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ENVIRONMENTAL IONIZING RADIATION DISTRIBUTION IN RIVERS STATE, NIGERIA

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Abstract. The distribution of ionizing radiation in Rivers State in the Niger Delta region of Nigeria is studied on the premise that the state – wide distribution of oil and gas operations leads to a homogeneous ionizing radiation environment. The state is sub divided into three self – consistent sub environments of an upland college campus environment, a rural riverine environment and an industrial sub zone environment. Available data give a mean dose equivalent of 0.745$\pm$ 0.085 mSv/yr (upland campus environment), 0.690$\pm$0.170 mSv/yr (rural riverine communities) and 1.270$\pm$0.087 mSv/yr (industrial zone) indicating an inhomogeneous radiation profile. The differences may be due to variations in levels of industrial activities and local geological peculiarities. Health implications are also examined.

Keywords: environment, ionizing radiation, riverine communities, oil and gas, Niger Delta.

1. Introduction

The Niger Delta region of Nigeria is a focal point nationally and internationally because of its abundant oil and gas reserves. Issues of environmental degradation and pollution through oil spillage, gas flaring, oil exploration, prospecting and exploitation along with ancillary technological and industrial activities are of concern in the region. There is also the challenge of elevated profile of ionizing radiation associated with activities of the hydrocarbon industry (Arogunjo *et al.* 2004; Rail Road … 2007; Patin, Cascio 1998).

Risk of exposure to radiation from radioactive substances is sometimes ignored with attendant grave health consequences as some associate such risks only with atomic and nuclear bombs and nuclear power plants. But as it has now been proved, man in his everyday experience is immersed in dangerous ionizing radiation occurring naturally in the everyday human environment (Hunt 1987). Contributions to this are radiations originating from sources beyond the earth's atmosphere and known as cosmic radiation. Cosmic radiation consists of gamma rays and such particles as ionized atomic nuclei and high energy protons. Contributions also arise from terrestrial sources which can be internal or external terrestrial sources. Internal radiations are those from within the bodies of organisms such as the radioisotope ^{40}K. External radiations are those from outside the bodies of organisms and include the natural radioactivity of the soil, minerals, rocks, plants and radioactive fall-outs from nuclear explosions.

Each individual is exposed to an average of 2.0 mSv/yr of ionizing radiation from natural sources alone (Hunt 1987). About 55% of this quantity is from gamma rays emitted by terrestrial radon; 8% is from cosmic ray; the natural radioactivity of environmental rocks (composed of such radionuclides as uranium, actinium, radium and thorium) and the absorbed dose from internal sources (Klement *et al.* 1992).

The background ionizing radiation (BIR) of particular environments is affected by a number of factors such as altitude and latitude. The dose from cosmic rays for instance changes by a factor of 3 from sea level to about 3,000 m above sea level and varies between 10% and 20% from 0–50^0 latitude (National Research…1972). The concentration of the radionuclides Radium and Thorium in rocks vary similarly (Sigalo and Briggs-Kamara 2004).

The multifaceted industrial activities in the Niger Delta region is expected to significantly affect the radiation profile of the region because contributions to the elevation of the natural ionizing radiation of a given area is not limited to natural sources alone, but also arise from man's activity in that environment (International Atomic … 1986; Oresegun and Babalola 1990). For example, any human activity in the environment that leads to the depletion of the ozone layer increases the BIR of the area as the depletion of the ozone layer means increase in the cosmic radiation that is able to reach the earth (Foland *et al.* 1995).

Water emanating from oil and gas operations has been found contaminated with Uranium and Thorium, two naturally occurring radioactive materials (NORM) and their daughters ^{226}Ra and ^{228}Ra (Patin, Cascio 1998).

