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Assessment of Radionuclides Concentrations in Groundwater Sources Within the Environment of Osun State Polytechnic Iree, Osun State, Southwest, Nigeria.

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Abstract
Radiological assessment of groundwater samples from selected wells within the Osun State Polytechnic environment in Iree, Osun State of Nigeria was carried out. The activity concentration of ^{40}K, ^{238}U and ^{232}Th in the groundwater samples taken from the study area were measured to assess the level of radionuclide content. Measurements were carried out using NaI(Tl) and the results obtained were used to estimate radiological health effects on the dwellers of the area. The values of the mean activity concentrations of ^{40}K, ^{238}U and ^{232}Th are 8.74±0.64, 3.50±0.85, and 1.55±0.18Bq/L, respectively. The radiological parameters- radium equivalent, absorbed dose rate, annual effective dose, external hazard index, internal hazard index and annual gonadal equivalent dose were estimated to be3.02 Bq/L,1.42 nGyh^{-1},1.75 µSv.y^{-1},0.04Bq/L, 0.22 Bq/L and 9.75 µSv.y^{-1}, respectively. All the mean values of the radiological parameters are below the recommended safety limits of UNSCER 2000.This indicates that the consumption of water in the study area has no significant consequential effect on the population. These data therefore represent baseline information on the natural radionuclides in the groundwater of the study area and further studies, however, on the groundwater of the study area are equally recommended.

Key words: *Activity Concentration, Radionuclides, Gamma Ray Spectrometry, Radiological Parameter, Groundwater.*

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I. Introduction

Several studies have shown that activity concentrations of naturally occurring radionuclides in groundwater are connected to the activity concentrations of thorium (^{232}Th) and uranium-radium (^{238}U – ^{226}Ra), their decay products and potassium (^{40}K) in the ground bedrock. This has been linked to the reactions of the water with the ground and the bedrock, releasing amounts of dissolved substances related to the mineralogical and geochemical constituents of the soil and rock of the area. Chemical constituents of the water are influenced by the degree of weathering of the rock, redox condition and the period of time the groundwater has resident in the soil and bedrock (Vesterbacka, 2007). It is important to examine the distribution of the radionuclides and their concentrations in our environment for the radiological assessment of the public.

The presence of naturally occurring radioactive substances in the environment, some technological processes using naturally occurring radioactive substances, and from industrial and medical use of radioactive substances, determines the radiological quality of groundwater of a particular location (Faanu*et al.*, 2011). During water extraction by drilling of holes in rocks or from springs flowing through surfaces with crystalline rocks, which have been characterized with higher uranium concentrations than the average bedrock, radionuclides find their ways into water supplies. Rock types such as granites, syenites, pegmatites, acid volcanic rocks, and acid gneisses reportedly have enhanced uranium concentrations higher than 5 ppm equivalent to 60 Bq/kg. While rock types which include sedimentary rocks (limestone, sandstone, and shales), igneous rocks, volcanic intermediate and basic rocks reportedly have low uranium concentrations. Water sources from the rock types with higher uranium concentrations contain groundwater with radon concentrations of range 50 – 500 Bq/L even higher, while those from the rock types with low uranium concentrations contain groundwater with radon concentrations of the range 5 – 70 Bq/L (Akerblom and Lindgren, 1997).These naturally occurring radioactive substances disintegrate and release ionizing radiation to the environment (Faure *et al.*, 2005). These radionuclides could be of great health issue to human (WHO, 2011). A harmless quality drinking water is important for human survival. However, a large percentage of the dwellers of many developing countries lack access to the portable drinking water (Khosravi*et al.*, 2017 and Masoudinejad*et al.*, 2018).

Supply of potable water to the Osun State Polytechnic Iree area and its environs is one of the critical challenges that confront the institution community. The community lacks potable pipe-borne water supply, the institution, students and community dwellers depend solely on boreholes and wells as their sources of water supply.Thus, many boreholes and wells have sprung up in different locations within Osun State Polytechnic Iree and Iree community. Iree town being a community characterised with rocks, majority of the buildings in the community are constructed on rocks and in most cases water extraction through boreholes and wells involves drilling of holes in rocks.

Radiological health hazards associated with natural radionuclides and their progenies due to the consumption of groundwater has become a global issue in recent times. Information gathered have shown that much have not been done in this area in Nigeria. Paucity information has only reached the public regarding possible radiological hazard associated with drinking. This study was carried out to assess the radionuclide concentrations in groundwater sources within the environments of Osun State Polytechnic Iree, Osun State, Southwest, Nigeria.

