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ASSESSMENT OF RADIONUCLIDE CONCENTRATION WITH DEPTH IN LITHOLOGY OF PORT HARCOURT, NIGERIA

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ABSTRACT

A survey of the Radionuclide concentration with depth in the lithology of Obio-Akpor Local Government of Rivers State was carried out. Samples were collected at 5m interval from 3 wells (randomly selected). The gamma radionuclide concentrations of the samples were measured using a well calibrated thalium-activated Sodium Iodide detector NaI(Tl). The average specific activity values obtained were 318.9 Bqkg^{-1}, 285.7 Bqkg^{-1} and 256.7 Bqkg^{-1} for well 1, well 2 and well 3 respectively for K-40 radioisotope; 15.5 Bqkg^{-1}, 13.8 Bqkg^{-1} and 15.7 Bqkg^{-1} for well 1, well 2 and well 3 respectively for Ra-226 radioisotope; and 11.9 Bqkg^{-1}, 11.5 Bqkg^{-1} and 10.6 Bqkg^{-1} for well 1, well 2 and well 3 respectively for Th-232 radioisotope. Also, the Absorbed Dose rate and the Equivalent Dose Rate were calculated and an average of 27.5nGy/hr and 0.2mSv/yr were obtained for well 1, 25.6nGy/hr and 0.2mSv/yr for well 2 and 25.9nGy/hr and 0.2mSv/yr for well 3. These obtained values were less than the international standards of 55nGy/hr and 0.7mSv/yr for Absorbed Dose rate and the Equivalent Dose Rate respectively. The results indicate that the radiation level within the sampled areas may pose no significant health-side effect on the populace. Also, it was observed that radionuclide concentration reduced with depth.

Key Words: lithology, radionuclides, activity concentration, absorbed dose, equivalent dose

INTRODUCTION

Natural radioactivity is common in the rocks and soil that make up our planet, in water and oceans, and in our building materials and homes. There is nowhere on Earth that you cannot find natural radioactivity (Brodsky, 1978). Some of these natural sources of radiation include: UV radiation, radon in soil and water and Technologically Enhanced Naturally Occurring Radioactive Materials (TENORMs). The natural radionuclides present in soil and water in an environment are present as daughters of Uranium (U-238), Thorium (Th-232) isotopes distributed by natural geological and geophysical processes in addition to potassium (K-40) and small quantities of fission products which are ^{90}Sr, ^{137}Cs, etc from atmospheric weapon test. Monitoring of radioactive materials are therefore of primary importance to man and environmental protection, especially that in the ground and accurate methods for the radioactivity measurement is essential (El-Bahi, 2004). Studies have shown that in soil and water

terrestrial radiation is highly dependent on the mineral content of the environment.

The study area is located in the geographical positions of N $04^0$51.5 and E $006^0$58.5, N$04^0$52.8 and E$007^0$01.6 and N$04^0$50.5 and E$007^0$03.2within the Port Harcourt municipal area of Rivers State. This state has one of the largest economies in Nigeria, mainly because of its crude oil potential. The State has two major refineries, two major seaports, an airport, and various industrial estates spread across it. Mineral contents of the study area are petroleum, natural gas, silica sand, glass and clay.

The exploration of portable water has led to the increased drilling of water bore holes in Nigeria especially the urban areas. During manual bore-hole drilling, local drillers arbitrarily bath with the mud drilled from the reservoir and other sediments associated with the process. The need to ascertain the radiological contents of these muds and examine the relationship between depth and the radiation level laid credence to this work.

MATERIALS AND METHODS

Sample Collection and Preparation: Sampling was done in three (3) wells located at Okporo Road, Eneka and Rumuibekwe Estate in Port Harcourt municipal. Soil samples were collected on the average of two samples from each profile to the aquifer level. Each well consists of 5 (five) profiles at a distance of about 5 m apart. The sampling characteristics are as shown in Tables 1 - 3. The collected samples were separately sealed in a black polythene bag prior to processing for γ-spectroscopy. The soil samples collected were spread in tray pans to dry after which the samples were properly crushed to particle sizes for analytical purpose, then sealed, weighed, and stored in laboratory beaker for a minimum of 28 days to enable secular equilibrium (IAEA, 1989). When this equilibrium state is attained, then the activity of each radionuclide of a given series is equal to the activity of the parent nuclide.

