.001	104.40	0.128	0.448
ABP4	0.014±0.001	121.80	0.149	0.522
ABP5	0.012±0.002	104.40	0.128	0.448
ABP6	0.015±0.003	130.50	0.160	0.560
ABP7	0.019±0.001	165.30	0.203	0.711
ABP8	0.016±0.006	139.20	0.171	0.599
ABP9	0.014±0.000	121.80	0.149	0.522
ABP10	0.013±0.001	113.10	0.139	0.487
Mean±SEM	0.0143±0.0019	124.4±33.21	0.153±0.022	0.534±0.077

Table 3: Measured BIR Exposure rate and associated radiological indices in Old Pack

Location Code	Exposure rate (mR/h)	Absorbed dose rate (nGy/h)	AEDE (mSv/yr)	ELCR×10^{-3}
OP1	0.011±0.001	95.70	0.117	0.410
OP2	0.010±0.000	87.00	0.107	0.375
OP3	0.011±0.001	95.70	0.117	0.410
OP4	0.010±0.000	87.00	0.107	0.375
OP5	0.010±0.002	87.00	0.107	0.375
OP6	0.012±0.002	104.40	0.128	0.448
OP7	0.010±0.001	87.00	o.107	0.375
OP8	0.014±0.003	121.80	0.149	0.522
OP9	0.013±0.004	113.10	0.139	0.487
OP10	0.011±0.001	95.70	0.117	0.410
Mean±SEM	0.0112±0.0014	97.44±12.170	0.1195±0.015	0.4187±0.052

Table 4: Measured BIR Exposure rate and associated radiological indices in New Market pack

Location Code	Exposure rate (mR/h)	Absorbed dose rate (nGy/h)	AEDE (mSv/yr)	ELCR×10^{-3}
NM1	0.010±0.000	87.00	0.107	0.375
NM2	0.010±0.001	87.00	0.107	0.375
NM3	0.016±0.002	139.20	0.171	0.599
NM4	0.010±0.001	87.00	0.107	0.375
NM5	0.008±0.001	69.60	0.085	0.298
NM6	0.011±0.001	95.70	0.117	0.410
NM7	0.009±0.001	78.30	0.096	0.336
NM8	0.013±0.003	113.10	0.139	0.487
NM9	0.014±0.002	121.80	0.149	0.522
NM10	0.013±0.002	113.10	0.139	0.487
Mean±SEM	0.0114±0.0025	99.18±21.780	0.1217±0.027	0.4264±0.094

Table 5: Measured BIR Exposure rate and associated radiological indices in Garriki Pack

Location Code	Exposure rate (mR/h)	Absorbed dose rate (nGy/h)	AEDE (mSv/yr)	ELCR×10^{-3}
GP1	0.013±0.001	113.10	0.139	0.487
GP2	0.016±0.001	139.20	0.171	0.599
GP3	0.012±0.001	104.40	0.128	0.448
GP4	0.014±0.002	121.80	0.149	0.522
GP5	0.014±0.001	121.80	0.149	0.522
GP6	0.012±0.002	104.40	0.128	0.448
GP7	0.017±0.003	147.90	0.181	0.634
GP8	0.015±0.001	130.50	0.160	0.560
GP9	0.012±0.002	121.80	0.128	0.448
GP10	0.010±0.002	87.00	0.107	0.375
Mean±SEM	0.0135±0.0021	119.19±17.90	0.144±0.023	0.5043±0.079

Table 6: Comparison of Mean BIR Exposure rate and associated radiological indices of the five Parks with world average value

Location	Mean Exposure Rate (mR/h)	Mean Absorbed Dose (nGy/h)	Mean AEDE (mSv/yr)	Mean ELCR×10^{-3}
Holy Ghost	0.0112±0.0024	97.44±20.420	0.119±0.025	0.418±0.087
Abakpa	0.0143±0.0019	124.41±33.210	0.153±0.022	0.534±0.077
Old Park	0.0112±0.0014	97.44±12.170	0.120±0.015	0.419±0.052
New Market	0.0114±0.0025	99.18±21.780	0.122±0.027	0.426±0.094
Gariki Park	0.0135±0.0021	119.19±17.900	0.144±0.023	0.504±0.079
World Average Value	**0.013**	**59.00**	**0.07**	**0.29**