II. Materials And Methods

THE STUDY AREA

The study area is Osun State Polytechnic and its environs. Iree (also Ire or IreeAlalubosa) is a Yoruba town in the north-eastern part of Osun State, Nigeria, West Africa. Its geographical coordinates are 7.55′ North and 4.43′East. Iree is one of the major towns in the Boripe Local Government Area of Osun State. The population of the Boripe Local Government was 139,358 (2006 Census). Iree is located on the Osogbo-Illa-Orangun road, about 30 km from Osogbo. It is surrounded by the following towns: Ikirun, Iba, Eripa, Ada, Aagba, Ororuwo, and Iragbiji. Iree is situated in a valley amidst seven prominent hills which,give the town an undulating kind of look in topography.It has a tropical wet and dry climate (Köppen climate classification) with a lengthy wet season and relatively constant temperatures throughout the course of the year. Iree's wet season runs from March through October, though August sees somewhat of a lull in precipitation. This lull nearly divides the wet season into two different wet seasons. The remaining months forms the city's dry season. Like a good portion of West Africa, Iree experiences the harmattan (dry and cold season) between the months of November and February. Figure 1 shows the map of Ireeas located within Boripe LGA in Osun State.

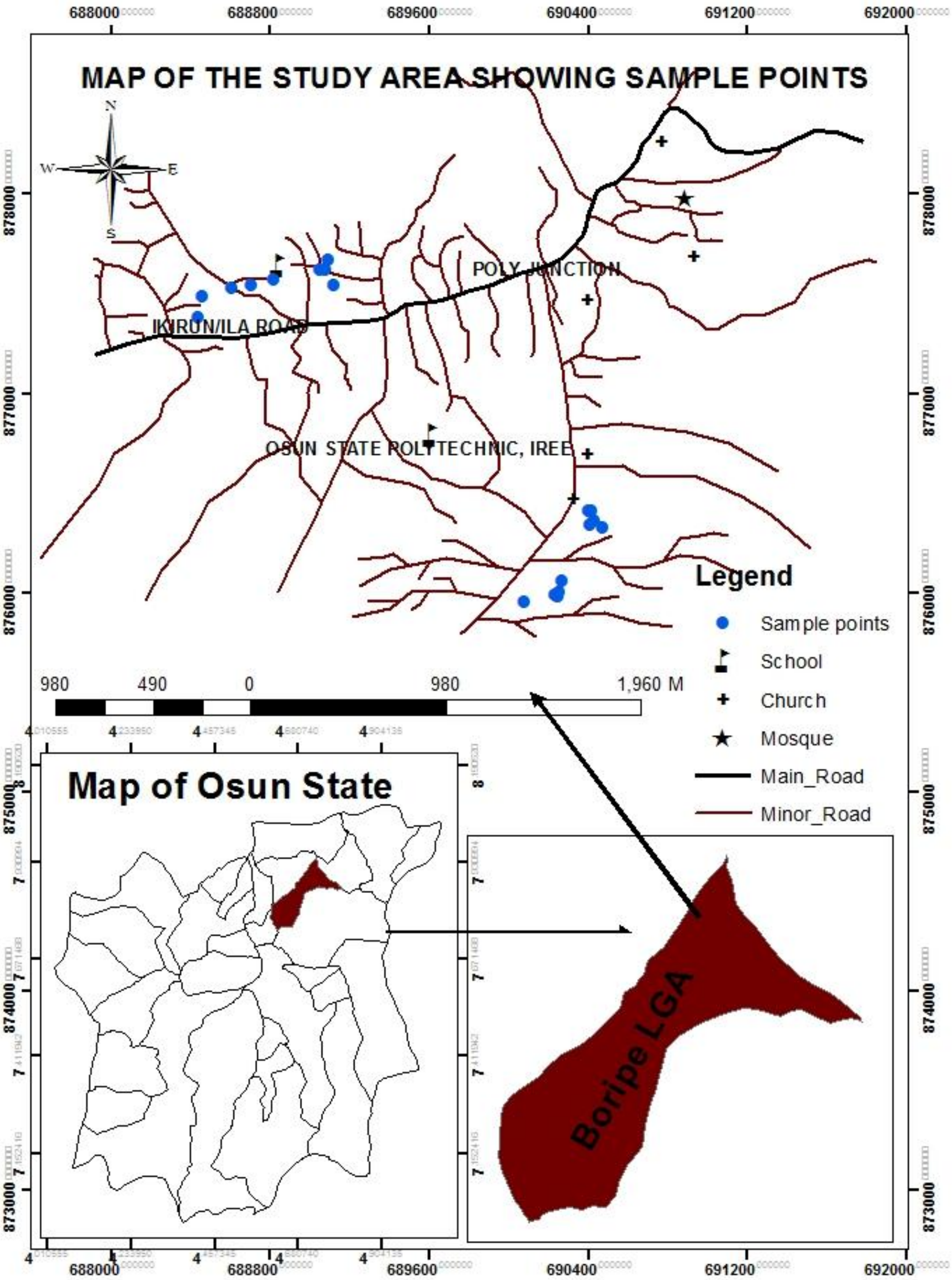

Figure 1: Map of the study area showing the sample locations

EXPERIMENTAL WORK

Sampling and sample preparation: A total number of twenty (20) water samples were collected from wells from four locations around the Osun State Polytechnic Iree, Osun State, Nigeria. The sampling locations include: Plastona area, Staff Club area, Estate area, and Ladoja area. Five (5) samples were collected in each location. The water samples were collected within the period of October and December in 2020. All the water sources are used for domestic consumption. The depths of the sampled wells were of the range 3.66 m to 7.32 m. All the sampled wells were well covered and their geographical coordinates were obtained and recorded with the aid of a ETREX 10 GARMIN, hand held Global Positioning System (GPS). Also, the pH, temperature and conductivity of the water samples were measured insitu during the sampling period using a portable water analysis equipment. Water samples were collected into 75 cl polyethylene plastic bottles and a few drops of hydrochloric acid were added to reduce the pH of the samples to an appreciable level of 2 in other to prevent adherence of the radionuclides to the walls of the containers (Lydie*et al.,* 2008; IAEA, 1986). The bottles were filled to the brim without any head space to prevent trapping of gas. The bottles were tightly covered with lids and labeled appropriately to avoid a mix-up and thereafter transported to the laboratory for analysis.

