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OCCUPATIONAL RADIATION PROFILE OF OIL AND GAS FACILITIES DURING PRODUCTION AND OFF- PRODUCTION PERIODS IN UGHELLI, NIGERIA

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Abstract. *The occupational ionization radiation profile of 30 locations of oil and gas facilities in Ughelli oil and gas industrial area, Nigeria, is investigated during both production and off-production periods using a Digilert Nuclear Radiation Monitor and a Geographical Positioning System (GPS). Mean radiation levels during production periods range from 15.50± 1.65μR/h (0.026±0.003mSv/wk) to 19.14±3.16μR/h (0.32±0.005mS/wk) and from 13.38±1.69μR/h (0.023±0.003mSv/wk) to 16.29±2.60μR/h (0.027±0.004mSv/wk) during the off-production periods. The highest level of 26.00±0.5.1μR/h (0.044±0.009mSv/wk) was recorded at the Kokori oil field during production. It is therefore observed that the radiation levels of this oil and work environments are higher during production periods than during off-production periods. Furthermore, the values for both periods are all within the safe radiation limit of 0.02mSv/wk as recommended by the UNSCEAR, but the exposure rates are far above the standard background level of 13.0μR/hr indicating a measure of radiation health hazard in these locations.*

Key Words: *Occupational radiation, oil and gas facilities*

INTRODUCTION

Safety in the workplace and its environment is of global concern (Arandelovic et al., 2006). Many parameters determine what constitutes a safe work environment. For example, the presence of certain levels of ionizing radiation in a given area can constitute an unsafe work environment. It has been established that one of the ways human activities contribute to the elevation of the background ionizing radiation (BIR) levels is by depleting the ozone layer which leads to an increase in the amount of cosmic radiations reaching the earth and hence an impact on the background ionizing radiation level (Foland et al., 1995). Also, studies have shown that the effects of industrial production on the radiation levels of host

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environments depend on the nature of input raw materials, effluents from the production process and the output production (Ebong and Alagoa, 1992).

The occupational ionizing radiation levels in the textiles industry production places have been investigated in Taiwan (Vucic and Stepanovic, 1999). Other works involving the radiation levels of the workplace include those in cement companies in Port Harcourt, Nigeria (Avwiri, 2005); the mining industry (Oresegun and Babalola; 1990), within the premises of Western Atlas, an oil and gas service company in Nigeria (Sigalo, 2000) and also that in the Physics Laboratory of an educational institution in Nigeria (Chad-Umoren et al., 2006). In addition to these factors, the indoor radiation profile is affected by the materials used in the construction of the building (Orsini et al., 1991; Vaitiekunas and Lukosiute, 2005; Mollah et al., 1986).

In the hydrocarbon industry, oil spillage, gas flaring and drilling activities are believed to raise the natural background radiation of the environment (Sigalo and Briggs- Kamara, 2004). Furthermore, oil and gas, by-products of the hydrocarbon industry and the chemicals used for crude oil exploration and exploitation may contain substances that are radioactive.

Operations of the oil and gas industry are known to have an impact on the radiation levels of an environment; consequently, the radiation levels in the work environment will be affected (Stanislav and Elena, 1998). This oil and gas work environment includes both 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 (www.epa.gov/radiation). The radionuclides ^{239}U and ^{234}Th and their radioactive daughters ^{226}Ra and ^{228}Rn have been found in wastewater from offshore facilities (RRC, 2007). Research in some parts of the Niger Delta region of Nigeria shows that the hydrocarbon industry contributes to the distribution of the natural radioactivity with mean activity concentrations for the radionuclides ^{40}K, ^{24}Th and ^{238}U given as 34.8$\pm$2.4, 24.4$\pm$4.7 and 16. 2$\pm$3.7 Bq/kg respectively (Arogunjo et al., 2004).

We had previously investigated the radiation around some oil and gas facilities in Ughelli (Avwiri et al., 2007). We now extend this previous work by studying the effects of production and off- production periods of these oil and gas facilities on the radiation levels to which the workers are exposed and by ascertaining the contribution of these facilities to the radiological burden of the environment. The Ughelli oil zone, situated in the heart of the hydrocarbon producing area of the Niger-Delta of Nigeria, plays host to numerous oil and gas activities/facilities that are involved in the various stages of crude oil production which is the mainstay of the national economy.

