ISSN No:-2456-2165

Assessment of Natural Radioactivity Level of Shallow Aquifers in Enugu Metropolis, Nigeria

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Abstract:- Thirteen samples from shallow aquifer in Enugu were assessed for Natural Radioactivity Level using High Purity Germanium (HPGe) Analyser. The radionuclides identified in the water samples are ^{238}U, ^{232}Th, ^{226}Ra and ^{40}K. The activity concentration values of ^{238}U range from below detection level to 0.49 ± 0.04Bql^{-1}, with an average of 0.19 ± 0.03Bql^{-1}; ^{226}Ra range from below detection level to 10.26 ± 0.72Bql^{-1}, with an average of 5.18 ± 0.42Bql^{-1}; ^{232}Th range from below detection level to 1.26 ± 0.11Bq l^{-1}, with an average of 0.63 ± 0.07Bql^{-1}; ^{40}K range from 9.67 ± 0.55Bql^{-1} to 16.52 ± 0.88Bql^{-1}, with an average of 14.44 ± 0.79Bql^{-1}. Comparing the result with the available standards, ^{226}Ra in the groundwater is above the guidance level. The seasonal variation in concentration of ^{238}U, ^{226}Ra, ^{232}Th and ^{40}K in groundwater are 0.28 ± 0.03, 8.45 ± 0.72, 0.96 ± 0.12 and 20.01 ± 1.08Bql^{-1} respectively. The annual effective dose due to ingestion of ^{238}U, ^{226}Ra, ^{232}Th and ^{40}K in groundwater received by adult in the study area ranges from 0.073mSvy^{-1} to 4.33mSvy^{-1} with an average value of 1.28mSvy^{-1} while that of the children ranged from 0.16 to 4.80mSvy^{-1}with an average of 1.37mSvy^{-1}. These exceeds WHO, and UNSCEAR recommended limit of 0.1mSvy^{-1}, 1.0mSvy^{-1} and 0.29mSvy^{-1}.

Keywords:- *Groundwater, Radionuclides, Aquifer, Natural radioactivity level, Enugu.*

I. INTRODUCTION

Millions of people especially in the developing world rely on groundwater, mostly through shallow wells. Groundwater is used by man for various purposes, ranging from agricultural to industrial, power generation and domestic consumption. Human activities and some natural phenomenon pollute and affect water quality. In addition to the release of substances, such as chemicals or microorganisms, water pollution may also include the release of energy, in the form of radioactivity or heat, into bodies of water [1]. Radioactive materials occur naturally everywhere in the environment [2]. Environmental radiation originates from a number of naturally occurring and human-made sources. Radioactivity in groundwater is one of the major sources of water pollution as it possesses serious health implications. Radioactive elements do not only come from artificial sources but mostly from natural terrestrial sources such as Naturally Occurring Radioactive Materials (NORMs). NORMs contain mainly Uranium, Thorium and Potassium and their progenies (decay daughters). Relatively abundant in the earth crust, ^{238}U and its descendant ^{234}U are often the most abundant radionuclides in water [3]. NORMs which are from the ^{40}K, ^{238}U and ^{232}Th series are more concentrated in deep groundwater than in surface water [4]. They contaminate water bodies directly with their radionuclide products; and indirectly, through the ^{222}Rn and ^{220}Rn gaseous products [5]. The presence of natural radionuclides in water depends on geological and geographical nature of the water origin [6]-[8]. Radiation is often categorized as either ionizing or non-ionizing depending on the energy. While alpha (α) particle is emitted from the nucleus of an unstable atom with low neutron-to-proton ratio, a beta particle is ejected from the nucleus of an unstable radioactive atom with high neutron-to-proton ratio [9]. A beta (β) particle is 7360-times less massive than an alpha particle. Depending on the isotope and mechanism of decay, the beta particle can be emitted with either a negative or positive charge.

Natural radiation is classified into cosmic rays and terrestrial radiation [10]. The activity concentration of radionuclide elements has been the focus of some researchers recently [11]-[20] The study aims at establishing the distribution of radioactive elements in shallow aquifers of Enugu Metropolis, Nigeria.

