JASEM ISSN 1119-8362

Full-text Available Online at
www.ajol.info and
www.bioline.org.br/ja

J. Appl. Sci. Environ. Manage. *June 2013*
Vol. 17 (2) 279-288

Radiological impact of oil and Gas Activities in selected oil fields in Production Land Area of Delta State, Nigeria

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Keywords*:* Radiological impact, Oil and Gas facilities, oil field, ionizing radiation levels.

ABSTRACT: A study of the radiological impact of oil and gas exploration activities in the production land area of Delta State has been carried out *in-situ* using two synchronized and calibrated radiation meters (Digilert 50 and 100) and a geographical positioning system (GPS). Ten oil field facilities were studied. At each facility, nine sampling locations and their host communities were evaluated making a total of 100 study points. Measured exposure rate in the oil field facilities ranged from $0.011\pm0.003 mRh^{-1}$ in Evwreni camp site to $0.031\pm0.01 mRh^{-1}$ at the Otorogu gas plant. Mean field exposure rates/equivalent dose rates ranged from $0.016\pm0.006 mRh^{-1}$($0.839\pm0.34 mSvy^{-1}$) to $0.0213\pm0.008 mRh^{-1}$($1.134\pm0.44 mSvy^{-1}$). In the host communities the values ranged from $0.0115\pm0.003 mRh^{-1}$ ($0.612\pm0.16 mSvy^{-1}$) in Evwreni community to $0.021\pm0.007 mRh^{-1}$ ($1.117\pm0.37 mSvy^{-1}$) in Otujeremi town, while for the control study area the value obtained was $0.009\pm0.002 mRh^{-1}$($0.479\pm0.11 mSvy^{-1}$). The results show that the radiation levels for the Ughelli East, Kokori, Eriemu, Evwreni, Eriemu, Oweh, Olomoro-Oleh oil and gas fields are within the $1 mSvy^{-1}$ maximum permissible limit recommended for the public and non-nuclear industrial environment, while the levels for the fields at Otorogu, Ughelli West, Afiesere and Uzere West and East and the host communities of Olomoro, Uzere and Emeragha exceeded the maximum recommended value, an indication that the oil fields and host communities environment have been impacted radiologically. However, these results obtained may not have immediate health hazard, but will pose some long-term health side effects on the staff working in the facilities and residents of the host communities. Interim proactive measures are recommended @JASEM

Radiation plays an important and sometimes vital role in our everyday lives. Everyday each of us is exposed to naturally occurring quantities of radiation through the air we breathe, the soil on which we walk the water we drink, the food we eat and even within our bodies (Ademola, 2008). Furthermore, certain industrial activities such as crude oil exploration result in enhanced ionizing radiation in the environment. Ionizing radiations such as α, β and γ radiations are often found in the petroleum matrix due to both contamination by radionuclides in the earth's crust and the materials used in the drilling process (Chad-Umoren, 2012; Laogun et al., 2006). Gamma rays 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). Also, it has been reported that naturally occurring radioactive materials (NORMS) associated with oil and gas production contain radioactive uranium, thorium and their progenies Ra-226 and Ra-228 (Abison, 2001; Avwiri et al., 2007a; Chad-Umoren, 2012).

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Radiation monitoring is of primary importance for environmental protection purposes (El-Bahi, 2004). A strong correlation has been found between oil and gas activities and elevated environmental ionizing radiation (Avwiri et al., 2007a; Avwiri et al., 2007b; Chad-Umoren, 2012; Chad-Umoren and Briggs-Kamara, 2010; Ononugbo et al., 2011) which are attributed to the industries' input raw materials and effluent discharge such as gas flaring and other output products.

Elena and Gracea (2004) conducted environmental monitoring of radioactivity in the environs of six oil fields in Bacau and Braila districts and reported that there was no immediate radiological challenge; however, the high radium-226 content of oil field formation waters could lead to environmental pollution. Laogun et al. (2006) studied the variation in well-head gamma radiation levels at an oil field in Ologbo, Edo state in the Niger delta region of Nigeria and reported that though the values obtained were somewhat higher than the normal background level, they were in agreement with the International Atomic Energy Agency's standard on background ionizing radiation level for such environment.

Avwiri et al. (2007) studied the terrestrial radiation at oil and gas facilities in Ughelli region of Nigeria and reported a range of $12.00\pm0.1\mu Rh^{-1}$ ($5.33\pm0.35\mu Sv/wk$) to $22.00\pm2.1\mu Rh^{-1}$(9.79 ± 0.16) in the oil fields and 09.00 ± 1.0 to $11.00\pm0.5\mu Rh^{-1}$ in the host communities. They concluded that though the radiation values were within international standards and in agreement with other reported values for similar areas of the country, the background ionizing radiation (BIR) levels exceeded the normal background level.