Gamma Spectrometric Analysis

The gamma ray spectrometry analysis was carried out at the National Institute of Radiation Protection and Research (NIRPR), University of Ibadan, Nigeria. The gamma spectrometric measurement was carried out using Gamma ray spectrometric system involving a NaI(Tl) model 802 scintillation detector. The detector was mounted vertically and coupled with 8K PC based Multi- Channel Analyzer (MCA) and the detector is enclosed in a massive lead shield of thickness 5 cm to reduce background radiation from the system. The detector was calibrated with point sources ^{60}Co, ^{137}Cs, ^{241}Am and ^{22}Na for energy calibration and the efficiency calibration of the detector was done with volume source, IAEA-385. Each water sample was sealed in an already washed Marinelli beaker left for 28days to allow for secular equilibrium between the uranium and thorium decay series and their short-lived progenies before gamma counting of ^{40}K, ^{238}U and ^{232}Th (Veiga and Bakert, 2004). Each sample was counted for a period of 36,000s to reduce the statistical uncertainty (Bello and Farinre, 2014; Senthilkumar, 2010). This detector has adequate lead shielding which would reduce the background radiation according to Alharbi (2013).Gamma counting was also conducted for equal time of 36,000s for the already washed empty Marinelli beaker under identical geometry to determine the background radiation level of the laboratory environment which was later deducted from the measured gamma ray spectra of each sample.

Calculation of the activity concentrations

The specific activity of ^{226}Ra was evaluated from gamma-ray lines of ^{214}Bi at 1,764 keV, while the specific activity of ^{232}Th was evaluated from gamma-ray lines of ^{212}Pb at 2,614 keV. The specific activity of ^{40}K was determined directly from its 1460 keV gamma-ray line and the activity concentrations in each sample was evaluated using the relation presented in equation 1 according to Ibrahim (1998) and Abbady (2005). The radioactivity concentration, in unit of Bq/L, of ^{226}Ra, ^{232}Th and ^{40}K was calculated according to Okedeyi *et al*. (2012).

$$A_c = \frac{A_{net}}{M_s X t_c X P_\gamma X \xi} \quad (1)$$

Where:

A_c: Activity concentration of radionuclide i (Bqkg^{-1})

A_{net}: Net area under the peak of radionuclide i

M_s: Mass of the sample (kg)

t_c: Counting time (sec)

P_γ: Emission probability

ξ: Detector efficiency

Radiological hazard indices

Radium equivalent activity (Ra_{eq}) concentration is used for assessing radiological hazard and is calculated as (Tawalbeh*et al*., 2013):

$$Ra_{eq}(BqKg^{-1}) = C_{Ra} + 1.43C_{Th} + 0.077C_K \quad (2)$$

Where:

C_{Ra}, C_{Th} and C_K are the activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K in Bq kg^{-1}, respectively.