Radiation monitoring in the Niger Delta region includes the studies at industrial facilities such as study at the fertilizer plant at Onne, Rivers State which showed significant increase in the radiation level there due to

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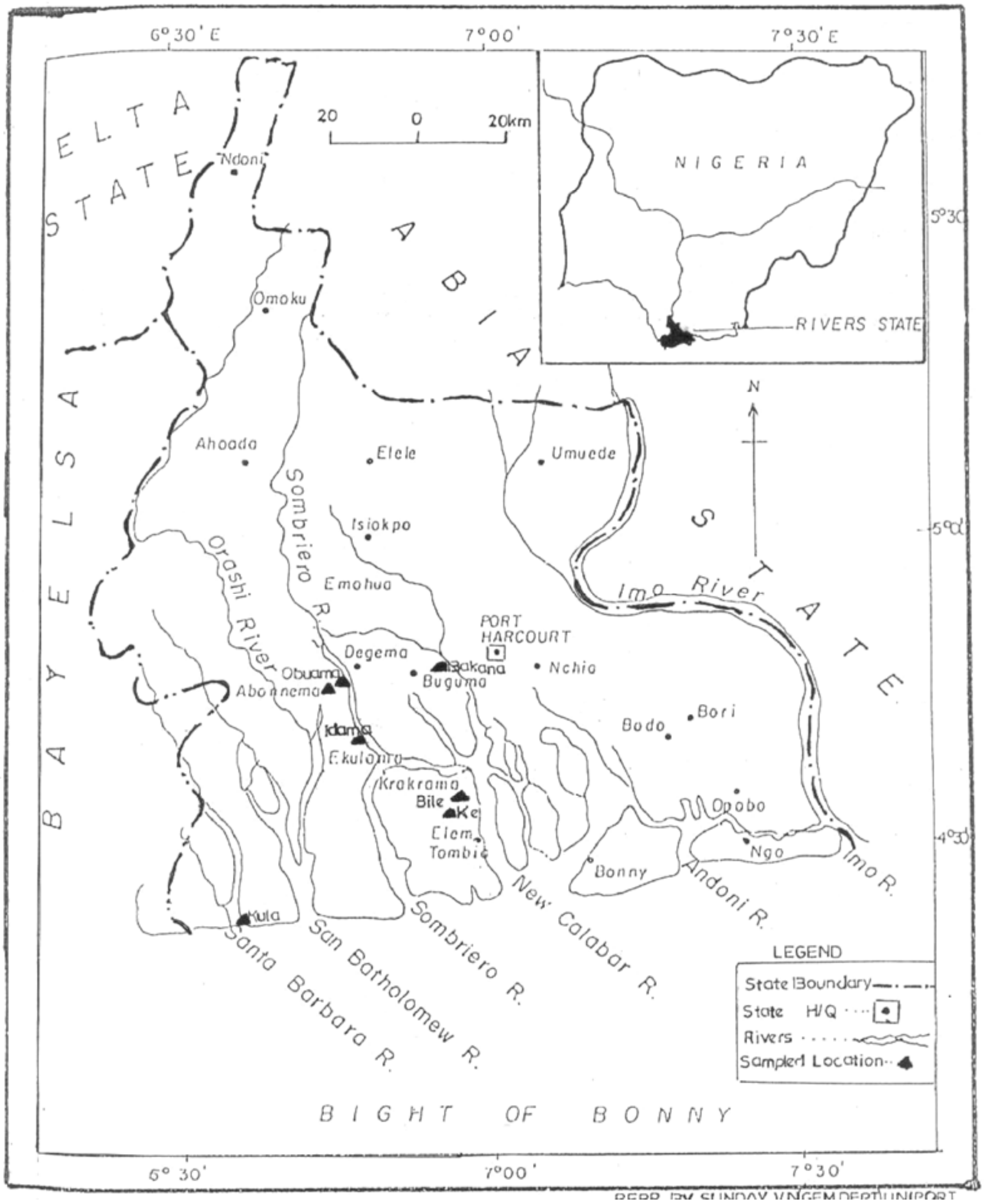

Fig. 1. Map of Rivers State showing study areas

the operations of the fertilizer production facility (Ebong and Alagoa 1992a, 1992b). Also, the BIR level of the premises of an oil and gas company, Western Atlas, Trans-Amadi, Port Harcourt has been surveyed (Sigalo 2000). Community wide projects have also been done. In Ikot Ekpene, Akwa Ibom State, an average activity level of 201.0±0.05 mBq was recorded with an out door exposure dose rate for gamma radiation in the area given as 0.067 x 10^{-2} μR/h (Louis *et al*. 2005). Recently, 21 facilities in four oil fields and their host communities were evaluated for terrestrial ionizing radiation in Ughelli, Delta State (Avwiri *et al.* 2007). This survey showed that the average exposure rate (dose equivalent) ranged between 12.00±0.1 μR/h (5.33±0.35 μSv/week) to 22.00±0.1 μR/h (9.79±0.16 μSv/week) to 22.00±0.35 μSv/week) for the oilfields and from 9.00±1.0 μR/h (4.01±0.45 μSv/week) to 11.00±0.5 μR/h (4.90±0.22 μSv/week) in the host communities.