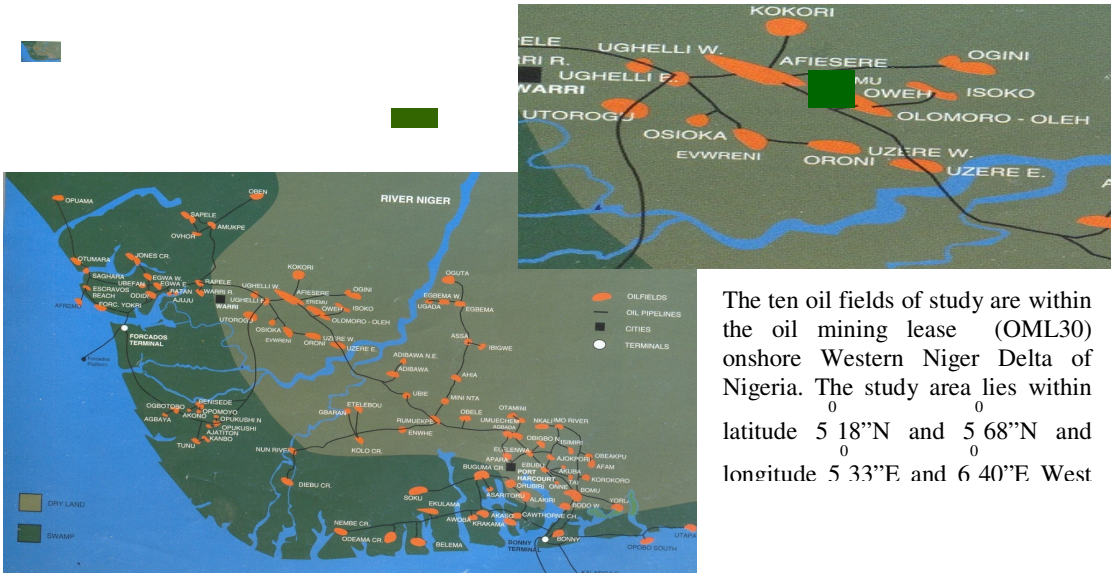
It is known that the more radiation dose from oil and gas installation a person receives, the greater the chance of developing cancer, leukaemia, eye cataracts, haematological depression and incidence of chromosome aberrations (EPA, 2009). This may not appear until many years after the radiation dose is received (typically, 10-40years).

This present study aims at assessing the radiological impact on both the environment and the population of the non-nuclear oil and gas industry in parts of Delta state, Nigeria. The study will also furnish baseline data on the background ionizing radiation (BIR) profile of the flow stations and their host communities and add to existing research information on the radiological profile of oil facilities in the region. The health implications on the personnel and residents of the host communities will also be examined.

EXPERIMENTAL METHOD

*Study Area:*The study area is located in Oil Mining Lease 30 (OML 30) onshore of Niger Delta (SPDC, FDP, 2004) and encompasses five local government areas of Delta State (Isoko North and South, Ughelli North and South and Ethiope East L.G). It comprises ten oil fields and lies within latitudes $5^{0}18$" N and 5°86" N and longitudes $5^{0}33$"E and $6^{0}40$ E", south-west of the Niger Delta region of Nigeria (UNDP, 2006) (Fig.1). The main geological elements of the area, at varying depths in thousands of meters, are the Benin formation, which is the youngest, underlain by the Agbada formation and followed by the oldest, the Akata formation (Doust and Omatsola, 1990). The three formations are differentiated by their ages and by their degrees of compaction. Their ages become progressively younger in down-dip direction (Taiwo and Akalia, 2009).

The Benin formation is composed mainly of sand, gravel and shale. The minor components of the formation include limonite coating, lignite streaks, hemalite and feldspar. Insignificant quantity of oil has been found in the formation. It is the major source of groundwater in the Niger delta. The lithologies of the Agbada formation are composed of alternating layers of sandstones, silts and shales, while the sandstone reservoirs account for the oil and gas wealth of the region. The Akata formation is composed of dark gray shales and silts with some streaks of sand of turbidite flow origin.



The ten oil fields of study are within the oil mining lease (OML30) onshore Western Niger Delta of Nigeria. The study area lies within latitude $5^{0}18$"N and $5^{0}68$"N and longitude $5^{0}33$"E and $6^{0}40$"E West

Fig.1: A map showing network of pipes of oil fields in onshore of the Niger Delta.

Data Collection: An ***in situ*** approach was employed using two well calibrated radiation meters, Digilert 50 and 100 nuclear radiation monitors containing a Geiger-Muller tube, each capable of detecting α, β, γ and x-rays within the temperature range of -10 to 50^{0}C. The standard errors detected were ±8% and

±5% for Digilert 50 and 100 respectively. Prior to use, the two meters were synchronized by resetting them.

