FUDMA Journal of Sciences (FJS)
ISSN online: 2616-1370
ISSN print: 2645 - 2944
Vol. 6 No. 3, June, 2022, pp 160 - 166
DOI: https://doi.org/10.33003/fjs-2022-0603-950

DETERMINATION OF ACTIVITY CONCENTRATION OF RADIOACTIVE ELEMENTS IN BOREHOLE AND WELL WATER SAMPLES FROM ADANKOLO NEW LAYOUT LOKOJA

***[1]Efenji, G. I., [1]Egeonu E. K., [1]Isah I., [1]Onimisi S. F., [1]Uloko, F. O., [1]Nakale, J. A., [1]Ayua, K. J. and [2]Idris, M. O.**

[1]Department of Physics, Federal University Lokoja, P.M.B. 1154, Lokoja, Kogi State.
[2]Department of Pure and Industrial Chemistry, Kogi State University, P.M.B. 1008, Anyigba, Kogi State.

*Corresponding authors' email: **godwin.efenji@fulokoja.edu.ng**

ABSTRACT

This study was conducted to determine and compare the activity concentration of natural radioactivity of ^{238}U, ^{232}Th, and ^{40}K in borehole and well water samples collected from Lokoja Nigeria, using Sodium Iodide−Thallium gamma spectroscopy. Samples from selected wells and borehole were collected using standard radiation protocol and analyzed. The result shows that the natural radioactivity concentration of the borehole water sample was 2.77±0.67 Bq/l; 2.30±0.27 Bq/l and 1.66±0.13 Bq/l for ^{238}U, ^{232}Th, and ^{40}K respectively, and 17.62±1.37 Bq/l for ^{40}K in well water while its ^{238}U and ^{232}Th are Below Detection Limit. The results obtained for well and borehole water samples were lower in terms of health risk compared to the World Health Organization (WHO) values (i.e., 10B q/l, 1Bq/l and 4.40 Bq/l for ^{238}U, ^{232}Th and ^{40}K respectively) except the ^{40}K in well water which was higher. The absorbed dose rate for the well water sample was found to be 0.49±62 nGy.hr^{-1} and 0.09±1.17 nGy.hr^{-1} for the borehole water. The radium equivalent activity for the well water sample was also calculated to be 1.36±62 Bq/l and 6.19±1.17 Bq/l for the borehole water sample. The evaluated annual effective dose for the well water sample was 0. 00060mSv.y^{-1} and 0.000096±1.17 mSv.y^{-1}for borehole water sample. The results of the estimated radiological parameters in this study are lower than the International Commission on Radiological Protection (ICRP) maximum permitted limit. Hence, most of them have no significant radiological effect on the environment and its populace except the ^{40}K in the well water sample which is higher.

Keywords: Efficiency, equivalent activity, radiological parameters, specific activity

INTRODUCTION

Adankolo New Layout is a thriving university community in Kogi State's Lokoja Local Government Area. Due to a variety of factors, including relative peace (which facilitated the establishment of Federal University Lokoja), a centre of business activities (which spawned small industries such as pure water, bakeries, and local soap production factories), and so on, this community has seen an increase in population in recent years. Even though the town has no manufacturing companies that use radioactive materials, the state's geology suggests that the level of environmental radiation in the state could be high.

The area has both basement complex rocks (the migmatite gneiss complex) and sedimentary rocks (sandstones and alluvial deposits) to the south. Natural radioactivity exists in the earth and its contents, and these rocks are a source of natural radioactivity. Naturally Occurring Radioactive Materials (NORM) are widely distributed throughout many geological formations and can contaminate groundwater.

The radioactivity of groundwater varies greatly in nature. It primarily comes from radioactive rocks and minerals that come into touch with the water. In Africa, groundwater is the preferred source of drinking water. This is typically because, it is assumed to be cleaner and easier to treat than surface water, numerous wells have been dug in that direction. Anthropogenic activity, on the other hand, can contaminate groundwater. It naturally contains several chemical components that might cause a variety of health issues (AlMasri and Blackburn 1995). A groundwater source may contain a variety of naturally occurring chemical components, many of which are not frequently examined as water quality indicators. The International Commission on Radiological Protection (ICRP) issues recommendations and guidelines on all aspects of ionising radiation protection, which are published in The Annals of the ICRP, the commission's official scientific magazine. The process of exposure begins with the consumption of radioactive groundwater or surface water. Radionuclides accumulate in the skeleton, liver, kidneys, and soft tissues after entering the human body.

