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RESEARCH ARTICLE

GIS MAPPING OF BIR LEVELS AROUND FOSSIL FUEL AND GAS DISPENSING STATIONS AND ASSESSMENT OF THEIR RADIOLOGICAL RISK IMPLICATIONS

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ABSTRACT

The assessment of terrestrial background ionizing radiation levels within fossil fuel and gas dispensing environments to evaluate the radiological risk around Warri metropolis has been conducted using a digilert 200 Nuclear Radiation monitor meter and a GPS. The GIS monitoring of the BIR levels was carried out between September and December 2018 by delineating the city into eight zones using GIS mapping. The measured average exposure rates ranged from 0.006mRh^{-1}(0.50 $mSvy^{-1}$) to 0.026mRh^{-1}(2.19$mSvy^{-1}$) with an overall mean value of 0.015$\pm$0.004mRh^{-1} (1.26$\pm$0.32 $mSvy^{-1}$). The estimated mean outdoor absorbed dose rate for the regions ranged from 116.60$\pm$40.38nGyh^{-1} in Jeddo region to 148.9$\pm$49.63nGyh^{-1} in PTI region and a mean of 129.82$\pm$32.98ηGyh^{-1}.The AEDE evaluated is 0.16$\pm$0.04 $mSvy^{-1}$ while the ELCR value is 0.56$\pm$0.014μSvy^{-1}. The estimated dose to organs testes receiving the highest organ dose of 0.10 $mSvy^{-1}$ while the liver receives the lowest dose to organ of 0.06 $mSvy^{-1}$. The GIS mapping of the examined facilities revealed that radiation levels in 38 of the 61 sampling locations (62.3%) exceeded the global ambient permissible level of 13.0 μRh^{-1} (1.0 $mSvy^{-1}$) reported by UNSCEAR, therefore the measured values are adjudged high and the environment radiologically impaired. But, these may not cause any short- team health risk to the fuel/gas attendants and attendees in these stations. The obtained estimated excess lifetime cancer risk indicates low chances of contracting cancer and the radiation doses to the adult organs investigated is insignificant.

KEYWORDS

GIS mapping, gamma radiation, fossil fuel, filling stations, Warri metropolis.

1. INTRODUCTION

It is a global knowledge and a proven fact that ionizing radiation may be detrimental and injurious to the human health and environment subject to the amount of radiation and the degree of exposure. The sources of ionizing radiation in any environment may be of different origin, which includes, cosmic rays (radiation from outer space), radiation from the radioactive atoms present in the earth surface, radiation from our own body and from radioactive laden materials like fossil fuel, crude oil and natural gasses etc. Ionizing radiation has the capacity to affect the chemical composition of a material and so cause change which are biologically important, due to its sufficient energy to knockout electrons from the outermost orbit of an atom, thereby altering the genetic make-up of human as shown in figure 1 *(Cutnell and Johnson, 1995)*.

Background ionization radiation with source(s) from either telluric, celestial or man-made, could be considered as environment pollution when it exceeds safe occupational and public limits. Studies have shown that the activities of the oil industries that includes; gas flare in the refinery and flare sites in flow stations, crude oil spill around facilities and on transit point, imported toxic chemicals and radionuclide materials for geological mapping, x-ray welding and well logging and other oil allied activities can also raise the BIR levels of the environment *(Avwiri et al., 2007; Agbalagba and Meindiyo, 2010)*. Beside human exposure to the ambient ionizing radiation level at its present rate on the earth surface, human activities have elevated the background radiation to a levels that may cause detrimental health effects to man if not properly monitored *(Murugesan et al., 2011)*.

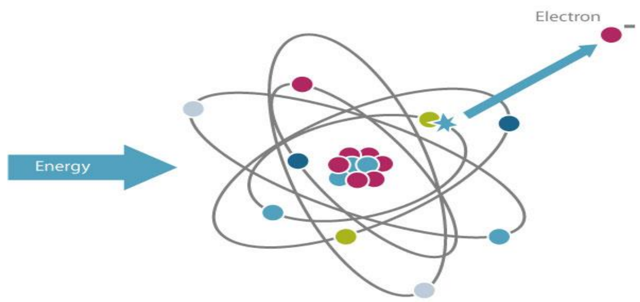

Figure 1: Knocking of electron from an atom due to exposure to ionizing radiation atom

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Scientific studies of elevated background ionizing radiation levels have been reported to cause cancer and mental retardation in children whose mothers are exposed to radiations during pregnancy period and high radiation doses can result to other health effects as eye cataract, leukaemia etc. *(NRC, 2006; Rafique et al., 2014).* A strong correlation had also been found between oil and gas activities and elevated environmental ionizing radiation levels, which were ascribed to the raw materials input and waste release to the environment *(Avwiri et al., 2007a; Avwiri et al., 2007b; Chad-Umoren, 2012; Agbalagba et al., 2013; Ononugbo et al., 2017)*. In the same vain, reported that ionizing radiation studies have shown a strong correlation between elevated radiation exposure and health hazard among the populace and workers in a given environment eco-system (*Avwiri, et al., 2007b)*. Moreso, the geology of the study area have been found to influence the BIR levels of the environment under investigation, when minerals are disintegrated through natural process, radionuclides are liberated into the soil by rain infiltration and percolation processes *(Taskin et al., 2009)*. It has been established that some minerals such as monazite, pyrochlore and xenotime, which are obtained as byproducts of tin mining are radioactive, *(Aigbedion and Iyayi, 2007)*. Exposure to radiations emitted by some of these radioactive minerals is a major source of health hazards in some environment *(Aigbedion and Iyayi, 2007)*.