External hazard index (H_{ex})

The external hazard index (H_{ex}) evaluates the external radiation exposure of natural gamma radiation:

$$H_{ex}(Svy^{-1}) = \frac{C_{Ra}}{370} + \frac{C_{Th}}{259} + \frac{C_K}{4810} \quad (3)$$

Internal hazard index (H_{in})

The internal hazard index (H_{in}) represents the internal radiation exposure associated with radon (^{222}Rn) and its daughter products:

$$H_{in}(Svy^{-1}) = \frac{C_{Ra}}{185} + \frac{C_{Th}}{259} + \frac{C_K}{4810} \quad (4)$$

3.3.4.3 Radioactivity level index

The radioactivity level index, $I_{\gamma r}$, is generally used to assess the hazardous level of radionuclides in the human body when exposed to an amount of external (indoor or outdoor) annual effective doses of radiations decayed from radioactive nuclides in soils. This index is very important for quality control of radiation annual effective doses and in monitoring radiation inside human body, to ensure that such radiation does not exceed the worldwide permissible high dose values (Al-Saleh and Al-Berzan, 2009). According to the European Commission, gamma activity concentration index ($I_{\gamma r}$) is derived for identifying whether a dose standard is met

(EC, 1999) and can be estimated according to the following semi-empirical formula (Dabayneh, *et al.*, 2008; Shams *et al.*, 2013)

$$I_{\gamma r} = \frac{C_{Ra}}{150} + \frac{C_{Th}}{100} + \frac{C_K}{1500} \quad (5)$$

3.3.5 Absorbed dose rate (D)

The absorbed dose rate (D) is one of the more common indices for assessing health risk from radiation. The equation was generated based on dose rates at 1m above the ground surface if natural radionuclides are uniformly distributed in the ground (Kohshi*et al*., 2001):

$$D\ (nGyh^{-1}) = 0.427C_{Ra} + 0.662C_{Th} + 0.043C_K \quad (6)$$

3.3.6 Effective dose rate (E)

The effective dose rate (E) is used for assessing health risk from radiation. The conversion coefficient from absorbed dose in air to effective dose of 0.7 Sv Gy^{-1}, received by adults combined with the outdoor occupancy factor of 20% (UNSCEAR, 2000), and the number of hours in one year (8760 h) are taken into account as shown below:

$$E(\mu Svy^{-1}) = D(nGyh^{-1}) X\ 8760hy^{-1} + 0.2\ X\ 0.7\ Sv.Gy^{-1}\ X\ 10^{-3} \quad (7)$$

3.3.7 Annual Gonadal Dose Equivalent (AGDE)

According to reference (UNSCEAR, 1982) the gonads, the active bone marrow and the bone surface cells are considered as the organs of interest. Therefore the Annual Gonadal Equivalent Dose (AGED μSv y^{-1}) for the residents of the study area due to the specific activities of ^{226}Ra, ^{232}Th and ^{40}K will be calculated according to the equation put forward by (Arafa, 2004):

$$AGED\ (\mu Svy^{-1}) = 3.09C_{Ra} + 4.18C_{Th} + 0.314C_K \quad (8)$$

III. Results And Discussion

The geographical coordinates, elevations and depths of well samples in this study are presented in Table 1. The activity concentrations of the identified radionuclides, ^{40}K, ^{238}U and ^{232}Th, in the well water samples investigated were calculated using Equation 1 and presented in Tables 2.The mean activity concentrations of^{40}K, ^{238}U and ^{232}Th in the groundwater samples are 8.74±0.64, 3.50±0.85,1.55±0.18 Bq/L respectively. The pH, temperature and electrical conductivity of the investigated groundwater samples with mean values of 7.9, 30°C and 906.7μs/cm are presented in Table 2. It is observed that ^{40}K with 8.74±0.64 Bq/L value has the highest activity concentration among the three identified radionuclides. This may be connected to the geological formations underlying the study area according to the reports of (Joel *et al.*, 2019).

Table 1: Coordinates of sampling locations using GPS.

