Radiation Dosimetry of Some Selected Industrial Sites at Onne Oil and Gas Free Trade Zone, Rivers State Nigeria

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Abstract: Measurement of radiation exposure rate of Onne Oil and Gas Free Trade Zone Authority, Rivers State, Nigeria was carried out in order to assess the radiological health implication of the exposed individuals. The area was divided into four zones namely Zone A, Zone B, Zone C and Zone D. An in-situ approach was adopted using two calibrated Nuclear Radiation meters (Digilert -50 and Radalert -100) and a Global Positioning System (GPS map-765). At each zone, eight (8) readings were taken making a total of thirty two (32) sampling points. The measured mean exposure rate of the four zones is 0.014, 0.015, 0.017 and 0.018mRh^{-1} respectively. About 78% of the sampling points have exposure rate higher than the normal standard radiation exposure rate of 0.013mRh^{-1}. The mean absorbed dose of the four zones is 118.54, 127.24, 147.9 and 152.3nGyh^{-1}. These values were higher than the world safe value of 84.0nGyh^{-1}. Annual effective doses of all the sampling point are within the safe value but the excess life time cancer risk estimated for all the sampling points exceeded the safe value of 0.29×10^{-3}. This study shows that there is no immediate health hazard on the workers, staffs and the general populace of the host communities but continuous and prolonged exposure may pose health challenges to the staff working within the free trade zones and those residing around the area.

Keywords: Excess life time cancer risk, exposure, radalert-100, radiation, onne, exploitation.

1. INTRODUCTION

Everywhere in the world, man is exposed to radiation from different sources including rocks, soil and solar system [1]. This radiation may be man-made especially in medical imaging and radiotherapy equipments, security screening equipments and smoke detectors [2]. In Oil and gas industries, human made radiation sources are employed in the following activities: welding, well logging, exploration, exploitation and petrochemicals [3]. The exploitation of oil and gas resources has contributed immensely to the environmental pollution and degradation [4]. Some of the activities like mining, milling, dredging greatly increase the background ionizing radiation in our surroundings [5].

Man benefits greatly from the use of X-rays, radioisotopes and fissionable materials in medicine, industry, and research and power generation. However, the realization of these gains entails the routine exposure of persons to radiation in the procurement and normal use of sources as well as exposures from accidents that might occur [6]. Since any radiation exposure involves some risk to the individual involved, the levels of exposure allowed should be worth the result that is achieved.

Human exposure to ionizing radiation mainly occurs from the natural sources (cosmic and terrestrial radiations). Cosmic rays from space include energetic protons, gamma ray, electrons and so on [7, 8]. The exposure to cosmic radiation depends mostly on altitude, latitude and solar activity [9]. Human external exposure to radiation from all source types is mainly due to gamma rays because of its penetrative ability [10]. 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 [6]. 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 [7].

Many studies have shown that radionuclides are known to be associated with organic materials in nature. Therefore, oil, gas and oil field brines frequently contain radioactive materials. Hydrocarbon exploration and exploitation activities have the potential to increase the risk of radiation exposure to the environment and humans releasing naturally occurring radioactive material beyond the normal levels [11]. Many researchers have conducted different studies for monitoring and risk assessment of radiation exposure [12-15]. They preliminarily monitored the dose rates and then tried to develop mathematical models in order to estimate the level of risk factor. In this study, we have monitored gamma dose rates while dividing the whole study area into four zones.

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E-ISSN: 2311-8741/16

Figure 1: Map of the study area.

However, there is no existing record of radiological studies done on the study area. It is therefore important to consider measurements of ionization and energy absorption as the basis for radiation dosimetry of the study area that is, quantitative determination of exposure of individuals, estimation of the health implication. The result of this study will serve as a baseline data for radiation levels and for radiological surveillance of the environment.