During the measurements the tube of the radiation meters were held at a standard distance of 1.0m above the ground and placed at about 2.0m away from the facilities. Their windows were first oriented vertically downwards and then towards the facility (Laogun et al., 2006; Avwiri et al., 2007a) and the geographical location of the particular facility determined using the geographical positioning system (GPS). At each facility, three readings were obtained at a time of 300secs each and their mean value recorded. In a given field, nine different facilities were surveyed to ensure adequate coverage. Finally, the radiation profile of the host community (i.e. the community of closest proximity to the facility) was also obtained.

To determine the whole body equivalent dose rate use was made of the following formula (NCRP, 1993):
$1mRh^{-1} = (76 \times 0.7)mSvy^{-1}$.

RESULTS AND DISCUSSION

Table 1: Otorogu Oil and Gas Field

S/N	SAMPLED AREA	GEOGRAPHICAL LOCATION	RADIATION LEVEL mRh^{-1}		AVE. RAD. VALUE mRh^{-1}	EQ. DOSE $mSvy^{-1}$
			RAD 50	**RAD 100**		
1	Crude Flow Pipe	NO5 32.297' E005 53.780'	0.019	0.018	0.0185±0.004	0.9843±0.32
2	Natural Gas Compressor	NO5 26.021' E005 52.940	0.025'	0.019	0.0220±0.008	1.170±0.43
3	Flow station entrance	NO5 26..057' E005 52.926'	0.017	0.018	0.01759±0.007	0.931±0.37
4	Well 7	NO5 25.918' E005 53.014'	0.021	0.024	0.2230±0.010	1.186±0.53
5	Pegging Manifold	N05 26.062' E005 52.901''	0.019	0.021	0.020±0.008	1.064±0.43
6	Well 10	N05 25.671' E005 52.930'	0.016	0.018	0.0170±0.006	0.9041±0.32
7	Flare Stack Site	N05 26.141 E005 52.653	0.024	0.025	0.0245±0.011	1.303±0.58
8	Well 5	NO5 25.701' E005 52.608'	0.018	0.020	0.0190±0.009	1.011±0.48
9	Olorogu Gas Plant	NO5 25.701' E005 52.608'	0.028	0.034	0.0310±0.010	1.649±0.53
10	***Otujeremi Town***	***NO5 25.865' E005 52.567'***	***0.022***	***0.020***	***0.0210±0.007***	***1.117±0.37***
	MEAN FIELD LEVELS				**0.0213±0.008**	**1.134±0.44**

Table 2: Ughelli West Oil and Gas Field

S/N	SAMPLED AREA	GEOGRAPHICAL LOCATION	RADIATION LEVEL mRh^{-1}		AVE. RAD. VALUE mRh^{-1}	EQ. DOSE $mSvy^{-1}$
			RAD 50	**RAD 100**		
1	Crude Flow Pipe	NO5 32.297' E005 53.780'	0.019	0.018	0.0185±0.004	0.9843±0.32
2.	Flow station entrance	NO5 32..303' E005 53.782'	0.029	0.024	0.0265±0.008	1.410±0.43
3	Well 7	NO5 32.338' E005 53.7954'	0.024	0.018	0.021±0.006	1.117±0.32
4	Limer & Serier (L&S) Tango piple	N05 32.279' E005 53.771'	0.023	0.020	0.0215±0.006	1.117±0.32
5	Crude oil control	N05 32.275' E005 53.759	0.016	0.018	0.0170±0.005	0.904±0.27
6	Flare knockout vessel	N05 32.282' E005 53.720'	0.015	0.018	0.0165± 0.06	0.878±10.32
7	Flare control valve	N05 32.295' E005 53.685	0.018	0.014	0.01605±0.005	0.851±0.27
8	Flare stack point	N05 32.307' E005 53.678	0.016	0.015	0.0155±0.005	0.825±0.27
9	Well 2	N05 32.112' E005 53.802'	0.018	0.020	0.0190±0.007	1.011±0.43
10	***Ekakpamre community***	***N05 31.071 E005 54.170***	***0.021***	***0.017***	***0.0190±0.008***	***1.011±0.43***
	MEAN FIELD				**0.0191±0.005**	**1.014±0.31**

Table 3: Ughelli East Oil and Gas Field

S/N	SAMPLED AREA	GEOGRAPHICAL LOCATION	RADIATION LEVEL mRh^{-1}		AVE. RAD. VALUE mRh^{-1}	EQ. DOSE $mSvy^{-1}$
			RAD 50	**RAD 100**		
1	Flow station entrance	NO5 30.850' E005 56.233'	0.021	0.019	0.0200±0.008	1.064±0.43
2.	Control station (UNC)	NO5 30.856' E005 56.229'	0.019	0.015	0.0170±0.006	0.904±0.32
3	L & S tango crude pipe	NO5 30.860' E005 56.210'	0.018	0.018	0.0180±0.007	0.958±0.37
4	Crude and Gas control valve	N05 30.864' E005 56.117	0.015	0.017	0.016±0.005	0.851±0.27
5	UPS Manifold	N05 30.750' E005 56.272	0.017	0.020	0.01856±0.007	0.984±0.37
6	Flare site	N05 30.984' E005 56.271'	0.016	0.04	0.0150± 0.05	0.798±10.27
7	Ughelli East Buster station	N05 31.004' E005 55.910'	0.018	0.018	0.01805±0.006	0.958±0.32
8	Well 5	N05 30.783' E005 56.310	0.016	0.014	0.0150±0.007	0.795±0.37
9	NGC station	N05 30.860' E005 56.199'	0.019	0.020	0.0185±0.008	0.986±0.43
10	***Eruemukohwara community***	***N05 31.598' E005 56.409'***	***0.011***	***0.014***	***0.0125±0.004***	***0.0665±0.21***
	MEAN FIELD LEVEL				**0.01731±0.007**	**0.925±0.35**

