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Quantitative Analyses of the Gross Alpha and Beta Activity Status of some Oil Producing Domains in Abia State, Nigeria

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Abstract: *A Survey of the gross alpha and beta activity of some oil producing areas of Abia state has been carried out using a well-calibrated IN-20 model gas-flow proportional counter. The results showed mean gross alpha activity of 13.67 Bq/kg, 19.71 Bq/kg, 14.53 Bq/kg (soil) and 284.78 Bq/kg, 237.78 Bq/ m^3, 267 Bq/m^3 (water) for oil fields 1, 2, 3 respectively and mean gross beta activity of 48.22 Bq/kg, 28.24Bq/kg, 24.33 Bq/kg (soil) and 1323.67 Bq/m^3, 1539.67Bq/m^3 1407.78 Bq/m^3 (water) for oil fields 1, 2, 3 respectively. The activity results were found to be greater than the gross alpha and beta activity for the control soil and water samples. The mean activity of the surveyed water samples was found to be greater than the World Health Organization permissible safe limit for drinking water (100 Bq/m^3 for gross alpha activity and 1000Bq/m^3 for gross beta activity). The results of the gross alpha and beta activity of the soil samples fall within the range of normal background radiation and may not pose any immediate danger to humans except when ingested or inhaled. The results of the gross alpha and beta activity of the water samples showed high elevation over the regulatory standards and may pose some radiological burden on the populace especially, when the water bodies serve as a major source of drinking water. Remediation processes were suggested to aid in reduction of the radioactivity load of the surveyed water bodies.*

Keywords: *Quantitative, Gross, Alpha, Beta, Activity, Oil Mineral.*

1. INTRODUCTION

Oil exploration activities enhance the radionuclide concentration of the environment. It has been established that Naturally Occurring Radioactive Materials (NORM) may accumulate in the oil/gas production process and can create radiation hazard for workers, the general public and the environment if adequate controls are not established [1]. According to [2], virtually all matter, including minerals, contains “NORM” and during processing of minerals, changes in concentrations of their components do occur. This also leads to an increase in “NORM” concentrations in mineral products and/or product wastes. Such phenomenon has been referred to as Technologically Enhanced Naturally Occurring Radioactive Materials (TENORM). Oil and gas production processing operations have been known to cause naturally occurring radioactive materials (NORMs) to accumulate at elevated concentrations as by-product waste streams [3].

Humans are exposed to environmental radiation through inhalation of dusts (contaminated with radiation) and gases, ingestion of dusts, soils, water, vegetation or meat and absorption of direct radiation from radioactive sources [4]. According to office of Environmental health Hazard Assessment [5], various forms of ionizing radiation lead to alteration in the structure and functions of the cells or organs. According to [6], country wide surveys of natural radioactivity in drinking water have been conducted in several European countries and the parameters of choice were the gross alpha and beta activity. The permissible limits were set at 100Bq/m^3 and 1000Bq/m^3 for gross alpha and gross beta activities respectively by the European drinking water directive of 1988.

According to [7], most of the environmental samples analyzed around six oil fields in Romania exceeded specific activity of 880 Bq/m^3 being the Romanian regulatory limit of activity concentration for surface water. A survey of gross alpha and gross beta radionuclide activity was carried out in Okpare-Creek Delta State Nigeria, and an average beta value activity concentration of 0.793±0.010 Bq $L^{-1.}$ and average alpha activity concentration of 10.296±0.489 were reported in this area [8]. The relatively high values of the alpha and beta activity were attributed to industrial activities in the course of the river as the geology does not reveal the existence of radionuclides. Selçuk et al [9] carried out analyses of gross alpha and beta radioactivity concentration in water, soil and sediment of the Bendimahi River and Van Lake (Turkey). It was found out that in May; gross-alpha and gross-beta activity concentrations in water samples varied between 0.063-0.782 and 0.021-0.816 Bq l(-1) and in August the values were 0.009-0.037 and 0.081-3.116 Bq l(-1), respectively. The gross-alpha and gross-beta activity concentrations in soil samples ranged from 0.800 to 4.277 Bq g(-1) and 0.951 to 11.773 Bq g(-1) in May and 0.686 to 4.713 Bq g(-1) and 0.073 to 9.524 Bq g(-1) in August, respectively. Dimovska [10] assessed the radioactivity concentration in soil from the city of Kavadarci (Republic of Macedonia) and its environs and found out that the mean values of gross alpha and gross beta activities were 522±192 and 681±146 Bq kg(-1). The results of the analyses showed strong correlation between the abundance of the natural radionuclides in soils and their geological origin. Kam and Bozkurt [11] carried out environmental radioactivity survey in Kastamonu region of northern Turkey and found out that the water samples collected from the region contained an average of 0.0089 Bq/l of gross alpha and 0.271 Bq/l of gross beta activities. They concluded that the results obtained in this study indicated that the region had a background radiation level that was within the natural limits and showed no significant departure from the other parts of the country. Peiquan et al [12] determined the gross beta radioactivity in the waters of East China Sea and adjacent region. The results showed that the gross beta radioactivity varied from 0.32 to 3.44 Pci/L, with a mean activity of 1.73 Pci/L. They concluded that there was no new source of contamination entering this area at that time.

