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RESEARCH ARTICLE

RADIOLOGICAL EVALUATION OF THE CONCENTRATION AND IMPACT OF OIL AND GAS ACTIVITIES IN ERUEMUKOHWARIEN AREA OF SOUTHERN NIGERIA

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ABSTRACT

The study was carried out in-situ using a Radalert 100 nuclear radiation monitor and a geographical positioning system (GPS). Five facilities were investigated at the rig site which included the rig site host community as well as the camp site for the oil workers at Ekapkamreh town. Ten 10 sampling locations were evaluated at a total of 60 study points. The values obtained range between 0.115±0.018 (μSv/hr) and 0.299±0.040 (μSv/hr) for the rig site environment, 0.111±0.006 (μSv/hr) and 0.337±0.031 (μSv/hr) for field logistic base (offices and workshops), 0.114±0.011 (μSv/hr) and 0.312±0.021 (μSv/hr) for components of the mud circulation section. Also, the radiological concentration of the Chemical Store ranged between 0.126±0.019 (μSv/hr) and 1.181±0.104 (μSv/hr), while the radiological values obtained from other facilities within the rig site ranged from 0.155±0.026 (μSv/hr) and 0.249±0.026 (μSv/hr). Radiation readings obtained for soil ranged from 0.149±0.05 (μSv/hr) to 0.219±0.025 (μSv/hr) and 0.114±0.039 (μSv/hr) to 0.219±0.051 (μSv/hr) respectively at the host community and camp site. Most of the results obtained showed that the general environment of the rig site is slightly above the permissible absorbed dose rate threshold of 0.15(μSv/hr) recommended by the United Nation Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) in 2009. However, the exposure rates exceed the standard background level of 13μR/hr (coequal to 0.13μSv/hr). There is high tendency for the industry workers to be exposed to radiation with time.

KEYWORDS

Radiological concentration, survey, oil and gas, rig site environment, immune system.

1. INTRODUCTION

Nuclear and other radioactive sources are used in key sectors of the world's economy, these includes Oil and Gas, Health, Manufacturing, Security, Agriculture, Mining, Engineering and Construction, Education and Research, Water Resources amongst others (Abison, 2001). The oil and gas industry (both up and downstream) operating in many countries of the world makes extensive use of radiation generators, sealed and unsealed radioactive sources, some of which are potentially harmful to human health and the environment if not properly controlled (IAEA, 2010). In addition, significant quantities of naturally occurring radioactive material (NORM) originating from sub surface formations are encountered during production, maintenance and decommissioning activities, thus the oil and gas industry is a potential sources of radioactivity in any given country where the natural resources are found (UNSCEAR, 2000). The Niger Delta region has abundant oil and gas reserves occurring in different host communities. It is expected that it presence in the area will result in the elevation of background ionizings radiation due to the deployment of numerous forms of radioactive sources that are associated with oil and gas formations occurring in these areas. Also, well logging, drilling operations (especially mud circulation) and the use of radioactive substances within flow stations as well as other oil processing units is of great concern as research has established a correlative spectrum between exposure to radiation and long-term health hazards (Jibril et al., 1999; Abison, 2001; Agbalagba et al., 2007).

Over the years, literature abound on studies that were carried out on the environmental impact of both onshore and offshore oil and gas facilities within Delta State and the effect of their activities on the radiation level on the environment have showed that background ionizing radiation levels (BIR), activity levels of soil, sludge and sediments and production waters from oil and gas contains naturally occurring radioactive elements (especially uranium and thorium) and their daughter progeny (^{226}Ra, ^{228}Ra and ^{222}Rn) that are elevated above ambient level. The isotopes that contained the radioactive substances are associated with the nature of the rock types (i.e. the lithology of the formations- the source and cap rocks hosting hydrocarbon). It is worth mentioning that the Akata and Agbada formations because of their sandy and shaley nature are favourable for radiogenic isotopes (Stanislav and Elena, 1998). The radionuclides migrate from formation rocks into the circulating mud and other drill fluids and because of this, they are produced with the oil and natural gas at well heads and can be distributed externally to oil facilities if present in sufficiently high concentration (Avwiri et al., 2007). Consequently, the radiation levels in the work environment will be affected (Stanislav and Elena, 1998). The oil and gas work environment include drilling, off-shore and on-shore facilities, and indoor and out-door environments. There is danger of radioactive contamination as oil and gas operations have been associated with a high incidence of the radioactive substance ^{226}Ra (Avwiri et al., 2009). Certain industrial activities such as crude oil exploration also result in enhanced concentration of ionizing radiation in quantities that may become toxic to both man and his environment. Ionizing radiations

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such as α, β and γ radiations are often found in the petroleum matrix due to both contaminations by radionuclides in the earth's crust and the materials used in the drilling process (Laogun et al., 2006; Chad-Umoren, 2012). Ionizing radiations (Gamma rays in particular) are highly penetrating and are products of the radioactive materials containing radon. These substances may be ingested or inhaled thereby exposing both the hydrocarbon industry personnel and members of the host communities to increase in the risk of lung cancer, eye cataracts and mental imbalance (Laogun et al., 2006). This concern has thus sparked an interest in the survey of the radiation concentration, impact and status in a drilling rig site at Eruemukohwaren oil producing community and its environs to ascertain the levels of contamination due to the oil activities ongoing in the rig site and the host community to the rig. This results of this study will help to evaluate the possible health impact due to activities of oil and gas exploration activity.