Table 4: Afiesere Oil and Gas Field

S/N	SAMPLED AREA	GEOGRAPHICAL LOCATION	RADIATION LEVEL mRh^{-1}		AVE. RAD. VALUE mRh^{-1}	EQ. DOSE $mSvy^{-1}$
			RAD 50	**RAD 100**		
1	Flow and compressor station gate	NO5' 32.888' E006 00.898'	0.017	0.020	0.0185±0.008	0.984±0.43
2.	Manifold	NO5' 3 2.871' E006' 00.892'	0.030	0.028	0.0290±0.012	1.543±0.64
3	Flare control valve	NO5' 32.899' E006' 00.808'	0.018	0.020	0.0190±0.007	1.011±0.37
4	L & S Tango flow crude pipe	N05' 32.903' E005 56.117	0.014	0.015	0.0145±0.007	0.771±0.37
5	Natural gas compressor (NGC) station	N05' 32.652' E006. 01.138	0.021	0.019	0.0206±0.008	1.064±0.43
6	Flare knockout vessel	N05' 32.801' E006 00.776'	0.016	0.015	0.0155± 0.006	0.825±10.32
7	Flare site	N05 32.906' E005 00.801'	0.023	0.020	0.0215±0.009	1.144±0.48
8	Well 27	N05" 32.863' E005 00.982	0.018	0.017	0.01750±0.008	0.931±0.43
9	Well 13	N05" 32.783' E005 01.035'	0.022	0.025	30.0235±0.008	1.250±0.43
10	***Emeragha community***	***N05 32.582' E005 01.530'***	***0.019***	***0.018***	***0.0185±0.006***	***0.984±0.32***
	MEAN FIELD LEVEL				**0.01991±0.008**	**1.058±0.43**

Table 5: Kokori Oil and Gas Field

S/N	SAMPLED AREA	GEOGRAPHICAL LOCATION	RADIATION LEVEL mRh^{-1}		AVE. RAD VALUE mRh^{-1}	EQ. DOSE $mSvy^{-1}$
			RAD 50	**RAD 100**		
1	Manifold	NO5' 38.624' E006 04.321'	0.017	0.025	0.0210±0.008	1.117±0.43
2.	Flow station Gate	NO5' 38.641' E006' 04'224'	0.018	0.020	0.0190±0.009	1.011±0.48
3	Natural Gas compressor (NGC) station	NO5' 38.638' E006' 04.215'	0.018	0.022	0.0205±0.010	1.091±0.53
4	L & S Tangle flow crude pipe	N05' 38.601' E006 04.226'	0.016	0.014	0.0150±0.007	0.795±0.37
5	Control valve (crude)	N05' 39.012' E006. 04.171	0.018	0.020	0.01906±0.007	0.795±0.37
6	Flare knockout drum	N05' 39.016' E006 0466'	0.017	0.020	0.0185± 0.006	0.984±0.32
7	Flare stock site	N05' 39.108' E005 00.801'	0.017	0.015	0.0160±0.006	0.851±0.32
8	Well 13, 34 & 35	N05" 38.844' E006" 04.030'	0.020	0.023	0.0215±0.011	1.144±0.598
9	Flare control valve	N05" 39.112' E006 04.192'	0.016	0.014	50.0150±0.008	0.795±0.27
10	***Erhioke Community***	***N05 38.602' E006" 04.227'***	***0.014***	***0.013***	***0.0135±0.004***	***0.718±0.21***
	MEAN FIELD LEVEL				**0.01841±0.007**	**0.977±0.41**