EXPERIMENTAL PROCEDURE

The study area consisted of 30 locations belonging to a major oil producing company in Nigeria. These locations lie between longitudes 6°.00′E and 5°.56′E and between latitudes 5° 38′ N and 5° 30′ N. The level of radiation was monitored using a Digilert 50 Nuclear Radiation monitor while the geographical location of the sampling areas was found with the help of a Geographical Positioning System (GPS). Sample integrity was preserved by our use of an *insitu* approach of background radiation monitoring. Also, following standard procedure (Ebong and Alagoa, 1992), the tube of the radiation meter was held at a distance of 1.0m above the ground. The window of the radiation meter was first oriented towards the oil and gas facility and then vertically downward towards the ground. The GPS readings for the particular location were then recorded.

For optimum results monitoring was carried out during the hours from 1300 to 1600 because the radiation meter has a maximum response to environmental radiation during this period (Ebong and Alagoa, 1992). At each facility three readings were taken and their mean recorded. In a given field the radiation levels of about six facilities were taken to ensure proper coverage of the facilities. Also, the radiation levels outside the oil and gas work-environment, that is of locations within the host communities, were also evaluated.

RESULTS AND DISCUSSION

Table 1 shows the exposure profile obtained for the eight studied facilities in the Afiesere oil field. The values obtained range between 8.00±0.7μR/h to 19.00±1.6μR/h with a mean value of 13.38±1.69μR/h for the off-production period and 11.00±0.2μR/h to 21.00±2.2μR/h with a mean value of 15.50±1.65μR/h for the production period. The Natural Gas Compressor (NGC) station recorded the highest equivalent dose rate while the least equivalent dose rate was recorded at wells 7, 10, and 14. The highest percentage deviation was recorded at the host community (Emeragha), which shows that the resumption of activities in the oil field has impacted the community significantly.

Table 1. Afiesere Oil Field

S/No	Oil & Gas Facility	Geographical Location	Radiation Levels (μR/h)		Deviation %	Mean Dose Equivalent (μSv/week)
			Off Production	Production Period		
1.	Afiesere Natural Gas Compressor Station (NGC)	N05^0 32.842 E006^0 0.100``	19.00±1.6	21.00±2.2	5.00	8.90±0.88
2.	Afiesere Flow & Compressor Station	N05^o 32.886” E006^o 0.892”	08.00±0.7	16.00±3.0	33.33	5.34±0.82
3.	Afiesere Flare Stack Site	N05^o 32.906” E006^o 00.801	14.00±2.0	19.00±3.2	15.15	7.34±1.16
4.	Afiesere Flare Knock-Out Vessel	N05^o 32.861 E006^o 0.776”	12.00±0.4	14.00±0.4	7.69	6.12±0.63
5.	Afiesere Manifold	N05^o 32.856” E006^o 2.888”	13.00±2.0	15.00±2.0	7.14	6.23±0.89
6.	Afiesere-Well location 4	N05^o 32.856” E006^o 01.479	12.00±2.1	12.00±2.1	11.11	6.01±0.71
7.	Afiesere Well location 7, 10 & 14	N05^o 32.329” E006^{o}01.808”	12.00±1.6	11.00±0.2	4.35	5.12±0.40
8.	Emeragha Community	N05^o 32.329” E006^o.01.530	09.00±1.1	21.00±2.1	40.00	6.68±0.71
MEAN			**13.38±1.65**	**15.50±1.65**	**15.47±2.50**	**6.43±0.75**

Table 2 shows the exposure rate determined for the seven facilities within the Eriemu field. The obtained values range from 09.00±1.0μR/h to 22.0±2.1μR/h for the off-production period and from 15.00±2.4μR/h to 23.00±4.4μR/h during the production period with the highest percentage deviation also obtained in the host community. The NGC stations also recorded high radiation levels. This may be attributed to the high pressure gas exchange from pipes of varying sizes with a proportional volume of radon gas and the linkages observed in the values.