Uranium isotopes decay to stable lead isotopes during disintegration, emitting beta and gamma radiations in the process. Natural radioactive elements in water, soils, and rocks account for around 29 millirems, or 8%, of the total radiation dosage a person receives each year (UNSCEAR, 1988). Uranium, Thorium, and Radium are radioactive isotopes of various elements found in the earth's crust, including potassium (AlMasri and Blackburn 1995).

The lithology, geomorphology, and other geological features of the area influence the uranium concentration in the groundwater. Over 80% of man's radiation exposure comes from naturally occurring radioactive materials, with the remaining 15% coming from cosmic rays and artificial sources. (Inyang and Ekpo, 2000). The concentration of radium in water is connected with its salinity, according to previous research. The mass of isotope proportions of uranium in nature are 99.275 percent for ^{238}U, 0.72 percent for ^{235}U, and 0.005 percent for ^{234}U. According to the United Nations Scientific Committee on the Effects of Atomic Radiation, the concentration of ^{235}U or ^{234}U in water is theoretically minimal when compared to ^{238}U. However, numerous questions remain on how radioactive materials behave in the rocks water system, owing to the relative importance of nuclear alpha particle recoil and chemical processes including ion exchange, absorption, and precipitation. Radioactivity in drinking water is a simple way for radionuclides to enter the human body. Tritium, radium, radon, and potassium, as well as their progeny, are the most common natural radionuclides in drinking water, emitting alpha, beta, and gamma radiation (Inyang and Ekpo, 2000). The alpha and beta radiation are high linear energy transfer

(LET) radiations, they deposit their energy over short distances and have substantial medical consequences for the body's organs and tissues. As a result, the presence of radionuclides in the water must be determined.

The quality of water in each location is affected by pollutants from household, industrial, and hospital waste, as well as fertilisers on farmlands, rainwater, and other NORMS. Some of these contaminants are radioactive, and their ingestion can be harmful to one's health. The rapid expansion in population in Adankolo New Layout has resulted in an increase in water pollution as a result of increased human activity; along with the natural radioactive occurrence, there is a constant pollution of water sources, affecting its quality. To evaluate if there are any radiological threats to the residents of Adankolo New Layout, the concentration of radionuclides presents in the water from the principal well water and borehole water samples taken must be determined, and the concentrations in the samples must be compared. As a result, this research work aims to: determine the activity concentration of some radionuclides (^{238}U, ^{232}Th, and ^{40}K) in water samples collected from Adankolo New Layout; determine the radionuclides present in the well and borehole water samples collected; identify the likely effects of the ^{238}U, ^{232}Th, ^{40}K to the inhabitants of Adankolo New Layout; determine the biological effects of the water samples and assess the more hazardous water source be.

Despite the expanding importance of the community, particularly as a University community, there is no documented data on radioactive materials in the water in Adankolo (well and borehole water). This survey is significant in that it will connect and fill in the gaps left by similar research work done elsewhere and by other researchers who have a direct impact on the public's health. The study will give background information on radiation dosage levels and distribution in the study area. This will be utilised to confirm and make safety judgments in the new Adankolo layout on any radiation-related health problems.

MATERIALS AND METHODS

The activity concentration level of various radioactive isotopes (such as ^{238}U, ^{232}Th, and ^{40}K) in water samples collected inside Adankolo New Layout Lokoja was determined using a sodium Iodide Thallium triggered scintillation detector and Gamma ray spectroscopy in this experiment. The research was carried out at the University of Ibadan Campus's National Institute of Radiation Protection and Research.

Figure 1: Map of Lokoja showing the study area

Sample Procedure

The water sample for this research were collected from the well and borehole water in the research locations (Lokoja, Kogi State). Both the well and borehole water yielded approximately 35 Cl of water sample. The samples were taken from a clean and empty bottled water container. They were then taken to the environmental laboratory at the National Institute of Radiation Protection and Research, University of Ibadan Campus Ibadan, where they were securely sealed and labelled for easy identification.