2. MATERIALS AND METHODS

2.1. Study Area

The study areas are situated in Onne Oil and Gas Free Trade Zone Authority (OGFZA) of Rivers State, Nigeria. The geographic location are within latitudes N04041’ and N04040’ and longitude E007^{0}10’ and E007009. The study area was divided into four zones to strategically capture some of the important areas. The areas were Brawal oil and gas Ltd, Brawal Jetty, Federal Ocean Terminals (FOT) and some zones along the Onne Oil and Gas Free Zone Authority. Onne oil and Gas Free Trade Authority (OGFZA) was officially opened in March 1997. It has more than 30 international oil and gas companies including many of the world’s largest corporations, which are now registered as free trade user. Onne oil and gas free trade zone is being managed by DMS International Ltd and dedicated solely to oil and gas industry.

Brawal oil and gas is situated within the FLT, which also accommodates a Jetty at the terminal where offshore vessels berth. Maintenance of offshore rigs, vessels and equipment are carried out in the Jetty. Within the premises are different stacking area and working area where fabrications are carried out. The stacking area and working area also housed offshore equipments like drill pipes. There also exists a chemical plant producing drilling fluid. Some of these areas also have stores, stacking areas and tank farms. The major industrial operations here are welding of pipes, maintenance of equipment, loading and offloading of petroleum products.

2.2. Field Measurement

An *in situ* approach of background ionization radiation measurement was preferred and adopted to enable sample maintain their original environmental statistics [12]. A well calibrated Digilert$_{Tm}$- 50 and Radalert$_{Tm}$-100 nuclear radiation monitoring meter (S.E. International Inc, Summer Town, USA) containing a Geiger-Muller tube capable of detecting alpha, beta, gamma and X-rays within the temperature range of –10^{o}C and 50^{o}C was used to measure radiation levels. The Geiger Muller tube generates a pulse current each time radiation passes through the tube and causes ionization [16]. Each pulse is electronically detected and registered as a count. The radiation meters were calibrated with a ^{137}Cs source of a specific energy and set to measure exposure rate in milli-Roetgen per hour. A geographical positioning system (GPS) was used to measure the precise position of sampling points. The readings were taken within the hours of 1300 and 1600 hours because exposure rate meter has a maximum response to environmental radiation within these hours [17]. The tube of the radiation meter was raised to a height of 1.0m above the earth surface with its window facing first the earth surface and then vertically downwards [18, 3]. For each location two measurements spanning over 2 minutes were carried out and these measurements were then averaged to single value. Data obtained for outdoor exposure rate in mR/h was converted into absorbed dose rate nGy/h using the conversion factor [19];

$$1\mu R/h = 8.7 nGy/h = 8.7 \times 10^{-3} \mu Gy / (1/8760) yr = 76.212 \mu Gy y^{-1} \quad (1)$$

2.3. Results and Discussion

The radiation exposure rate measured in Brawal oil and gas free trade zones and its environs with their associated radiation risk parameters were presented in

Table 1: Mean Radiation Exposure at North of Brawal Oil and Gas and its environs (Zone A)

S/N	Sample Area	Geographical Coordinates	Av. Exposure Rate(mR/h)	D (nGy/h)	AEDE (mSv/y)	ELCR × 10^{-3}
1.	Admin block	N04^{0}41'52.0"	0.017 ± 0.001	147.9	0.23	0.79
		E007^{0}10'24.5"				
2.	Ware house1	N04^{0}41'49.4"	0.015 ± 0.002	130.5	0.20	0.70
		E007^{0}10'37.1"				
3.	Ware house2	N04^{0}41'49.0"	0.015 ± 0.002	130.5	0.20	0.70
		E007^{0}10'36.5"				
4.	Car park	N04^{0}4148.3"	0.016 ± 0.001	139.2	0.21	0.75
		E007^{0}10'36.1"				
5.	Portacabin	N04^{0}41'50.3"	0.013 ± 0.001	113.1	0.17	0.61
		E007^{0}10'24.9"				
6.	Ware house3	N04^{0}41'48.0"	0.012 ± 0.001	104.4	0.16	0.56
		E007^{0}10'35.2"				
7.	Stacking Area1	N04^{0}41'51.4"	0.012 ± 0.002	104.4	0.16	0.56
		E007^{0}10'37.4"				
8.	Stacking Area2	N04^{0}41'57.1"	0.009 ± 0.001	78.3	0.12	0.42
		E007^{0}10'33.9"				
	Mean		0.014 ± 0.001	118.54	0.17	0.64