Gamma (γ) Ray Analysis: The method of γ-ray spectrometry was adopted in the analysis. Each sealed sample was placed on the sodium iodide detector and counted for 36000 seconds. The gamma-ray counting of the samples was performed on a lower gamma ray spectrometer consisting of a detector called Sodium Iodide (NaI) coupled with an amplifier, which amplifies the incoming signals and integrates them to volts (0=10 volts). It also consists of an analog-to-digital converter (A.D.C) and an S100 Multi-Digital Analyzer card hosted in an IBM-PC. This gamma-ray spectrometer is produced by Canberra. After the gamma ray counting of each sample, the energy level is saved immediately to forestall loss of count as a result of power failure.

The specific activity concentrations A_K, A_U, and $A_{Th}$for K- 40, Ra- 226, and Th- 232 respectively were computed for the various samples using the relation (Beck, *et al.*, 1972),

$$A_C = \frac{A \cdot A_{CS} \cdot M_S}{A_S \cdot M} \qquad (1)$$

Where;

A_C= Specific Activity of the particular identified radionuclide in each sample,

A = net photo peak area of an identified sample,

A_{CS} = Activity of same identified nuclide identified in the standard sample,

Ms= mass of standard sample,

As = Net full peak area of this nuclide in the standard sample,

M = mass of sample.

The total absorbed dose rate (D) of each sample was calculated using the formula (Beck *et al*, 1972),

$$D = 0.042\ A_{k-40} + 0.429\ A_{Ra-226} + 0.66 A_{Th-232} \qquad (2)$$

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Where 0.042, 0.429, 0.6 are dose constants for k-40, Ra-226 and Th-232 respectively.
Using the conversion factor of 1 nGy/hr = 1 nSv/hr = 0.00876mSv/yr, the Equivalent dose rate (EDR) was calculated in mSv/yr.

RESULTS AND DISCUSSION

The sample codes and sample types at various sampling depths from the surveyed locations are presented in Tables 1 – 3. Also, the results of the mean specific activity concentration of the radionuclides and absorbed dose rate are presented in Tables 4 - 6 for well 1, well 2, and well 3 respectively and a plot of the variation of the radiation absorbed dose rate with depth is presented in Figure 1.

Table 1: Well 1 (Okporo Road)

Elevation above sea level: 61.5m; Geographical Coordinates: N 04^0 51.516 and E 006^0 58.529

S/No	Dept(m)	Sample Code	Sample Type	Profile
1	5.00	RV/OB/OKO1	Peat	1
2	10.00	RV/OB/OKO2	Peat/clay	1
3	15.00	RV/OB/OKO3	Clay	2
4	20.00	RV/OB/OKO4	Silt/clay	2
5	25.00	RV/OB/OKO5	Silt/clay	3
6	30.00	RV/OB/OKO6	Silt	3
7	35.00	RV/OB/OKO7	Sand	4
8	40.00	RV/OB/OKO8	Sand	4
9	45.00	RV/OB/OKO9	Sandstones	5
10	50.00	RV/OB/OK1O	Gravels	5

Table 2: Well 2 (Eneka Road)

Elevation above sea level: 5.7m; Geographical Coordinates: N04^0 52.806 and E007^0 01.673

S/No	Dept(m)	Sample Code	Sample Type	Profile
1	5.00	RV/OB/EN 01	Peat	1
2	10.00	RV/OB/EN 02	Peat	1
3	15.00	RV/OB/EN 03	Clay	2
4	20.00	RV/OB/EN 04	Clay	2
5	25.00	RV/OB/EN 05	Silt/clay	3
6	30.00	RV/OB/EN 06	Silt/clay	3
7	35.00	RV/OB/EN 07	Sand	4
8	40.00	RV/OB/EN 08	Sand	4
9	45.00	RV/OB/EN 09	Sandstones	5
10	50.00	RV/OB/EN 10	Gravels and pebble	5