Table 2. Eriemu Oil Field

S/No	Oil & Gas Facility	Geographical Location	Radiation Levels (μR/h)		Deviation %	Mean Dose Equivalent (μSv/week)
			Off Production	Production Period		
1.	Eriemu Well location 13 & 19	N05^o 32.181 " E006^o 02.251"	18.00±4.2	20.00±31	5.26	8.846±1.62
2.	Eriemu pigging manifold	N05^o 32.181" E006^o 01.063	15.00±4.4	16.00±3.2	3.32	6.90±1.69
3.	Eriemu natural gas compressor station vessel (NGC)	N05^o 31.211" E006^o 03.428"	22.00±2.1	23.00±4.4	2.22	10.10±1.45
4.	Eriemu flow station	N05^o 31.224" E006^o 03.488	19.00±2.1	21.00±3.0	5.00	8.90±1.13
5.	Eriemu flare knock-out vessel	N05^o 31.268" E006^o 03.492	16.00±1.0	15.00±2.4	3.23	6.90±1.76
6.	Eriemu flare stack site	N05^o 31.291" E006^o 31.520	15.00±3.6	21.00±3.3	16.67	8.01±1.54
7.	Gana Agbarhaotor	N05^o 31.505" E006^o 03.041	9.00±0.8	18.00±2.7	33.33	6.01±0.82
MEAN			**16.29±2**	**19.14±3.16**	**9.85±1.20**	**7.88±1.29**

Table 3 presents the data obtained from the seven oil facilities, all measured in the Kokori oil and gas field. The results show a value range of 11.00±0.7μR/h to 17.00±3.1μR/h for the off-production period and a range of 13.00±1.1μR/h to 26.00±5.1μR/h for the production period. The highest percentage deviation was recorded at the flare stack site, while the highest radiation level was obtained at the flare knock-out drum. These high radiation levels recorded during the production period at the flare stack site and the knock-out drum may suggest the presence of radioactive elements (radon) in associated gas and crude oil. The results obtained in the host community in the two periods show an elevation of the background radiation level during production.

Table 3. Kokori Oil Field

S/No	Oil & Gas Facility	Geographical Location	Radiation Levels (μR/h)		Deviation %	Mean Dose Equivalent (μSv/week)
			Off Production	Production Period		
1.	Kokori manifold	N05^{o} 38.624 E006^{o} 04.321”	14.00±2.1	16.00±21	12.50	6.68±0.63
2.	Kokori flow station	N05^{o} 38.664 E006^{o} 04.224”	14.00±3.0	13.00±1.1	3.70	6.01±0.91
3.	Kokori natural gas compressor station (NGC)	N05^{o} 38.543 E006^{o} 04.173”	12.00±3.1	17.00±4.2	10.53	8.46±1.62
4.	Kokori flare knock-out drum	N05^{o} 39.016 E006^{o} 04.166”	15.0±2.1	26.00±5.1	26.83	9.12±0.40
5.	Kokori flare stack site	N05^{o} 39.108 E006^{o} 04.200”	12.00±1.0	22.00±3.2	29.41	7.57±0.63
6.	Kokori well location 13, 34 & 35	N05^{0} 38.844” E006^{0} 04.030”	12.00±1.07	14.00±2.1	7.69	5.79±0.85
7.	Erhioke Community	N05^{0} 38.572” E006^{0} 04.138”	11.00±0.5	17.00±1.0	21.43	6.23±0.33
MEAN			**13.57±1.80**	**18.43±2.68**	**16.01±2.40**	**7.12±0.99**

Table 4 shows the exposure profile determined for eight oil and gas facilities measured in the Ughelli East Oil Field. The results obtained range from 10.00±1.2μRh^{-1} to 19.00±3.2$\mu Rh^{-1}$for the off-production period and from 11.00±1.2μRh^{-1} to 23.00±4.2μRh^{-1} for the production period, with the host community still recording the highest percentage of deviation. The high radiation values recorded at the flare stack site, crude storage tank, knock-out vessel and the gas plant may be due to the input and output of radionuclide bearing material/equipment used in these areas and the elemental composition of crude oil and gas which have been reported to contain radioactive material such as uranium and thorium and their daughter progenies as a result of sub-surface formation processing of oil and gas (RRC 2007, Arogunjo et al., 2004).