Table 2: Mean Radiation Exposure at South of Brawal Oil and Gas and its Environs (Zone B)

S/N	Sample Area	Geographical Coordinates	Average Exposure Rate (mR/h)	D (nGy/h)	AEDE (mSv/yr)	ELCR × 10^{-3}
1.	Brawal Clinic	N04^{0}41'46.6"	0.016± 0.002	139.2	0.21	0.75
		E007^{0}10'33.5"				
2.	Security post	N04^{0}41'48.6"	0.014 ± 0.002	121.8	0.19	0.65
		E007^{0}10'29.5"				
3.	Entrance Gate	N04^{0}41'48.0"	0.014 ± 0.003	121.8	0.19	0.65
		E007^{0}10'25.3"				
4.	Working Area1	N04^{0}41'47.5"	0.016 ± 0.002	139.2	0.21	0.75
		E007^{0}10'25.0"				
5.	Working Area2	N04^{0}41'47.5"	0.014 ± 0.002	121.8	0.19	0.65
		E007^{0}10'24.8"				
6.	Working Area3	N04^{0}41'48.9"	0.014 ± 0.001	121.8	0.19	0.65
		E007^{0}10'30.0"				
7.	Stacking Area3	N04^{0}41'50.4"	0.015 ± 0.002	130.5	0.20	0.70
		E007^{0}10'30.2"				
8.	Stacking Area4	N04^{0}41'50.4"	0.014 ± 0.002	121.8	0.19	0.65
		E007^{0}10'30.2"				
			0.015 ± 0.002	127.24	0.20	0.68

Tables **1-4**. The comparism of the entire exposure rate measured in the four zones with the international committee of radiation protection [20] is shown in Figure **2**. Radiation contour of the area which shows the distribution pattern of radionuclides were shown in Figures **3** to **6**.

2.4. The Annual Effective Dose Equivalent (AEDE)

The risk for all stochastic effects for an exposed individual is represented by the effective dose. It is defined as the sum of the weighted equivalent doses over all tissues. The absorbed gamma dose rates were

Table 3: Mean Radiation Exposure at Brawal Jetty and its Environs (Zone C)

S/N	Sample Area	Geographical Coordinates	Mean Exposure Rate (mR/h)	D (nGy/h)	AEDE (mSv/y)	ELCR × 10^{-3}
1.	Hamilton Operation	N04^{0}41’59.5” E0071053.5	0.016±0.001	139.2	0.21	0.75
2.	Hamilton Chemical tank	N04^{0}41’53.6” E007^{0}10’53.5”	0.015±0.003	130.5	0.20	0.70
3.	Hamilton office	N04^{0}41’54.8”	0.014±0.003	121.8	0.19	0.65
		E007^{0}10’51.2”				
4.	Quayside1	N04^{0}41’46.8”	0.022±0.005	191.4	0.29	1.03
		E007^{0}10’38.3”				
5.	Brawal Jetty	N04^{0}41’48.0”	0.021±0.002	182.7	0.28	0.98
		E007^{0}10’47.0”				
6.	Quayside2	N04^{0}41’50.0”	0.021±0.003	182.7	0.28	0.98
		E007^{0}10’47.0”				
7.	Loading Area1	N04^{0}41’49.6”	0.014±0.003	121.8	0.19	0.65
		E007^{0}10’38.2”				
8.	Loading Area2	N04^{0}41’49.1”	0.013±0.001	113.1	0.17	0.61
		E007^{0}10’37.2”				
			0.017	147.9	0.19	0.76

Table 4: Mean Radiation Exposure at FOT and its Environs (Zone D)