The oil mineral producing communities of Abia state are faced with a lot of environmental degradations such as oil spillages, gas flaring, destruction of water bodies and aquatic lives, depletion of biodiversity, loss of soil fertility; and according to [13], these phenomena could lead to accumulation and venting of radon gas, leaching of radionuclide contaminated sludges into underground and surface water bodies, etc. According to [14], major sources of domestic water supply in Owaza, an oil producing community in Abia State (Owaza River) are polluted and the inhabitants are afflicted with severe eye, ear and pre-natal ailments suspected to be linked with oil spills in the area. According to [15], gross alpha/beta counting has become the most widely used method of monitoring for the presence of radioactivity in the environment to comply with the international regulatory environmental standards hence, the need to ascertain the environmental status of the gross alpha and beta activity of the surveyed oil mineral producing areas.

2. MATERIALS AND METHODS

This study was conducted between January and March, 2009 around three selected oil mineral producing fields in Abia state, Nigeria. Fifty four samples of soil and water were collected around oil spilled areas and surface water bodies within the three selected oil producing fields. Also, six control samples of soil and water were collected.

The samples were carefully prepared according to International Atomic Energy Agency [4] specifications for gross alpha and beta analyses, after which the samples (contained in their planchets) were stored in desiccators awaiting counting. These samples were analyzed for gross alpha and beta activity using an IN-20 model gas-flow proportional counter at the Centre for Energy Research and Training, Ahmadu Bello University, Zaria, Nigeria. Each sample was counted three times and the mean used in computing the activity. The operational modes used for the counting were the α-only mode for the alpha counting and the β (+α) mode for the Beta counting.

The count rate of each sample was automatically processed by the computer using the equation [16];

$$A_{(\alpha,\beta)} = B_{(\alpha,\beta)} \times 60 / T \tag{1}$$

Where A (α, β) = the count rate (cpm) of the alpha or Beta particle,

B (α, β) = raw count of the alpha or Beta particle,

T = count time (2700 seconds).

Also the activity of each sample was calculated using the equation [16]

$$C_{(\alpha,\beta)} = \left[A_{\alpha,\beta} - G_{\alpha,\beta}\right] \times \frac{U_{\alpha,\beta}}{H_{\alpha,\beta} \times S_{\alpha,\beta} \times V} \qquad (2)$$

Where $C_{(\alpha,\beta)}$ = alpha or beta activity (Bq/L or Bq/g)

$A_{(\alpha,\beta)}$ = count rate of alpha or beta particle

$G_{(\alpha,\beta)}$ = background count of alpha or Beta particle.

$U_{(\alpha,\beta)}$= unit coefficient of alpha or beta particle (1.67 x 10^{-2} - conversion factor from cpm to cps, where cps = 1Bq)

$H_{(\alpha,\beta)}$ = channel efficiency for alpha or beta counting

$S_{(\alpha,\beta)}$ = sample efficiency for alpha or beta counting

V = sample volume or mass (litre or g)

The sample efficiency for the soil samples was computed using,

$$\varepsilon_{SS} = \frac{Mr}{Mi} \times 100 \qquad (3)$$

Where Mr = Recovered mass after pellet was formed

Mi = Initial Mass of the sample in powdery form.