Table 3: Well 3 (Rumuibekwe Estate)

Elevation above sea level: 5.7m, Geographical Coordinate: $N04^0$ 50.524 and $E007^0$ 03.256

S/No	Depth (m)	Sample Code	Sample Type	Profile
1	5.00	RV/OB/RM01	Peat	1
2	10.00	RV/OB/RM02	Clay	1
3	15.00	RV/OB/RM03	Clay	2
4	20.00	RV/OB/RM04	Clay	2
5	25.00	RV/OB/RM05	Silt	3
6	30.00	RV/OB/RM06	Silt/Sand	3
7	35.00	RV/OB/RM07	Sand	4
8	40.00	RV/OB/RM08	Sand	4
9	45.00	RV/OB/RM09	Sand Stone	5
10	50.00	RV/OB/RM10	Gravel	5

Table 4: Radionucide Concentration of Well 1 (Okporo Road)

S/No	Samples Code	K-40 ($Bqkg^{-1}$)	Ra -226 ($BqKg^{-1}$)	Th – 232 ($Bqkg^{-1}$)	Absorbed Dose Rate (nGy/hr)
1	RV/OB/OKO1	385.5±0.93	26.5±0.23	17.3±0.80	38.9
2	RV/OB/OKO2	376.4± 1.55	22.8±2.32	16.8±1.82	36.7
3	RV/OB/OKO3	364.9± 1.55	21.0±1.27	15.8±0.80	34.8
4	RV/OB/OKO4	343.0.±4.98	16.8±1.97	15.8±0.91	32.0
5	RV/OB/OKO5	317.2± 1.09	13.7±1.16	11.8±1.25	27.0
6	RV/OB/OKO6	301.3±4.35	13.3±1.16	11.8±0.68	26.1
7	RV/OB/OKO7	286.0±2.95	11.9±2.32	9.4±0.46	23.3
8	RV/OB/OKO8	265.5±0.31	10.8±2.20	8.0±0.46	21.1
9	RV/OB/OKO9	238.6±0.78	9.6±2.20	6.5±9.35	18.4
10	RV/OB/OK10	211.0±0.75	9.0±0.46	6.4±1.03	16.9
	Mean Value	318.9±1.92	15.5±1.45	12.0±1.75	27.5

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Table 5: Radionuclide Concentration of Well 2 (Eneka Road)

S/No	Samples Code	K-40 ($Bqkg^{-1}$)	Ra -226 ($BqKg^{-1}$)	Th – 232 ($Bqkg^{-1}$)	Absorbed Dose Rate (nGy/hr)
1	RV/OB/ENO1	376.7±2.18	22.8±1.85	18.7±0.68	38.0
2	RV/OB/ENO2	369.1±0.93	21.6±2.90	18.3±0.34	36.8
3	RV/OB/ENO3	345.3±1.55	17.2±1.62	16.6±0.91	32.8
4	RV/OB/ENO4	328.5±0.78	16.3±2.09	14.3±0.91	30.2
5	RV/OB/ENO5	278.8±3.11	12.9±0.35	12.1±0.68	25.2
6	RV/OB/ENO6	264.8±3.73	11.9±0.46	10.1±0.57	22.9
7	RV/OB/ENO7	236.6±1.71	10.3±0.81	7.9±0.11	19.6
8	RV/OB/ENO8	234.1±0.16	9.1±0.58	7.2±0.11	18.5
9	RV/OB/ENO9	217.9±2.18	8.6±0.46	5.8±0.11	16.7
10	RV/OB/EN10	209.7±0.16	8.1±1.51	4.3±0.23	15.1
	Mean Value	285.7±1.65	13.8±1.26	11.4±0.50	25.6

Table 6: Radionuclide Concentration of Well 3 (Rumuibekwe)