2. Materials and Methods

2.1 Study Location

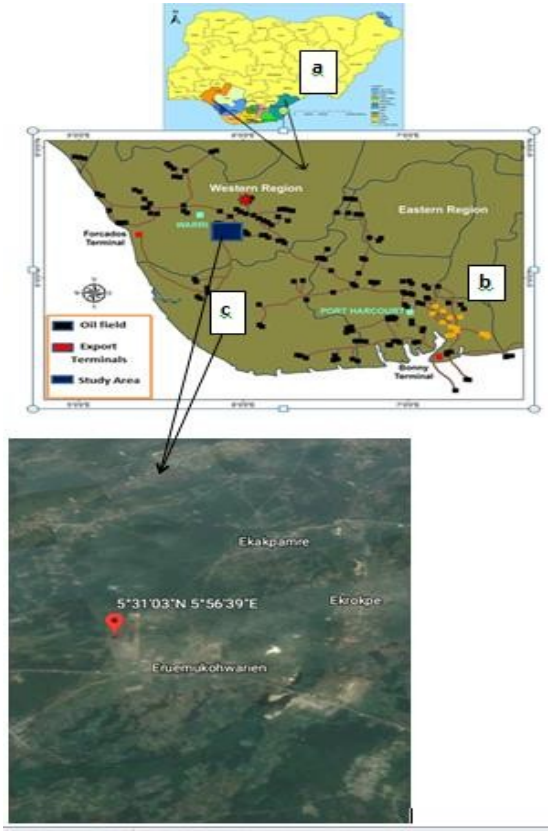

Figure 1: a. Map of Nigeria showing the Niger Delta Region b. Map of various oil fields (represented in black boxes), after Adeoti et al., 2015; the purple lines show interconnection of oil and gas pipelines, the red boxes further shows the terminals for exportation and importation of oil and gas resources. c. Google satellite map of the study Area (Rig site with red pin, Eruemukohwarien host community and Ekakpamre campsite).

The location of the study area lies between longitudes 005°54′02"E and 005°56′24"E and between latitudes 5°30′39"N and 5°32′18"N and the rig site is situated between longitudes 005°56′18"E and 005°56′24"E and latitudes 5°30′39"N and 5°32′44"N (Figure 1). Samples obtained were from 101 points within a total of 7 facilities belonging to a major onshore oil producing company (Nigerian Petroleum Development Company/ND-Western). The maximum and minimum elevations of the study area are 31m and 6m respectively, while the average elevation is 14m.

2.2 Experimental procedures

An *in-situ* approach of background ionizing radiation measurement was adopted and preferred to enable samples maintain their original environmental characteristics. A digilert 100 nuclear radiation monitor (S.E international, INC. summer town, USA), containing a Geiger Muller tube capable of detecting α, β, γ and x – rays, but pre- set for γ measurement within the temperature range of -10 to 50^0c and a geographical positioning system (GPS) was used to measure the precise location of sampling as reported elsewhere (Agbalagba, 2017). The assessment was achieved using a factory calibrated Inspector Digilert 100 Nuclear radiation meter (SN:35440, by SE international, Inc. USA). The meter's sensitivity is 3500 CPM/ (mRh^{-1}) referenced to Cs-137 and its maximum alpha and beta efficiencies are 18% and 33% respectively. It has a halogen-quenched Geiger-Muller detector tube of effective diameter of 45 mm and a mica window density of 1.5-2.0 $mgcm^{-2}$ (Inspector alert operation manual).

The radiation monitoring research lasted for a period of 8days. For optimum results, monitoring was carried out during the hours of 11.00am to 5.00pm because the radiation meter has a maximum response to environmental radiation during this period (Avwiri et al., 2009). At each facility four readings were taken, and their mean recorded. At the rig site, the radiation level of almost all the facilities were taken to ensure proper coverage of the area. Also, the radiation levels outside the oil and gas work-environment (that is of locations within the host communities) were also evaluated and results taken were analyzed.

