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Survey of Gross Alpha and Gross Beta Radionuclide Activity in Okpare-Creek Delta-State Nigeria

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Abstract: A survey of the gross alpha and beta radionuclide activity of Okpare Creek in Delta state has been carried out. Twenty samples of the creek water were collected from the farming, residential/commercial and industrial zones along the creek and were analyzed using the eurysis system-eight-channels-gas-filled proportional counters. The count results show that the average alpha activities in the farming, residential/commercial and industrial zones are 1.003±0.097, 4.261±0.109 and 10.296±0.489 Bq L^{-1}, respectively. The average beta activities in the three zones are 0.129±0.100, 0.523±0.003 and 0.793±0.010 Bq L^{-1}, respectively. The overall results show that the alpha and beta activities in the three zones are far below the practical screening levels of radioactivity in drinking water of 100 Bq L^{-1} for alpha and 100 Bq L^{-1} for beta recommended by CEC-FAO and WHO and therefore may not pose any serious detrimental health side-effects to the public users of the creek.

Key words: Gross alpha and beta, radionuclide activity, Okpare-Creek

INTRODUCTION

Natural and man-made sources of ionizing radiation are present in the environment in which man lives; there is continuous bombardment of man and his environment by these ionizing radiations (Eisenbud and Gesell, 1997). This is as a result of the presence of radionuclides in all activities undertaken by man. Naturally occurring radionuclide are present in the food we eat, the air we breathe and the water we drink and have resulted in health hazard among the general public. Some of these exposures are relatively constant and uniform to all individuals throughout the world (Aregunjo *et al*., 2004).

Jibiri *et al.* (1999) reported that an increase in the background ionizing radiation from numerous sources has various health side-effects on the populace. Also, photographs, exposing the body parts to radiation in the course of treatment of cancer and digital mammography can lead to high exposures (Andrew and Len, 1993). Radionuclides from both natural and artificial sources can come into contact with water though several ways. They may be deposited from air; they may also be released to the water from the ground through erosion, seepage or human activities such as mining and drilling (Aregunjo *et al*., 2004). Cothern and Lappenbush (1990) measured uranium in ground and surface water in the USA and reported that many of the community drinking water supplies exceeded a uranium concentration of 370 and 185 Bq L^{-1} limits by USAEPA and WHO respectively. Bawaja *et al.* (1987) surveyed the lake Ontario and reported that uranium and ^{226}Ra levels were in an average of 0.7×10^{-6} and 1.2 m Bq L^{-1}, respectively while in lake Michigan, Nelson and Metta (1983) measured the levels of ^{232}Th and obtained an average value of 28×10^{-6} Bq L^{-1}. Avwiri *et al.* (2005) surveyed the radionuclide concentration of soil, sediments and water in Aba River, Nigeria and reported that the results obtained for the observed radionuclide isotopes were below international standard and concluded that the river has no radiological burden on the populace.

The geographical/geological formation of an area determines to some extent the radionuclide present in water (Baratha, 1990). In order to give an approximate idea of the amount the radionuclide in water, the gross alpha and gross beta activities are measured, this gives the degree of contamination (Semko and Parekh, 2000). Gross alpha is more of a concern than gross beta for natural radioactivity in water as it refers to the radioactivity of Th, U, Ra as well as Rn and daughter isotopes. For anthropogenic radioactivity, gross alpha may pertain to screening for transuranics in wastes, while gross beta to screening for fission products in accidental reactor releases (Anonymous, 1997a; Semko and Parekh, 2000). CEC-FAO and WHO in 1990 recommended a standard practical screening level of radioactivity in drinking water of 100 Bq L^{-1} for alpha and 1000 Bq L^{-1} for

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beta (Cothern and Lappensbush, 1990). Onoja (2004) surveyed the gross alpha and gross beta radioactivity in well water in Zaria and reported an average alpha activity of 6.35±0.45 and 75.34±1.53 Bq L^{-1} for beta activity. Juliet (2006) also measured the gross alpha and beta radioactivity in River Kaduna and reported a mean value of 0.117±0.002 and 0.439±0.006 Bq L^{-1} for alpha and beta activity, respectively. The overall results in the two separate research work show that both alpha and beta activities are below the WHO practical screening level of radioactivity in drinking water.