S/No	Samples Code	K-40 ($Bqkg^{-1}$)	Ra -226 ($BqKg^{-1}$)	Th – 232 ($Bqkg^{-1}$)	Absorbed Dose Rate(nGy/hr)
1	RV/OB/RMO1	354.9±0.31	21.5±1.51	16.1±0.11	34.70
2	RV/OB/RMO2	343.1±3.32	20.8±0.23	15.6±0.80	33.60
3	RV/OB/RMO3	321.1±1.09	18.8±0.70	15.7±0.34	31.88
4	RV/OB/RMO4	310.5±0.16	17.6±1.27	13.7±0.34	29.59
5	RV/OB/RMO5	295.2±0.62	15.4±1.04	11.9±0.34	26.93
6	RV/OB/RMO6	288.7±4.82	14.3±1.74	9.9±1.71	24.78
7	RV/OB/RMO7	267.3±0.47	13.4±0.70	9.8±0.80	23.42
8	RV/OB/RMO8	254.5±3.58	13.1±1.74	6.1±0.68	20.28
9	RV/OB/RMO9	223.7±1.24	11.3±0.12	4.3±0.57	17.06
10	RV/OB/RM10	220.6±1.24	11.0±1.85	4.2±0.46	16.74
	Mean Value	256.7± 1.54	15.8± 1.18	10.6± 0.56	25.90