S/N	Sample Area	Geographical Coordinates	Mean Radiation level (mR/h)	D (nGy/h)	AEDE (mSv/yr)	ELCR × 10^{-3}
1.	FOT Gate	N04^{0}41’28.0”	0.021± 0.001	182.7	0.28	0.98
		E007^{0}09’14.4”				
2.	Chevron	N04^{0}41’01.7”	0.021± 0.003	182.7	0.28	0.98
		E007^{0}09’17.2”				
3.	Sahara PWSL	N04^{0}41’07.8”	0.015 ± .002	130.5	0.20	0.70
		E007^{0}09’11.1”				
4.	Tonimas Sludge tank	N04^{0}40’57.2”	0.012± 0.002	104.4	0.16	0.56
		E007^{0}09’08.9”				
5.	Mobil	N04^{0}41’03.1”	0.017± 0.002	147.9	0.23	0.79
		E007^{0}09’10.6”				
6.	NAE	N04^{0}41’11.5”	0.017± 0.002	147.9	0.23	0.79
		E007^{0}09’12.3”				
7.	WACT Security post	N04^{0}40’31.2”	0.021± 0.002	182.7	0.28	0.98
		E007^{0}09’02.2”				
8.	NPDC	N04^{0}41’17.8”	0.016± 0.002	139.2	0.21	0.75
		E007^{0}09’20.2”				
			0.018± 0.002	152.3	0.23	0.82

used to calculate the annual effective dose equivalent (AEDE) received by individuals in the study area. In calculating AEDE, dose conversion factor of 0.7 Sv/Gy and the occupancy factor for outdoor and indoor of 0.25 (6/24) and 0.75 (18/24) respectively was used. The occupancy factor for outdoor and indoor was calculated based upon interviews with peoples of the area. People of the study area spend almost 6 hours outdoor and 18 hours indoor daily due to the nature of their custom. The annual effective was determined using the following equation [9];

AEDE (outdoor) (mSv/y) = Absorbed dose rate (nGy/h) ×8760 h ×0.7Sv/Gy × 0.25 (2)

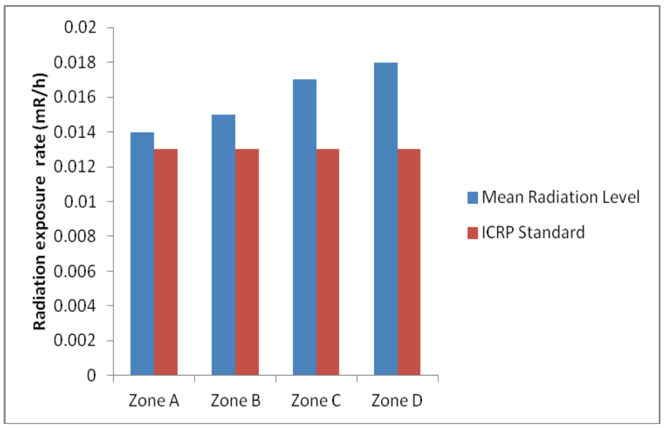

Figure 2: Comparison of radiation exposure rate with ICRP standard.

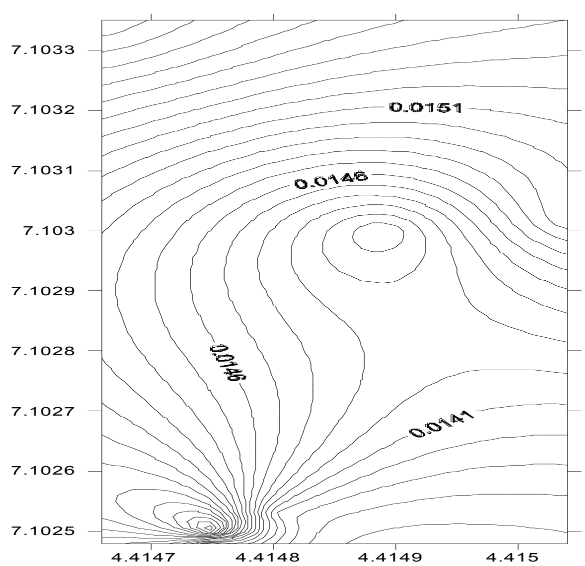

Figure 3: Contour radiation map of zone B.