Table 6: Eriemu Oil and Gas Field

S/N	SAMPLED AREA	GEOGRAPHICAL LOCATION	RADIATION LEVEL mRh^{-1}		AVE. RAD. VALUE mRh^{-1}	EQ. DOSE $mSvy^{-1}$
			RAD 50	RAD 100		
1	Field logistic base (FCB)	NO5' 32.770' E006 02.716'	0.022	0.016	0.0190±0.009	1.011±0.48
2.	Well 3	NO5' 31.264' E006' 03 501	0.014	0.019	0.0165± 0.007	0.878±0.37
3	Pegging manifold	NO5' 31.550' E006' 03.430'	0.016	0.013	0.0145±0.004	0.771±0.21
4	N.G.C Station	N05' 31.211' E006 03.428'	0.019	0.017	0.0180±0.008	0.958±0.43
5	Flow station Gate	N05' 31.218' E006. 03.488'	0.012	0.014	0.01306±0.005	0.692±0.27
6	Gas Vent (knockout drum)	N05' 31.488' E006 03.498'	0.017	0.018	0.015± 0.007	0.931±0.37
7	Flare stack site	N05' 31.305' E006 03.519'	0.013	0.019	0.0160±0.006	0.851±0.32
8	L & S Tango Crude flow pipe	N05" 31.246' E006" 03.473'	0.013	0.016	0.0145±0.005	0.771±0.27
9	Well 13 & 19	N05" 32 .181' E006' 02.251'	0.018	0.020	0.0190±0.007	1.011±0.32
10	***Gana Agbarh-otor community***	***N05 38.578' E006" 03.75'***	***0.017***	***0.014***	***0.0155±0.007***	***0.8258±0.32***
	MEAN FIELD LEVEL				**0.01641±0.006**	**0.875±0.34**

Table 7: Evwreni Oil and Gas Field

S/N	SAMPLED AREA	GEOGRAPHICAL LOCATION	RADIATION LEVEL mRh^{-1}		AVE. RAD. VALUE mRh^{-1}	EQ. DOSE $mSvy^{-1}$
			RAD 50	RAD 100		
1	Camp site	NO5' 22.720' E006 02.962'	0.011	0.011	0.0110±0.003	0.585±0.16
2.	Well 13	NO5' 22.615' E006' 02 640'	0.015	0.014	0.0145± 0.005	0.771±0.27
3	Manifold	NO5' 22.405' E006' 02.405'	0.019	0.013	0.0160±0.006	0.851±0.32
4	Well 1	N05' 22.327' E006' 02.410'	0.017	0.014	0.055±0.005	0.825±0.27
5	Flow station Gate	N05' 22.445' E006. 02.470'	0.015	0.016	0.0155±0.006	0.825±0.32
6	L & S Tanga crude flow pipe	N05' 22.428' E006" 02 500'	0.015	0.014	0.0145± 0.005	0.771±0.27
7	Gas vent (knockout drum)	N05' 22.432' E006 22.482'	0.020	0.022	0.0210±0.009	1.117±0.48
8	Flare stock site	N05" 22.361' E006" 02.451'	0.021	0.018	0.0195±0.008	1.0371±0.83
9	Well 11	N05" 22 .394' E006' 02.439'	0.014	0.014	0.0140±0.005	0.771±0.27
10	***Evwreni Community***	***N05' 24.243' E006" 03.451'***	***0.017***	***0.014***	***0.0155±0.007***	***0.8258±0.32***
	MEAN FIELD LEVEL				**0.0160±0.006**	**0.839±0.34**

Table 8: Oweh Oil and Gas Field

S/N	SAMPLED AREA	GEOGRAPHICAL LOCATION	RADIATION LEVEL mRh^{-1}		AVE. RAD. VALUE mRh^{-1}	EQ. DOSE $mSvy^{-1}$
			RAD 50	RAD 100		
1	Flow Station Gate	NO5' 29.271' E006 08.101'	0.016	0.012	0.0140±0.005	0.745±0.27
2.	Crude oil control valve	NO5' 08.101' E006' 08'	0.019	0.019	0.0190± 0.007	1.011±0.37
3	Gas vent (knockout drum)	NO5' 29.289' E006' 08.201'	0.017	0.016	0.0165±0.006	0.878±0.32
4	Flare stack site	N05' 29.304' E006' 08.244'	0.016	0.018	0.017±0.005	0.904±0.27
5	NGC Station	N05' 29.216' E006. 08.132'	0.022	0.020	0.0210±0.008	1.117±0.43
6	L & S tango Crude flow pipe	N05' 29.285' E006" 28 185'	0.016	0.014	0.0150± 0.006	0.798±0.32
7	Manifold	N05' 28.185' E006 07.720'	0.019	0.018	0.01850±0.008	0.984±0.43
8	Well 12	N05" 29.666' E006" 06.567'	0.020	0.018	0.0190±0.007	1.011±0.37
9	Well 2	N05" 29 .219' E006' 08.128'	0.018	0.023	0.0205±0.010	1.091±0.53
10	***Otor-Oweh community***	***N05' 29.614' E006" 06.248'***	***0.012***	***0.014***	***0.0130±0.005***	***0.692±0.27***
	MEAN FIELD LEVEL				**0.0178±0.007**	**0.949±0.37**