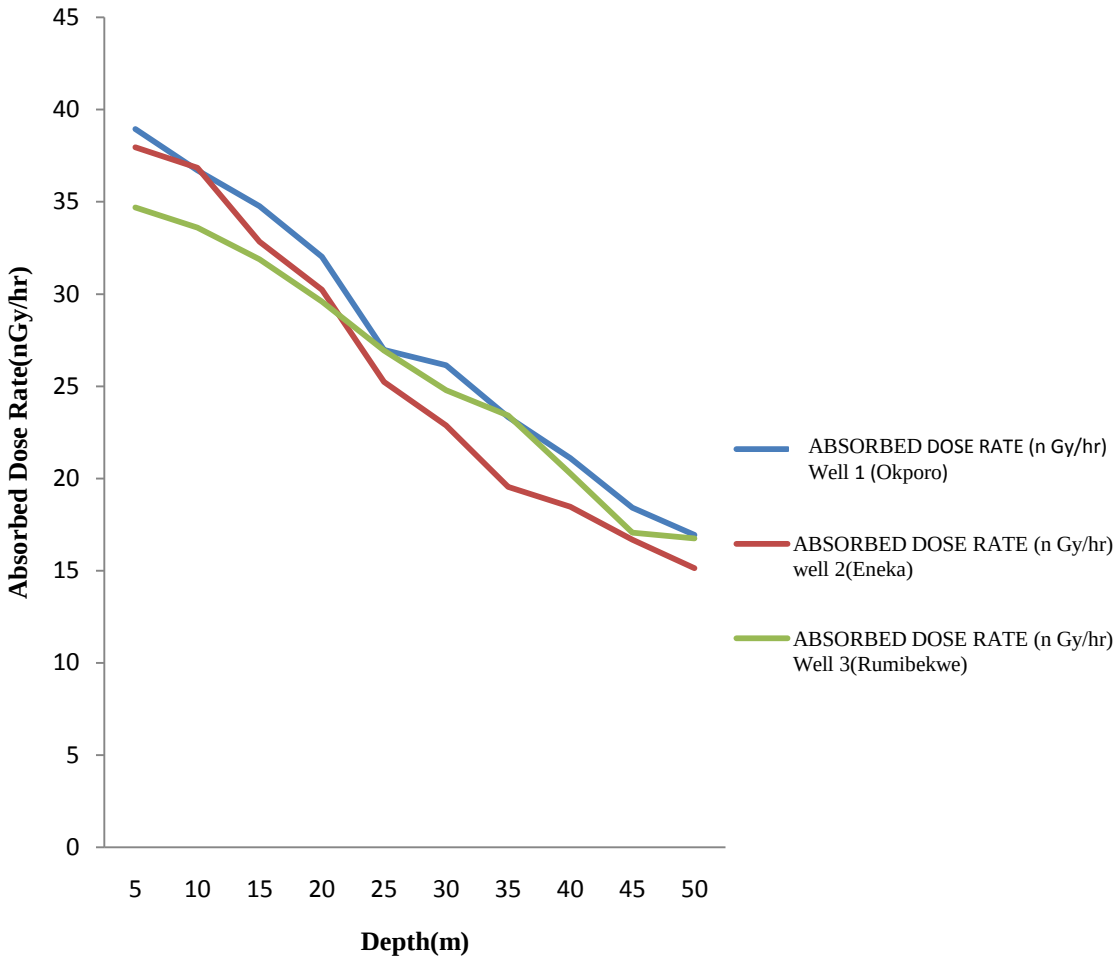

Fig 1: Variation of Radiation Absorbed Dose Rate with Depth

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The results of the study showed that the radionuclides identified are Ra- 226 which belongs to the decay series of U-238 and Th-232 respectively and a non-series radionuclide, K-40.

The high values of K-40 may be as a result its abundance in the earth crust (Tchokossa et al 1999). The concentration of R-226 was higher compared to that of Th-232. This may be as a result of the fact that Ra-226 is moderately soluble in water (Ashraf et al, 2001).

Also, the results obtained are comparable to that obtained by Ajayi et al (1991) in the study of rocks found in Ekiti, but less than the world average value for K-40, Ra-226 and Th-232 which are 400 $Bqkg^{-1}$, 35 $Bqkg^{-1}$ and 30 $Bqkg^{-1}$ respectively (UNSCEAR, 2000).

The absorbed dose rate (ADR) and the equivalent dose rate (EDR) were calculated. Well 1 (Okporo Road) has the highest mean value of 27.5 nGy/hr and 0.24 mSv/yr for the ADR and EDR respectively. Well 2 (Eneka) has the lowest mean values of 25.58 nGy/hr and 0.22 mSv/yr for the absorbed dose rate and equivalent dose rate respectively. Furthermore, the combined profile showed that well 1(Okporo road) has the highest value of the absorbed dose rate (ADR) and the equivalent dose rate (EDR) at the surface. This could be attributed to the fact that Okporo road in Port-Harcourt has the highest population density and industrial activities compared with other areas of the study such as Eneka that is a rural dwelling with little or no industrial activities that could contribute to technologically enhance natural occurring radioactive materials (TE-NORMs) of the environment. Also, between depth of 10 – 50 m, Okporo road and Rumuibekwe housing Estate continue to show elevation above the rural dwelling of Eneka. These values are lower than that of the cement companies in Port-Harcourt (Avwiri, 2005) and higher than that obtained by Odunaike (2008) for Ibadan Metropolis, Oyo State which is devoid of major industrial activity with minimal contribution to TE-NORMs.

The results were lower compared with that obtained by Muhammad (2010) in the environment around the Center of Atomic Energy Commission, Ahmadu Bello University, Zaria which may have accumulated sources of radiation. Furthermore the results were lower than the standard maximum exposure to gamma-ray of 0.7 mSv/yr (ICRP, 1991) and the UNSCEAR report which have the average absorbed dose rate in air outdoor from terrestrial gamma radiation as 55 nGy/hr (UNSCEAR 2000). Therefore, exposure to the drilling mud by the drillers and other workers will pose no significant health threat and the environment is radiologically safe. Generally, the results showed that the radionuclide concentration reduces with depth in the lithology, this may be due to the fact that there is more concentration at the top profile and the concentration continues to reduce with depth in the lithology where the different profiles continue to act as a filter and buffer**.**

CONCLUSION

The radionuclides that were found in the soil samples collected from 3 wells are K-40, Ra-226 and Th-232. And also, the concentration of the radionuclides decreases with depth of the profile of the aquifer. The average radionuclide levels of the aquifer were lower than the world maximum exposure for such environment. Therefore, exposure to the drilling mud by the drillers and other workers will pose no significant health threat and the environment is radiologically safe.

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