The count rate per minute recorded in the meter was converted to milli-roentgen per hour (mRh^{-1}) using the relation.

$$\text{Count rate per minute (CMP)} = 10^{-3}\ \text{roentgen} \times \text{Q.F} \quad (1)$$

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

To estimate the whole-body equivalent dose rate over a period of one year, we use the National Council on Radiation Protection and Measurement recommendation (NCRP, 1993; Avwiri et al., 2013):

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

The annual effective dose equivalent (AEDE) received by workers, people living around the area and visitors was calculated in (μSv/yr) using the relation;

$$\text{AEDE (μSv/yr)} = \text{ADR} \times \text{T} \times \text{OF} \times 10^{-3} \quad (3)$$

Where, ADR is the absorbed dose rate, T is the total time per year in hours (365×24 = 8640secs.) and OF is the occupancy factor. For this research, the 0.2 standard OF that was recommended by the UNSCEAR, 2008 was used.

3. Results and Discussion

Figure 2: a. Shows sludge generated during drilling operations. b. Shows one of the well heads at the oil field.

Figure 2: Photograph showing the effect of sludge, scales and waste muds (especially oil-based mud) on the enhancement of radioactivity concentration and environmental faunal and floral degradation.

The results of the survey are presented in Tables 1- 8 and Figure 1 -4. Five facilities were studied in the rig site; the rig site host community was also monitored as well as the camp site for the oil workers at Ekapkamreh town. At each of the five facilities at the rig site, at least 10 sampling points were evaluated given a total of 60 study points. In Table1, the values obtained range between 0.115±0.018μSv/hr and 0.299±0.040 μSv/hr for

the rig site environment, 0.111±0.006 μSv/hr and 0.337±0.031μSv/hr for field logistic base (offices and workshops), 0.114±0.011 μSv/hr and 0.312±0.021μSv/hr for components of the mud circulation section. Also, the radiological concentration of the Chemical Store ranged between 0.126±0.019μSv/hr and 1.181±0.104 μSv/hr, while the radiological values obtained from other facilities within the rig site ranged from 0.155±0.026 μSv/hr to 0.249±0.026 μSv/hr. Radiation readings obtained from soil ranged from 0.149±0.05 μSv/hr to 0.219±0.025 μSv/hr and 0.114±0.039μSv/hr to 0.219±0.051 μSv/hr respectively at the host community and camp site.

Table 1: Rig Site Environmental Assessment Readings

LOCATION CODE	GPS READING	ADRs (μSv/hr)	ADR (μSv/hr)	AEDR (μSv/yr)
A1	N05°30'41.3" E005°56'19.0"	0.113+0.119+0.118+0.114	0.116±0.021	0.200
A2	N05°30'41.5" E005°56'18.7"	0.154+0.186+0.166+0.197	0.176±0.031	0.304
A3	N05°30'39.2" E005°56'24.0"	0.289+0.269+0.217+0.237	0.253±0.039	0.437
A4	N05°30'40.5" E005°56'25.2"	0.192+0.154+0.148+0.186	0.170±0.038	0.294
A5	N05°30'41.3" E005°56'25.9"	0.341+0.296+0.257+0.302	0.299±0.040	0.517
A6	N05°30'44.5" E005°56'20.7"	0.237+0.224+0.275+0.288	0.256±0.030	0.442
A7	N05°30'42.2" E005°56'19.1"	0.164+0.151+0.158+0.171	0.161±0.027	0.278
A8	N05°30'41.4" E005°56'21.2"	0.253+0.218+0.195+0.230	0.224±0.019	0.387
A9	N05°30'41.3" E005°56'20.8"	0.255+0.249+0.301+0.295	0.275±0.036	0.475
A10	N05°30'49.6" E005°56'22.7"	0.176+0.161+0.158+0.173	0.167±0.039	0.289
A11	N05°30'41.7" E005°56'24.1"	0.267+0.280+0.218+0.231	0.249±0.021	0.430
A12	N05°30'41.3" E005°56'23.2"	0.101+0.129+0.132+0.098	0.115±0.018	0.199
A13	N05°30'42.3" E005°56'20.9"	0.250+0.303+0.278+0.225	0.264±0.026	0.456
A14	N05°30'43.1" E005°56'21.6"	0.142+0.139+0.131+0.128	0.135±0.011	0.233
A15	N05°30'39.2" E005°56'24.0"	0.192+0.215+0.183+0.206	0.199±0.026	0.344
Mean ± SD			**0.204±0.028**	**0.352 ± 0.012**