Okpare Creek in Nigeria lies within latitude 05°, 27 N and 05°, 33 N and longitude 005°, 53 E and 006°, 04 E of the Niger Delta, the Creek runs North-West to South-East. It has its sources at both Umuaja in Umutu and River Niger and empty into Atlantic Ocean at Forcados (Agbalagba, 2007). Its geology is consistent with the general geology of the Niger-Delta complex. The creek plays host to various farming activities, commercial/residential refuse dumps and industrial effluent discharges from rubber processing factories and asphalt plants at various point along the Creek, thus the Creek is classified into three zones (farming Zone (A), commercial/Residential Zone (B) and industrial Zone (C)) for the purpose of this research work to know the radionuclide distribution pattern and the area of high activity concentration.

The awareness of the potential degradation of the water body and its environments by the activities of the farmers, residence/commercial activities and the effluents discharge from these companies is on the increase and there have bevarious claims and counterclaims of degradation of the Okpare creek by the host communities. This study therefore, determines the level of radionuclide concentrations (gross alpha and beta activity) in the Creek and ascertains the radiological health side-effects on the populace and the environment. These results will therefore form a base-line data of radionuclide activity for the Okpare creek.

MATERIALS AND METHODS

Sample collection and preparation: Twenty water samples were collected at 20 sampling spots using the stratified random sampling method and sample preparation procedures followed as reported earlier (Onoja, 2004). The samples were collected along the course of the river to reflect the economic and industrial activities in the river. The samples were analyzed at the Center for Energy Research and Training, Ahmadu Bello University, Zaria, Nigeria.

The background measurements, sample efficiency and the plateau test were carried out using standard methods (ASTM, 1995).

Counting: The counting equipment, a Eurysis System-eight-channel-gas-filled proportional counter is automated. The procedure involves entering the present time, number of cycles and the counting (operational) voltages. Also the counter characteristics (channel efficiency and background count rate), volume of sample used and sample efficiency were entered. The sample efficiency was calculated as:

$$\text{Sample efficiency } = \frac{\text{MT}}{0.1} \times 100\% \tag{1}$$

Where:

M_T = The mass of residue in the planchette got from sample preparation

0.1 A (mg) = The expected mass of the residue in the planchette

Gross alpha counting: For gross alpha counting the high voltage was set at 1600 volts and samples were counted for 3 cycles of 3600 sec per cycle. The results were displayed as raw counts, count rate (count/min) activity and standard deviation. The data were acquired for alpha only mode and the alpha count rate as well as alpha activity were calculated using the formula (ASTM, 1995)

$$\text{Activity } \alpha = \frac{\dfrac{\text{Rate } \alpha \times \text{Bgd} \times \alpha}{\text{unit coefficient}}}{\text{Channel eff} \times \text{sample eff} \times \text{sample volme}} \tag{2}$$

Where, (α) unit coefficient is the multiplication coefficient making it possible to obtain the results expressed in the units used by the operator, eff is efficiency and Bgd is the background detection limit.

Gross beta counting: The high voltage for gross beta counting was set at 1700 volts and sample were counted for 3 cycles of 3600 sec per cycle in beta only mode. The count rate and the activity were calculated using the formula (ASTM, 1995).

$$\text{Rate } \beta \text{ (count sec}^{-1}) = \frac{\text{Raw } \beta \text{ count} \times 60}{\text{Count time(sec)}} \tag{3}$$

$$\text{Activity } \beta = \frac{\text{Rate x Bgd} \times \beta \text{ unit coefficient}}{\text{Channel } \beta \text{ eff x sample eff.} \times \text{sample volume}} \quad (4)$$