Substantial research effort have been channel into the investigation of BIR levels in terrestrial environment, indoor and outdoor environment, solid mineral and oil and gas facilities, the obtained results in most cases are influenced by human activities in the area outside natural radioactive emitting sources in the environment *(Farai and Jibiri 2000; Akpabio et al., 2005; Agbalagba et al., 2009; Rafique et al., 2014; Osimobi et al., 2015)*. A group researcher examined the earth's surface radiation levels in oil and gas installations in Nigeria and reported that the radiation levels obtained are within international standard and are in consonant with other reported values in the country (Avwiri et al., 2007a). However, later studies on similar environment indicate that the BIR levels exceeded the ambient background levels and show a significant raise in the levels of radiation of the areas *(Agbalagba, et al., 2009, Agbalagba and Meindiyo 2010, Avwiri and Agbalagba, 2012)*.

In Pakistan, estimates the excess life time cancer risk from BIR levels measured and reported a mean ELCR indoor value of 1.629×10^{-3} and outdoor value of 1.629×10^{-3} with the indoor value found to be greater than the global ambient value of $780 \mu Gy.y^{-1}$ (Rafique et al., *2014)*. Another group reserchers examined the BIR levels in selected solid mineral mining locations in Eastern Nigeria and revealed a 38.5% elevation above the ambient background radiation value of $13 \mu Rh^{-1}$ of the area (Osimobi et al., *(2015)*. However, most of the terrestrial radiation studies have excluded the fossil fuel and gas dispensing environment though it is a critical terrestrial environment where human activities peak during the early hours of the morning and late at eventide.

Previous study on the BIR levels within the twin cities of Warri and Effurun shown that 64 sampled sites out of the 94 sampled locations exposure levels surpassed the global ambient value of $13 \mu Rh^{-1} (1.0 mSvy^{-1})$ recommended and reported by UNSCEAR, which is 68.1% increase and these values reported were higher compare to values obtained in literatures *(Agbalagba, 2017).* Although that study was conducted in the terrestrial environment of Warri and environ, the petroleum products and gas dispensing stations were not put into consideration despite the known and proven facts that oil and gas contain a significant level natural radioactive materials (NORMs) and radon content that can contribute significantly to the exposure levels of the environment. This study is therefore aimed at evaluating the BIR levels within major fossil fuel and gas dispensing stations with focus on Warri metropolis as a microcosm of Nigeria, the values obtained will be used to evaluate the radiological risks associated with those working (attendants) at these dispensing stations and those visiting the stations for the purchase of these products. To the best of the researchers' knowledge, no known gamma radiation levels study have been dedicated to fossil fuel dispensing stations in Nigeria or the case studied environment.

The study will therefore avail the opportunity to ascertain the radiological status of this peculiar environment and the possible health hazard associated with the area. Moreso, the data presented in this report will represents the first set of information and may serve as baseline and reference data of the background ionizing radiation levels of fossil fuel dispensing environment. Evaluation of radiological risk parameters is of enormous significance as it will help in estimating the radiation impact and the likelihood of developing various health related effects (risks) to the stations attendants and attendees in the study area. The risk parameter were evaluated by computing for the equivalent dose rate, the absorbed dose rate, the annual effective dose equivalent rate (AEDE) and the excess life time cancer risk (ELCR) to ascertain the radiological health implications to users and workers alike.

2. Materials and Methods

2.1 Study Area

The study area (Warri metropolis and its suburbs in Niger delta region of Nigeria) lies within longitude $5^0 41''$E and $5^0 48''$E and latitude $5^0 30''$N and $5^0 36''$N and the study was carried out between the month of February and December 2019. Warri is strategically location in the heart of the Niger Delta in the Gulf of Guinea. The Warri sea port and Warri refinery and petrochemical company (WRPC) is located in the heart of the city, making it a commercial centre with high influx of job seekers *(Agbalagba, 2017).* Warri metropolis is made up of two local government area (Uvwie and Warri South LGA) in Delta State. It is one of the city in the Niger Delta region that have grown steadily four the past two decades and the fourth most populated city in Nigeria with a population of about one million six hundred thousand people *(NPC, 2010)*.

Its proximity and hosting of the crude oil and natural gas (petroleum products and gas) and the market potential of the refined products of oil and gas have increase the numbers of filling stations and gas dispensing outlets within the metropolis. Most of these filling stations are licensed by the Department of Petroleum Resources (DPR) to operate twenty- four hours services because of the commercial activities within the city, with some of the stations' attendants working over twelve hours daily. The spillage of the fossil fuel during offloading and dispensing in the environment where they are sold allow for escape into the air atmosphere radon gas due to its volatile nature and other ionizing radiation. These can elevate the background ionizing radiation levels within these dispensing stations above the ambient level of $0.013 mRh^{-1}$ and increase the dose rate to the stations attendants which can increase the potential of contacting radiation induced sicknesses. This is so because this natural resources are known to contain radioactive materials and high level of radon gas *(Avwiri et al., 2007a; Rafique et al., 2014)*.