Our aim in this work is to study the environmental ionizing radiation profile of Rivers State, Nigeria (Fig. 1). The state is located between latitude 4^0 15'N and 6^0 45'N and between 6^0 30'E and 7^0 45'E and covers a total land area of about 12,190 sq km. The state is central in the strategic Niger Delta region of Nigeria. Oil and gas operations are widespread in the state so that in this study we treat the state as a homogeneous environment of oil and gas and oil and gas related activities. Our basic assumption is that the radiation profile of the state will correlate with this homogeneous oil and gas activity in the state so that we expect a homogenous ionizing radiation profile for the entire state. For the purpose of the study we delineate the state into three fairly self-consistent sub environments:

1. An upland college campus environment;
2. A rural riverine environment;
3. An industrial zone environment.

Previous radiation survey in the college campus, the Rivers State College of Education, Port Harcourt, had studied the in-door background ionizing radiation profile of the Physics laboratory (Chad-Umoren *et al.* 2006). In the neighbourhood of the campus is the production plant of the Eagle cement company with the capacity to contribute to the observed BIR level of the campus (Avwiri 2005; Jibiri *et al.* 1999). This threat is enhanced by the system of interconnecting underground and surface waterways existing between the college and the cement factory capable of acting as transport routes for the radioactive substances that may emanate from the cement plant (Jibiri *et al.* 1999; Canadian Centre …2007).

Information on the ionizing radiation profile of the rural riverine communities of the state is important because many of these communities lack such basic amenities like potable drinking water so that the creeks and rivers also serve as sources of drinking water. This leads to significant health risks as radioactive substances that may be present in such sources are inadvertently ingested by their users.

2. Materials and methods

The BIR profile for the college campus and the levels for the riverine communities were determined using Mullard type ZP 1481 Geiger-Muller tubes with associated scalar and stop-watch. These tubes are cylindrical in shape having a length of 65 mm, an internal diameter of 20 mm with mica end window and a mean dead time of 208$\pm$40 μs. Tube sensitivity is enhanced by a protective open mesh plastic guard over the mica end window.

For the work on the campus 10 experimental locations were chosen viz, the area around the Physics laboratory; the area adjoining the Chemistry laboratory; English department; Social Science; Geography department; Education block; Old Staff quarters and New Staff quarters. Each location was further split into 3 experimental monitoring areas where actual monitoring was done. Counts were recorded at intervals of 20 mins for each monitoring area.

The surveys in the rural riverine communities were carried out in 7 communities (Sigalo and Briggs-Kamara 2004): Abonnema, Kula, Idama, Bile, Ke, Obuama and Bakana, Counts were taken for one hour at each location at intervals of 10minutes. For the monitoring in the industrial areas 10 locations were chosen (Avwiri and Ebeniro 2002). The survey used an assembly of two calibrated G – M tubes with an MX123 type tube and a Digilent nuclear radiation monitor. Measurements were done at 10-min interval for 10 successive readings at each location. In all cases the G-M tubes were oriented vertically downwards with their windows to the ground at a distance of 1.0m according to regulations of the National Council on Radiation Protection, NCRP (Avwiri and Ebenniro 2002). Also, except for the data on the BIR profile of the industrial areas, computed count rates were converted to dose equivalent.