Below is the coding of the sample and the locations where they were gotten.

Table 1: shows the code number/ locations of the collected samples

S/N	Code No	Location
1	W.W. S	Represent the public well water sample from Joseph Micheal compound
2	B.W. S	Represent the borehole water sample from Alhaji Abdulazeez residence

Sample Preparation.

The water samples were first distilled at the National Institute of Radiation Protection and Research, University of Ibadan, to eliminate the non-volatile quenching materials. The samples were then vertically placed in the detector and counted for 2 hours (9000 seconds). The concentration of ^{40}K in the sample was determined using 1460keV gamma radiation. The content of uranium 238 was determined using the gamma transition energy of 59.54 keV 214 Po, whereas the concentration of ^{232}Th was determined using the gamma transition energy of 11173.24 and 1332.49 KeV 60 Co.

Sample Counting

In replicable sample detector geometry, each sample was counted over a lifetime of 9000 seconds. The configuration and geometry were preserved throughout the analysis, as previously determined using a well-established laboratory methodology at the University of Ibadan's National Institute of Radiation Protection and Research.

The gamma ray spectrometry setup includes a 7.62 cm by 7.62 cm NaI (TI) detector (Model No 802 series, Canberra Inc) with an energy resolution (FWHM) of roughly 0.662 MeV and an operating voltage of 600 V, as well as copper sheets to help reduce background radiation. For data collecting and analysis of gamma spectra, a computer based Multichannel Analyzer (MCA) with Genie 2k software, and a preamplifier base (model 2007p) was utilised

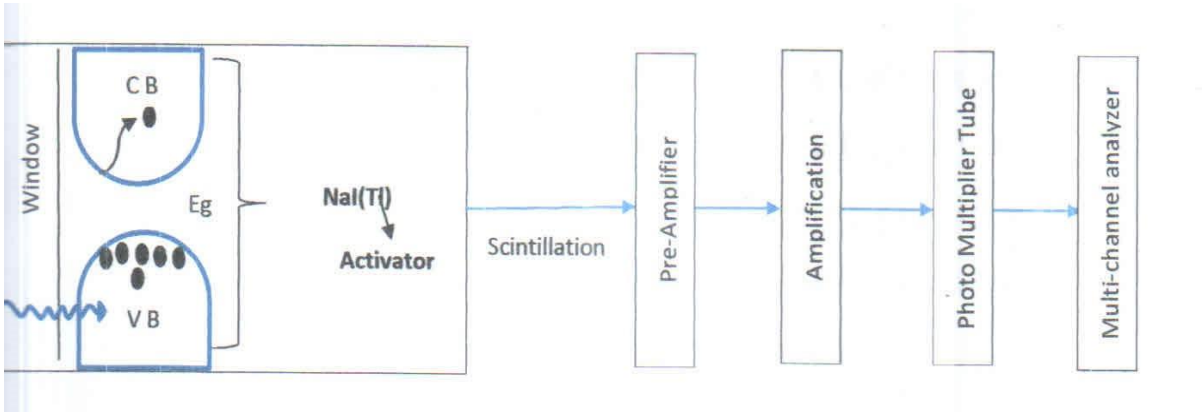

Figure 2: Block diagram of scintillation detector.

Two types of calibration were used in this study. The first step, known as energy calibration, was completed in order to assign correct channel numbers to corresponding gamma ray energy peaks in keV. This was accomplished by employing a variety of known-energy gamma emitting sources. The IAEA provided point sources of 241Am (59.54 KeV), 60C0 (11173.24 and 1332.49 KeV), and 137Cs (661.66 KeV). The emitting sources were exposed to the HPGe detector for 100 seconds while the gamma spectrum was recorded. The efficiency calibration procedure was used to determine the detector's efficiency in producing a spectrum with a specific set of various energies. This was accomplished by employing a 650g mixed CANBERRA soil standard containing 125 Sb, 155 Eu, 54 Mn, 65 Zn, and 40 KM in a Marinelli beaker in the range of 35.5kev to 1460.8 KeV, with the standard reference sample and experimental sample containers geometrically identical. Using the equation (1) below, the detection absolute efficiency for each of the gamma energies studied was calculated.

$$E = \frac{NCi}{Ai \times Yi \times M \times T} \quad . \quad . \quad (1)$$

Where, E= efficiency of the NaI at the energy of the i^{th} radionuclides, Nc_i = net counts of the i^{th} radionuclides (background subtracted) in the corresponding photo peaks, A_i = is the activity concentration of the i^{th} radionuclides in Bq/kg, Y_i = is the emission probability of the i^{th} radionuclides M = mass of the sample in kg, and T = is the counting time (9000 seconds).