Sample Code	Longitude	Latitude	Accuracy (m)	Elevation (m)	Well Depth (m)
PLW1	0690271	0876059	2	469	4.572
PLW2	0690256	0876002	3	468	3.658
PLW3	0690251	0875983	3	466	6.401
PLW4	0690081	0875951	3	485	6.401
PLW5	0690237	0875990	2	473	7.315
SCW1	0690428	0876359	3	478	6.401
SCW2	0690417	0876413	3	485	3.658
SCW3	0690403	0876410	3	483	3.658
SCW4	0690409	0876340	2	485	6.401
SCW5	0690475	0876330	2	476	6.401
ESW1	0689084	0877619	2	432	5.486
ESW2	0689056	0877617	2	433	6.401
ESW3	0690251	0875983	3	466	6.401
ESW4	0689096	0877672	2	432	5.486
ESW5	0689126	0877541	3	430	3.658
LAW1	0688823	0877575	3	426	7.315
LAW2	0688706	0877544	3	420	3.658
LAW3	0688610	0877533	3	416	6.401
LAW4	0688443	0877385	3	417	6.401
LAW5	0688464	0877489	3	412	5.486

PLW: Plastona water, **SCW**: Staff club water, **ESW**: Estate water, **LAW**: Ladoja water

Table 2: Activity concentrations of ^{40}K, ^{238}U and ^{232}Th, pH, T (^oC) and EC in the water samples

Sample Code	K-40	U-238	Th-232	pH	T(^oC)	EC (µs/cm)
PLW1	0.86±0.07	1.95±0.48	BDL	7.2	29	655.3
PLW2	2.75±0.23	BDL	BDL	7.2	30	644.6
PLW3	4.35±0.37	BDL	BDL	7.7	30	700.3
PLW4	5.28±0.35	BDL	0.57±0.06	7.1	28	688.9
PLW5	9.83±0.78	BDL	1.05±0.12	7.5	30	700.4
SCW1	12.86±0.84	BDL	2.40±0.26	7.9	31	992.4
SCW2	11.19±0.89	BDL	1.73±0.21	9.3	30	998.8
SCW3	1.75±0.14	BDL	0.46±0.06	8.9	30	1000.3
SCW4	6.41±0.42	BDL	0.11±0.01	9.1	30	988.4
SCW5	11.01±0.72	BDL	BDL	8.8	28	1006.7
ESW1	27.93±2.11	BDL	BDL	8.6	29	1164.7
ESW2	19.99±1.53	BDL	BDL	8.6	29	1200.4
ESW3	10.37±0.80	0.57±0.15	BDL	7.5	30	992.4
ESW4	9.76±0.64	BDL	0.53±0.06	7.4	29	999.8
ESW5	10.40±0.83	3.97±0.98	2.57±0.30	7.2	29	1001.7
LAW1	BDL	1.14±0.27	BDL	6.8	28	886.5
LAW2	2.14±0.17	BDL	0.44±0.05	7.5	29	887.1
LAW3	3.46±0.29	4.95±1.21	4.10±0.48	7.7	30	800.8
LAW4	7.52±0.61	8.44±2.02	1.52±0.18	7.3	30	1000.8
LAW5	8.23±0.67	BDL	3.14±0.37	7.8	30	823.8
Mean±SD	8.74±0.64	3.50±0.85	1.55±0.18	7.9	30	906.7

PLW: Plastona water, **SCW**: Staff club water, **ESW**: Estate water, **LAW**: Ladoja water

Radiological Impacts of the Groundwater Samples

The radiological impacts of the groundwater samples in terms of the absorbed dose rate, D ($nGyh^{-1}$), the annual effective dose, E (µSv/y), external hazard index, (H_{ex}) Bq/L, internal hazard index, (H_{in}) Bq/L, representative gamma index, ($I_{γr}$), radium equivalent activity (Ra_{eq}) and annual gonadal equivalent dose, AGED (µSv/y) are presented in Table 3.

The mean absorbed dose rate observed for the groundwater samples was calculated using Equation 6 and presented in column 1 of Table 3. The values ranged from 0.12 – 4.98 nGy/hr with the estimated mean value of 1.42nGy/hr. This value is less than the population weighted average absorbed dose rate (60 nGy/hr) in outdoor air from terrestrial gamma radiation and that of the worldwide average of 55 nGy/hr (UNSCEAR, 2000).The annual effective dose was calculated using Equation 7 and presented in column 2 of Table 3, with range values of 0.15 – 6.01 µSv/yr and the mean annual effective dose due to ingestion of radionuclides in groundwater from the study area is 1.75 µSv/yr. This is less than the World permissive annual dose limit of 1.0 mSv/yr (UNSCEAR, 2000).This implies that consumption of the groundwater from the study area may not cause the respiratory related diseases such as asthma and cancer or external diseases such as erythema, skin cancer and cataracts.