Calibration of equipment was done as follows: a dosimeter calibrated in absorbed does was first exposed to gamma (γ) – radiation from ^{137}Cs (0.662 MeV) and ^{60}Co (1.17 and 1.33 Mev) at a distance of one metre from the respective sources. Dose rates were calculated using time intervals that varied between 1 to 24 hours. The dosimeter was then substituted with the G-M tube and the corresponding count rates recorded. Following this procedure count rates were converted to absorbed doses. We then have:

$$1 \text{ cpm} = 0.5 \times 10^4 \text{ R/h}.$$

Also:

$$1 \text{ cpm} = 0.044 \text{ mSv/yr}.$$

3. Results and discussion

The count rate (R.), deviations from mean count rate (ΔR), dose equivalent (D;), deviations from mean dose equivalent (ΔD) and percentage deviations from mean (%Δ) for the 10 locations of the college campus environment are displayed in Table 1. We find a variation in the dose equivalent from the minimum value of 0.704$\pm$ 0.106 mSv/yr (or a count rate of 16.0$\pm$2.4 cpm) recorded for the New Staff quarters to the maximum dose equivalent of 0.805$\pm$0.070 mSv/yr (18.3$\pm$1.6 cpm) obtained in the immediate vicinity of the Physics laboratory. The value of 0.704$\pm$0.048 mSv/yr (16.0$\pm$1.1 cpm) was also recorded at the English department. We find a minimum percentage deviation of 0.2% and a maximum percentage deviation of 7.5%.

The mean values of the radiation parameters for the campus environment are presented in Table 2 showing an overall mean dose equivalent, <D> for the campus as 0.745$\pm$ 0.085 mSv/yr (or 16.93$\pm$1.93 cpm).

Table 3 presents data obtained in the 7 rural riverine communities (Sigalo and Briggs-Kamara 2004). The highest dose equivalent is 0.81$\pm$0.19 mSv/yr (18.50$\pm$ 4.30 cpm) measured at Bakana while the lowest value is 0.57$\pm$0.16 mSv/yr (13.04$\pm$3.61 cpm) occurring at Ke community. These give an average of 0.690$\pm$ 0.170 mSv/yr (15.67$\pm$3.95 cpm) for the rural riverine communities).

For the industrial areas of the state (Tables 4 and 5) (Avwiri and Ebeniro 2002), we have computed the dose equivalent (Table 6) to afford easy comparison of the data for the three sub environments of the state. For the 10 industrial locations, the highest dose equivalent is 1.332$\pm$0.076 mSv/yr occurring at the Mobil area, while the lowest dose equivalent is 1.226$\pm$0.044 mSv/yr recorded at Arker Base. The mean dose equivalent for the industrial locations is 1.270$\pm$0.087 mSv/yr (0.0145$\pm$ 0.001 mR/hr).

Comparing the data for the three sub-environments, we find that the highest dose equivalent of 1.332$\pm$ 0.076 mSv/yr occurs in the industrial zone while the lowest value of 0.57$\pm$0.16 mSv/yr occurs in the rural riverine sub environment. The mean dose equivalent for the three zones show that the industrial sector has the highest mean value of 1.270$\pm$0.087 mSv/yr, the upland college campus has 0.745$\pm$0.085 mSv/yr while the rural riverine communities have a mean dose equivalent of 0.690$\pm$ 0.170 mSv/yr. One study in Chavara in the South

Table 1. Count rate (R), dose equivalent (D), deviations from mean count rate (ΔR) and dose equivalent (ΔD) and percentage deviation from mean (%Δ) for various locations (upland college campus environment).