Table 6 shows the comparison between the mean exposure rates, mean absorbed dose, mean AEDE and mean ELCR of the five locations with the world average value (WAV). The mean exposure rates for the five locations ranged from 0.0112±0.0024 mR/h to 0.0143±0.0019 mR/h. The mean absorbed dose values ranged from 97.44±20.420 nGy/h to 124.41±33.210 nGy/h. The mean values of AEDE ranged from 0.119±0.025 mSv/yr to 0.153±0.022 mSv/yr and the mean ELCR ranged from 0.418±0.087×10^{-3} to 0.534±0.077×10^{-3}.In all the locations, Abakpa has the maximum mean exposure rate, absorbed dose, AEDE and ELCR followed by Garriki, New Market, Old Park and Holy Ghost. The mean exposure rate at Holy Ghost, Old Park and New Market are below the world average value of 0.013 mR/h [7, 10] while that of Abakpa and Garriki are slightly greater than the world average value. The corresponding absorbed doses as a result of BIR exposure in the locations are far higher than the recorded world average of 59.00 nGy/h [10, 12] and recommended safe limit of 84.0 nGy/h [2, 13]. Fig. 1 and Fig. 2 show respectively the graphs of mean exposure rate and mean absorbed dose of the locations with the world average value (WAV). The variation in the exposure rate and doses arising from BIR in the locations is attributed to the natural radionuclides concentration and their decay products which are widely spread in soil, water and rock and they depend on the geological formation and geophysical conditions of the studied environment. Also the BIR of the environment is enhanced by the various human activities taking place in the areas such as exhaust emission of combustion products in engines of cars and generating plants, petrol filling stations, market, and dumping of municipal wastes. All thing activities are associated with one form of radionuclide or the other. Furthermore, the exposure and absorbed dose readings indicate that Abakpa is on a higher background radiation level than the other areas as illustrated in Fig. 1 and Fig. 2.

Radiation absorbed dose is a measure of the amount of energy absorbed per unit mass. It quantifies the radiation energy that might be absorbed by a potentially exposed individual as a result of a specific exposure. For whole body exposure, the quantity effective dose equivalent is used to measure the whole body absorbed dose. The annual effective dose equivalent (AEDE) is used in radiation assessment and protection to quantify the whole body absorbed dose per year. In this study, the mean AEDE reported at Holy Ghost, Abakpa, Old Park, New Market and Garriki are 0.119±0.025 mSv/yr, 0.153±0.022 mSv/yr, 0.120±0.015 mSv/yr, 0.122±0.027 mSv/yr and 0.144±0.023 mSv/yr respectively with Abakpa having the maximum value and Holy Ghost having the minimum value. All the mean AEDE are higher than the world average value of 0.07 mSv/yr [10, 14] but lower than the ICRP recommended permissible limits of 1.00 mSv/yr for the general public and 20.00 mSv/yr for occupational workers respectively within a year [11]. This indicates that the studied areas are in good agreement with permissible limit and do not constitute any immediate radiological health effect on the general public due to BIR exposure. However, periodic assessment of activity concentration of natural radionuclides and BIR levels in the areas should be carried out in order to ensure that exposure to radiation within the areas is kept to as low as reasonably achievable. The mean AEDE reported in the five locations are closely in line with those of 0.15±0.03 mSv/yr to 0.20±0.06 mSv/yr reported by [10] in similar Warri and Effurun environment of Delta State, Nigeria.

One of the aims of radiological risk assessment is the estimation of the probability of a fatal cancer development over a lifetime exposure. For low dose radiation exposure, cancer may occur when an exposed individual has reached an advanced age, if it will occur at all. The term 'excess lifetime cancer risk' (ELCR) is therefore used to define the probability that an individual will develop cancer over his lifetime of exposure to radiation [1]. The estimated mean ELCR reported in this work (Table 6) are $(0.418\pm0.087)\times10^{-3}$, $(0.534\pm0.077)\times10^{-3}$, $(0.419\pm0.052)\times10^{-3}$ $(0.426\pm0.094)\times10^{-3}$ and $(0.504\pm0.079)\times10^{-3}$ respectively for Holy Ghost, Abakpa, Old Park, New Market and Garriki. These values are higher than the average standard value of 0.29×10^{-3} [2, 15]. The implication of these ELCR values is that there exists the possibility of one developing cancer over a life time of exposure within the studied environments. The ELCR values recorded in this study as illustrated in Fig. 4 are due to the absorbed dose and AEDE resulting from BIR exposures which are attributed to enhanced concentration of natural radionuclides in the environment due to human activities. The ELCR in this work are slight lower than those reported by [10] for Warri and Effurun environment of Delta State, Nigeria. Also the values here are far lower than those of 1.007×10^{-3} for Okposi Okwu salt late and 1.173×10^{-3} for Uburu salt lake environments both in Ebonyi State, Nigeria reported by [15].