The sample efficiency for the water samples was computed using,

$$\varepsilon_{Sw} = \frac{Mr}{77mg} \times 100 \qquad (4)$$

The error associated with the sample activity was computed using [16]

$$Er = \frac{\left(B + \frac{(100000)^2}{T_{bgd}} X\ G\right)^{1/2}}{100000} \ X\ \frac{U}{H\ X\ S\ X\ V} \qquad (5)$$

Where B = sample raw count, H = channel efficiency

T_{bgd} = background Count Time, S = sample efficiency

U = unit Coefficient (1.67 x 10^{-2}), V = sample Volume or mass.

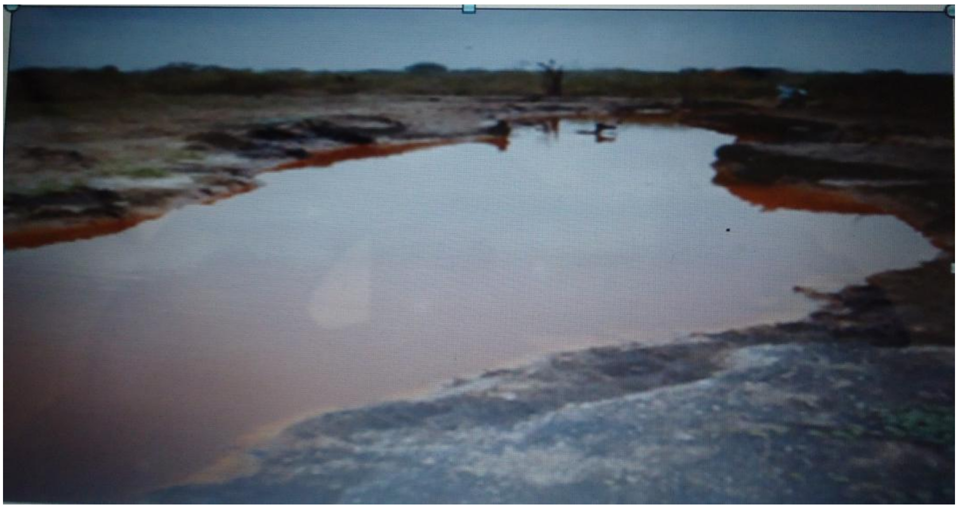

Fig.1. *Picture showing a polluted river as a result of oil spillage*

3. RESULTS AND DISCUSSION

Results

Table 1 shows the summary of the range of results of the mean gross alpha and beta activity of the surveyed oil fields while Figs 1 – 4 compare the results of the surveyed oil fields with the control and regulatory standards. The control samples used were firstly, the alpha and beta average activity of soil **(CSS α and** $CSS_β$**)** and water samples (**CWS α and** $CWS_β$**)** collected from neutral environments (from the same geology with the surveyed areas) devoid of oil exploration and industrial activities and secondly, World Health Organization (WHO) permissible safe limit for drinking water.

Discussion

From the data presented in Table 1 and illustrated with the bar charts of Figs 1 and 2, the gross α and β activity of the soil samples are greater than that of the **CSS α** and $CSS_β$ with an elevation of over 1000%, implying that oil exploration activities within these environments have contributed to the elevation of the natural background radiation. These results fall within the ranges of 2.4-120 Bq/kg, 60- 330 Bq/kg, 8- 87 Bq/kg and 53- 960 Bq/kg as recorded by Elena (2004) to be typical of soil associated with oil and gas industry. However, the results of the present study are below that of [11] who analyzed the radioactivity concentration in soil from the city of Kavadarci (Republic of Macedonia) and its environs and found out that the mean values of gross alpha and gross beta activities were 522±192 and 681±146 Bq kg(-1) respectively. These variations might be due to the difference in the geology of these two different surveyed areas.