Table 4. Ughelli East (Eruemukohwarien) Oil Field

S/No	Oil & Gas Facility	Geographical Location	Radiation Levels (μR/h)		Deviation %	Mean Dose Equivalent (μSv/week)
			Off Production	Production Period		
1.	Ughelli East UPS Manifold	N05° 30.750 " E005°56.272"	15.00±4.0	19.00±3.0	11.76	7.57±1.56
2.	Ughelli East flow station	N05° 30.878" E005°56. 55''	17.00±4.0	14.00±2.3	9.68	6.90±1.40
3.	Ughelli East	N05° 30.860" E005°56.199"	19.00±3.2	22.00±2.6	7.32	9.12±1.29
4.	Ughelli East flare knock-out vessel	N05° 30.870" E005° 56.195	18.00±3.3	23.00±4.2	12.20	9.12±1.67
5.	UQCC crude storage tank	N05° 30.923" E005° 6.079''	15.00±1.2	22.00±2.0	18.92	8.23±0.76
6.	Ughelli East flare stack site	N05° 31.004" E005° 5.940''	12.00±2.0	11.00±1.2	4.35	5.12±0.71
7.	Ughelli East booster station	N05° 31.004" E005° 6.085''	18.00±1.3	20.00±4.1	5.26	8.46±1.20
8.	Eruemukohwarien community	N05° 31.544" E005° 6.085''	10.00±1.2	17.00±2.0	5.00	6.01±0.71
MEAN			**15.50±2.53**	**18.50±2.68**	**11.81±1.20**	**7.57±1.18**

Table 5 presents the mean radiation levels to which workers are exposed both during production and off-production periods in the oil fields. The Eriemu oil field has the highest radiation levels in the two periods under investigation with a mean equivalent dose rate of $7.88\pm1.29\mu Rh^{-1}$, while the Kokori oil field has the highest percentage radiation deviation of 15.19%.

Table 5. Mean Exposure Rates in the Oil Fields.

Field code	Surveyed oil and gas field	Mean radiation levels (μR/h)		Mean Deviation (%)	Mean dose equivalent rate (μSv/wk)
		Off -production	Production period		
ADF	Afusere oil field	13.38 ±1.69	15.50±1.65	**7.34**	**6.43**±0.75
EOF	Eremu oil field	16.29±2.60	19.14±3.16	**8.04**	**7.88**±1.29
KOF	Kokori oil field	13.57±1.80	18.43±2.68	**15.19**	**7.12**±0.99
UOF	Ughelli oil field	15.50±2.53	18.50±2.68	**8.82**	**7.57**±1.16
MEAN		**14.69**±2.16	**17.89**±2.54	**9.85**	**7.25**±1.65

Figure 1 shows the comparison between the mean radiation levels for the off-production period, the production period and the standard background level. In all the four fields investigated, the exposure rates exceed the standard background level and the previous values reported by Avwiri and Ebeniro (1998). Also, there is a significant elevation of the radiation levels especially during the production period, which is in accordance with the results from a previous study carried out in a similar environment (Arogunjo et al., 2004, Louis et al., 2005). The difference in the exposure rates between the off-production period and the production period could be attributed to increased usage of radionuclide materials, exposure to flowing crude oil (spillage) and gas flaring activities that are grouped during production period.