2.2 Experimental Procedure

The study locations was delineated into eight regions for easy coverage of the sixty selected fuel filling and gas dispensing stations. Measurements were conducted *insitu* in the petroleum products and gas dispensing stations within the Warri metropolis. The *insitu* approach of the gamma radiation measurement was chosen and adopted to enable samples maintain their original environmental characteristics. A digilert 200 nuclear radiation monitor meter (S.E international, INC. summer town, USA), containing a Geiger Muller tube with ionizing chamber which was pre- set to detect γ- radiation within a temperature range of -10 to 50^0C was applied for the gamma radiation measurement and a geographical positioning system (GPS) was used for the measurement of the point of sampling. The radiation meter's sensitivity was 3500 CPM/ (mRh^{-1}) referenced to Cs-137 with a halogen-quenched Geiger-Muller detector tube of 45 mm in diameter and a1.5-2.0 $mgcm^{-2}$ mica window density (Inspector alert operation manual (*Agbalagba, 2017)*. During measurement, the tube of the radiation monitoring meter was raised to a standard height of 1.0m above the ground *(Ajayi and Laogun, 2006; Avwiri, et al., 2013)*, with its window facing the suspected source (products dispensing meters and the attendants) at a standard distance of 1.0 m and the GPS values taken at the spot of radiation measurement. Readings were taken trice and average values obtained in accordance with NCRP recommendation *(NCRP, 1993; Rafique et al., 2014)*. The count rate per minute recorded in the meter was converted to milli-roentgen per hour (mRh^{-1}) using the relation *(Avwiri, et al., 2013; Rafique et al., 2014; Osimobi et al., 2015):*

Count rate per minute (CMP) = 10^{-3} roentgen x Q.F (1)

Where Q.F is the quality factor, which is unity for external environment

3. Results and Discussion

3.1 Results Presentation

The results of the BIR measured and the computed radiological risk parameters from the BIR in petroleum products and gas dispensing stations in Warri metropolis and its environs are presented in Tables 1-8

Table 1: Measured exposure rate and calculated hazard indices in Sapele Road region of Warri (1)

S/N	Name of Filling Station	Geographical Location	AV. BIR Levels (mRh^{-1})	Equivalent Dose (mSvy^{-1})	Absorbed Dose Rate (ηGyh^{-1})	Annual Effective Dose Equivalent (mSvy^{-1})	Excess Lifetime Cancer Risk (μSvy^{-1})
1.	NNPC- Mofor	N 05^{0}33.478′ E 005^{0}47.061′	0.009	0.76	78.30	0.10	0.35
2.	Delta Gasoline	N 05^{0}36.449′ E 005^{0}42.327′	0.018	1.51	156.60	0.19	0.67
3.	CONOIL	N 05^{0}36.992′ E005^{0}42.641′	0.013	1.09	113.10	0.14	0.49
4.	NNPC-Uti Junction	N 05^{0}36.760′ E 005^{0}42.549′	0.011	0.93	95.70	0.12	0.42
5.	Fejikev Gas	N 05^{0}32.636′ E 005^{0}42.671′	0.020	1.68	174.00	0.21	0.74
6.	CHRISDOR	N 05^{0}32.458′ E 005^{0}45.303′	0.014	1.18	121.80	0.15	0.53
7.	White Flag Dynamic Coy.	N 05^{0}33.969′ E 005^{0}45.226′	0.015	1.26	130.50	0.16	0.56
8.	PEDCO Ent. Ltd.	N 05^{0}36.457′ E 005^{0}42.328′	0.016	1.34	139.20	0.17	0.60
MEAN VALUE			**0.015±0.03**	**1.22±0.28**	**126.2±29.0**	**0.16±0.011**	**0.55±0.20**

Table 2: Measured exposure rate and calculated hazard indices in Enerhen region of Warri (2)

S/N	Name of Filling Station	Geographical Location	AV. BIR Levels (mRh^{-1})	Equivalent Dose (mSvy^{-1})	Absorbed Dose Rate (ηGyh^{-1})	Annual Effective Dose Equivalent (mSvy^{-1})	Excess Lifetime Cancer Risk (μSvy^{-1})
1.	Inene Nig. Ltd.	N 05^{0}31.649′ E 005^{0}46.652′	0.016	1.35	139.20	0.17	0.60
2.	Frankies Ltd.	N 05^{0}31.888′ E 005^{0}51.962′	0.013	1.09	113.10	0.14	0.49
3.	FOYAL	N 05^{0}31.986′ E 005^{0}51.455′	0.014	1.18	121.80	0.15	0.53
4.	Mobile Filling Station	N 05^{0}31.433′ E 005^{0}50.535′	0.007	0.59	60.90	0.07	0.24
5.	MRS Station	N 05^{0}31.606′ E 005^{0}46.266′	0.011	0.93	95.70	0.12	0.42
6.	OANDO	N 05^{0}31.004′ E 005^{0}45.053′	0.014	1.18	121.80	0.15	0.53
7.	Mobile Garage	N 05^{0}30.965′ E 005^{0}45.449′	0.015	1.26	130.50	0.16	0.56
8.	FORTRE Oil	N 05^{0}30.976′ E 005^{0}45.403′	0.023	1.93	200.10	0.25	0.88
MEAN VALUE			**0.014±0.04**	**1.19±0.36**	**122.89±37.20**	**0.15±0.05**	**0.53±0.70**

Table 3: Measured exposure rate and calculated hazard indices in Water Resources region of Warri (3)

S/N	Name of Filling Station	Geographical Location	AV. BIR Levels (mRh^{-1})	Equivalent Dose (mSvy^{-1})	Absorbed Dose Rate (ηGyh^{-1})	Annual Effective Dose Equivalent (mSvy^{-1})	Excess Lifetime Cancer Risk (μSvy^{-1})
1.	ETSL	N 05^{0}31.513′ E 005^{0}45.775′	0.015	1.26	130.50	0.16	0.56
2.	Adene Assoc. Services	N 05^{0}31.579′ E 005^{0}45.669′	0.017	1.43	147.90	0.18	0.63
3.	FORTRE Oil	N 05^{0}31.591′ E 005^{0}45.502′	0.016	1.35	139.20	0.17	0.60
4.	French Joga	N 05^{0}31.635′ E 005^{0}44.336′	0.012	1.01	104.40	0.13	0.45