The activity concentrations (A_c) for the natural radionuclides in the measured samples were computed using the relation.

$$Ac = \frac{NC}{Lt}\sigma^{-1} \quad . \quad . \quad . \quad (2)$$

Where, Nc is the net count Lt is the lifetime of counting, σ is the conversion factor which is constant for each radio nuclides at constant geometry and is a characteristic of the NaI (TI) detector assembly used (Ibeanu I.G.E, 1999).

All the raw data obtained from the detector were converted to conventional units using calibration factor to determine the activity concentrations of 238-U, 232-Th, and 40-K respectively as presented in table (1). The external absorbed doe rates were calculated using the equation:

$$D = 0.0090A_U + 0.0070A_{Th} + 0.028A_K \quad . \quad . \quad (3)$$

Were A_U, A_{Th}, and A_K are the activity concentration of 238-U, 232-Th, and 40-K respectively in Bq/kg^{-1}

The conversion factors 0.0090, 0.0070, and 0.028 are expressed in ($nGy.h^{-1}Bq.kg^{-1}$)

Using equation (3), we solved the absorbed dose rates for the samples: For well water sample (WWS).

$D = 0.0090\ (0) + 0.0070\ (0) + 0.028\ (17.62) = 0.49\ nGyh^{-1}$

And for borehole water sample (BWS).

$D = 0.0090\ (2.77) + 0.0070\ (2.30) + 0.028\ (1.66) = 0.088\ nGyh^{-1}$

The results of these absorb doses are presented in table (2)

The estimated absorbed dose rate, the conversion coefficient (0.7 Sv/Gy) and outdoor occupancy factor (0.2) were used to determine the annual effective doses using the relation:

$E_d = D \times T \times F$ . . . (4)

Where, E_d is the annual effective dose in (mSv.y−1), D is the value of absorbed dose rates in (nGy.h−1), T is occupancy time 0.2 × 8760 in (hr. y^{-1}) and F is conversion factor 0.7 × 10^{-6} in (mSv/nGy) (Harb S. et al.., 2010)

Using (4), we solved the annual effective dose for the Well Water Sample thus.

$E_d = 0.49 \times 1752 \times 0.7 \times 10^{-6}$

$= 0.00060$ mSv.y^{-1}

And that of B.W.S was solved as.

$D = 0.088 \times 1572 \times 0.7 \times 10^{-6}$

$= 0.000096$ mSv.y^{-1}

The results of these annual effective doses are presented in table (2)

To determine effective radiation hazard, we compared the combined radiological effect (radiation hazard) due to the natural radionuclides to the standard values. It is now common practice to calculate the radium equivalent activity (Ifeoluwa *et al.,* 2014), using the equation.

$Ra_{eq} = 0.077AK + AU + 1.43ATh$. (5)

Where, A_U, A_{Th} and A_K are the activity concentrations of ^{238}U, ^{232}Th and ^{40}K respectively, in Bq/kg^{-1}

Radium equivalent activity for W.W.S is solved thus.

$Ra_{eq} = 0.077\ (17.62) + (0) + (0)$

$= 1.36$ Bq. L^{-1}

For B.W.S,

$Ra_{eq} = 0.077\ (1.66) + 2.77 + 1.43\ (2.30)$

$= 6.19$ Bq. L^{-1}

The results of these radium equivalent activities are also presented in table (2)

Detection Limit

The detection limit of any measuring system measures the operating capability system without the influence of the sample. Although the operating voltage used for this work is about 600v. The detection limit (DL), which is required to estimate the minimum detection level for appropriate determination of radionuclides in each sample were obtained using the expression:

$$\mathrm{DL}(BqKg^{-1}) = \frac{1.96\left[\frac{B}{T} + SD_b{}^2\right]^{\frac{1}{2}}}{K \times \varepsilon \times m} \quad . \quad . (6)$$

Where, SD_b is the estimated standard error of the net background count in the spectrum of the radionuclides, B is the background count, T is the sample counting time (S) M is the mass of the sample in kg, K is the factor that converts count per seconds (cps) to Bq, and 1.96 represents a 95% confidence level (Ayeyemi and Aizebeokhai, 2015).