The calculated radiation hazards in the representative groundwater samples were presented in Table 3.The external hazard index was calculated using Equation 3 and the results were presented in column 3 of Table 3. The values ranged from 0.01 – 0.09 Bq/L with mean value of 0.04 Bq/L. Similarly, the internal hazard index was calculated using Equation 4 and the results presented in column 4 of Table 3. The values ranged from 0.01 – 0.09 Bq/L with the estimated average value of 0.04 Bq/L.Since the average values of the internal hazard and external hazard indices (H_{ex},H_{in}) are both less than 1.0, hence the radiation hazard due to consumption of the investigated groundwater samples is considered insignificant.

The annual gonadal equivalent dose to the dwellers of the study area due to the specific activities of ^{40}K, ^{238}U and ^{232}Th was calculated using Equation 8 and as presented in column 7 in Table 3, the ranges between 0.86 – 34.79 µSv/y, with the mean annual gonadal equivalent does of 9.75 µSv/y. This is low compared with the World average of 300 µSv/y (UNSCEAR, 2000). The radium equivalent (Ra_{eq}) was calculated using Equation 2 and the results presented in column 6 of Table 3. The values ranged from 0.21 – 11.19 Bq/L with the mean value of 3.02 Bq/L. This value is below the World average of 370 Bq/L.The representative gamma index ($I_{γr}$) was calculated using Equation 5,and presented in column 5 of Table 3, with range values of 0.01 – 0.77 and estimated mean value of 0.22. Since the mean value is less than unity, it suggests exhibition of low gamma radiation by the groundwater samples under investigation. Considering the radiological parameters above, it follows that the groundwater samples from the study area exhibited inconsequential low gamma radiation.

Table 3: Radiological Assessment of the Radionuclides in the Groundwater Samples.

Sample Code	D(nGyh^{-1})	E (μSv/y)	H_{ex} (Bq/L)	H_{in}(Bq/L)	$I_{\gamma r}$	Ra_{eq} (Bq/L)	AGED (μSv/y)
PLW1	0.87	1.07	0.05	0.01	0.14	2.02	6.30
PLW2	0.12	0.15	0.06	0.06	0.02	0.21	0.86
PLW3	0.19	0.23	0.09	0.09	0.03	0.34	1.37
PLW4	0.60	0.74	0.03	0.03	0.01	1.22	4.04
PLW5	1.12	1.37	0.06	0.06	0.17	2.26	7.48
SCW1	2.14	2.63	0.02	0.02	0.33	4.42	14.07
SCW2	1.63	1.99	0.09	0.09	0.25	3.34	10.75
SCW3	0.38	0.47	0.02	0.02	0.06	0.79	2.47
SCW4	0.35	0.43	0.02	0.02	0.05	0.65	2.47
SCW5	0.47	0.58	0.02	0.02	0.07	0.85	3.46
ESW1	1.20	1.47	0.06	0.06	0.19	2.15	8.77
ESW2	0.86	1.05	0.04	0.04	0.13	1.54	6.27
ESW3	0.69	0.85	0.04	0.05	0.11	1.37	5.02
ESW4	0.77	0.95	0.04	0.04	0.12	1.51	5.28
ESW5	3.84	4.71	0.02	0.04	0.59	8.45	26.28
LAW1	0.49	0.60	0.03	0.06	0.08	1.14	3.52
LAW2	0.38	0.47	0.02	0.02	0.06	0.79	2.51
LAW3	4.98	6.1	0.03	0.04	0.77	11.08	33.52
LAW4	4.93	6.05	0.03	0.05	0.77	11.19	34.79
LAW5	2.43	2.98	0.01	0.01	0.37	5.12	15.71
RANGE	0.12 – 4.98	0.15 – 6.01	0.01 – 0.09	0.01 – 0.09	0.01 – 0.77	0.21 – 11.19	0.86 – 34.79
MEAN	1.42	1.75	0.04	0.04	0.22	3.02	9.75

PLW: Plastona water, **SCW**: Staff club water, **ESW**: Estate water, **LAW**: Ladoja water

Comparison of the activity concentrations of present study with similar studies

Table 4 shows the activity concentrations of radionuclides (^{40}K, ^{238}U and ^{232}Th) of the groundwater samples under investigation compared with similar studies. The results of the present study are lower compared to the findings of Ajayi and Adesida, 2009, in the Radioactivity in some sachet drinking water samples produced in Nigeria; the report of Nwankwo, 2013, in determination of natural radioactivity in groundwater in Tanke-Ilorin, Nigeria and the report of Adegunwa*et al.*, 2019, in Investigation of Radionuclide Levels in Groundwater Around Transmission Company of Nigeria for Environmental Impact Assessment. Comparing the results of the present study with reports of Al-Alawy*et al*., 2018, in the determination of Radioactivity Levels, Hazard, Cancer Risk and Radon Concentrations of Water and Sediment Samples in Al-Husseiniya River (Karbala, Iraq), ^{40}K of the present study is lower, whereas, the concentrations of ^{238}U and ^{232}Th were higher. The variation in the findings could be due to different geological formation between the present study area and the areas of the compared results.