5.	COSCO Service Ltd.	N 05⁰31.528′ E 005⁰44.678′	0.011	0.93	95.70	0.12	0.42
MEAN VALUE			**0.014±0.02**	**1.20±0.19**	**123.54±20.4**	**0.15±0.02**	**0.53±0.8**

Table 4: Measured exposure rate and calculated hazard indices Ajamogha region of Warri (4)

S/N	Name of Filling Station	Geographical Location	AV. BIR Levels (mRh^{-1})	Equivalent Dose (mSvy^{-1})	Absorbed Dose Rate (ηGyh^{-1})	Annual Effective Dose Equivalent (mSvy^{-1})	Excess Lifetime Cancer Risk (μSvy^{-1})
1.	BUVEL Nig. Ltd.	N 05⁰31.669′ E005⁰45.198′	0.012	1.01	104.40	0.13	0.45
2.	KUMOIL Ltd. Service Station	N 05⁰31.672′ E005⁰45.071′	0.018	1.51	156.60	0.19	0.07
3.	TOTAL Station	N 05⁰31.770′ E005⁰44.784′	0.016	1.35	139.20	0.17	0.60
4.	HQ Station	N 05⁰31.381′ E005⁰44.762′	0.017	1.43	147.90	0.18	0.63
5.	Mobile Station	N 05⁰31.826′ E005⁰44.789′	0.019	1.60	165.30	0.20	0.70
MEAN VALUE			**0.016±0.002**	**1.38±0.20**	**142.68±21.02**	**0.17±0.03**	**0.61±0.09**

Table 5: Measured exposure rate and calculated hazard indices Effurun region of Warri (5)

S/N	Name of Filling Station	Geographical Location	AV. BIR Levels (mRh^{-1})	Equivalent Dose (mSvy^{-1})	Absorbed Dose Rate (ηGyh^{-1})	Annual Effective Dose Equivalent (mSvy^{-1})	Excess Lifetime Cancer Risk (μSvy^{-1})
1.	BUBBLE BLUE	N 05⁰33.722′ E005⁰47.520′	0.11	0.93	95.40	0.12	0.42
2.	RANO Oil and Gas	N 05⁰33.743′ E005⁰47.123′	0.014	1.18	121.80	0.15	0.53
3.	SMILE	N 05⁰33.886′ E005⁰47.092′	0.019	1.60	165.30	0.20	0.70
4..	TOTAL	N 05⁰34.099′ E005⁰47.102′	0.015	1.26	130.50	0.16	0.56
5.	TOP RANK	N 05⁰34.111′ E005⁰47.063′	0.010	0.84	87.00	0.11	0.39
6.	APRIBET VENTURES	N 05⁰34.151′ E005⁰46.629′	0.012	1.01	104.40	0.13	0.45
7.	WILMAS	N 05⁰34.147′ E005⁰46.105′	0.013	1.09	113.10	0.14	0.49
8.	OVUS Pet. Diesel	N 05⁰34.168′ E005⁰44.676′	0.017	1.43	147.90	0.18	0.63
MEAN VALUE			**0.014±0.003**	**1.17±0.24**	**120.71±24.77**	**0.15±0.03**	**0.52±0.10**

Table 6: Measured exposure rate and calculated hazard indices in Refinery - Ekpan region of Warri (6)

S/N	Name of Filling Station	Geographical Location	AV. BIR Levels (mRh^{-1})	Equivalent Dose (mSvy^{-1})	Absorbed Dose Rate (ηGyh^{-1})	Annual Effective Dose Equivalent (mSvy^{-1})	Excess Lifetime Cancer Risk (μSvy^{-1})
1.	JOCECO Depot	N 05⁰33.964′ E005⁰44.621′	0.016	1.35	139.20	0.17	0.60
2.	GOD'STIME Petroleum	N 05⁰33.740′ E005⁰44.655′	0.023	1.93	200.10	0.25	0.88
3.	CUMONO Ventures Ltd	N 05⁰33.745′ E005⁰44.87′	0.011	0.93	95.70	0.12	0.42
4.	AGBA-SOL Nig. Ltd.	N 05⁰33.855′ E005⁰45.253′	0.012	1.01	104.40	0.13	0.45
5.	FOMAS Marine& Engr. Services	N 05⁰33.849′ E005⁰45.306′	0.014	1.18	121.80	0.15	0.53
6.	ASCON Petroleum Nig. Ltd.	N 05⁰33.915′ E005⁰45.464′	0.011	0.93	95.70	0.12	0.42
7.	CHIT-LISH Nig. Ltd.	N 05⁰33.950′ E005⁰45.609′	0.015	1.26	130.50	0.16	0.56
8.	BOROSA Refilling Cooking Gas Plant	N 05⁰33.915′ E005⁰45.583′	0.024	2.02	208.80	0.26	0.91
MEAN VALUE			**0.016±0.005**	**1.33±0.40**	**137.03±41.67**	**0.17±0.05**	**0.60±0.18**