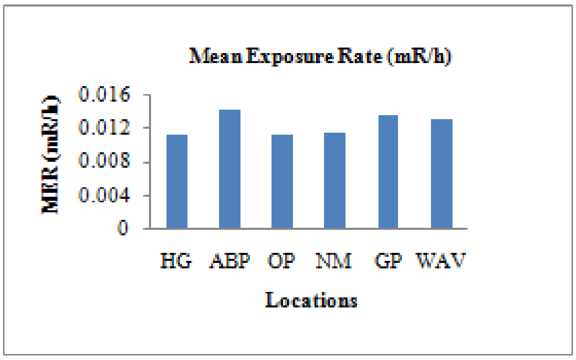

Figure 1: Graph of Mean Exposure Rate of study locations with world average value

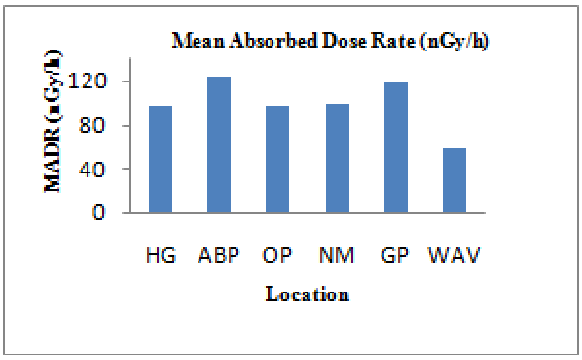

Figure 2: Graph of Mean absorbed dose of study locations with world average value

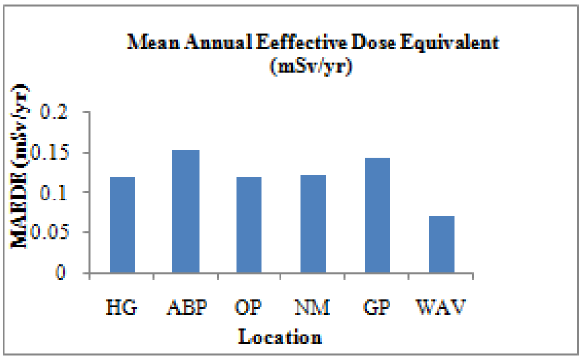

Figure 3: Graph of Mean AEDE of study locations with world average value

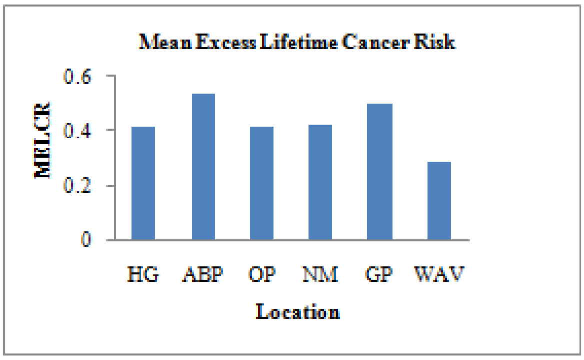

Figure 4: Graph of Mean ELCR of study locations with world average value

IV. Conclusion

The qualitative and quantitative assessment of radiation exposure level and doses within an environment is an important aspect of radiation protection since human exposure to natural background radiation is a continuous and unavoidable feature of human existence. The present study has been designed in this regard to quantitatively assess the background radiation levels in some major parks in Enugu city and to estimate their radiological impact on the environment. The results have revealed that Abakpa has the highest BIR level followed by Garriki, New Market, Old Park and Holy Ghost. The BIR levels of the areas are enhanced by the various human activities been carried out in the areas. The radiological assessment shows that the areas do not constitute any immediate radiological health effect on the general public due to BIR exposure but there exist the possibility of one developing cancer over a life time of exposure within the studied environments. We recommend that the various human activities that enhance the BIR levels in the areas should be minimized and periodic assessment of activity concentration of natural radionuclides and BIR levels in the areas should be carried out to keep the radiation level to as low as reasonably achievable. The time spent within the areas should also be reduced. The study has been well characterized and the results will serve as a base-line data of essential importance to public health agencies and the government in planning and monitoring of radiation protection programs and for future research purposes.

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