Table 1 shows the exposure profile obtained from 15 studied points within the environment of the rig site at Eruemukohwarien oil field. The values obtained range between 0.115±0.018 μSv/hr and 0.299±0.040 μSv/hr (A5) with a mean and standard deviation values of 0.204 and 0.028 μSv/hr respectively. The Mud pits where sludge and scales are accumulated recorded the highest equivalent dose rate while the least equivalent dose rate was recorded at the well head 3 (A12) at oil field. Table 2 shows the radioactivity exposed rate determined for the ten facilities within the oil field. The obtained values range from 0.111±0.006 μSv/hr to 0.337±0.031 μSv/hr for the field logistic base (which include offices and workshops). The radiation level of the fabrication/welding center (mechanical workshop) as well as power house recorded to be high. This may be attributed to the materials that are used during welding processing and the gases that are emitted from the heavy power plants. Table 3 presents the absorbed dose rate exposed rate collected from fifteen facilities within the mud section of the Eruemukohwarien rig site. The obtained values range from 0.100±0.013 μSv/hr to 0.312±0.021 μSv/hr for the facilities within the mud section. The KCI is poured into the mixing hopper where it forms brine when mixed with water from the mud tank. The tank that contains brine which has been prepare to be used for the well bore cleaning after the last cementing operation recorded the highest radiation level of 0.312±0.021 μSv/hr. This is because KCl (which is highly radioactive) was to the major constituent chemical used in the brine production.

Table 2: Field Logistic Base (Offices and Workshop Radiological Concentration)

LOCATION CODE	FACILITY	GPS READINGS	ADRs (μSv/hr)	ADR (μSv/hr)	AEDR (μSv/yr)
B1	NPDC Safety Supervisor's office	N05°30'41.0" E005°56'21.0"	0.178+0.155+0.152+0.175	0.165±0.036	0.285
B2	Recreation Room	N05°30'41.5" E005°56'22.7"	0.163+0.188+0.201+0.176	0.182±0.026	0.315
B3	Mess Hall	N05°30'41.2" E005°56'21.8"	0.131+0.125+0.123+0.129	0.12 7±0.024	0.220
B4	Mud Laboratory	N05°30'42.5" E005°56'21.2"	0.108+0.099+0.123+0.114	0.111±0.006	0.192
B5	Mechanical Workshop	N05°30'42.3" E005°56'19.0"	0.348+0.330+0.326+0.344	0.337±0.031	0.582
B6	BOP Koomey Unit	N05°30'43.2" E005°56'22.8"	0.176+0.153+0.142+0.165	0.159±0.018	0.275
B7	Mud Unit Dog House	N05°30'44.5" E005°56'21.9"	0.126+0.140+0.127+0.115	0.127±0.016	0.220
B8	Medic	N05°30'44.3" E005°56'23.3"	0.190+0.215+0.184+0.159	0.187±0.021	0.323
B9	Well Engineer's office	N05°30'40.8" E005°56'18.6"	0.156+0.162+0.180+0.174	0.168±0.035	0.290
B10	Mud logging Laboratory	N05°30'41.9" E005°56'23.7"	0.213+0.205+0.193+0.201	0.203±0.047	0.351
Mean ± SD			**0.177± 0.026**	**0.177± 0.026**	**0.305 ± 0.042**

Table 3: Radiological Result Obtained from Mud Section Equipment

LOCATION CODE	EQUIPMENT	GPS READINGS	ADR (μSv/hr)	ADR (μSv/hr)	AEDE (μSv/Yr)
C1	Mixing Hopper	N05°30'43.2" E005°56'20.8"	0.168+0.194+0.183+0.179	0.181±0.016	0.313
C2	Shale Shaker	N05°30'42.4" E005°56'21.1"	0.109+0.135+0.115+0.129	0.122±0.017	0.211
C3	Degaser	N05°30'43.8" E005°56'21.6"	0.134+0.177+0.113+0.156	0.145±0.031	0.251
C4	Desander	N05°30'43.5" E005°56'21.2"	0.249+0.197+0.210+0.236	0.223±0.021	0.385
C5	Flowline to Solid Control Unit	N05°30'42.9" E005°56'22.0"	0.114+0.108+0.122+0.112	0.114±0.011	0.197
C6	Agitator	N05°30'44.8" E005°56'21.3"	0.114+0.086+0.095+0.105	0.100±0.013	0.173
C7	Tank 6 (Brine)	N05°30'44.2" E005°56'21.3"	0.335+0.327+0.289+0.297	0.312±0.021	0.539
C8	Tank 2 & 3 (Oil Based Mud)	N05°30'44.5" E005°56'21.4"	0.188+0.169+0.173+0.154	0.171±0.016	0.295
C9	Tank 4 (Base Oil)	N05°30'44.5" E005°56'22.3"	0.175+0.196+0.187+0.166	0.181±0.034	0.313
C10	Tank 5 (Synthetic Oil Based Mud)	N05°30'43.6" E005°56'22.1"	0.113+0.122+0.108+0.114	0.114±0.019	0.197
C11	Possum Belly	N05°30'40.8" E005°56'18.6"	0.137+0.109+0.119+0.127	0.123±0.027	0.213
C12	Mud Pump Manifold	N05°30'41.9" E005°56'23.7"	0.216+0.182+0.198+0.232	0.207±0.014	0.358
C13	Trip Tank	N05°30'42.8" E005°56'24.6"	0.171+0.148+0.159+0.182	0.165±0.029	0.285
C14	Mud Pump	N05°30'42.1" E005°56'23.9"	0.179+0.209+0.215+0.185	0.197±0.023	0.340
C15	Sand Trap	N05°30'42.4" E005°56'23.7"	0.106+0.124+0.119+0.111	0.115±0.025	0.199
Mean ± SD			**0.165± 0.022**	**0.165± 0.022**	**0.285 ± 0.037**