Table 7: Measured exposure rate and calculated hazard indices in P.T.I region of Warri (7)							
S/N	**Name of Filling Station**	**Geographical Location**	**AV. BIR Levels (mRh^{-1})**	**Equivalent Dose ($mSvy^{-1}$)**	**Absorbed Dose Rate (ηGyh^{-1})**	**Annual Effective Dose Equivalent ($mSvy^{-1}$)**	**Excess Lifetime Cancer Risk (μSvy^{-1})**
1.	FALCON BAY OIL	N 05⁰34.168′ E005⁰48.019′	0.019	1.60	165.30	0.20	0.70
2.	MATRIX	N 05⁰34.147′ E005⁰47.861′	0.021	1.77	182.70	0.22	0.77
3..	BENELTA Gas	N 05⁰34.131′ E005⁰47.902′	0.014	1.18	121.80	0.15	0.53
4.	BP Oil	N 05⁰33.993′ E005⁰47.760′	0.018	1.51	156.60	0.19	0.67
5.	OMOSIBO	N 05⁰33.827′ E005⁰47.664′	0.023	1.93	200.16	0.25	0.88
6.	RAIN OIL	N 05⁰33.785′ E005⁰47.679′	0.013	1.09	113.10	0.14	0.49
7.	ADMUS Concept Nig. Ltd.	N 05⁰33.731′ E005⁰47.623′	0.014	1.18	121.80	0.15	0.53
8.	Long-live Filling Station	N 05⁰33.618′ E005⁰47.591′	0.006	0.50	52.20	0.06	0.21
9.	AWENODE Pet. Ltd.	N 05⁰33.606′ E005⁰47.591′	0.026	2.19	226.20	0.28	0.98
MEAN VALUE			**0.017±0.006**	**1.44±0.48**	**148.9±49.63**	**0.18±0.06**	**0.64±0.22**

Table 8: Measured exposure rate and calculated hazard indices in Jeddo region of Warri (8)							
S/N	**Name of Filling Station**	**Geographical Location**	**Av. BIR Levels (mRh^{-1})**	**Equivalent Dose ($mSvy^{-1}$)**	**Absorbed Dose Rate ($nGyh^{-1}$)**	**Annual Effective Dose Equivalent ($mSvy^{-1}$)**	**Excess Lifetime Cancer Risk (μSvy^{-1})**
1.	LUSUA GAS PLANT	N 05⁰35.870′ E005⁰47.560′	0.020	1.68	174.00	0.21	0.73
2.	LUSUA NIG. LTD	N 05⁰34.882′ E005⁰46.550′	0.007	0.59	60.90	0.07	0.24
3.	CONOIL Ltd.	N 05⁰34.535′ E005⁰46.312′	0.020	1.68	174.00	0.21	0.73
4.	AGES Gas Ltd.	N 05⁰35.330′ E005⁰47.118′	0.008	0.67	69.60	0.09	0.32
5.	KIKRO Cooking Gas Plant	N 05⁰34.541′ E005⁰47.342′	0.010	0.84	87.00	0.11	0.39
6.	RURE Oil	N 05⁰34.631′ E005⁰46.235′	0.013	1.09	113.10	0.14	0.49
7.	REWOG Ltd.	N 05⁰34.471′ E005⁰46.218′	0.015	1.26	130.50	0.16	0.56
8.	JENITE Oil	N 05⁰34.597′ E005⁰47.133′	0.007	0.59	60.90	0.07	0.24
9.	Mekavel Pet. Ltd.	N 05⁰34.762′ E005⁰46.667′	0.012	1.01	104.40	0.13	0.45
10.	NNPC Filling St	N 05⁰34.770′ E005⁰47.558′	0.022	1.85	191.40	0.23	0.81
MEAN VALUE			**0.013±0.05**	**1.21±0.45**	**116.60±40.38**	**0.14±0.06**	**0.50±0.20**

Table 9: Summary of the BIR exposure rate and the estimated Hazard indices in Warri Metropolis						
S/N	**MAPPED AREA**	**BIR LEVELS (mRh^{-1})**	**EQUIVALENT DOSE ($mSvy^{-1}$)**	**ABSORBED DOSE ($nGyh^{-1}$)**	**AEDE($mSvy^{-1}$)**	**ELCR(μSvy^{-1})**
1.	EAST/WEST SAPELE ROAD	0.015±0.003	1.22±0.28	126.2±29.20	0.16±0.011	0.55±0.12
2.	ENERHEN ZONE	0.014±0.004	1.19±0.36	122.89±37.02	0.15±0.05	0.53±0.17
3.	WATER RESOURCES ZONE	0.014±0.002	1.20±0.19	123.54±20.14	0.15±0.02	0.53±0.08
4.	AJAMOGHA ZONE	0.016±0.002	1.38±0.20	142.68±21.02	0.17±0.03	0.61±0.09
5.	EFFURUN ZONE	0.014±0.003	1.17±0.24	120.71±24.77	0.15±0.03	0.52±0.10
6.	REFINERY-EKPAN ZONE	0.016±0.005	1.33±0.40	137.03±41.67	0.17±0.05	0.60±0.18
7.	PTI ZONE	0.017±0.006	1.44±0.48	148.9±49.63	0.18±0.06	0.64±0.22

8.	JEDDO ZONE	0.013±0.005	1.12±0.45	116.60±40.38	0.14±0.06	0.50±0.20
TOTAL MEAN		**0.015±0.004**	**1.26±0.32**	**129.82±32.98**	**0.16±0.04**	**0.56±0.14**
WORLD STANDARD		**0.013**	**1.00**	**59.00**	**0.07**	**0.29**

Table 10: Comparison of estimated Effective dose rate to different organs and tissues and ICRP recommendation.

Organs	Lung	Ovary	Bone marrow	Testes	Kidney	Liver	Whole Body
ICRP 1996, UNSCEAR, 2000 Recommendation	0.64	0.58	0.69	0.82	0.62	0.42	0.68
D_{organ} ($mSvy^{-1}$)	0.08	0.07	0.09	0.10	0.08	0.06	0.09

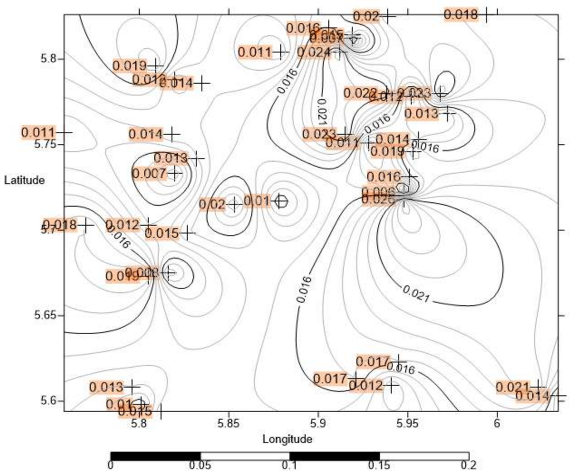

Figure 2: GIS contour map of the study area showing sampled points with BIR exposure rate