Data presentation

Alpha-activity: The alpha activity is expressed as activity concentration C in Becquerel per liter (Bq L^{-1}). The activity concentration C is calculated using formula (Anonymous, 1997b).

$$C = \frac{R_b - R_0 \times a_s \times m \times 1.02}{R_s - R_0 \times 1000 \times v} \quad (5)$$

Where, R_b is observed sample count rate (s^{-1}), a_s is the specific activity of the alpha standard, V is the volume of the sample evaporated in liter and m is the mass in mg of the residue from volume V and the factor 1.02 is included to correct for 20 mL of nitric acid added per liter as a stabilizer.

Beta-activity: The gross beta activity is expressed as activity concentration C in Bq L^{-1} calculated

$$C = \frac{R_b - R_0 \times a_s \times m \times 1.02}{R_s - R_0 \times v} \times \frac{14.4}{1000} \quad (6)$$

Where, $\frac{14.4}{1000}$ represent the specific activity of ^{40}K in KCl, all other terms have their usual meaning.

The standard deviation (σ), associated with the activity of the sample collected for background is calculated (Anonymous, 1997)

$$\sigma = \sqrt{\frac{R_b}{t_b} + \frac{R_0}{t_0}} \times \frac{m}{(R_b - R_0)} \times \frac{14.4}{1000} \quad (7)$$

Other materials/equipment used in this research work are the Geographical Positioning System (GPS) for sampling precise geographical positioning and a watch for timing.

RESULTS AND DISCUSSION

Table 1 and 2 show the preliminary results of the detector characterization while Table 3 shows the major result of the analysis. The results of the average efficiencies of the different channels of the detector in

Table 1: Channel efficiencies for different modes of measurement (Nov. 2006)

Channel No.	Alpha only mode R^2	Alpha only mode 4π Efficiency	Beta only mode R^2	Beta only mode 4 π Efficiency
1	0.9500	35.29	0.41470	56.37
2	0.9080	35.96	0.08832	51.93
3	0.9176	35.02	0.63440	52.06
4	0.8770	35.65	0.87460	50.79
5	0.9514	34.67	0.81850	51.40
6	0.9084	35.24	0.84400	51.92
7	0.9906	35.33	0.79570	51.55
8	0.9002	35.26	0.90880	52.82
Average		35.32±0.05		53.58±0.11

Where, r is the radius of the plenchette

Table 2: Limit of detection of proportional counter per channel

Channel No.	Limit of detection Bq α	β
1	0.0051	0.0214
2	0.0051	0.0279
3	0.0048	0.0206
4	0.0075	0.0457
5	0.0044	0.0193
6	0.0115	0.0325
7	0.0079	0.0296
8	0.0063	0.0867
Average	0.0080±0.001	0.053±0.002

alpha only mode is 35.32±0.05 while that of beta in beta only mode is 53.58±0.11, thus the average efficiency of beta is greater than the average efficiency of alpha with the alpha to beta efficiency ratio approximately 4/5. The limit of detection gives the lowest activity that could be detected by the detector.

The results show that the limit of detection for alpha particles ranges from 0.0044 Bq to 0.0115 Bq with an average value of 0.0080±0.001 Bq while the limit for detection of beta ranges from 0.0193 Bq to 0.0867 Bq with an average value of 0.0529±0.002 Bq. The overall result of the preliminary investigation revealed low background, good plateau and low detection (Table 2).