RESULTS AND DISCUSSION

The results for the activity concentrations of ^{238}U, ^{232}Th and ^{40}K in the water samples taken, as well as the computed absorbed dose rates, yearly effective dosage, and radium equivalent dose for the same sample, are shown in this section.

Table 2: Shows the activity concentration of water samples.

SAMPLE	^{238}U (Bqkg^{-1})	^{232}Th (Bqkg^{-1})	^{40}K (Bqkg^{-1})	Total Activity Conc. per sample (Bqkg^{-1})
W. W	B. W	BDL	17.62 ± 1.37	17.62 ± 1.37
B. W	2.77 ± 0.67	2.30 ± 0.37	1.66 ± 0.13	6.73 ± 1.17
WHO VALUE	10.00	1.00	4.40	

In the borehole water sample, the observed activity concentrations of natural and anthropogenic radionuclides (^{238}U, ^{232}Th, and ^{40}K) were 2.77 0.67, 2.30 0.37, and 1.66 0.13, respectively. ^{40}K activity was determined to be 17.62 1.37 in the well water sample, while ^{232}Th and ^{238}U were found to be below detection limits. The content of ^{40}K in the well water sample is obviously higher in comparison.

Table 3: Show the Absorbed Dose Rate, Annual Effective Dose, Radium equivalent and Activity.

S/N	SAMPLE	Absorbed Dose (n Gy.hr^{-1})	Annual Effective Dose (mSv.y^{-1})	Radium Equivalent Activity (Bq. L^{-1})
1	W. W	0.49±62	0.00060±1.37	1.36±62
2	B. W	0.09±1.17	0.000096±1.17	6.19±1.17

On both well water and borehole water samples, Table 3 shows the average absorbed dose rates, annual effective dose rates, and radium equivalent activity of ^{338}U, ^{232}Th, and ^{40}K. Because the values are all within the World Health Organization's (WHO) and ICRP's standard permissible limits, exposures to them have no major impact on human or animal health, and the environment is radiologically safe.

The activity concentration of ^{40}K in the sample was found to be high. The percentage concentration poses no significant harm to human intake when compared to Gosselin R.E. and Smith R.P. In cells, potassium and sodium keep the osmotic pressure normal. Potassium is needed for insulin secretion, creatinine phosphorylation, glucose metabolism, and protein synthesis, among other things. In healthy people, adverse health effects from potassium ingestion from drinking water are rare. This is because, potassium is promptly eliminated in the absence of pre-existing renal injury and large single doses usually elicit vomiting. Potassium poisoning via consumption is uncommon (Gosselin *et al.*, 1984).

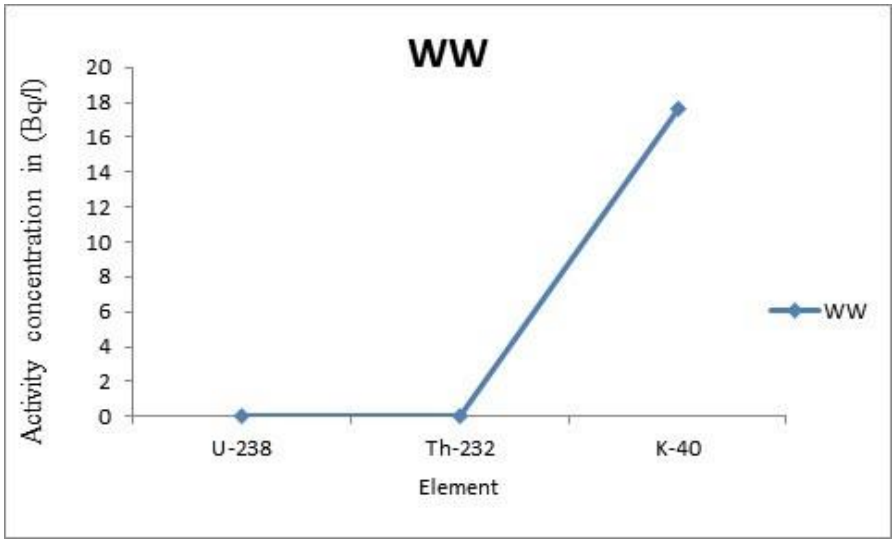

Figure 4.1: shows the graph of activity concentration of borehole water sample.