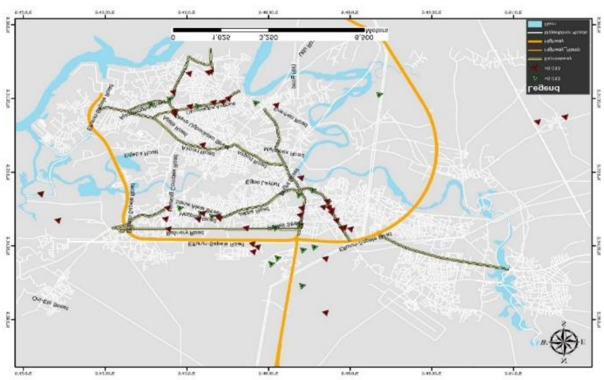

Figure 3: GIS map of the sampled area showing sampled points with BIR exposure rate within and above world normal BIR level (0.013mRh-1)

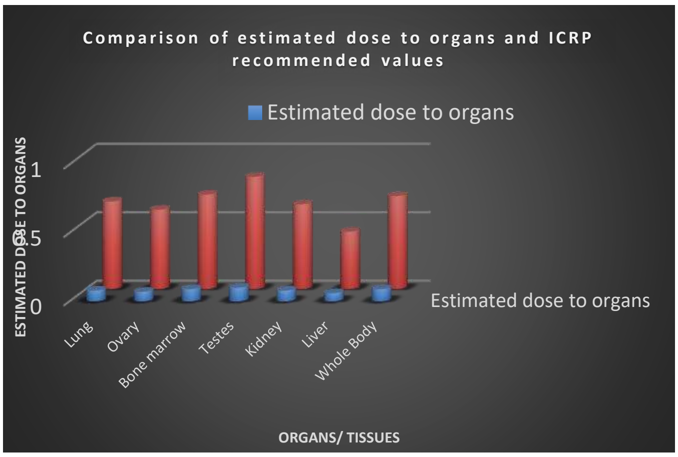

Figure 4: Comparison of estimated dose to organs and ICRP recommended standard

3.2 Discussion of Results

The obtained values of the measured background ionizing radiation levels and their computed radiological risk parameters for the eight delineated regions that were grouped within Warri metropolis for this research convenience are presented in Tables 1-8 while Table 10 present the summary of the results obtained. It has been proven that to arrive at an unbiased, reliable and fair conclusion on radiological health side-effect status to human in a given radiation enveloped environment or an irradiated population, the following five radiation hazard indices are used as tools: equivalent dose, absorbed dose rate, annual effective dose equivalent, excess lifetime cancer risk and effective dose to different organs.

3.2.1 Background Ionizing Radiation (BIR) Levels

The obtained values of the BIR levels measured as presented in column 4 of Tables 1-8 in the eight regions that constitute the study area show that in Sapele road region (1) along the East-West road, the BIR levels ranged from 0.009mRh^{-1} NNPC filling station at Mofor to 0.020mRh^{-1} in FEJIKEV gas station, with a mean exposure rate of 0.015±0.003mRh^{-1}. In the Enerhen region (2), the BIR levels ranged from 0.011mRh^{-1} to 0.023mRh^{-1} with a mean value of 0.014±0.004mRh^{-1}. The BIR levels ranged from 0.011mRh^{-1} to 0.017mRh^{-1} with a mean value 0.014±0.002 at the Water resources region (3), while in the Ajamogha region (4), the exposure levels ranged from 0.012mRh^{-1} to 0.019mRh^{-1} with a mean value of 0.016±0.002mRh^{-1}. The mean exposure values for the Effurun region (5), the refinery-Ekpan region (6), the PTI region (7) and the Jeddo region (8) are 0.014±0.003mRh^{-1}, 0.016±0.005mRh^{-1}, 0.017±0.006mRh^{-1}, and 0.013±0.005mRh^{-1} respectively. The mean values obtained in all the regions except at Jeddo region are above the world ambient BIR levels of 0.013mRh^{-1}, which indicates that the exposure levels in most of the stations in Warri metropolis are elevated. The values obtained in the filling stations are comparable to previously reported values in oil and gas installations environment, but they are slightly higher than values previously reported in Warri metropolis *(Agbalagba, 2017; Agbalagba et al., 2009, Agbalagba and Meindiyo, 2010; Avwiri and Agbalagba, 2012)*. The mean BIR level of 0.013±0.005mRh^{-1} obtained at Jeddo region may be attributed to the abandonment of most of the fuel filling stations where readings are obtained while some of them are out of stock of products at the time of the study. Figures 2 and 3 show the contour and GIS map of the assessed radiation levels in the study area, they revealed at a glance that the BIR level exceeded the worldwide average in most of the sample sites. The elevation in the BIR level in most of fuel stations can be attributed to the emission of γ-ray from the dispensed fuel and gas as readings were taken while fuel is being dispensed and when gas are being filled at the stations. These obtained exposure levels are comparable to values reported in literatures in some cities of Nigeria and in some regions and countries of the World *(Farai and Jibiri, 2000; Akpabia et al., 2005; Avwiri et al., 2007a; Sadiq and Agba, 2011; Ramli et al., 2014; Osimobi et al,. 2015; Chikasawa et. al.2001; Clouvas, et al. 2004; Erees et al. 2006; Senthilkumar et al. 2010; Rafique et al. 2013; Rafique 2013)*.