II. THE STUDY AREA

The study area lies between latitudes 6^0 21'N and 6^0 30'N and longitudes 7^{0}28'E and 7^0 37'E Fig. 1. It is located in Anambra Basin in the south-eastern section of the provincially broad northeast-southwest trending Benue Trough. Studies have indicated that the basin was formed as a result of the Late Jurassic to Cretaceous basement breakup [21]-[22]. From gravity measurements, the total sediments thickness in Anambra Basin is estimated to range from 1000 – 4500m [23]. The area characterized by two climatic conditions of rainy season (April to September) and dry season (October to February) with annual rainfall amount of about 2000mm [24]. The area is also characterized by unequal elevation attributed to undulating topography.

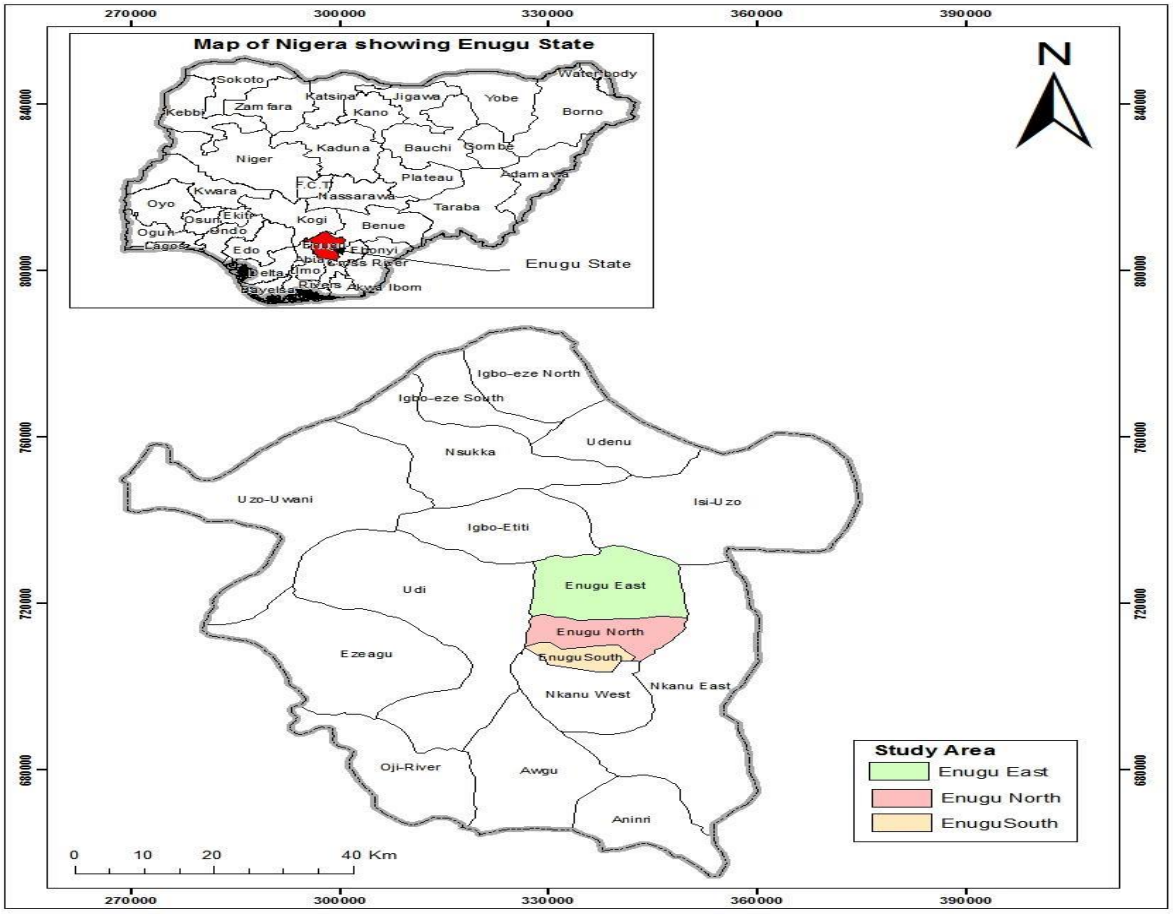

Fig.1: Location Map of the study area

Geologically, the study area is underlain by highly fractured Enugu Shale which is a soft grey-blue shales with frequent bands and nodules of clay-ironstone deposited in a marine environment during the Campanian - Maestrichtian period. Enugu Shale comprises mainly of carbonaceous shales and coals [23].

