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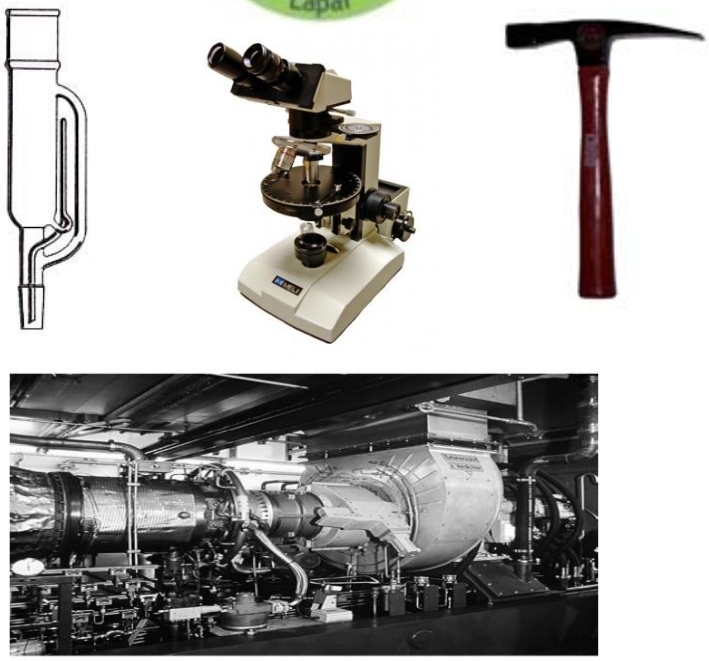

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Development Journal of Science and Technology Research (DJOSTER)

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CONTENT: VOLUME 12, NUMBER 1, 2023

EVALUATION OF ANNUAL EFFECTIVE DOSE RATES AND EXCESS LIFETIME CANCER RISK ASSOCIATED WITH GAMMA DOSE RATES AND NATURAL RADIONUCLIDES IN RIVER KADUNA SEDIMENTS.

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Abstract

The health hazard associated with gamma dose rates and natural radionuclides in river Kaduna sediments were assessed by evaluating the annual effective dose equivalent and excess lifetime cancer exposure risk. Absorbed dose rates (Ds) were measured above the ground surface (at 100 cm) in the field using Rados survey meter. Soil samples were also taken and measured in the laboratory using low-level gamma-ray detector (3 × 3 inches NaI:Tl). The activity concentration of K-40, U-238 and Th-232 ranges from 400.5 ± 3.9 - 643.6 ± 7.5Bqkg^{-1}, 8.1 ± 3.6 - 25.5 ± 7.7 Bqkg^{-1} and 38.0 ± 1.3 - 103.4 ± 2.9Bqkg$^{-1,}$ respectively. The weighted average of K-40 (525.4 ± 8.3 Bqkg^{-1}) and Th-232 (71.7 ± 2.1 Bqkg^{-1}) are above the worldwide mean of 400Bqkg^{-1} and 30Bqkg^{-1}, respectively (UNSCEAR, 2000). The weighted average of U-238 (13.9 ± 4.1 Bqkg^{-1}) is below the worldwide mean of 35Bqkg^{-1}. The estimated average annual effective dose equivalent (aede) from both field (0.23mSvyr^{-1}) and laboratory (0.10 ± 0.01mSvyr^{-1}) measurements are above the 0.07mSvy−1 world average value. The Excess lifetime cancer risk (elcr) values ranges from 0.81 x 10^{-3} - 1.05 × 10^{-3} and (0.22 ± 0.07) × 10^{-3} - (0.44 ± 0.11) × 10^{-3} for field and laboratory measurements, respectively. The elcr values from the field measurements are higher than those from laboratory measurements which could be due to the radon continuously produced in air and cosmic rays. The average elcr estimated from both field (0.89 × 10^{-3}) and laboratory ((0.30 ± 0.02) × 10^{-3}) measurements are greater than that of the world average of 0.29 × 10^{-3}. This result shows that there is increase in the likelyhood of developing cancer when expose to such environment for long.

Keywords: Sediments, aede, elcr, survey meter.