2.5. Excess Lifetime Cancer Risk (ELCR)

The annual effective dose calculated was used to estimate the excess lifetime cancer risk (ELCR) is calculated using equation (3).

Excess Lifetime cancer risk (ELCR) = AEDE × Average duration of life (DL) × Risk factor (RF) (3)

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 [21, 19].

Table **1** shows the radiation exposure rate of North of Brawal Oil and Gas and its environs (Zone A). The radiation exposure rate range from 0.009 ± 0.001 to 0.017 ± 0.001mRh^{-1} with an average of 0.014 ± 0.001mRh^{-1}. The highest value recorded at Admin block might be as result of its proximity to the jetty where maintenance of offshore facilities is ongoing. About 50% of the sample points in this zone were above the ICRP standard value of 0.013mRh^{-1}. These values were converted to absorbed dose rate of radiation using equation 1 above. The absorbed dose rate of zone A ranges from 78.3$nGyh^{-1}$ to 147.9$nGyh^{-1}$ with mean value of 118.54$nGyh^{-1}$. The annual effective dose rate ranges from 0.12 to 0.23$mSvy^{-1}$ while the excess lifetime cancer risk estimated ranges from 0.42×10^{-3} to 0.79 $\times10^{-3}$ with mean value of 0.64×10^{-3}. Oil and gas activities in this area has enhanced the background ionizing radiation this zone.

Table **2** shows the exposure rate of South of Brawal Oil and Gas and its environs (Zone B). The radiation level ranges from 0.014 to 0.016mR/h with an average value of 0.015 ± 0.002mR/h. Radiation levels of all the sampling points in this zone exceed the ICRP maximum permissible level of 0.013mR/h. The highest value was recorded at Brawal clinic and working Area1. Brawal clinic is situated very close to Hamilton Technologies Ltd where different chemicals like drilling fluid and other offshore support product are produced. This chemical contains some level of radionuclides which might contribute to increase in the radiation level of this area [22, 23]. Also activities like welding, painting and maintenance of marines and offshore craft might also contribute to slight increase in background radiation in the working Area 1[24]. The distributions of these radiations within the sampling points are represented with the contour map shown in Figure **4**. The absorbed dose rate ranges from 121.8 to 139.2$nGyh^{-1}$ with mean value of 127.24$nGyh^{-1}$ while the mean annual effective dose recorded was 0.20mSv which is below the safe level. The excess lifetime cancer risk estimated ranges from 0.65×10^{-3} to 0.75×10^{-3} with mean value of 0.68×10^{-3}. The excess lifetime cancer risk estimated is slightly higher than the world acceptable safe value of 0.29×10^{-3}.

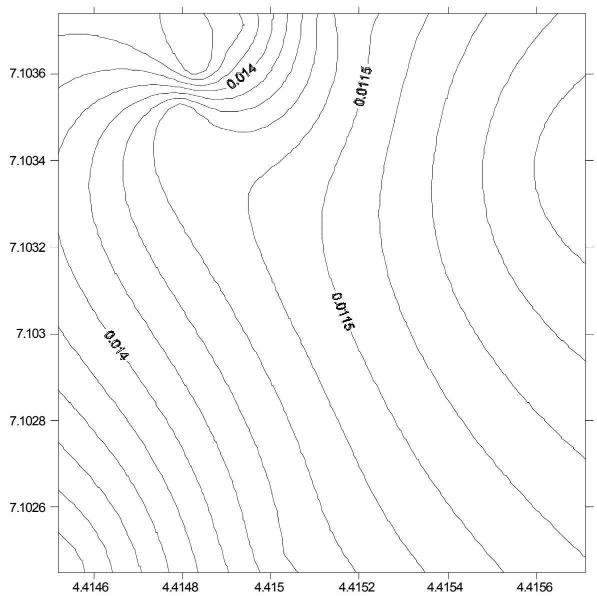

Figure 4: Contour radiation map of zone A.