Table 9: Olomoro-Oleh Oil and Gas Field

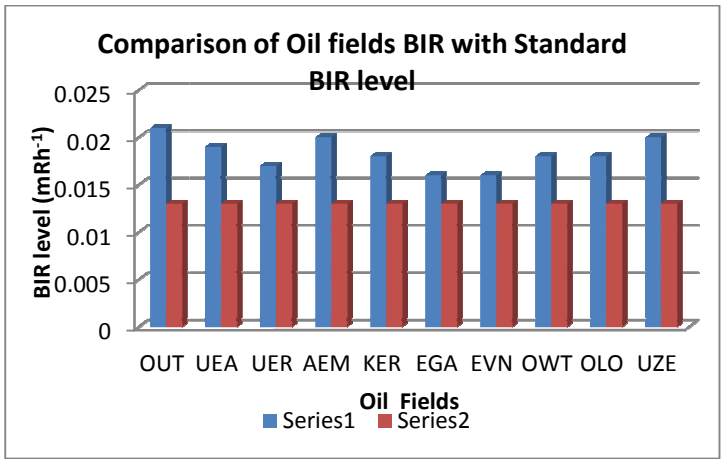
S/N	SAMPLED AREA	GEOGRAPHICAL LOCATION	RADIATION LEVEL mRh^{-1}		AVE. RAD. VALUE mRh^{-1}	EQ. DOSE $mSvy^{-1}$
			RAD 50	RAD 100		
1	Well 14	NO5' 27.984' E006 09.856 '	0.021	0.015	0.0180±0.007	0.958±0.32
2.	Well 20	NO5' 27.441' E006' 10.470''	0.015	0.021	0.0180± 0.006	0.958±0.32
3	Flow station Gate	NO5' 27.410' E006' 10.736'	0.015	0.021	0.0150±0.007	0.958±0.37
4	L & S Tango crude flow pipe	N05' 27.422' E006' 10.778'	0.016	0.019	0.0175±0.006	0.931±0.32
5	Gas vent (knockout drum)	N05' 27.521' E006. 10.811'	0.026	0.022	0.0240±0.010	1.1277±0.53
6	Flare stock site	N05' 27.541' E006" 10 826'	0.020	0.024	0.0220± 0.009	1.170±0.42
7	NGC	N05' 27.303' E006 10.781'	0.017	0.020	0.01850±0.008	0.984±0.43
8	Manifold	N05" 27.226' E006" 10.702'	0.014	0.015	0.0145±0.006	0.771±0.32
9	Field logistic base (FLB)	N05" 27 .256' E006' 10.985'	0.008	0.610	0.009±0.002	0.479±0.11
10	***Olomoro Community***	***N05' 26.989' E006" 11.820'***	***0.017***	***0.018***	***0.0175±0.005***	***0.931±0.27***
	MEAN FIELD LEVEL				**0.0177±0.007**	**0.943±0.37**

Table 10: Uzere East and West Oil and Gas Field

S/N	SAMPLED AREA	GEOGRAPHICAL LOCATION	RADIATION LEVEL mRh^{-1}		AVE. RAD VALUE mRh^{-1}	EQ. DOSE $mSvy^{-1}$
			RAD 50	RAD 100		
1	Manifold	NO5' 20.080' E006 14.865 '	0.016	0.015	0.0155±0.006	0.525±0.32
2.	Buster station	NO5' 20.162' E006' 14 .781''	0.017	0.014	0.0155± 0.005	0.825±0.27
3	NGC Station	NO5' 19.751' E006' 14.762'	0.016	0.019	0.0175±0.006	0.931±0.32
4	Flow station Gate	N05' 19.627' E006' 14.655'	0.027	0.028	0.0275±0.013	1.463±0.69
5	L & S Tango crude flow pipe	N05' 19.167' E006. 14.642'	0.022	0.024	0.230±0.010	1.224±0.53
6	Flare knock out down	N05' 19.601' E006" 14. 633'	0.020	0.018	0.01900± 0.008	1.011±0.43
7	Flare stack site	N05' 19.584' E006' 14.566'	0.017	0.021	0.0190±0.007	1.011±0.37
8	Well 6	N05" 19.251' E006" 15.960'	0.019	0.023	0.0205±0.009	1.277±0.64
9	Well 2	N05" 19 .421' E006' 15.862'	0.022	0.026	0.0240±0.012	1.277±0.64
10	***Uzere community***	***N05' 20.268' E006" 14.338'***	***0.016***	***0.019***	***0.0175±0.007***	***0.931±0.27***
	MEAN FIELD LEVEL				**0.0202±0.008**	**1.075±0.45**

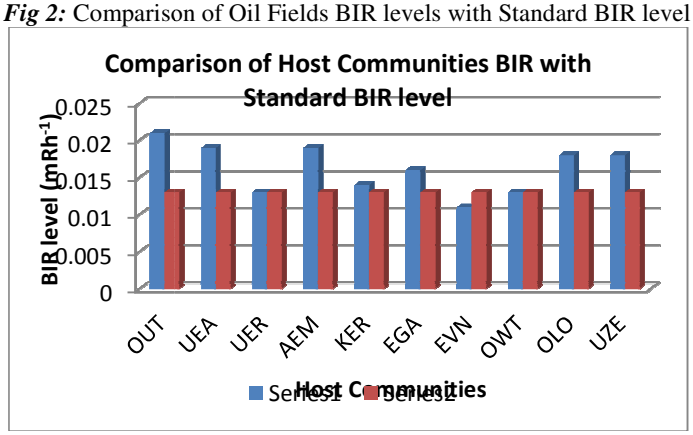
Table 11: Comparison of Studies fields and Host Communities Radiation Data