1. Introduction

Radiation in the environment comes from cosmic ray (extremely energetic particles from the sun and stars that enter Earth's atmosphere), terrestrial radiation (naturally occurring radioactive minerals in the ground, soil, and water) and anthropogenic sources (human activities) (Bashir, 2020). According to National Council on Radiation Protection and Measurements (NCRP, 2006) report, radon and its progenies are the largest contributors to background radiations followed by cosmic radiation, then primordial radiation. Human exposure to radiation from sediment can either be internal due to inhalation of radon and its progenies or whole body due to external radiation from terrestrial radiation (Hameed et al., 2014; Jibiri and Okeyedo, 2012; Ngachin et al., 2007). Exposure to radiation over a long period of time can cause chronic lung cancer and leukemia (Qureshi et al., 2014). As the end result of fertilizer washing and industrial activities, river sediments contain substantial amount of natural radionuclides (Krmar et al., 2009).

This work aims to estimate the health hazard associated with Ds and natural radionuclides in river Kaduna sediments by evaluating the aede and elcr. The area is within the industrial area of Kaduna state of Nigeria and river Kaduna has some links with generated wastes from the industrial activities which when flooding of the river occur, some of waste were deposited at the river bank.

2. Methodology

The study area was partitioned into 20 × 20 m2 grid points labelled A1-C3. Measurements were made in the field and soil samples taken for laboratory measurement.

In the field, the absorbed dose rates (Ds) were measured at 1 m above the ground surface at each grid point using Rados (model RDS 990097 and RDS 251012) survey meter. Each measurement was performed three times spanning over 2 min with both survey meters and then averaged to a single value.

Soil samples (sediments) were taken at the surface of each grid point between 0-5cm depth. The samples were air dried for 24hours in the laboratory, then pulverized, sieved, homogenized, filled into 25 g plastic containers and sealed to avoid the escape of radon gas from the samples (Bashir et al., 2013). The samples were weighed and stored for at least 24 days before measurement in

order to attain radioactive secular equilibrium. A low-level gammaray detector (3 × 3 inches NaI:Tl) was used to measure each sample for 24 hours. Prior to sample measurement, the detector was energy calibrated using Cs-137 (661.6 keV) and Co-60 (1173.2 keV and 1332.5 keV) sources and the efficiency calibration was done using IAEA reference materials; RGK-1 for K-40, RGU-1 for U-238 and RGTh-1 for Th-232. The background (an empty plastic container) was also measured and the counts subtracted from each sample count. The activity concentration of K-40 was assessed using its 1460 keV gamma line. The 1764 keV gamma line of Bi-214 and 2614.5 keV gamma line of Tl-208 were used to assess U-238 and Th-232 activity concentrations, respectively.

The Ds in $nGyh^{-1}$ for the uniform distribution of the naturally occurring radionuclides (K-40, U-238 and Th-232 in measured sediment) due to gamma radiations above the ground surface (at 100 cm) was estimated using equation 1 (UNSCEAR, 2000).

$$D_s = 0.042A_K + 0.462A_U + 0.604A_{Th} \quad (1)$$

where A_K, A_U and A_{Th} are the activity concentrations of K-40, U-238 and Th-232 in $Bqkg^{-1}$, respectively.

The outdoor aede in $mSvyr^{-1}$ was estimated from the outdoor D_s, time spent outdoor (20% of 8760 $hryr^{-1}$) and the conversion factor (cf = $0.7SvGy^{-1}$) to convert the D_s to effective dose (UNSCEAR, 2000):

$$aede(mSvyr^{-1}) = Ds(nGyhr^{-1)} \times 0.7(SvGy^{-1}) \times 8760(hryr^{-1}) \times 0.2 \times 10^{-6} \quad (2)$$

Excess lifetime cancer risk deals with the probability of developing cancer over a lifetime at a given exposure level. It is presented as a value representing the number of extra cancers expected in a given number of people on exposure to a carcinogen at a given dose. The elcr was estimated as follows (UNSCEAR, 2000):

$$elcr = aede \times dl \times rf \quad (3)$$

Where, dl is average life duration (estimated to be 70years) and rf is the fatal cancer risk factor for stochastic effects ($0.055Sv^{-1}$ for the public (ICRP, 2007)).