Table 4: Radioactivity Values Obtained from Chemical Storage Facility

LOCATION CODE	STORED CHEMICAL	GPS READING	ADR (μSv/hr)	ADR (μSv/hr)	AEDR (μSv/yr)
D1	KCl_A	N05°30'45.0" E005°56'22.0"	1.148+1.216+1.126+1.058	1.137±0.099	1.965
D2	KCl_B	N05°30'45.23" E005°56'22.8"	1.200+1.162+1.153+1.209	1.181±0.104	2.041
D3	$CaCO3_A$	N05°30'45.60" E005°56'22.4"	0.213+0.230+0.245+0.228	0.229±0.073	0.396
D4	$CaCO3_B$	N05°30'45.80" E005°56'23.10"	0.207+0.199+0.169+0.177	0.188±0.018	0.325
D5	Bentonite	N05°30'45.90" E005°56'21.20"	0.081+0.124+0.092+0.135	0.108±0.012	0.187
D6	Lubra-glide	N05°30' 45.80" E005°56'21.70"	0.298+0.325+0.329+0.356	0.327±0.035	0.565
D7	Lc Lube	N05°30'44.3" E005°56'21.90"	0.663+0.523+0.447+0.587	0.555±0.019	0.959
D8	Emulcifiers	N05°30'44.00" E005°56'22.60"	0.347+0.313+0.295+0.329	0.321±0.024	0.555
D9	Organophilic Clay	N05°30'45.80" E005°56'22.8"	0.305+0.296+0.263+0.272	0.284±0.028	0.491
D10	Well Cleaning Detergent	N05°30'44.8" E005°56'21.3"	0.117+0.119+0.135+0.133	0.126±0.019	0.218
Mean ± SD				**0.446± 0.035**	**0.770 ± 0.156**

Evaluation of Table 4 evidently shows a high concentration of radioactivity within the chemical storage facility. This no doubt conforms to the fact that KCl is stored in large quantity within the storage facility. This also made the radiation level of the brine to increase and thus the radiation value in Table 4. The measured and recorded minimum and maximum values ranged between 0.108±0.012 (D5) and 1.181±0.104 (D1) respectively. The results obtained at the KCl storage unit were extreme high this is as a result of potassium being a natural radionuclide with high concentration. Table 5 shows the radiological values obtained from other facilities within the rig site and the measured and recorded values range from 0.117±0.011 μSv/hr to 0.249±0.026 μSv/hr. The radioactivity concentration measured and recorded at the rig floor showed in Table 6 was the lowest of all the values obtained. This could be attributed to the difference in altitude as the elevation of the rig floor averaged 20.3m on the G.P.S, while the rig site environment generally averaged 14m.

Table 5: Various Rig Site Facilities and Their Radioactivity Level

LOCATION CODE	FACILITY	GPS READING	ADR (μSv/hr)	ADR (μSv/hr)	AEDR (μSv/yr)
E1	Production Tubings	N05°30'45.0" E005°56'22.0"	0.274+0.224+0.231+0.267	0.249±0.026	0.430
E2	Well Head 1 Christmas Tree (UE31)	N05°30'45.23" E005°56'22.8"	0.176+0.185+0.197+0.206	0.191±0.044	0.330
E3	Well Head 2 Christmas Tree (UE32)	N05°30'45.60" E 005°56'22.4"	0.183+0.161+0.194+0.150	0.172±0.037	0.297

E4	Well Head 3 Christmas Tree (UE35)	N05°30'45.80" E005°56'23.10"	0.198+0.149+0.158+0.207	0.178±0.031	0.308
E5	Flow Lines from Wells	N05°30'45.90" E005°56'21.20"	0.164+0.182+0.134+0.152	0.158±0.021	0.273
E6	Sludge for OBM	N05°30' 45.80" E005°56'21.70"	0.255+0.214+0.241+0.282	0.248±0.019	0.429
E7	Waste Pit for WBM (Produced Water)	N05°30'44.3" E005°56'21.90"	0.257+0.195+0.230+0.222	0.226±0.036	0.391
E8	Skippers	N05°30'44.00" E005°56'22.60"	0.243+0.205+0.257+0.219	0.231±0.023	0.399
E9	Subsurface Safety Control Valve 31,32&35	N05°30'45.80" E005°56'22.8"	0.121+0.113+0.132+0.102	0.117±0.011	0.202
E10	Solid Control	N05°30'44.8" E005°56'21.3"	0.167+0.136+0.174+0.143	0.155±0.037	0.268
Mean ± SD				**0.193± 0.031**	**0.333 ± 0.048**