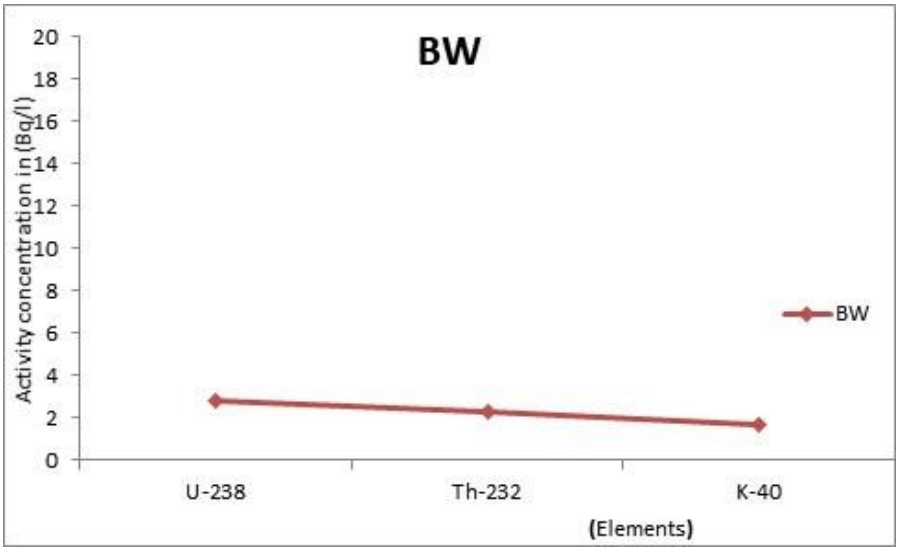

Figure 4.2: shows the graph of activity concentration of well water sample

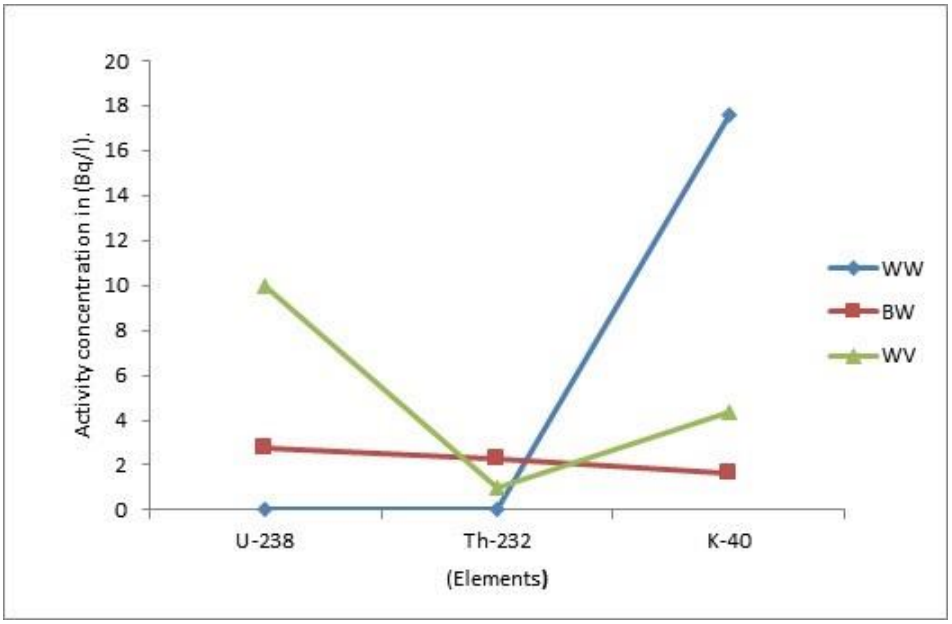

Figure 4.3: Aactivity concentration of borehole and well water samples compared

The data demonstrate a general trend of activity concentrations in borehole water samples that is within the World Health Organization's threshold level (WHO). In comparison to the plot of World Health Organization (WHO) value, the ^{40}K activity content of the well water sample indicates a high elevation.