Table 1. *Summary of Results of Gross Alpha and Beta Activity (CSS: α=1.23Bq/kg, β= BDL; CWS: α=3.4 Bq/m³, β= 15.3 Bq/m³; WHO: α=100 Bq/m³, β= 1000 Bq/m³) N/b: BDL = below detection limit*

Sample Type	**Location**	**α- Activity Range**	**β - Activity Range**	**(α / β)** % deviation from CSS	**(α / β)** % deviation from CWS	**(α / β)** % deviation from WHO
Soil	Oil Field 1 (OWS1-OWS9)	3.4± 1.00 ↔ 33± 1.00 (Mean = 13.67) Bq/kg	14± 1.00 ↔ 110± 2.00 (Mean= 48.22) Bq/kg	1011/ ∞	–	–
	Oil Field 2 (IMS1-IMS9)	6.2± 1.00 ↔ 48± 1.00 (Mean= 19.71) Bq/kg	BDL↔ 88± 2.00 (Mean= 28.42) Bq/kg	1502/ ∞	–	–
	Oil Field 3 (UMS1-UMS9)	7.3± 1.00 ↔ 32± 1.00 (Mean= 14.53) Bq/kg	BDL↔ 76± 1.00 (Mean= 24.33) Bq/kg	1081/ ∞	–	–
Water	Oil Field 1 (OWR1-OWR9)	17± 1.00 ↔ 690± 4.00 (Mean = 284.8) Bq/m^3	23± 2.00 ↔ 3350± 8.00 (Mean =1323.7) Bq/m^3	–	8276/ 8551	185/ 32
	Oil Field 2 (IMR1-IMR9)	30± 1.00 ↔ 450± 3.00 (Mean= 237.8) Bq/m^3	27± 2.00 ↔ 2900± 8.00 (Mean =1539.7) Bq/m^3	–	6894/ 9963	138/ 54
	Oil Field 3 (UMR1-UMR9)	20± 1.00 ↔ 450± 3.00 (Mean= 267) Bq/m^3	110± 2.00↔3200± 8.00 (Mean= 1407.8) Bq/m^3	–	7752/ 9101	167/ 41

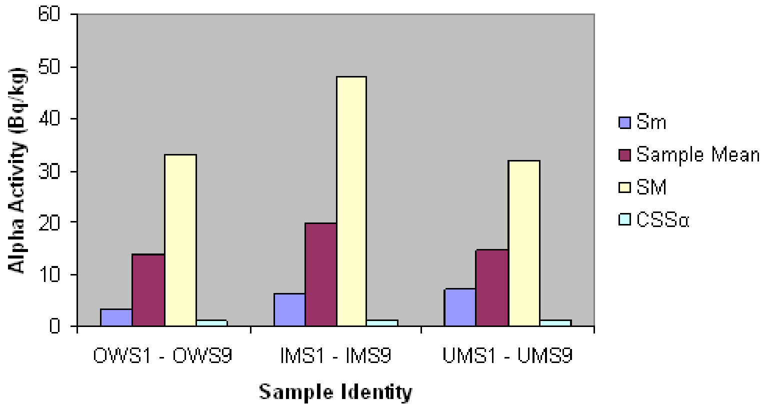

Fig 1. *Comparison of the α-Activity of the Soil Samples with the Mean α-Activity of Control Soil Sample (CSSα =1.2 Bq/kg, Sm = Sample minimum activity, SM = Sample maximum activity)*

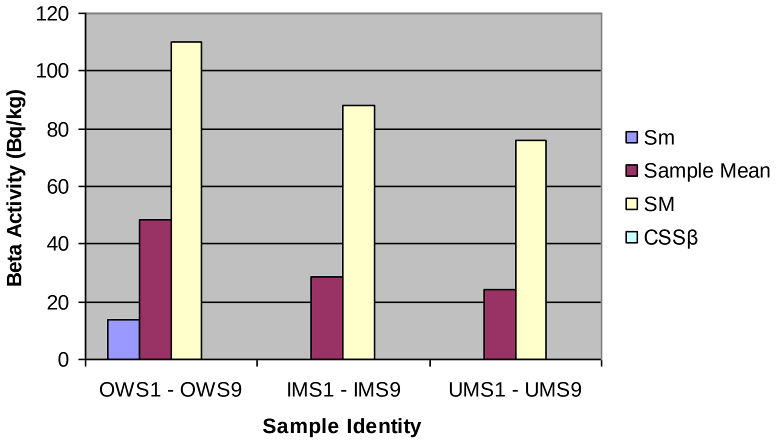

Fig 2. *Comparison of the β-Activity of the Soil Samples with the Mean β-Activity of Control Soil Sample (CSSβ =1.2 Bq/kg, Sm = Sample minimum activity, SM = Sample maximum activity)*