Table 6: Rig Floor Readings

LOCATION CODE	FACILITY	ADRs (µSv/hr)	ADR (µSv/hr)	AEDR (µSv/yr)
F1	Doghouse1	0.098+0.116+0.105+0.109	0.107±0.038	0.185
F2	Dog house2	0.051+0.073+0.069+0.055	0.062±0.029	0.107
F3	Driller's Console	0.103+0.128+0.137+0.112	0.120±0.014	0.207
F4	Hydraulic Power Station	0.072+0.103+0.087+0.118	0.095±0.023	0.164
F5	Rotary Table	0.129+0.105+0.111+0.087	0.108±0.019	0.187
F6	General Rig floor	0.141+0.121+0.115+0.135	0.128±0.014	0.221
Mean ± SD			**0.103±0.028**	**0.179**

Table 7: Host Community Rig Site

LOCATION CODE	GPS READING	DRs FROM SOIL (µSv/hr)	DRs FROM AIR (µSv/hr)	ADR FROM SOIL (µSv/hr)	ADR FROM AIR (µSv/hr)	SOIL AEDR (µSv/yr)	AIR AEDR (µSv/yr)
G1	N05°30'40" E005°56'20"	0.166+0.149+0.140+0.157	0.114+0.132+0.146+0.100	0.153±0.030	0.123±0.009	0.264	0.213
G2	N05°30'53" E005°56'25"	0.219+0.226+0.205+0.198	0.177+0.139+0.169+0.131	0.212±0.025	0.154±0.016	0.366	0.266
G3	N05°30'54" E005°56'28"	0.171+0.194+0.198+0.221	0.147+0.116+0.107+0.138	0.196±0.013	0.127±0.032	0.339	0.219
G4	N05°30'57" E005°56'30"	0.145+0.169+0.176+0.138	0.138+0.134+0.122+0.118	0.157±0.023	0.128±0.028	0.271	0.221
G5	N05°30'59" E005°56'31"	0.184+0.152+0.161+0.175	0.165+0.158+0.134+0.127	0.168±0.029	0.146±0.016	0.290	0.252
G6	N05°31' 00" E005°56'33"	0.193+0.210+0.164+0.181	0.161+0.145+0.123+0.139	0.187±0.012	0.142±0.012	0.323	0.245
G7	N05°31'03" E005°56'34"	0.209+0.199+0.181+0.191	0.179+0.137+0.168+0.140	0.195±0.026	0.156±0.040	0.337	0.270
G8	N05°31'05" E005°56'34"	0.163+0.187+0.197+0.221	0.153+0.170+0.142+0.115	0.192±0.049	0.145±0.051	0.332	0.251
G9	N05°31'06" E005°56'41"	0.132+0.144+0.174+0.162	0.187+0.149+0.184+0.124	0.153±0.031	0.156±0.006	0.264	0.264
G10	N05°31'08" E005°56'39"	0.174+0.149+0.181+0.152	0.152+0.141+0.191+0.172	0.164±0.014	0.164±0.011	0.283	0.283
G11	N05°31'11" E005°56'40"	0.148+0.189+0.151+0.192	0.104+0.127+0.144+0.121	0.170±0.010	0.124±0.017	0.292	0.214
G12	N05°31'12" E005°56'42"	0.225+0.196+0.203+0.232	0.185+0.143+0.167+0.125	0.214±0.025	0.155±0.023	0.370	0.268
G13	N05°31'16" E005°56'44"	0.226+0.207+0.212+0.231	0.174+0.181+0.121+0.128	0.219±0.025	0.151±0.040	0.378	0.261
G14	N05°31'15" E005°55'42"	0.224+0.187+0.191+0.154	0.182+0.217+0.159+0.194	0.189±0.019	0.188±0.012	0.326	0.325
G15	N05°31'18" E005°55'44"	0.188+0.235+0.173+0.220	0.176+0.161+0.173+0.158	0.204±0.021	0.167±0.006	0.352	0.289
G16	N05°31' 22" E005°55'43"	0.180+0.117+0.136+0.199	0.150+0.129+0.168+0.189	0.158±0.037	0.159±0.025	0.273	0.274
G17	N05°31'23" E005°55'19"	0.166+0.167+0.145+0.134	0.138+0.148+0.162+0.176	0.153±0.015	0.156±0.046	0.264	0.270
G18	N05°31'27" E005°55'40"	0.218+0.169+0.184+0.233	0.141+0.157+0.193+0.177	0.201±0.040	0.167±0.039	0.347	0.289
G19	N05°31'20" E005°55'22"	0.192+0.178+0.215+0.155	0.136+0.145+0.151+0.160	0.185±0.008	0.148±0.019	0.320	0.256
G20	N05°31'20" E005°55'35"	0.127+0.160+0.138+0.171	0.199+0.174+0.165+0.146	0.149±0.050	0.171±0.015	0.257	0.295
Mean ± SD				**0.181±0.026**	**0.151±0.023**	**0.326±0.051**	**0.261±0.056**