3. Results and Discussion

Table 1 show the activity concentrations of K-40, U-238 and Th-232 in measured soil sediments. The activity concentrations of K-40 ranged from 400.5 ± 3.9 - 643.6 ± 7.5Bqkg^{-1} which are within the worldwide range of 140-850Bqkg^{-1} (UNSCEAR, 2000). The weighted average of K-40 (525.4 ± 8.3Bqkg^{-1}) is above the worldwide mean of 400Bqkg^{-1} (UNSCEAR, 2000). The activity concentration of U-238 ranges from 8.1 ± 3.6 - 25.5 ± 7.7Bqkg^{-1} with a weighted average of 13.9 ± 4.1Bqkg^{-1} which are all within the worldwide range and mean of 17-60Bqkg−1 and 35Bqkg−1, respectively. The activity concentration of Th-232 ranged from 38.0 ± 1.3 - 103.4 ± 2.9Bqkg^{-1} with a weighted average of 71.7 ± 2.1Bqkg^{-1}, respectively. The activity concentration of Th-232 is above the worldwide upper range and mean of 11-64Bqkg^{-1} and 30Bqkg^{-1} (UNSCEAR, 2000). The high concentration of Th-232 in some soil samples could the reason for it. It can be observed that K-40 in the soil sediments is more concentrated, which can be attributed to the industrial wastes channel into the river.

Table 1: The activity concentrations of K-40 (A_K), U-238 (A_U) and Th-232 (A_{Th}) in sediments measured in the laboratory all in Bqkg−1.

Location	A_K	A_U	A_{Th}
A1	495.3 ± 8.2	8.2 ± 2.4	38.0 ± 1.3
A2	462 ± 8.3	8.1 ± 4.6	59.8 ± 2.3
A3	643.6 ± 7.5	25.5 ± 7.7	73.5 ± 2.0
B1	597.4 ± 9.9	13.8 ± 2.2	103.4 ± 2.9
B2	579.5 ± 11.0	19.4 ± 7.1	99.8 ± 3.6
B3	539.3 ± 5.3	10.5 ± 2.1	81.5 ± 2.2
C1	598 ± 11.8	13.9 ± 5.7	76.7 ± 2.5

C2	400.5 ± 3.9	17.9 ± 1.5	49.7 ± 0.7
C3	412.8 ± 8.6	8.1 ± 3.6	62.5 ± 1.5
Weighted average	525.4 ± 8.3	13.9 ± 4.1	71.7 ± 2.1

The D_s, outdoor aede and elcr results are shown in Table 2. The D_s value ranges from 120.0 - 155.0nGyhr^{-1} with a weighted average of 131.7nGyhr^{-1} for field measurement. Whereas the D_s for laboratory measurement ranges from 47.4 ± 8.6 - 93.7 ± 10.5nGyhr^{-1} with a weighted average of 65.1 ± 2.6nGyhr^{-1}. The weighted average dose rate in this work is slightly greater than the world average value of 59.0nGyhr^{-1} (Agbalagba, 2017; Monica et al., 2016) but within the safe limit of 84.0nGyhr^{-1} recommended (UNSCEAR, 2008).

The outdoor aede from the field measurement ranges from 0.21 - 0.27mSvyr^{-1} with a weighted average of 0.23mSvyr^{-1}. Whereas the outdoor aede estimated from measured sediment in the laboratory ranges from 0.06 ± 0.02 - 0.11 ± 0.03mSvyr^{-1} with a weighted average of 0.10 ± 0.01mSvyr^{-1}. It can be observed that the value of aede measured in the field is higher than that estimated from measured sediments radioactivity, this could be due to radon produced continuously in air. Both the field and laboratory aede are above the world average values of 0.07mSvy^{-1} (UNSCEAR, 2000) but within the 1.0mSvy^{-1} set limit (ICRP, 1991).

The elcr estimated from field measurement varies from 0.81 x 10^{-3} - 1.05 × 10^{-3} with an average of 0.89 × 10−3 while that estimated from laboratory measurement varies from (0.22 ± 0.07) × 10^{-3} - (0.44 ± 0.11) × 10^{-3} with an average of (0.30 ± 0.02) × 10^{-3}. It can be observed that the weighted average elcr value from both field and laboratory measurements are greater than the world average of 0.29 × 10−3 (Ravisankar et al., 2007). This means extra cancers is expected from the exposed population of people living in this environment.