Table **3** shows the radiation exposure rate of the Jetty and its environs (Zone C). The radiation level ranges from 0.013 ± 0.001to 0.022 ± 0.003mRh^{-1} with an average value of 0.017 ± 0.003mRh^{-1}. The highest value was recorded at the Quayside 1 which might be as a result of maintenance of oil rig and marine vessels at the site [2]. The absorbed dose rate ranges from 113.1 to 191.4nGyh^{-1} with a mean value of 147.9nGyh^{-1} while the mean value of annual effective dose is 0.19mSv. The excess lifetime cancer risk estimated ranges from 0.61×10^{-3} to 1.03×10^{-3} with mean value of 0.76×10^{-3}. The distribution of the radiation level is shown in Figure **5**.

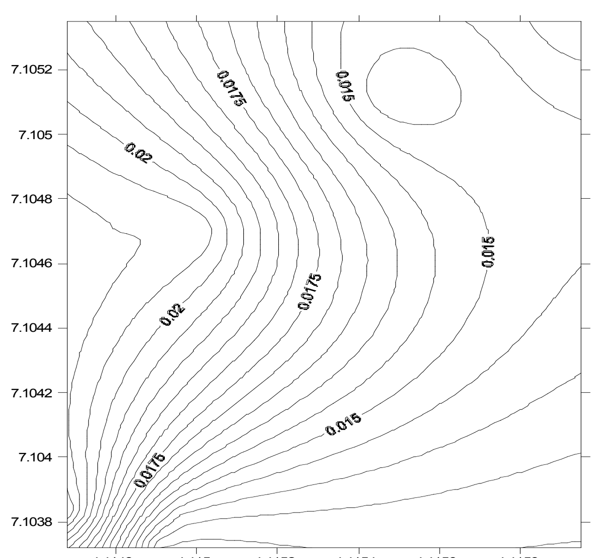

Figure 5: Contour radiation map of zone C.

Table **4** shows the radiation exposure rate at the FOT and its environs (Zone D). The radiation exposure rate of this zone ranges from 0.015 to 0.021mR/h with an average value 0.018 ± 0.002mRh^{-1}. The highest value was recorded at FOT gate, WACT security post and Chevron area. The value recorded at FOT gate and WACT security gate might be due to the different activities going in that area like excavation, dredging and quarrying due to ongoing construction of Intel berth 9 and berth 10 of the FOT section [25, 26]. The absorbed dose of radiation ranges from 104.4 to 182.7nGyh^{-1} with mean value of 152.3nGyh^{-1}. The excess lifetime cancer risk estimated range from 0.56×10^{-3} to 0.98×10^{-3} with mean value of 0.64×10^{-3}. Generally, it was observed that the least mean radiation exposure value was recorded at Zone A and the highest value was recorded in Zone D. This high value might be as a result of Custom Container scanning centre located within the zone [27, 26, 28]. Also, the massive excavating and dredging activities due to ongoing construction of Intel's berth 9 and berth 10, might also bring about increase in background ionizing radiation in that zone [3].

Figure **2** shows the comparison of radiation exposure rate of all the four zones with International Commission on Radiological Protection (ICRP) standard. From the results, the exposure rates recorded in all the zones were higher than the standard value of 0.013mRh^{-1}. The overall result shows that 78% of the sample point exceed the result reported by James *et al*. [29], Nwankwo and Akoshile [30] and Inyang *et al*. [31] but are within the range of values recorded by Ononugbo *et al*., [3] Nwankwo *et al*. [25] and Avwiri *et al*, [16].

CONCLUSION

Radiation dosimetry of some selected industrial sites in Onne Oil and Gas Free Trade Zone Authority (OGFZA) has been carried out. The in-situ measurement of the radiation rate of the four zones of the study area was done using radalert -100 and digilert-50. Radiation exposure rate measured in all the zones (A, B, C and D) exceeded the ICRP, [20] safe limit. The absorbed dose and excess lifetime cancer risk estimated exceeded the UNSCEAR, [9] standard of 84.0nGyh^{-1} and 0.29×10^{-3} respectively. The annual effective doses calculated were all below the standard safe value of 0.48mSv. The result of this study clearly shows that the area understudy has been impacted radiologically, therefore though no immediate health hazard is expected but prolonged exposure might lead to higher probability of cancer induction since the cancer risk estimates exceeded the safe value. We therefore recommends as follow:

- Federal ministry of Environment and other regulatory bodies should regularize the operations of oil and gas activities in that zones to reduce emissions of radioactive gas.
- Routine radiological monitoring of the area and further studies on other environmental media of the area.