	Location	Count rate R_i (cpm)		ΔR_i (cpm)	Dose Equivalent, D_i (mSv/yr)		ΔD_i	%Δ
		Site	Location average		Site	Location average		
1.	Physics Lab Area	17.00	18.3± 1.6	1.37	0.748	0.805±0.070	0.060	7.5
		18.00			0.792			
		16.50			0.726			
		19.00			0.836			
		21.00			0.924			
2.	Chemistry Lab Area	15.00	16.3± 1.5	–0.63	0.660	0.717±0.066	0.028	3.5
		17.00			0.748			
		14.00			0.616			
		17.50			0.770			
		18.00			0.792			
3.	English Dept	16.00	16.0± 1.1	–0.93	0.704	0.704±0.048	0.041	5.8
		17.00			0.748			
		15.00			0.660			
		14.50			0.638			
		17.50			0.770			
4.	Social Science	16.50	16.6± 3.0	–0.33	0.726	0.730±0.132	0.015	2.0
		17.00			0.748			
		19.00			0.836			
		11.00			0.484			
		19.50			0.858			
5.	Geography Dept	17.50	16.4± 1.6	–0.53	0.770	0.722±0.070	0.023	3.2
		16.50			0.726			
		15.50			0.682			
		18.50			0.814			
		14.00			0.616			
6.	Female Hostel	21.50	17.5± 2.1	0.57	0.946	0.770±0.092	0.025	3.3
		17.00			0.748			
		17.50			0.770			
		15.50			0.682			
		16.00			0.704			
7.	Refectory Area	19.00	17.8± 1.8	0.87	0.836	0.783±0.099	0.038	4.9
		17.00			0.748			
		15.50			0.682			
		20.50			0.902			
		17.00			0.748			
8.	Education Block	17.50	17.5± 2.1	0.57	0.770	0.770±0.092	0.025	3.3
		17.00			0.748			
		16.00			0.704			
		15.50			0.682			
		21.50			0.946			
9.	Old Staff Quarters	14.00	16.9± 2.1	–0.03	0.616	0.744±0.092	0.001	0.2
		15.50			0.682			
		19.50			0.858			
		16.50			0.726			
		19.00			0.836			
10.	New Staff Quarters	18.00	16.0± 2.4	–0.93	0.792	0.704±0.106	0.041	5.8
		12.50			0.550			
		17.00			0.748			
		14.50			0.638			
		19.00			0.836			

Table 2. Mean count rate (<R>), mean dose equivalent (<D>), mean deviations from mean (<ΔR>, <ΔD>) and mean percentage deviation from mean (<%Δ>)(upland college campus environment)

<R> (cpm)	<ΔR> (cpm)	<D> (mSv/yr)	<ΔD> (mSv/yr)	<%Δ>
16.93±1.93	0.68	0.745±0.085	0.030	3.99

Table 3. Showing count rates and dose equivalents for Abonnema, Kula, Idama, Bile, Ke, Obuama and Bakana (Riverine communities) (Sigalo and Briggs-Kamara 2004)

S/N	Location	Time (Mins)	Count per minute (cpm)	Mean count rate (cpm)	Dose Equivalent (mSv.yr)
1	Abonnema	10	13.40	13.91±3.73	0.61±0.16
		20	13.90		
		30	13.97		
		40	13.93		
		50	14.02		
		60	14.23		
2.	Kula	10	16.70	15.18±3.90	0.67±0.17
		20	15.40		
		30	14.50		
		40	14.53		
		50	14.76		
		60	15.17		
3.	Idama	10	18.30	17.86±4.23	0.79±0.19
		20	17.70		
		30	18.10		
		40	17.90		
		50	17.72		
		60	17.45		
4.	Bile	10	13.80	13.56±3.68	0.60±0.16
		20	13.95		
		30	13.97		
		40	13.33		
		50	13.18		
		60	13.10		
5.	Ke	10	13.10	13.04±3.61	0.57±0.16
		20	13.30		
		30	13.10		
		40	12.88		
		50	12.90		
		60	12.98		
6.	Obuama	10	17.50	17.66±4.20	0.78±0.18
		20	18.20		
		30	17.63		
		40	17.55		
		50	17.55		
		60	17.55		
7.	Bakana	10	19.60	18.50±4.30	0.81±0.19
		20	19.20		
		30	18.30		
		40	17.80		
		50	17.48		
		60	18.60		

Table 4. Stations for experiment (Industrial environment) (Avwiri and Ebeniro 2002)

Station									
1	2	3	4	5	6	7	8	9	10
Names									
PHRC	PHRC Juct. Alesa	NPA Onne	NAFCON, Onne	Bori/Onne Juct.	Rumuokoro Juct.	Choba (Wilbros)	Nkporlu Village	Arker Base	Mobil Area.