The study area is drain by two major river systems [25]. Ekulu River originates as a spring from the Ajali aquifer in the Enugu escarpment (Udi Plateau). Enugu falls within Anambra Basin Hydrogeological province. The semi-confined and unconfined aquifers units of Ajali Sandstone constitute the sources of most springs which fo**rm** the headwaters of the various rivers draining the basin [26]-[27]. Because of this aquitard nature of the shale, hand dug well is the most prevalent source of groundwater in the area.

III. METHODOLOGY

Thirteen water samples were collected at various locations using 1litre plastic sample containers following standard procedure. The samples were subsequently stored in a conducive environment for 28 days to ascertain secular equilibrium between ^{238}U and ^{232}Th and their respective daughters before X-ray spectrometry analysis was carried out. This method has been commonly used by researchers [28]-[31]. Spectra analysis software, SAMPO 90 was used to match various gamma energy peaks to library of possible radionuclides [32]-[35].

IV. RESULT AND DISCUSSION

The radionuclides identified in the water samples and quantified from the gamma ray spectra are ^{238}U, ^{232}Th, ^{226}Ra and ^{40}K. The seasonal activity concentration of naturally occurring radionuclides for the thirteen (13) samples analysed are shown in Fig. 2. The activity concentration values of ^{238}U in the groundwater samples range from below detection level (BDL) to $0.47 \pm 0.04 Bql^{-1}$,with an average of $0.05 \pm 0.01 Bql^{-1}$ during the dry season; and BDL to $1.03 \pm 0.09 Bql^{-1}$ with an average of $0.32 \pm 0.04 Bql^{-1}$for the wet season; ^{226}Ra range from BDL to $20.52 \pm 1.43 Bql^{-1}$, with an average of $9.40 \pm 0.78 Bql^{-1}$ during the dry season and BDL to $5.15 \pm 0.30 Bql^{-1}$ with an average of 0.95 ± 0.06 Bql^{-1}during wet season while ^{232}Th range from BDL to $2.52 \pm 0.21 Bql^{-1}$, with an average of $1.11 \pm 0.13 Bql^{-1}$ during dry season and BDL to 0.59 ± 0.05 Bql^{-1} with an average of 0.15 ± 0.01 Bql^{-1} for wet season and ^{40}K range from $18.64 \pm 1.04 Bql^{-1}$ to $31.15 \pm 1.67 Bql^{-1}$, with an average of $24.44 \pm 1.33 Bql^{-1}$ at dry season. The concentration of the radionuclides occurred in the order of $^{40}K > ^{226}Ra > ^{232}Th > ^{238}U$ during the dry season with an average seasonal concentration of $1.06 \pm 0.16 Bql^{-1}$; $9.14 \pm 0.65 Bql^{-1}$, $1.33 \pm 0.12 Bql^{-1}$; and $12.06 \pm 0.67 Bql^{-1}$ for ^{238}U, ^{226}Ra, ^{232}Th and ^{40}K respectively.

ISSN No:-2456-2165

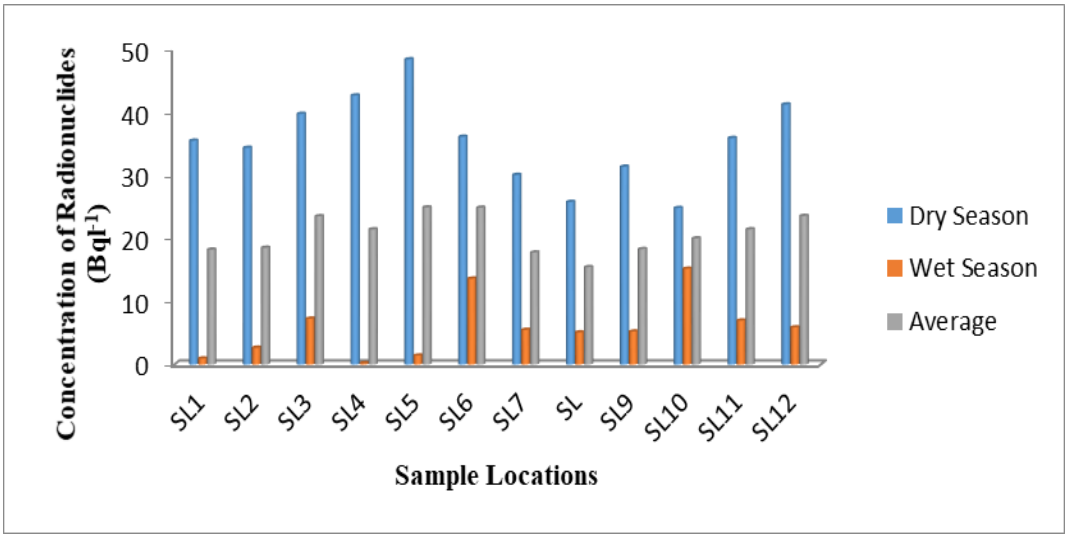

Fig. 2: Sum of the Activity concentration of all the natural radionuclide at each sample location.