REFERENCES

[1] DOE (Department of Energy). Decommissioning Radiological and Hazardous Chemical Human Health Impacts Evaluation, Environmental Impact Statement, DOE/EIS-0337F, West Valley Area Office, New York 2008.

[2] OGP. Guidelines for the management of Naturally Occurring Radioactive Material (NORM) in the oil and gas industry, International Oil and Gas producers' publication 2008.

[3] Ononugbo CP, Avwiri GO and Chad-Moran YE. Impact of Gas Exploitation on the Environmental Radioactivity of Gobi / Abeam/ Nona Area. Nigeria Energy and Environment 2011; 22(8) 1017- 1029. http://dx.doi.org/10.1260/0958-305X.22.8.1017

[4] Chad-Umoren YE and Ohwekevwo E. Influence of crude oil spillage on the gamma radiation status of water and soil in Ogba/Egbema/Ndoni area, Nigeria. Energy and Environment Research 2013; 3(2): 1-8. http://dx.doi.org/10.5539/eer.v3n2p45

[5] Agbalagba EO, Avwiri GO and Ononugbo CP. Evaluation of Naturally Occurring Radioactivity Materials (NORM) of Soil and Sediments in Oil and Gas Wells in Western Niger Delta Region of Nigeria. 2013 Journal of Environmental Earth Sciences Springer.

[6] James ET. Atoms, Radiation and Radiation Protection. Third completely revised and enlarged edition. Wiley-VcH Verlag GmbH and co. kGaA.

[7] Sadegh H, Hadi S, Mojtaba A, Babak A, Hasan F and Soheila R. Assessment of Gamma dose rate in indoor environment in selected districts of Ardabil Province, Northwestern Iran. Intl journal of occupational Hygiene 2010; 2: 42-45.

[8] Uosif MA, Mahmond T, Shams AM and Reds E. Naturally Occurring Radionuclides in Sludge samples from some Egyptian Drinking water Purification Stations. International Journal of Advanced Science and Technology 2012; 42: 69-81.

[9] UNSCEAR. Ionizing radiation: Sources and biological effects. Reports to the general assembly with scientific annexes. 2000, New York, United Nations.

[10] Al-Saleh FS. Measurement of indoor gamma radiation and radon concentration in dwellings of Riyadh city, Saudi Arabia. Appl radiat Isot 2007; 65(7): 843-8. http://dx.doi.org/10.1016/j.apradiso.2007.01.021

[11] Mahmoud A, Dar Mahmoud I and EL Saman. The interactions of some radioelements activity patterns with some hydrographic parameters at the petroleum and phosphate regions in the Red sea, Egypt. Journal of Research and Applied Sciences 2014; 7: 292-304.

[12] Avwiri GO, Egieya JM and Ononugbo CP. Radiometric survey of Aluu landfill in Rivers State, Nigeria. The International Institute for Science, Technology and Education 2013, 22www.iiste.org.

[13] Ononugbo CP and Nwii. Indoor and Outdoor Effective Doses from Background Ionizing Radiation in Private Medical Diagnostic centers in Bori, Rivers state. Journal of Environmental and Earth Science 2015; 5(9): 25-29.

[14] Ononogbo CP, Avwiri GO and Komolafe ET. External Ionizing Radiation Exposure during Cargo/Vehicle Radiographic Inspection of Nigerian Ports Authority, Onne, Rivers State, Nigeria. Journal of Environment and Earth Science 2015; 5(11): 1-9.