Table 5. T-test for stations at 5% confidence level and (n-1) degrees of freedom showing mean counter rate (*), mean background radiation (μ), standard deviation(s), computed t and critical t (tc) with sample size (n) of 10 (Industrial environment) (Avwiri and Ebeniro 2002)

Station	Counter	*mR/hr	S	μ	t	tc	Remarks
1	3	0.0149	0.0008	0.0144	1.98	2.26	t<tc
	2	0.0154	0.0006	0.0144	5.27	2.26	t>tc
	1	0.0128	0.0008	0.0144	–6.32	–2.26	t<tc
2	3	0.0148	0.0008	0.0143	1.93	2.26	t<tc
	2	0.0159	0.0007	0.0143	7.23	2.26	t>tc
	1	0.0122	0.0010	0.0143	–6.04	2.26	t<tc
3	3	0.0145	0.0006	0.0146	–0.53	2.26	t<tc
	2	0.0156	0.0011	0.0146	6.04	–2.26	t>tc
	1	0.0138	0.0022	0.0146	–1.15	–2.26	t>tc
4	3	0.0151	0.0007	0.0145	2.71	2.26	t>tc
	2	0.0159	0.0011	0.0145	4.02	2.26	t>tc
	1	0.0124	0.0007	0.0145	–4.50	–2.26	t<tc
5	3	0.0150	0.0006	0.0143	3.69	2.26	t>tc
	2	0.0150	0.0006	0.0143	3.69	2.26	t>c
	1	0.0121	0.0007	0.0143	–9.94	–2.26	t<tc
6	3	0.0148	0.0009	0.0147	0.032	2.26	t<tc
	2	0.0160	0.0008	0.0147	4.30	2.26	t>tc
	1	0.0136	0.0019	0.0147	–2.00	–2.26	t>tc
7	3	0.0147	0.0003	0.0147	–0.109	–2.26	t>tc
	2	0.0155	0.0008	0.0147	3.35	2.26	t>tc
	1	0.0138	0.0006	0.0147	–4.688	–2.26	t<tc
8	3	0.0141	0.0009	0.0144	0.94	–2.26	t>tc
	2	0.0155	0.0012	0.0144	3.00	2.26	t>tc
	1	0.0135	0.0015	0.0144	–1.83	–2.26	t>tc
9	3	0.0130	0.0006	0.0140	–5.47	–2.26	t<tc
	2	0.0154	0.0006	0.0140	7.79	2.26	t>tc
	1	0.0135	0.0004	0.0140	–3.25	–2.26	t<tc
10	3	0.0155	0.0007	0.0152	1.26	2.26	t<tc
	2	0.0168	0.0013	0.0152	3.86	2.26	t>tc
	1	0.0132	0.0006	0.0152	–10.89	–2.26	t<tc

Table 6. Dose equivalent, D computed for the data of Table 5 (Industrial environment)

Station	Mean exposure rate R (mR/hr)	Dose equivalent D (mSv/yr)
1	0.0144±0.0007	1.261±0.064
2	0.0143±0.0008	1.253±0.073
3	0.0146±0.0013	1.279±0.114
4	0.0145±0.0008	1.270±0.073
5	0.0143±0.0019	1.253±0.166
6	0.0147±0.0012	1.288±0.105
7	0.0147±0.0006	1.288±0.053
8	0.0144±0.0012	1.261±0.105
9	0.0140±0.0005	1.226±0.044
10	0.0152±0.0009	1.332±0.076

of India indicates that the general population there is exposed to a dose equivalent of 20 mSv/yr (Sundaram 1997). This study further provides evidence of how man's activities can result in the elevation of the radiation level of the environment.

The industrial environment of the state has the highest dose equivalent in the state. Also, the values for this environment are all higher than the European Council for Nuclear Research (CERN) recommended value of 1.0 mSv/yr for the general population who are not engaged in nuclear radiation related occupations (CERN… 1995). The values for the other two environments are within the CERN regulations.

4. Conclusion and further research

1. Based on the state-wide spread of oil and gas operations we assumed Rivers State, a Nigeria Niger Delta state, to possess a homogeneous ionizing radiation environment, but available data as presented in this study is at variance with this assumption. The data shows that the industrial zone sub environment has a higher level of ionizing radiation than the upland college campus and rural riverine sub environments of the state. This can be attributed to three factors:

(a) The higher concentration of oil and oil related establishments and operations in the industrial zone sub environment (Arogunjo *et al.* 2004; Hunt 1987; Rail Road…2007; Patin, Cascio 1998).

(b) Possible local geological variations showing the presence of the radionuclide bearing mineral, monazite (Arogunjo *et al.* 2004; Avwiri *et al.* 2007). Environmental radiation levels as high as 100–200mSv/yr have been reported in some areas of Brazil, China and India due to the geology of the environment (Holmes-Siodle and Adams 1993).