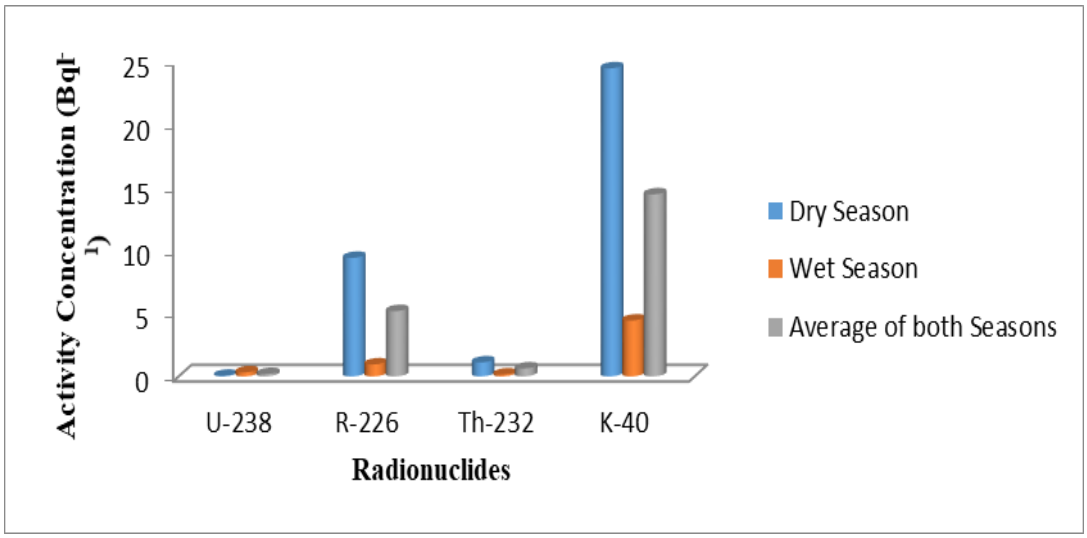

Fig. 3: Activity concentration of the radionuclides at both seasons

The activity concentration of the radionuclides is higher during the dry season compared to the wet season Fig. 3. This may be due to dilution. The seasonal variation in concentration of ^{238}U, ^{226}Ra, ^{232}Th and ^{40}K in groundwater are 0.28 ± 0.03, 8.45 ± 0.72, 0.96 ± 0.12 and 20.01 ± 1.08 Bql^{-1} respectively. The concentration of the radionuclides is greater at the southeastern part of the study area while the static water level reveals that the groundwater is shallower in the northern part of the study area Fig. 4 and Fig. 5. It may be inferred that the concentration of radionuclides in groundwater is directly related to groundwater depth.