According to [17], inhalation of radioactive particles occurs for workers and close residents of oil production sites especially, when contaminated scales or sludges are cleaned from the inside surfaces of equipment during well work over operations. According to EPA-600 model, the daily frequency of soil ingestion by a typical child per day is about 0.2 g [18]. This quantity of soil if ingested for at least ninety days per annum results to an intake of about 18g/yr. This implies that a child who lives within the oil spilled area of Oil field1 (whose soil has gross β- activity concentration of 110Bq/kg) is likely to ingest 1.98Bq of activity of beta particles per year. Also if same child ingests soil of α- activity concentration of 48 Bq/kg, the child in addition receives an internal exposure of 0.846 Bq of activity of alpha particles per year. These levels of internal radiation exposure are capable of destabilizing the natural equilibrium content of radioactivity in the body. More so, this becomes more dangerous over years as continuous ingestion of such radioactive particles could build up the internal radioactivity content of the body and overburden the normal body system.

From the data presented in Table 1 and illustrated with the bar charts of Figs 3 and 4, the gross alpha and gross beta activity of the water samples showed a very strong elevation in activity over the gross alpha (3.4 Bq/m^3) and gross beta (15.3 Bq/ m^3) activity of the **control water samples (CWS)**. Also, the average results of the water samples showed a strong elevation over the World Health Organization [19] permissible safe limit for drinking water which are 100 Bq/ m^3 for gross alpha activity and 1000Bq/m^3 for gross beta activity. The results were also found to be above the water drinking safe limit of 554 Bq/m^3 and 1850 Bq/m^3 reported by [20]. Also, the results of this work are far above the results reported by [21] in a similar work done on the gross alpha and beta radioactivity of Kaduna River which they reported as 0.3 Bq/ m^3 and 43.67 Bq/ m^3 respectively. Also, the results of the present study are greater than that of [22] where it was reported that the gross alpha and beta activity concentrations in groundwater from Katsina area of Northern Nigeria ranged from 80 ± 0.05 to 2300 ± 0.41 Bq m^{-3} and 120 ± 0.08 to 4970 ± 0.78 Bq m^{-3}, respectively.

The elevation of the gross alpha and beta activity of the study areas could be attributed to incessant oil spillages and gas flaring associated with oil production activities in Nigeria. This view is in agreement with the work on the radiological impact of oil and gas industry in Romanian oil-field where it was reported that ground water that coexists with deposits of oil can unusually have high concentrations of dissolved radioactive constituents that build up during prolonged periods of water/rock contact [7]. The results of the present study are also in agreement with the reports of [23] which stated that Naturally Occurring Radioactive Materials (NORMS) associated with oil and gas production originate in the sub-surface formations which may contain radioactive materials like uranium and thorium and their daughter products(Ra-226 and Ra-228). These radioactive materials could interact with the environmental components during oil spillages and gas flaring and increase their radioactivity level. It has been reported that radioactive materials (through well logging, use of radiotracers, mapping and evaluation of geological formations, etc.) are applied in oil production activities both onshore and offshore and interaction of the spilled oils with the environment will imply extending these radioactive materials to the environment [24] and this report is in agreement with the present study.