Table 7 presents the radiometric values of the activity concentration in soil and air within the rig site host community of Eruemukohwarien and its environs. For the soil surveyed around the study area, the radiological values obtained typically ranges between 0.149±0.05 µSv/hr and 0.219±0.025 µSv/hr, while the measured and values for air general ranged between 0.123±0.009 µSv/hr and 0.188±0.012 µSv/hr. The mean radiation level values determined for both soil and air are 0.181±0.026 µSv/hr and 0.151±0.023µSv/hr respectively. Table 8 represents the radiometric values determined for the Campsite and the host community of the campsite at Ekakpamhre town. The radiological values are relatively low when correlated with the radiological concentration values obtained from the host community to the rig site. The soil radiation level typically

ranges between 0.114±0.039 µSv/hr and 0.219±0.051 µSv/hr and the results obtained from air ranged from 0.095±0.011 µSv/hr to 0.197±0.012 µSv/hr. The mean activity concentrations of these values compared well with values reported in Egypt, America, Europe, Saudi Arabia, Syria, Ghana and Australia but they are above values reported in some part of Nigeria (Rood, 2001; El Afifi et al., 2004; USEPA, 1993; Vandenhove, 2002; SARPM, 2004; Al-Masri; Aba, 2005; Darko et al., 2010; ICRP, 2012; Faanu et al., 2013; David, 2016; IAEA, 2003; ARPNSA, 2008; Agbalagba, 2013; Avwiri et al., 2009; Elena and Gracae, 2004). The mean radiation level of the rig site falls slightly higher than the permissible standard threshold of 0.150 µSv/hr recommended by UNSCEAR and W.H.O in 2009, making the industrial work environment more radiologically contaminated than the host communities.

Table 8: Radiation Results from Campsite/Host Community

LOCATION CODE	GPS READING	ADR FROM SOIL (µSv/hr)	ADR FROM AIR (µSv/hr)	ADR FROM SOIL (µSv/hr)	ADR FROM AIR (µSv/hr)	SOIL AEDR (µSv/yr)	AIR AEDR (µSv/yr)
H1	N05°31'55" E005°54'02"	0.178+0.186+0.156+0.148	0.161+0.123+0.149+0.11	0.167±0.016	0.136±0.024	0.289	0.235
H2	N05°31'56" E005°54'01"	0.121+0.103+0.126+0.107	0.112+0.138+0.122+0.096	0.114±0.039	0.117±0.021	0.197	0.202
H3	N05°31'57" E005°53'59"	0.201+0.206+0.182+0.191	0.183+0.168+0.142+0.127	0.195±0.018	0.155±0.013	0.337	0.268
H4	N05°31'57" E005°53'58"	0.144+0.191+0.218+0.172	0.188+0.212+0.206+0.182	0.181±0.035	0.197±0.012	0.313	0.313
H5	N05°31'59" E005°53'58"	0.164+0.183+0.169+0.188	0.178+0.207+0.198+0.169	0.176±0.021	0.188±0.042	0.304	0.304
H6	N05°32'04" E005°53'59"	0.237+0.193+0.185+0.229	0.087+0.111+0.143+0.119	0.211±0.040	0.115±0.057	0.365	0.199
H7	N05°32'05" E005°53'20"	0.152+0.180+0.161+0.171	0.074+0.089+0.116+0.101	0.166±0.006	0.095±0.011	0.287	0.164
H8	N05°32'7" E005°53'50"	0.249+0.234+0.204+0.189	0.121+0.131+0.177+0.187	0.219±0.051	0.154±0.033	0.378	0.266
H9	N05°32'57" E005°53'49"	0.156+0.198+0.218+0.176	0.163+0.141+0.131+0.109	0.187±0.028	0.136±0.031	0.323	0.235
H10	N05°32'08" E005°53'46"	0.213+0.204+0.183+0.196	0.149+0.137+0.121+0.109	0.199±0.046	0.129±0.024	0.344	0.223
H11	N05°32'05" E005°53'45"	0.201+0.187+0.133+0.147	0.187+0.141+0.149+0.187	0.167±0.011	0.166±0.026	0.289	0.287
H12	N05°32'07" E005°53'44"	0.166+0.149+0.195+0.178	0.157+0.138+0.198+0.179	0.172±0.032	0.168±0.017	0.297	0.290
H13	N05°32'12" E005°53'41"	0.134+0.127+0.166+0.173	0.167+0.185+0.179+0.161	0.150±0.029	0.173±0.013	0.259	0.299
H14	N05°32'14" E005°53'40"	0.129+0.145+0.185+0.169	0.144+0.124+0.152+0.172	0.157±0.019	0.148±0.009	0.271	0.256
H15	N05°32'18" E005°53'38"	0.177+0.165+0.129+0.141	0.160+0.191+0.121+0.152	0.153±0.013	0.156±0.028	0.264	0.270
Mean ± SD				**0.174± 0.027**	**0.149± 0.024**	**0.301± 0.091**	**0.254± 0.075**