Area Code	Oil and Gas Field	Host Community	Mean field dose rate ($mSvy^{-1}$)	Host Community dose rate ($mSvy^{-1}$)	Difference (%)
OUT	Otorugu	Otujeremi	1.134±0.31	1.117±0.37	1.51
UEA	Ughelli West	Ekakpamre	1.014±0.31	1.011±0.43	0.30
UER	Ughelli East	Eruemukaharie	0.925±0.35	0.665±0.21	39.10
AEM	Afiesere	Emeragha	1.058±0.43	0.984±0.32	7.52
KER	Kokori	Erhioke	0.977±0.41	0.718±0.21	36.07
EGA	Eriemu	Gana-Agbarha	0.875±0.34	0.825±0.32	6.06
EVN	Evwreni	Evwreni	0.839±0.34	0.612±0.16	22.70
OWT	Oweh	Otoweh	0.949±0.37	0.692±0.27	37.14
OLO	Olomoro-Oleh	Olomoro	0.943±0.37	0.931±0.27	1.29
UZE	Uzere West & East	Uzere	1.075±0.45	0.931±0.37	14.4



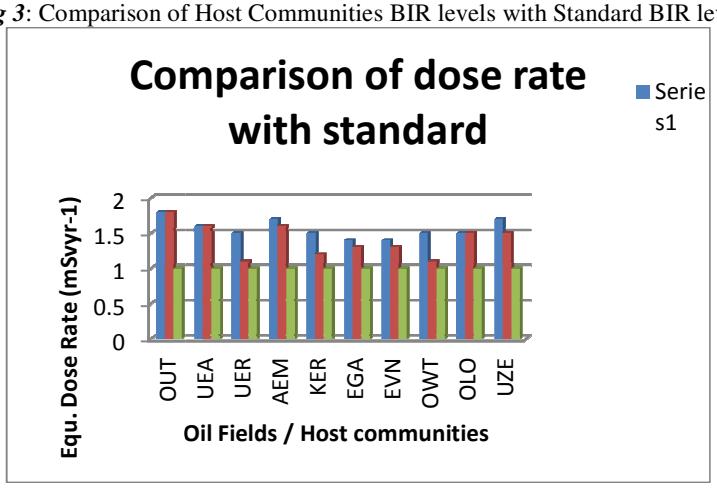
Series1*: Oil field BIR levels,* ***Series2****: World BIR level (UNSCEAR)*

Fig 2: Comparison of Oil Fields BIR levels with Standard BIR level



Series1*: Host Communities BIR levels,* ***Series2****: World BIR level (UNSCEAR)*

Fig 3: Comparison of Host Communities BIR levels with Standard BIR level



Series1*: Oil field,* ***Series2****: Host communities and* ***Series3****: Standard equivalent dose rate*
Fig 4**:** Comparison of Equivalent Dose Rate of Oil Fields and their host communities with UNSCEAR standard

Tables 1–10 show the results of the *in-situ* measurements carried out in the ten oil and gas fields studied in this work. The exposure rates range from $0.011\pm0.03 mRh^{-1}$ at the campsite in Evwreni oil field

(Table 7) to 0.031±0.01mRh^{-1} at the Otorogu gas plant in the Otorogu field (Table 1). The high values obtained at the Otorogu gas plant may be due to the incidence of high radon concentration accompanying natural gas production (Chad-Umoren, 2012).

The mean exposure rates and equivalent dose rates for the oil fields range from 0.016±0.006mRh^{-1} (0.839±0.34mSvy^{-1}) in the Evwreni field to 0.0213±0.008 mRh^{-1} (1.134±0.44mSvy^{-1}) in the Otorogu field (Table 1). The comparatively lower radiation level at the Evwreni field can be attributed to the temporary shutdown of operations there at the time of this study, while the high levels at some of the other fields, especially the Otorogu field, can be attributed to the development of new wells and also to the turnaround maintenance that were on-going at some of the facilities at the time of this survey. The mean radiation values show that the values for Ughelli East, Kokori, Eriemu, Evwreni, Oweh, Olomoro-Oleh fields are within the 1.0mSvy^{-1} maximum permissible limit recommended for non-nuclear work environments and the general public (ECNR, 1995; ICRP, 1999), while the values for Otorogu, Ughelli West, Afiesere and Uzere West and East fields exceed this limit.