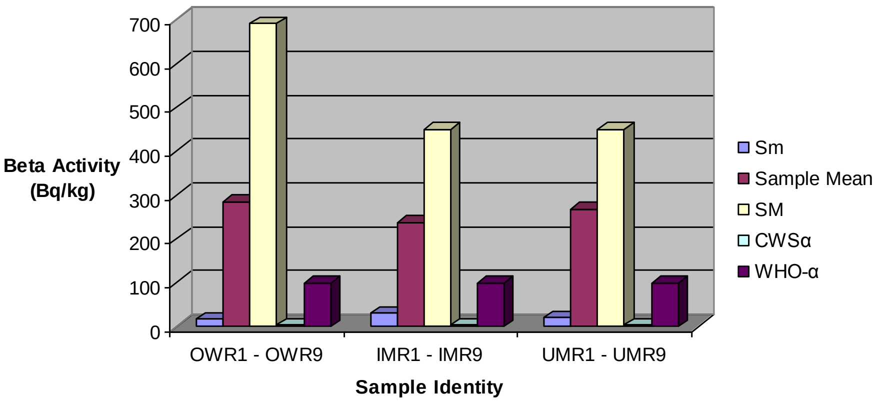

Fig 3. *Comparison of the α-Activity of the Water Samples with the Mean α-Activity of Control Water Sample (CWSα =3.4 Bqm^{-3}; WHO Limit =100 Bqm^{-3}; Sm = Sample minimum activity, SM = Sample maximum activity)*

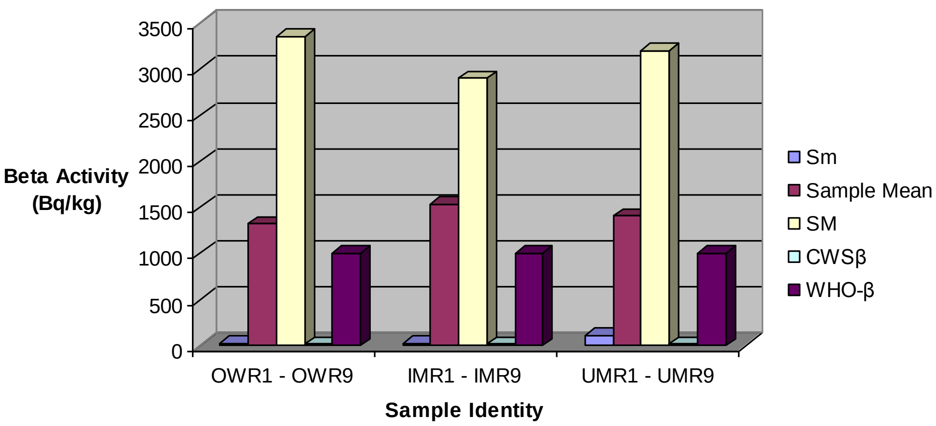

Fig 4. *Comparison of the β -Activity of the Water Samples with the Mean β –Activity of Control Water Sample (CWSβ =3.4 Bqm^{-3}); WHO Limit =1000 Bqm^{-3}; Sm = Sample minimum activity, SM = Sample maximum activity)*

4. CONCLUSION

An analytical method has been adopted in the determination of the gross alpha and beta activity of the surveyed areas. The results showed an elevation in activity over the control soil and water samples. The gross alpha and beta activity of the water samples were also found to be above the recommended permissible limits of 100 Bq/m^3 and 1000Bq/m^3 [18] respectively. The above scenario calls for specific radionuclide analyses to ascertain the average annual effective doses of radiation taken by workers and the public in the surveyed areas. To buttress this claim, other researchers such as [3] Carried out radiological studies on the oil refining industry in Egypt and found out that the average annual effective dose for workers due to direct exposure to gamma radiation and dust inhalation were 0.6 μSv and 3.2 mSv, respectively. He concluded that special care must be taken during cleaning operations in order to reduce the personnel's exposure due to maintenance as well as to avoid contamination of the environment.

The negative impact of elevated gross alpha and beta activity of the environmental components assessed would be felt more if ingested or inhaled. This is because according to Environmental Agency for Toxic Substances and Disease Registry [25], external exposure is of far less health concern than internal exposure. If alpha emitters have been inhaled, ingested or absorbed into the blood stream, sensitive living tissues could be exposed to alpha radiation. The resulting biological damage increases the risk of cancer (especially, lung cancer) in humans. Also, direct exposure to beta particles is a hazard because; emissions from strong sources can redden or even burn the skin. Also, emissions from inhaled or ingested beta particle emitters can disrupt cell functions. Therefore, it is suggested that remediation processes such as methods of granular activated carbon (GAC) filtration and membrane techniques such as reverse osmosis (RO) or nano filtration (NF) should be adopted to clean up or at least reduce the level of natural radionuclides in water bodies so as to help reduce radionuclide intake arising from water consumption. Also, ingestion or inhalation of soil from oil spilled areas, especially by children should be discouraged.

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