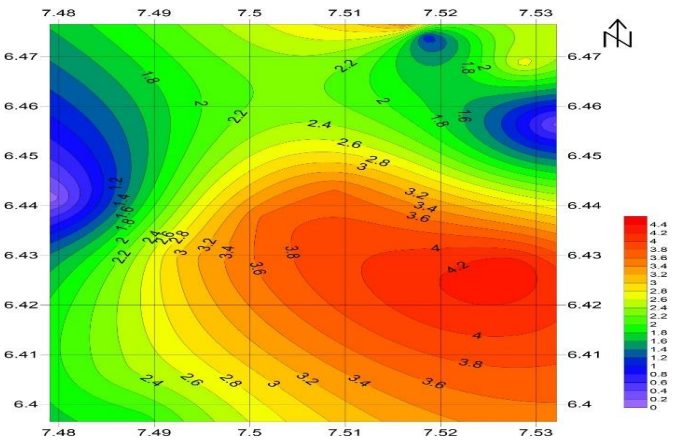

Fig. 4: Concentration of radionuclides

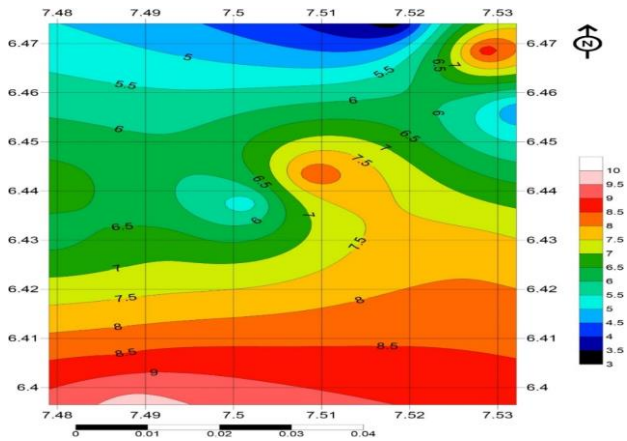

Fig 5: Static water level (dry season)

The guidance level for the activity concentration in Bql^{-1} of ^{238}U, ^{232}Th, ^{226}Ra and ^{40}K are 10, 1, 1 and 10 respectively [28]. The guidance level for the activity concentration of ^{226}Ra was exceeded in the sample except DSL_8 and DSL_{10} and $WSL5$, WSL_9, WSL_{10}. ^{232}Th exceeded the recommended guidance level for the activity concentration in samples DSL2, DSL3, DSL8 and DSL9. The guidance level for the activity concentration of ^{40}K in all the samples exceeded the recommended limit in both seasons except in WSL6. ^{40}K has the highest activity concentration in the samples analysed Fig. 6a and 6b.

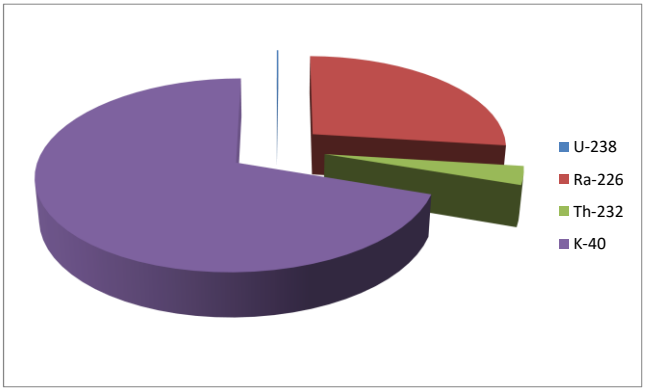

Fig. 6(a): Dry Season Activity concentration

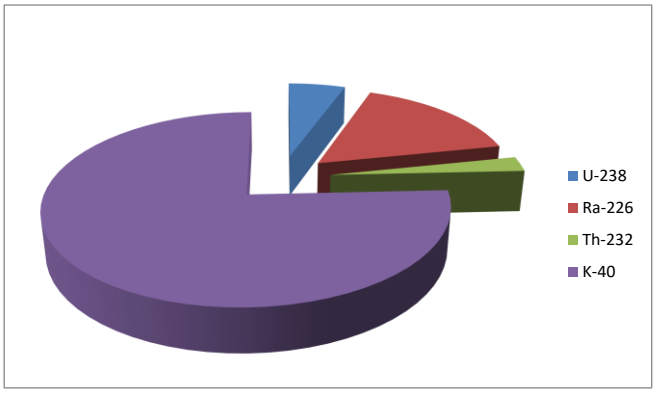

Fig. 6(b): Wet Season Activity concentration

V. CONCLUSION

Over the decade, the microbial, physical and chemical parameters of water are commonly assessed prior to consumption of water in Nigeria. The radiological aspects of water are disregarded due to the general belief that there are little or no nuclear activities that could increase radioactivity and possible contamination of groundwater. Knowledge of the radiological aspects of water is a requirement in analyzing the safety of drinking water. It is therefore important to determine the amount of radioactivity in drinking water so as to protect people from deleterious effects. Therefore information on the level of radioactive elements in the environmental system is vital for good natural resource management and sustainable public health.

ACKNOWLEDGMENT

The author acknowledges the Department of Nnamdi Azikiwe University for the financial assistance and facilities that led to the sources of this research.

CONFLICT OF INTEREST

The authors declared no conflict of interest.

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