The exposure rates for the host communities range from 0.0115±0.003mRh^{-1}(0.62±0.16mSvy^{-1}) in Evwreni community to 0.021±0.007mRh^{-1} (1.117±0.37mSvy^{-1}) in Otujeremi town. It was observed that proximity plays an important role in the radiation impact and distribution. The results for the host communities (Table 11) show that the equivalent dose rate for Otujeremi and Ekakpamre communities exceed the 1.0mSvy^{-1} maximum permissible limit recommended for the general public. In some of the other communities such as Emeragha, Olomoro and Uzere with equivalent dose rates lying within, but very close to the 1.0mSvy^{-1} limit, further radiation accumulation may result in the permissible limits for the public being exceeded, thereby resulting in health hazards in these communities.

Table11 shows the comparison of the radiation data for the host communities and the surveyed oil fields. The percentage deviation is least at Ughelli West oil and gas field with a percentage difference of 0.30% and maximum at Ughelli East with 39.10 %. This could also be attributed to the proximity of the oil and gas facilities to the host communities.

The result obtained for the control site (a non-oil bearing community, but having the same geological, hydrological and geomorphologic features as the surveyed oil fields) is 0.009±0.002mRh^{-1} (0.479±0.11mSvy^{-1}), showing a significant difference in the BIR levels with the host communities.

Fig. 2 shows the comparison of the mean radiation levels for the oil and gas fields with the standard background radiation level of 0.013mRh^{-1} (ICRP, 1999). The results show that in all the oil fields, the radiation levels exceed the standard BIR level, with the maximum field exposure rate exceeded by 63.8% while the minimum mean exposure field level is exceeded by 23.1%. These values are well above previously reported values in similar environments (Arogunjo et al., 2004; Laogun et al., 2006; Avwiri et al., 2007a).

Fig. 3 compares the average BIR levels for the host communities with the standard background level of 0.013mRh^{-1} (ICRP, 1999). The results show that the exposure rates for about 70% of the host communities exceed the standard background radiation level, with the most affected host community (Otujeremi) being 161.5% of the standard background level while the least (Evwreni) is 84.6% of the standard background level. The exposure rate for the control site (a non-oil bearing community) is 69.2% of the standard background level. A comparison of the host community mean equivalent dose rate, oil fields dose rate and ICRP maximum permissible limit (Fig. 4) shows that 40% of the surveyed oil field facilities have radiation exposure rates that exceed the maximum permissible limit while 20% exceed the limit in the host communities.

The findings of the present work accords with previous studies in the Niger delta region. In agreement with the work of Chad-Umoren (2012), the present study shows that areas and facilities related to gas exploitation consistently exhibit very high radiation levels. This was also the finding of Ononugbo et al (2011) in a study to assess the extent to which gas exploitation activities in Ogba/Egbema/Ndoni area of Rivers State in the heart of the Niger delta region had impacted on the ionizing radiation profile of the area. Also, in agreement with another previous work in which a comparative study of the effect of production and off-production periods was carried out, the present study indicates that areas where oil and gas activities had been temporarily suspended exhibited lower radiation levels than those with facilities in active operations (Avwiri et al, 2007b). Also, a survey of the ionizing radiation patterns in Rivers State by Chad-Umoren and Briggs-Kamara (2010) indicated that activities of the hydrocarbon industry contributed to elevating the ionizing radiation levels of the environment

Conclusion: The radiological impact of oil and gas activities on field workers and host community residents in production land area of Delta State was investigated in this work. The findings agree with previous studies in parts of the study area and similar oil environments in other parts of the world. The elevated radiation levels reported here, when

compared to recommended maximum permissible limits, is evidence that both the host communities and the workers operating the surveyed facilities are exposed to radiation risks. Although the radiation levels in some cases only slightly exceed internationally recommended permissible limits and may therefore appear to pose insignificant health risks, in the long term, the cumulative dose can become hazardous.

It can be deduced from this study that the surveyed areas will be more radiologically healthy if the exploration and exploitation activities of the oil and gas industry in the area are discontinued. Such a step will of course be injurious to the economy of Nigeria and hence her development as the earnings from the activities of the hydrocarbon industry alone accounts for more than 90% of the nation's income. However, in order that the baby is not discarded along with the dirty bath water, we recommend as follows:

The government of Nigeria should ensure that the ionizing radiation enhancing practise of gas flaring is abolished and the gas efficiently harnessed, which will, in addition to reducing the ionizing radiation levels, also boost the economic growth of the nation.

Enforcement by relevant government agencies such as the Nigeria Nuclear Regulatory Authority (NNRA) of relevant laws governing the utilization of ionizing radiation in the hydrocarbon industry.

Public enlightenment and education of hydrocarbon industry personnel and host community residents should form important components in any strategy designed to effectively minimize the risk of radiation exposure and contamination.

Regular environmental ionizing radiation monitoring around oil and gas facilities and their neighbourhoods to ensure that areas of potential risks are identified early enough and the risk mitigated.

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