(c) Apart from the geology, a given environment may experience seasonal dose rate variations due to precipitation, humus and vegetation (Holmes-Siodle and Adams 1993).

2. The high dose equivalents for the industrial environment imply the presence of radioactive substances in the area.

3. There is a definite health risk in the industrial environment due to exposure to harmful ionizing radiation. But the other two environments – the upland college campus and the rural riverine communities at the present time face insignificant health hazards.

4. Appropriate government regulatory agencies should compel companies to enforce safe operating standards.

5. Though the college population and the rural riverine communities surveyed in this work face no immediate threat, the dynamic nature of the industrial operations in the region demands that ionizing radiation levels of the region be periodically monitored for any sudden variations. The case of the rural riverine communities is particularly significant as the numerous creeks and rivers there also serve as sources of drinking water and therefore there is the threat of ingestion of harmful radioactive substances that may be present in the water.

6. There is need to carry out extensive determination of the radionuclide contents of the water and soil in the three sub environments that were studied in this work to see how these correlate with the findings here. Such radionuclide analysis that have been carried out within the Rivers State environment includes that at the fertilizer plant at Onne (Avwiri 2002) and that for cement companies in Port Harcourt (Avwiri 2005).

7. Free flowing bodies of water can serve as transport routes for radioactive substances (Jibiri *et al.* 1999; Canadian Centre … 2007). Work needs to be done to clarify the effect of the many creeks and rivers on the radiation profile and radionuclide distribution within the Rivers State environment.

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APLINKOS JONIZUOJANČIOS SPINDULIUOTĖS PASISKIRSTYMAS RIVERS VALSTIJOJE, NIGERIJOJE

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S a n t r a u k a

Jonizuojančiosios spinduliuotės pasiskirstymas Rivers valstijoje Nigerio deltos regione, Nigerijoje, yra nagrinėjamas remiantis prielaida, kad valstijos mastu naftos ir dujų veiklos plėtra gali turėti įtakos aplinkos jonizuojančiosios spinduliuotės homogenizacijai. Tirti pasirinktos trys būdingos aplinkos vietos: universiteto teritorija, esanti vasltijos aukštumoje, kaimo paupio teritorijos bei pramoninė aplinka. Gauti rezultatai parodė, kad vidutinės dozės ekvivalentai atitinkamai pasirinktose vietose yra 0,745±0,085 mSv/yr, 0,690±0,170 mSv/yr ir 1,270±0087 mSv/yr. Rezultatai paneigė prielaidą apie galimą aplinkos jonizuojančiosios spinduliuotės homogenizaciją. Šiems skirtumams įtakos gali turėti nevienodi pramoninės veiklos mastai bei vietiniai geologiniai ypatumai. Taip pat darbe skiriama dėmesio jonizacijos reikšmingumui sveikatai.

Reikšminiai žodžiai: aplinka, jonizuojančioji spinduliuotė, paupio bendruomenės, nafta ir dujos, Nigerio delta.

РАСПРЕДЕЛЕНИЕ ИОНИЗИРУЮЩЕГО ИЗЛУЧЕНИЯ В ОКРУЖАЮЩЕЙ СРЕДЕ ШТАТА РИВЕРС В НИГЕРИИ

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Р ез ю м е

Распределение ионизирующего излучения в штате Риверс региона дельты Нила в Нигерии анализируется на основании предпосылки о том, что расширение деятельности по добыче нефти и газа в масштабе штата может оказать влияние на гомогенизацию ионизирующего излучения в окружающей среде. Для исследований были подобраны три наиболее характерных места окружающей среды: территория университета, находящаяся на высоком месте штата, сельские территории вблизи реки и промышленная среда. Полученные результаты показали следующие эквиваленты средних доз в выбранных местах: 0,745±0,085 mSv/yr, 0,690±0,170 mSv/yr и 1,270±0,087 mSv/yr и опровергли предпосылку о возможной гомогенизации ионизирующего излучения в окружающей среде. Разница в результатах может быть объяснена разными масштабами промышленной деятельности и местными геологическими особенностями. Также обращено внимание на значение ионизации для здоровья людей.

Ключевые слова: окружающая среда, ионизирующее излучение, общественность, нефть и газ, дельта Нила.

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