Table 3 shows the values of the alpha and beta activity concentration in the three zones: viz., farming zone (A), residential/commercial zone (B) and industrial zone (C). The alpha activity concentration have an average activity concentration of 1.003±0.097 Bq L^{-1} in the farming zone (A), in the Residential/Commercial zone (B), the activity concentrations have an average activity concentration of 4.261±0.109 Bq L^{-1}. In the industrial zone (C), the average activity concentration of 10.296±0.489 Bq L^{-1} was obtained. Comparing these values with that obtained by Juliet (2006) in River Kaduna show that Okpare Creek mean alpha activity is 5.07±0.168 Bq L^{-1} higher than that obtained at River Kaduna. The mean alpha activity concentration

Table 3: Alpha/Beta activity concentrations of the water samples analyzed (November 2006)

Sample code	Sample geographical location	α-activity (Bq L^{-1})	β-activity (Bq L^{-1})	Sample zone
UGH01	N05°27.687 E005°53.833	3.009±0.193	0.290±0.005	A
UGH02	N05°27.588 E005°54.063	0.653±0.103	0.139±0.003	-do-
UGH03	N05°27.894 E005°54.772	0.318±0.024	0.034±0.001	-do-
UGH04	N05°28.472 E005°56.296	0.360±0.038	0.086±0.001	-do-
UGH05	N05°28.562 E005°56.436	0.737±0.132	0.129±0.003	-do-
UGH06	N05°28.777 E005°56.523	0.400±0.090	0.094±0.003	-do-
UGH07	N05°29.651 E005°58.782	8.390±0.186	0.121±0.003	B
UGH08	N05°29.566 E005°58.574	0.468±0.100	0.125±0.010	-do-
UGH09	N05°29.768 E005°59.053	2.820±0.070	0.086±0.001	-do-
UGH10	N05°29.824 E005°59.326	8.426±0.169	0.170±0.002	-do-
UGH11	N05°29.898 E005°59.473	3.210±0.072	0.237±0.002	-do-
UGH12	N05°30.191 E006°00.090	4.898±0.086	0.853±0.006	-do-
UGH13	N05°30.382 E006°00.537	3.615±0.083	0.072±0.001	-do-
UGH14	N05°30.520 E006°00.779	58.018±0.981	4.263±0.026	C
UGH15	N05°32.122 E006°02.155	5.345±0.112	0.265±0.002	-do-
UGH16	N05°32.091 E006°02.256	3.421±0.067	0.204±0.003	-do-
UGH17	N05°32.545 E006°03.194	2.088±0.160	0.030±0.003	-do-
UGH18	N05°32.495 E006°03.268	0.038±0.520	0.158±0.009	-do-
UGH19	N05°33.322 E006°04.621	0.335±0.084	0.071±0.002	-do-
UGH20	N05°33.491 E006°04.883	2.825±0.438	0.558±0.009	-do-

(5.187±0.170 Bq L^{-1}) of the Creek is 5.033 Bq L^{-1} higher than the 0.154 Bq L^{-1} obtained in Mills Creek Australia and 1.587 Bq L^{-1} higher than the 3.600 Bq L^{-1} reported in Woronora River Down stream also in Australia (Onoja, 2004). The beta activity concentrations in zone (A) have an average activity concentration of 0.129±0.10 Bq L^{-1}. In the residential/commercial zone (B), the average activity concentration is 0.523±0.003 Bq L^{-1}. while in the industrial zone (C), its average value activity concentration is 0.793±0.010 Bq L^{-1}. The results of the beta activity obtained is 0.043±0.014 Bq L^{-1} higher than the value reported in River Kaduna (Juliet, 2006). The mean beta activity concentration of the Okpare Creek is 0.296 Bq L^{-1} higher than the 0.186 Bq L^{-1} recorded at Mills Creek; Australia and is 0.427 Bq L^{-1} higher than the values recorded at Causeway river in Australia (Onoja, 2004). These high values of the alpha activity and beta activity could be attributed to the activities in the course of the river as the geology does not reveal the existence of radionuclide.