CONCLUSION

In this study, gamma spectrometer was used to compare the concentration of radionuclides using the water samples collected from the major well and borehole water sources in Adankolo New Lay−Out Lokoja, Kogi State, Nigeria.

The overall findings show that most frequent radionuclides are not evenly distributed in the water sample, as seen in figure 4.3.

The activity concentrations of ^{238}U, ^{232}Th, and ^{40}K in borehole water samples were calculated to be 2.77 0.67, 2.30 0.27, and 1.66 0.13, respectively, and 17.62 1.37 for ^{40}K in well water, whereas ^{232}Th and ^{238}U were below Detection Unit (BDL). The absorbed dose rate owing to radionuclides in the samples was calculated to be between 0. 00060 $mSv.y^{-1}$ and 0. 000096 $Sv.y^{-1}$ for well water and borehole water, respectively. The water samples' radium equivalent activity was likewise calculated to be 1.36 Bq/l for well water and 6.19 Bq/l for borehole water. When compared to the World Health Organization's standard guideline limits, the ^{40}K in well water is greater, suggesting that exposure to it could be harmful to human health. Meanwhile, all radionuclides discovered in the borehole water sample are within the standard suggestion.

When comparing the results of the well water sample with the results of the borehole water sample, it is clear from figures 4.1 and 4.2 that the ^{40}K in the well water sample is higher, which may influence human health, whereas the radionuclides in the borehole water sample are all within the standard limits, posing no risk to human health.

As a result, borehole water is both safer and more dependable than well water.

This research provides important information on how to calculate the activity concentration of various radionuclides in Adankolo New Layout Lokoja. Table 4.1 shows specific information on the Absorbed Dose Rate, Annual Effective Dose, and Radium Equivalent Activity, all of which are within regulation limitations set by the World Health Organization.

The results of the radiological events, as shown in table 4.3, indicate that the specific activity of the radionuclides is within World Health standard limits, except for ^{40}K in well water, which is higher.

I recommend that more of this kind of research should be done from time to time not only in Adankolo New Lay−Out but also in the entire Lokoja, kogi states so that we can discover the external dose of radionuclides in our water and treat them so as to have a safe and quality water for drinking and other usefulness in Lokoja.

REFERENCES

Ali, N. (2004). Survey on Aspects of Pollution of Makera Drain, a Tributary of River Kaduna: Unpublished M.Sc. Thesis, Ahmadu Bello University, Zaria.

Al−Masri, M. S, and Blackburn, R. (1995). Application of Cerenkov Radiation for the Assay of Radium 226 in Natural Water. Sci. Total Environ. 173, 53−59

Alvarado J.S (1995). Rapid Determination of Radium Isotopes by Alpha Spectrometry. Journal of Nuclear Chemistry 194 (1) ppl 163

Audeen, W. (1989). How Do Radioactive Materials move through the Environment to people? Water Pathway, Battelle Press, Columbia, Ohio.

Belloni P. Cavaioli, M. Ingrao, G. Mancini, C. and Vasseli, R. (1995). Optimization and Comparison of Three Different Methods for Determination of Radium − 222 in Water, Science Total Environ. 173 174 (1 6) pp. 47 55Bou−Rabee F. and Bem H. (1996). National radioactivity in building materials utilized in the State of Kuwait, Journal of Radio analytical and Nuclear Chemistry 213 (2),143−149.

Briggs Kamara, M. (2014). Radiation and Environmental Physics. 36th Annual National Conference (pp. 37 39). Uyo: NIP Book of Abstract.