Study	**Radionuclides**		
	^{40}K (Bq/L)	^{238}U (Bq/L)	^{232}Th (Bq/L)
Present results	8.74±0.64	3.50±0.85	1.55±0.18
Ajayi and Adesida, 2009	19.09	7.75	2.03
Nwankwo, 2013	NDT	3.70	3.60
Al-Alawy, *et al.,* 2018	10.08	1.90	1.23
Adegunwa, *et al.,* 2019	202.70	8.38	6.45

NDT: Not Determined

IV. Conclusion

The activity concentrations of the identified radionuclides (^{40}K, ^{238}U and ^{232}Th) in the groundwater samples collected from the residential areas around the Osun State Polytechnic, Iree, Osun State, Nigeria, were investigated for their radiological effects. From this study, the mean values obtained for the radiological parameter viz; the radium equivalent activity, absorbed dose rate, annual effective dose, external hazard index, internal hazard index, representative gamma index and annual gonadal equivalent dose were found to be lower than the recommended safety limits of UNSCER 2000. Hence, the groundwater samples from the study areas are therefore considered suitable for consumption without fear of possible significant concentration of natural radionuclides.

References

[1]. Abbady, A.G.E., Uosif, M.A.M. and EL-Taher, A. (2005). Natural radioactivity and dose assessment for phosphate rocks from Wadi El-Mashash and El-Mahamid Mines, Egypt. *Journal of Environmental Radioactivity* 84(1): 65-78.

[2]. Adegunwa, A.O.,Awojide, S.H. and Ore, O.T. (2019). Investigation of Radionuclide Levels in Groundwater Around Transmission Company of Nigeria for Environmental Impact Assessment. *Journal of Nuclear Science*, vol. 4(4): 66 – 71. doi: 10.11648/j.ns.20190404.15.

[3]. Ajayi, O.S. and Adesida, G. (2009). Radioactivity in some sachet drinking water samples produced in Nigeria. *Iran. J. Radiat. Res.*, 7 (3): 151-158.

[4]. Akerblom, G. and Lindgren J., (1997).Mapping of groundwater radon potential. IAEA-TECDOC-980, pp: 237-255.

[5]. Al-Alawy I. T., Mohammed R. S., Fadhil H. R. and Hasan A. A. (2018). Determination of Radioactivity Levels, Hazard, Cancer Risk and Radon Concentrations of Water and Sediment Samples in Al-Husseiniya River (Karbala, Iraq) *Journal of Physics: Conf. Series* 1032: 1 – 19 https://doi.org/10.1088/1742-6596/1032/1/012012

[6]. Alharbi, W.R. (2013). Natural Radioactivity and Dose Assessment for Brands of Chemical and Organic Fertilizers Used in Saudi Arabia. *Journal of Modern Physics*4: 344-348.

[7]. Al-Saleh, F. and Al-Berzan, B. (2009). Measurements of natural radioactivity in some kinds of marble and granite used in Riyadh Region. *J Nuclear Rad Phys* 2: 25 – 36.

[8]. Arafa, W. (2004). Specific activity and hazards of granite samples collected from the Eastern desert of Egypt. *Journal of Environmental Radioactivity*. 75: 315− 322.

[9]. Bello, R. and Farinre, O. Z. (2014). Assessment of activity concentrations of radionuclide with depth in wasteland soils in Abeokuta, Southwest Nigeria. *Physical Science International Journal* 5(1): 51-60.

[10]. Dabayneh, K.Mashal, L.and Hasan, F.(2008). Radioactivity concentration in soil samples in the southern part of the West Bank, Palestine. *Radiat Prot Dos* 131: 265 - 271.

[11]. European Commission, (EC). (1999). Report on Radiological Protection Principle concerning the natural radioactivity of building materials. Directorate-General Environment, Nuclear safety and civil protection. *Radiation Protection*, 112:1-16.