Figure 3 presents the results obtained from the rig site environment at Eruemukohwarien oil field and their relationship with the standard background radiation recommended by UNSCEAR. The results generally showed that the radiation concentration level of the oil field, with sampling point D1 slightly exceeded the recommended threshold value of 0.15 µSv/hr. The chemical storage unit presented an extreme concentration value of 0.446 µSv/hr. The oil and gas workers responsible for the chemical unit are the most exposed to the harmful effect of ionizing radiation. To reduce the level of high risk in this location, greater safety measure must be employed. The use of robots could be a possible option, while relocation of any settlement has to be immediately carried or plans for future settlements should not be allowed, even after decommissioning of the facility. Rather, extensive remediation has to be implemented and monitoring of both staff and nearby inhabitants be carried out on a regular basis. Comparatively, the rig site does not generally indicate any immediate health hazard for the host communities and the personnel working in the oil fields.

The measured and recorded radiation concentration level for soils in Eruemukohwarien and Ekakpamreh host communities exceeded the standard recommended background radiation. This may have the tendency to impact on the radiation concentration of agricultural produces grown within the areas. Consequently, been transferred to human system that could have long time effect to human health, where the residents of the area stand at disadvantage. The concentration values obtained for air in the host communities fell within the recommended standard background radiation level. It is important to mention here that, because of the sandy, shaley/clay nature of the Akata and Agbada formation, there are natural occurring radiation associated to formation which could have the possible tendency to increase the radiation concentration of the soils in the area.

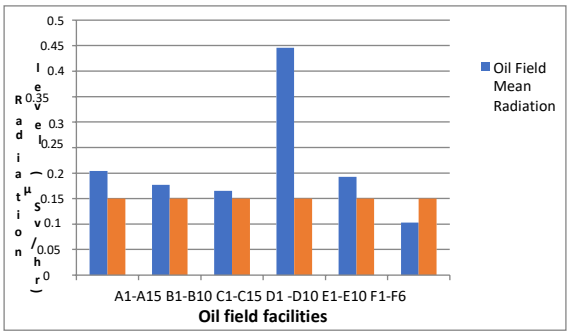

Figure 3: Correlation of mean radiation levels (µSv/hr) with the standard background radiation in the Eruemukohwarien oil field.

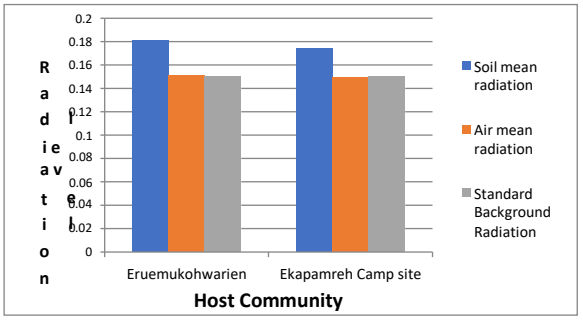

Figure 4: Correlation of mean radiation levels (µSv/hr) for soil and air with the standard background radiation in the Eruemukohwarien and Ekakpamreh host communities.

4. Conclusion

The survey of the BIR levels in oil drilling environment have been carried out in-situ, Five facilities were studied in the rig site; the rig site host community was also monitored as well as the camp site for the oil workers at Ekapkamreh town. The activity levels of the radionuclides have clearly showed enhanced activity concentrations across the study area due to oil and gas exploration activities. This relative increase in radiation level across the globe over the permissible world average is partly attributed to TENORM from oil and gas exploration and exploitation activities. However, the calculated hazard indices to estimate the potential radiological health risk in samples and the dose rate associated with it are within the permissible limit recommended by UNSCEAR, 2009. It can therefore be concluded that the air, soil and sediment (sludges and scales) of the Eruemukohwarien area have no immediate health implication for the inhabitants and they can be used as materials for construction of residential and industrial buildings without posing any significant radiological threat to the population, but long term accumulative effect should be guided against especially for the oil field workers and host *community* residents. Baseline information on the natural radioactivity concentration and status in the study area and any other similar oil and gas onshore exploration environment in the world (especially Niger delta in particular) has been established by this field-based research project and this work will serve as a reference for future studies.

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