Cember, H. (1995). Introduction to Health Physics, 3rd Edition Mc Graw−Hill, Inc, Toronto PP

Damaris, Osaga Aibangbee. (11, November 2014). Osiga AibangbeeDamaris "Radiation Level Management in Delta State University Campus III, Abraka, Nigeria. Sci−AFRI Journal of Scientific Issues, Research and Essay. Vol.2, 503 517

Ekpo, N.M and Inyang, L.E.D. (2000). Radioactivity, Physical and Chemical Parameters of Underground and surface waters in Qua Iboe River Estuary; Nigeria. Environ. Monit. Assess, 60 (1). Pp. 47 55

Fenyves E. and Haiman O. (1969). The Physical Principle of Nuclear Radiation Measurements Academic, 256.

Gosselin R.E., Smith R.P., Hodge H.C. (1984). Clinical toxicology of commercial products, 5th edition, Williams and Wilkins, Baltimore, MD, 1984 ix + 2002 pages (ISBN 0-683-03622-7)

Harb S., D.K Salahel, A. Abbady and M. Mostafa, p. 10 −14 (2010), Activity concentration for surface soil samples collected from Arment, Qena, Egypt, Proceedings of the 4th Environmental Physics Conference, (pp. 10 14). Qena.

Ibeanu, I.G.E. (1999). Assessment of Radiological E ects of Tin Mining Activities in Jos and its Environs. Ph.D. Thesis. Ahmadu Bello University (Unpubl)

ICRP (1979). Limits for Intakes of Radionuclides by Workers, International Commission on Radiological Protection, Pergamon Press New York. Pp277.

Ifeoluwa, O. P. and Obed, R. O. I (May 26 29 2014). Assessment of the Natural Radioactivity and its Biological Hazards in Prospective Ore Deposit Sites in South-western Nigeria. Conference Proceedings of Nigerian Institute of Physics (pp. 324 332). UYO: Nigeria Institute of Physics.

Isma M.C. (1993). Floride in Local Water Supplies in Zaria. Unpublished Associateship in Civil Engineering project, Ahmadu Bello University, Zaria.

Knoll G.F., (2000). Radiation Detection and Measurement. New York: Wiley and Sons

Nwogu, I.M (2001), Water Analysis Commercial Water Samples. Unpublished B.Sc. Thesis, Ahmadu Bello University, Zaria. P46 50

Odogu, D.O (2001). Analysis of Heavy Metals in Fadama Water, Soil and Vegetable (Spinach) Plant behind Sabon Gari, Zaria. Unpublished B.Sc. Thesis, Ahmadu Bello University, Zaria. P48-50

Ososami, I.A. (1994). Assessment of the Ground Water in the Kaduna Valley with Particular Reference to its use in Ahmadu Bello University, Zaria. Unpublished Thesis of M.Sc. Thesis. Ahmadu Bello University, Zaria.

Robertson, D.E, Schilk, A.J, Abel K.E., Lepel, E.A, Thomas, C.W. and Pratt, S.L.s, (1995). Chemical Speciation of Radionuclides Migrating in Ground Waters

Sajobohus, L. Gomez, J., Capote, T., Greaves, E.D., Herrera, O., Salazar, V and Smith, A. (1997) Gross Alpha radioactivity of Drinking Water in Venezuela. J. Environ. Radioactivity 3: 305−312

Sureck, H. (1995). Determination of Natural Radionuclides in Drinking Water. A Tentative Protocols. Total Environ 173−174 (1−6) 91−99.

Szabo.G.(1993). 160 (4) 619−648Water Quality Management Public Health,

Tuner,J.E. (1995). Atoms, Radiation and Radiation protection. John Wiley and Sons Inc. New York/Chichester/Brisbane/Toronto.

Umar, A.M., Onimisi, M.Y., and Jona, S. A (2012). Baseline Measurement of Natural Radioactivity in Soil, Vegetation and Water in the Industrial District of the Federal Capital Territory (FCT) Abuja, Nigeria. British Journal of Applied Science &Technology 2(3), 266 274.

UNSCEAR. (1988). United Nations Scientific Committee on the E ect of Atomic Radiation, sources, e ects and risks of ionizing radiation. New York: United Nations.

UNSCEAR. (2000). Sources, effects, and risks of ionizing radiation. New York: United Nation.

Van−Briston, G., Slowikowski, B., and Bickel, M (1995). A Rapid Method for Detection of Uranium in Surface Waters. Total Environs. 173−174 (1−6) 83−89