[12]. Faanu, A., Adukpo, O.K., Okoto, R.J.S., Diabor, E., Darko,E.O.G. Emi-Reynolds, G., Awudu, A.R., Glover, E.T., Tandoh, J.B., Ahiamadjie, H., Otoo, F., Adu, S. and Kpordzro, R. (2011). Determination of Radionuclides in Underground Water Sources Within the Environments of University of Cape Coast. *Research Journal of Environmental and Earth Sciences*1 – 6.

[13]. Faure, G. and Mensing, T.M., (2005). Isotopes, Principles and Applications, third ed. John Wiley & Sons, p. 897.

[14]. Ibrahim, N. (1998). Determination of natural radioactivity in fertilizers using Gamma Ray Spectroscopy. *Journal of Nuclear Physics and Chemistry* 51(46): 621-627.

[15]. International Atomic Energy Agency (1986).*Summary Report on the post-accident review meeting on the Chernobyl accident.*Safety Ser. 75- INSAG-1, IAEA, Vienna.

[16]. Joel, E.S., Maxwell, O., Adewoyin, O.O., Olawole, O.C., Arijaje, T.E., Embong, Z., andSaeed, M.A. (2019).Investigation of natural environmental radioactivity concentration in soil of coastaline area of Ado-Odo/Ota Nigeria and its radiological implications.Scientific Reports, 9 (1).doi: 10.1038/s41598-019-40884-0.

[17]. Khosravi, R., Eslami H., Ali Almodaresi S., Heidari M., Ali Fallahzadeh R., Taghavi M., Khodadadi M, Peirovi R., (2017). Use of geographic information system and water quality index to assess groundwater quality for drinking purpose in Birjand City, Iran. Desalin. Water Treat. 67, 74-83.

[18]. Kohshi, C., Takao, I. and Hideo, S. 2001. Terrestrial gamma radiation in Koshi prefecture, Japan.*Journal of Health Science* 47(4): 362–372.

[19]. Lydie, R.M. and Nemba, R.M.(2008).Quantitative determination of ^{226}Ra and ^{228}Ra in reservoir and tap water in Yaounde area, Cameroon.*Glob.J. envir. Res.* 2(3): 110‑113.

[20]. Masoudinejad, M. and Ghaderpoury, A.(2018). Data on phosphorous concentration of rivers feeding into Taham dam in Zanjan, Iran. 7, 564-569 http://dx.doi.org/10.1016/j.dib.2018.01.068

[21]. Nwankwo, L.I. 2013. Determination of natural radioactivity in groundwater in Tanke-Ilorin, Nigeria.*West African Journal of Applied Ecology*21(1): 111-119.

[22]. Okedeyi, A.S., Gbadebo, A.M., Arowolo, T.A., Mustapha, A.O. and Tchokossa, P. 2012. Measurement of Gamma-emitting Radionuclides in Rocks and Soils of Saunder Quarry Site, Abeokuta, Ogun State, Nigeria. *Journal of Applied Science* 12(20): 2178 – 2181.

[23]. Senthilkumar, B., Dhavamani, V.,Ramkumar, S. and Philominathan, P. 2010. Measurement of gamma radiation levels in soil samples from Thanjavurusing γ-ray spectrometry and estimation of population exposure. *Journal of Medical Physics*35(1): 48 – 53.

[24]. Shams, I., Mohamed, U., and Reda, E. (2013).Gamma radioactivity measurements in Nile River sediment samples, Turkish.*J. Eng. Env. Sci.* 37: 109 - 122.

[25]. Tawalbeh, A.A., Samat, S.B. andYasir, M.S. 2013. Radionuclides level and its radiation hazard index in some drinks consumed in the central zone of Malaysia. *Sains Malaysiana* 42: 319–323.

[26]. United Nation Scientific Committee on the Effects of Atomic Radiation (UNSCEAR), (1982). Ionizing radiation: sources and biological effects. Report of the General Assembly, with annexes, United Nation, New York, 79 - 169

[27]. United Nations Scientific Committee on the Effect of Atomic Radiation (UNSCEAR), (2000), Sources and Effects of Ionizing Radiation. *Report to General Assembly with Scientific Annexes*, New York: United Nations, ISBN 92-1-142238-8, 1: 19 – 497

[28]. Veiga M. M. and Baker R. F. (2004). Protocols for environmental and health assessment of mercury released by artisanal and small scale gold miners.Vienna: GEF/UNDP/UNIDO, 1 - 170

[29]. Vesterbacka, P., (2007). Natural Uranium in drinking water in Finland.*Boreal Environ. Res* 12: 11-16.