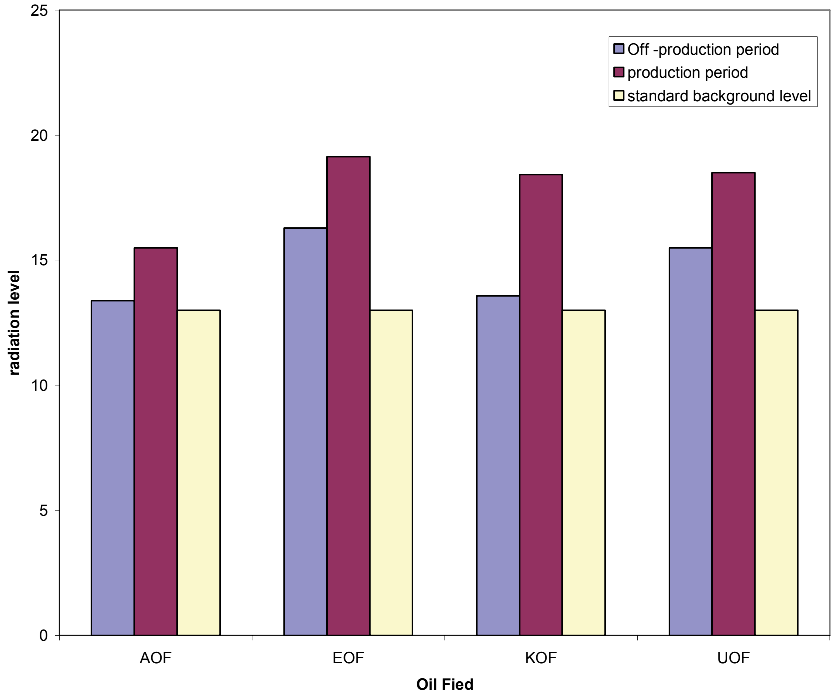

Fig. 1. Comparison of mean radiation levels (μR/h) in the fields with standard background level

These results obtained do not indicate any immediate health hazard for the host communities and the personnel working in the oil fields. The highest mean equivalent dose of $7.88 \pm 1.29 \mu Sv/wk$ for the Eriemu field is well within the UNSCEAR recommended $200 \mu Sv/wk$ for the public. However, there is still a likelihood of future health effects due to the accumulative dose intake by the personnel and the host community members. The flared ionizing radiations (radon gas) into the atmosphere precipitate upon condensing as rain water, thereby constituting radioactive rain water pollution. Unfortunately, this rain water serves as a major source of water for drinking and agriculture in the surveyed area, increasing the radionuclide dose intake by the host communities. In addition, a great proportion of this rain water leaks from the oil/gas reservoir and carried to the sub-surface, where it can make contact with sea water. In the sea water, it partially precipitates, while the rest is consumed by aquatic animals and hence poses a radiological risk to aquatic families and the like (Stanislav, 1998).

CONCLUSION

The study of the occupational radiation profile of oil and gas facilities during the production and off-production periods in Ughelli, Nigeria have been carried out. The study reveals that the background radiation levels of these areas have been affected by oil activity especially during this period of resumption of activities/operations. Though the dose equivalent is still within the safe radiation limit of 200μSv/wk, recommended by the UNSCEAR, the radiation levels within the oil field and the immediate host communities are far above the standard background levels. This implies that some of the input materials used by the company, their operations and effluent generated during production processes, are radioactive. We draw this conclusion because the geology of the area shows no trace of a radionuclide-bearing mineral nor is there any reported evidence of the existence of radioactive materials in the sub-surface in the investigated environment (Arogunjo et al., 2004).

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RADIJACIONI PROFIL NAFTNIH I GASNIH POSTROJENJA TOKOM I NAKON PERIODA PROZVODNJE U MESTU UGHELLI, NIGERIJA

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RadiJacioni profil ukupno 30 lokacija sa naftnim i gasnim postrojenjima u industrijskoj regiji Ughelli, Nigerija, proučavan je tokom i nakon perioda prozivodnje uz pomoć Digilert monitora za nuklearnu radijaciju i Geografskog pozicionog sistema (GPS). Srednje vredosti radijacije tokom perioda proizvodnje kreću se od 15.50± 1.65μR/h (0.026±0.003mSv/wk) do 19.14±3.16μR/h (0.32±0.005mS/wk) i od 13.38±1.69μR/h (0.023±0.003mSv/wk) do 16.29±2.60μR/h (0.027±0.004mSv/wk) tokom perioda nakon proizvodnje. Najveća vrednost 26.00±0.5.1μR/h (0.044±0.009mSv/wk) zabeležena je na Kokori naftnom polju tokom proizvodnje. Zbog toga se može zaključiti da su nivoi radijacije na ovom naftnom i radnom polju veći tokom perioda prozvodnje nego tokom perioda kada je prozvodnja obustavljena. Dalje, vrednosti za oba perioda su u okviru bezbednih vrednosti od 0.02mSv/wk prema preporukama UNSCEAR, ali je stepen izlaganja znatno veći od standardnog nivoa od 13.0μR/hr što je indikacija opasnog uticaja radijacije na zdravlje u ovim oblastima.

Ključne reči: *radijacija na poslu, naftna i gasna postrojenja*