[15] Rafique M, Basharat M, AzharSaeed R and Rahamn S. Effect of geology and altitude on ambient outdoor gamma dose rates in district poonch, Azad Kashmir, Carpathian. Journal of Earth and Environmental Sciences 2013; 8(4): 165-173.

[16] Avwiri GO, Alao AA and Onuma EO. Survey of Terrestrial Radiation levels of Onne Seaport, Rivers State, Nigeria. Asian Journal of Natural and Applied Science 2012; 1(3): 107-114.

[17] Louis EA, Etuk ES and Essien U. Environmental Radioactivity level in Ikot Ekpene, Nigeria, Nigeria Journal of Space research 2005; 1: 80-87.

[18] Avwiri GO and Agbalagba OE. Survey of gross alpha and gross beta radionuclide activity in Okpara creek, Delta state, Nigeria. Asia Network for science Information Journal of Applied Science 2007; 7(22): 3542-3547.

[19] Muhammad R, Saeed Ur R, Muhammad B, Wajid A, Iftikhar A, Khursheed A, *et al*. Evaluation of Excess life time cancer risk from gamma dose rates in Jhelum valley. J of Radiat Res and Appl Sc 2014; 7: 29-35. http://dx.doi.org/10.1016/j.jrras.2013.11.005

[20] International Commission on Radiological Protection (ICRP). Relative Biological Effectiveness Radiation weighting and quality factor Annals of ICRP-33, 2003; Pergamon press, Oxford.

[21] Taskin H, Karavus M, Ay P, Topuzoghi A, Hindiroglums S and Karahan G. Radionuclide concentrations in soil lifetime cancer risk due to gamma radioactivity in Kirklaeli, turkey. Journal of Environmental Radioactivity 2009; 100: 49-53. http://dx.doi.org/10.1016/j.jenvrad.2008.10.012

[22] Okeyode IC and Jibiri NN. Excess lifetime cancer risk associated with the use of sediments from Ogun River as building materials. Research Journal of Physics 2013; 7: 1-8. http://dx.doi.org/10.3923/rjp.2013.1.8

[23] IPIECA/OGP. Drilling fluids and health risk management. International Petroleum Industry Environmental Conservation and International Association of Oil and Gas Producer, London, United Kingdom 2009.

[24] NRPA. NORM in Oil and Gas industries. Radiation at work series, Norwegian Radiation Protection Authority 1999.

[25] Nwankwo LI, Akoshile CO, Alabi AB, Ojo OO and Ayodele TA. Environmental Ionizing Radiation survey of Quarry sites in Ilorin Industrial Area. Nigerian Journal of Basic and Applied Science 2014; 22(1-2): 1-4. http://dx.doi.org/10.4314/njbas.v22i1.1

[26] American Cancer Society (ACS), (2013). X-rays, Gamma rays and cancer risk.

[27] Institute of Medical Research and Occupational Health (IMRH). Scientific Study of External Ionizing Radiation exposure during Cargo/Vehicle radiographic inspections, Zagreb. Journal of HR excellence in research 2012; 5(3): 1-10.

[28] Khan MS, Nicholas EP and Terpilak SM. Radiation Dose Equivalent to Stowaways in Vehicles. Health physics publication 2004; 86(5); 483-492.

[29] James IU, Moses IF and Vandi JN. Assessment of Gamma Dose Rate within Idu Industrial Area of Federal Capital Territory (FCT) Abuja, Nigeria. The International Journal of Engineering and Science 2013; 2(11) 52-55.

[30] Nwankwo LI and Akoshile CO. Monitoring of external background radiation level in Asa Dam Industrial area of Ilorin, Kwara State, Nigeria. Journal of Applied Science and Environmental Management 2005a; 9(3): 91-94.

[31] Iyang SO, Iyang IS and Egbe NO. Radiation exposure levels within timber industries in Calabar, Nigeria Journal of medical physics 2009; 32(2): 97-100. http://dx.doi.org/10.4103/0971-6203.51937

Received on 10-06-2016 Accepted on 25-06-2016 Published on 30-06-2016

DOI: http://dx.doi.org/10.12974/2311-8741.2016.04.01.1