3.2.2 Equivalent Dose Rate

When exposed to ionizing radiation, it is appropriate to evaluate the dose rate to the entire body per year, in line with the National Council on Radiation Protection recommendation *(NCRP, 1993; Avwiri et al., 2013)*.

Using the National Council on Radiation Protection and measurements recommendation:

$$1.0\ mRh^{-1} = \frac{0.96\times24\times365}{100}\ \mathrm{mSvy^{-1}} \quad (2)$$

Column 5 of Tables 1-8 present the estimated whole body equivalent dose rate. The results obtained show mean values of 1.22±0.28 $mSvy^{-1}$ for the Sapele road region, 1.19±0.36 $mSvy^{-1}$ in Enerhen region, 1.20±0.19 $mSvy^{-1}$ in Water Resources region and 1.38±0.20 $mSvy^{-1}$ for Ajamogha region. The obtained values for the Effurun, Refinery-Ekpan, PTI and Jeddo regions are 1.17±0.24 $mSvy^{-1}$, 1.33±0.40 $mSvy^{-1}$, 1.44±0.48 $mSvy^{-1}$ and 1.12±0.45 $mSvy^{-1}$ respectively. The computed equivalent dose rates obtained for the eight regions are well above the standard permissible limit of 1.0mSvy^{-1} recommended as safe for the global society. The values when compared with previous research findings from hydrocarbon and crude covered laden and contaminated environment, shows a strong correlation which suggested that these gas and petroleum filling stations are radiologically contaminated, but higher than values reported in urban environment of some regions and countries of the world *(Arogunjo et al, 2004; Akpabio et al., 2005; Avwiri et al., 2007a; Agbalagba and Meindiyo, 2010; Avwiri and Agbalagba, 2012; Avwiri, et al., 2013; Osimobi et al., 2015; Agbalagba, 2017; Chikassawa et al., 2001; Erees et al., 2006; Clouvas et al., 2013; Rafique et al., 2013)*.

3.2.3 Absorbed Dose Rate

The external exposure rate data obtained for the BIR levels were used for the evaluation of the absorbed dose rates nGyh^{-1} using the conversion factor *(Rafique et al., 2014)*:

$$1\mu Rh^{-1} = 8.7\eta Gyh^{-1} = 8.7x10^{-9}\mu Gy\ x\ 8760\ y^{-1} = 76.212\ \mu Gyy^{-1} \quad (3)$$

The results of the Columns 6 of the absorbed dose rates at the dispensing stations for the eight regions/ districts are presented in Tables 1-8. The obtained results indicates a mean value of 126.20±29.20 $nGyh^{-1}$ for Sapele road region (East-West road), 122.89±37.02 $nGyh^{-1}$ for Enerhen region, 123.54±20.14 $nGyh^{-1}$ for Water Resources region and 142.68±21.02 $nGyh^{-1}$ for Ajamogha region. The obtained values for the fuel, DPK, Gasoline and gas filling and dispensing stations in Effurun, Refinery-Ekpan, PTI and Jeddo regions are 120.71±24.77 $nGyh^{-1}$, 137.03±41.67 $nGyh^{-1}$, 148.9±49.63 $nGyh^{-1}$ and 116.60±40.38 $nGyh^{-1}$ respectively, and an overall mean absorbed dose rate value of 129.82±32.98 $nGyh^{-1}$. The obtained mean gamma absorbed dose rate of the studied sites is lower than the 143.55±52.20 ηGyh^{-1} reported in coal mining environment in Nigeria and the 141.30 ± 31.31 nGyh^{-1} earlier reported in Warri metropolis but higher than the 81.61 $nGyh^{-1}$ values of absorbed dose previously reported for Muzaffarabad city, 102.70 $nGyh^{-1}$ for Poonch in Turkey, 78.30 $nGyh^{-1}$ also in the City of Turkey and 32 $nGyh^{-1}$ for Greece *(Clouvas et al., 2004; Erees et al., 2006; Rafique, 2013; Rafique et al., 2014; Agbalagba et al., 2016; Agbalagba, 2017)*. They are also higher than the values reported in some of the countries of the world as documented in the *UNSCEAR* report (*UNSCEAR, 2000)*. These countries include New Zealand (20 $nGyh^{-1}$), the United States (38n $nGyh^{-1}$), the United Kingdom (60 $nGyh^{-1}$), Poland (67 $nGyh^{-1}$), Norway (80 $nGyh^{-1}$), china (100 $nGyh^{-1}$), Portugal (102 $nGyh^{-1}$), and Italy (105 $nGyh^{-1}$). However, the gamma dose rates obtained in the study area agrees with the range of values reported in turkey (78.30-135.70 $nGyh^{-1}$) and lower than the maximum value of 509.38nGyh^{-1} reported in Japan *(UNSCEAR, 2000)*. The mean value of 129.82±32.98 $nGyh^{-1}$ obtained in studied is 2.20 magnitude higher than the world population weighted average gamma dose rate value of 59 $nGyh^{-1}$, which an indication that the environments where these refined natural mineral resources are dispensed for use are radiologically polluted.