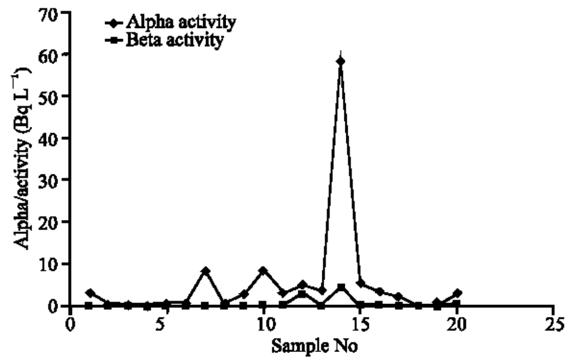

Fig 1: Alpha/Beta activity in the sample

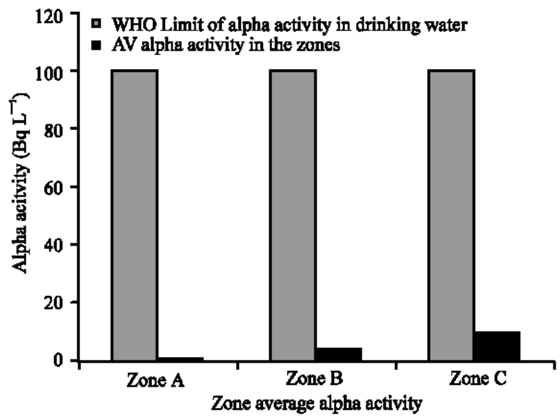

Fig. 2: Comparison of average Alpha activity in the Zones with WHO limit for drinking water WHO limit for drinking water

Examination of the graph shows a general low distribution of beta activity in the three zones (Fig. 1). The alpha activity shows about 9% elevation over beta activity in the farming zone, about 27% elevation over beta activity in Residential/Commercial zone and about 35% elevation in the Industrial zone. The comparative low activities in the farming zone may be as a result of good agricultural practice i.e., low usage of fertilizer. The relatively high beta and alpha activities concentration recorded in the industrial zone may be attributed to the effluents discharge into the river by the rubber processing factory, the two asphalt plants and the oil spillage point at spots UGH14, UGH15, UGH16 and UGH20, respectively. The results of the values obtained are far below the 100 Bq L^{-1} for alpha and 100 Bq L^{-1} for beta WHO recommended practical screening levels of radioactivity in drinking water and therefore the activities in the river may not have increased the radionuclide concentration of the water and will not have health side-effects (Fig. 2 and 3).

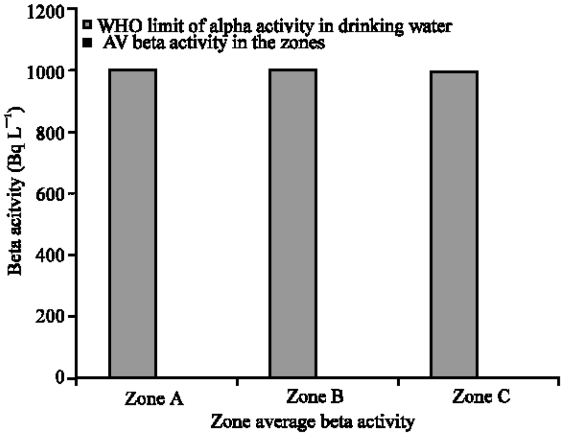

Fig. 3: Comparison of average beta activity concentration in the Zones with WHO limit for drinking water

Although, the results obtained are below the international standard recommended permissible limits for drinking waters, a regular programme of environmental audit and monitoring is hereby recommended.

CONCLUSIONS

The survey of gross alpha and gross beta radionuclide activity in Okpare Creek has been studied. The gross alpha and beta activity concentration along the Okpare Creek differ in quantity from location to location. This is explained by the heterogeneity of radionuclide deposits, water transportation and precipitation by organic metabolism and effluent discharge. The overall low value of radionuclide observed may be due to the present of non nuclear facilities in the studied area and the low level of radionuclide bearing rock and soil formations that constitute the geology of the area.

The measured alpha and beta activity are higher than those reported in other parts of the country. However, the values obtained are far below the WHO recommended maximum permissible limit and may not pose any serious health side-effects to the public users of the creek.

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