3.2.4 The Annual Effective Dose Equivalent (AEDE)

The annual effective dose equivalent (AEDE) received by the stations attendants who spend an average of twelve hours per day dispensing fuel and gases were calculated from the absorbed dose rates, dose conversion factor of 0.75Sv/Gy recommended by UNSCEAR for the conversion coefficient from the absorbed dose in air received by adults and an occupancy factor of 0.2 for outdoor exposure. The annual effective dose equivalent was evaluated using the equation *(UNSCEAR, 2000)*:

$$AEDE\ (outdoor)\ (mSvy^{-1}) = Absorbed\ dose\ (nGyh^{-1})x1.2264 \times 10^{-3} \quad (4)$$

The computed annual effective dose equivalent shows a mean value of 0.16±0.011 $mSvy^{-1}$ for the Sapele road region, 0.15±0.05 $mSvy^{-1}$ for the Enerhen region, 0.15±0.02 $mSvy^{-1}$ for Water Resources region and 0.17±0.03 $mSvy^{-1}$ for the Ajamogha region. For the Effurun, Refinery-Ekpan, PTI and Jeddo regions, the estimated values for the annual effective dose equivalent are 0.15±0.03$mSvy^{-1}$, 0.17±0.05$mSvy^{-1}$, 0.18±0.06$mSvy^{-1}$ and 0.14±0.06 $mSvy^{-1}$ respectively, with an overall mean value of 0.16±0.04 $mSvy^{-1}$. The annual effective dose equivalent values obtained are comparable to the values reported in Al-Rakkah, Saudi Arabia *(Al Mugren, 2015)*. The values obtained in this study are well above the world average annual effective dose level of 0.07 $mSvy^{-1}$for outdoor environment which is an indication of radiological contamination of the studied environment *(UNSCEAR 2000; Amekudzie et al., 2011; Al Mugren, 2015)*. The inhalation of the elevated level of ionizing radiation (radon gas) emitted from the dispensed petroleum products and cooking gas by these attendants can lead to lung cancer from accumulated doses *(Ademola and Onyema, 2014)*.

3.2.5 Excess Lifetime Cancer Risk (ELCR)

The Excess Life Cancer Risk estimates the likelihood of contacting cancer over a lifetime period at a specific exposure rate in a given population of persons. The excess lifetime cancer risk (ELCR) was estimated based on the computed values of AEDE using the equation:

ELCR = AEDE × average duration life (DL) × risk factor (RF) (5)

Where AEDE, represent the annual effective dose equivalent, DL, is the duration of life (70years) and RF is the fatal cancer risk factor (Sv^{-1}). For low dose background radiation which is considered to produce stochastic effects, ICPR 60 uses a fatal cancer risk factor value of 0.05 for public exposure. The mean estimated excess lifetime cancer risk (ELCR) values are 0.55±0.12, 0.53±0.17, 0.53±0.08 and 0.61±0.09 for the Sapele road, Enerhen, Water Resources and Ajamogha regions respectively. While the mean values for the Effurun, Refinery-Ekpan, PTI and Jeddo regions are 0.52±0.10, 0.60±0.18, 0.64±0.2 and 0.50±0.20, respectively with an overall mean excess lifetime cancer risk (ELCR) of 0.56±0.14. The average ELCR value obtained in the current study area is less than the world average value of 0.29×10^{-3}. This ELCR value obtained indicates a likelihood of contracting cancer by workers at these fuel and gas dispensing stations of the study area is insignificant.

3.2.6 Effective Dose Rate (D_{Organ}) to Different Body Organs and Tissues

The model of the annual effective dose to organs estimates the amount of radiation intake by a person that accumulates in various body organs and tissues. The effective dose rate to a particular organ can be estimated using the relation *(Rafique et al., 2014; Agbalagba, 2017; Ekong et al., 2019)*.

$$D_{organ}\ (mSvy^{-1}) = O\ x\ AEDE\ x\ F \quad (6)$$

Where AEDE is annual effective dose, O represent the occupancy factor which have a value of 0.8 and F stands for the conversion factor for organ dose from ingestion whose values for different organs and tissues are presented in Table 10, with the F values as reported by ICRP. Seven organs and tissues were examined as presented in Table 10, the results as presented in Figure 4 show that the testes received the highest dose with an average value of 0.10mSvy^{-1} while the liver received the lowest dose with a value of 0.06mSvy^{-1}. The estimated doses to the different organs examined revealed that values were considerably below the international tolerable limits of 1.0 mSv annually. The relatively higher dose to the testes and low dose intake to the liver is justified by the absorption rate of the organs (Agbalagba, 2017). This result shows that the exposure to BIR levels around fuel/gas dispensing stations in Warri city contributions to the radiation dose to these organs in adults are insignificant.

The overall results show moderate elevation of the BIR exposure level equivalent dose rate, absorbed dose rate and annual effective dose equivalent of the studied environment over previous study carried out within the Metropolis and other parts of the world. However, these values obtained from the study may not constitute any immediate health risk for the populace especially fuel/gas attendants working for long periods (more than eight hours per day over a period of 30 years) in these stations.

4. Conclusion

The study of the Terrestrial background ionizing radiation around selected fuel/gas dispensing stations Warri city to estimate the radiological implications cum the associated excess lifetime cancer risk has been conducted. The following conclusions and recommendations were reached from the present study:

- The study revealed that the background ionizing radiation levels around fuel/gas dispensing stations of the study area exceeded normal BIR levels, thus the environments around fuel and gas dispensing stations have be impacted radiologically.
- The elevation of the BIR levels above the world ambient level of $0.013Rh^{-1}$ was attributed to the presence of the fossil fuel in the environment.
- Three out of the five risk parameters examined exceeded global levels and the world ambient radiation permissible limit for the public of $1.0mSvy^{-1}$ reported by (UNSCEAR, 2000; ICRP. 1996). The calculated excess lifetime cancer risk and the exposure dose rate to the adult organs investigated are insignificant. Thus, the elevated values may not constitute any immediate health risk to the stations attendants.
- However, the attendants of these dispensing outlets are cautioned against prolonged exposure to avoid future accumulative health risks.
- Periodic monitoring of these study sites for BIR status is recommended.

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