Table 2: The Ds in nGyh−1, outdoor aede in $mSvyr^{-1}$ and elcr for both field and laboratory measurements.

Location	Field			Laboratory		
	Ds	AEDE	ELCR ($\times 10^{-3}$)	Ds	AEDE	ELCR ($\times 10^{-3}$)
A1	145	0.25	0.98	47.4 ± 8.6	0.06 ± 0.02	0.22 ± 0.07
A2	130	0.23	0.88	59.1 ± 9.8	0.07 ± 0.02	0.28 ± 0.08
A3	125	0.22	0.84	83.0 ± 10.9	0.10 ± 0.02	0.39 ± 0.09
B1	155	0.27	1.05	93.7 ± 10.5	0.11 ± 0.02	0.44 ± 0.08
B2	130	0.23	0.88	93.4 ± 13.6	0.11 ± 0.03	0.44 ± 0.11
B3	125	0.22	0.84	76.6 ± 6.1	0.09 ± 0.01	0.36 ± 0.05
C1	125	0.22	0.84	77.7 ± 13.3	0.10 ± 0.03	0.37 ± 0.10
C2	120	0.21	0.81	55.0 ± 4.2	0.07 ± 0.01	0.26 ± 0.03
C3	130	0.23	0.88	58.7 ± 9.4	0.07 ± 0.02	0.28 ± 0.07
Weighted average	132	0.23	0.89	65.1 ± 2.6	0.10 ± 0.01	0.30 ± 0.02

4. Conclusion

The absorbed dose rates (Ds) of river Kaduna sediments of Kudenda area were measured above the ground surface (at 100 cm) in the field using Rados survey meter. Soil samples (sediments) were also taken and measured using low-level gamma-ray detector (3 × 3 inches NaI:Tl) in the laboratory. The Ds was used to estimate the outdoor aede and elcr. The aede and elcr values

obtained from field measurement were higher than those from laboratory measurement. The result -from this work were higher than the world average. There is increase in the likelyhood of developing cancer when exposed to such an environment for long.

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TITANITE-ILMENITE ASSEMBLAGE IN GRANODIORITE OF WASIMI, SOUTHWESTERN NIGERIA

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Abstract

Mineral assemblage observed is amphibole + biotite + plagioclase + quartz + titanite + ilmenite + apatite. Titanite occur as anhedral grains interstitial between biotite and plagioclase feldspars, intergrown with amphibole (or as inclusion) and biotite (or replacing it). Also, anhedral titanite forms reaction rim around ilmenite. Amphiboles have sieve textures with inclusions of plagioclase, titanite, ilmenite and quartz. In addition, amphibole forms reaction rim around biotite, plagioclase and quartz. Two sets of plagioclase were identified, Plagioclase 1 occur as inclusion in biotite and amphibole, while Plagioclase 2 mantles both amphibole and biotite. Anhedral quartz occur as interstitial grains in contact with amphibole and plagioclase, and in some cases mantles plagioclase feldspar. Textural observations made on the rock strongly suggest that Plagioclase 1 could have supplied Ca, while ilmenite loses its FeO to the formation of titanite rims and subsequent formation of biotite. Biotite could have taken K_2O and FeO and Plagioclase 2 enriched in albitic component. The reaction rim of amphibole on most of the other minerals is an indication that amphibole formed in the late stage of crystallization.

Key words: Anhedral titanite, ilmenite, reaction rim, magmatic phases, sieve texture

1. Introduction

Titanite which commonly occur as accessory mineral can crystallize in both igneous and metamorphic rocks (Franz and Spear, 1985; Lucassen et al., 2003; Pan et al., 2018), and can have magmatic, metamorphic and hydrothermal origins (Mazdab et al., 2007). Igneous titanite occurs mostly as a late-stage mineral in felsic calcalkaline plutons (Kohn, 2017). Titanite are common accessory mineral in granodiorites (Carcangiu et al., 1997; Uher et al., 2019). Accessory titanite has the capability to record formation ages as well as crystallization conditions of magmatic process (Jiang et al., 2016). The iron in titanite is Fe^{3+} and occupies the Ti site (Seifert and Kramer, 2003). Titanite can thus be considered an important store or repository for Rare Earth Elements (REE) and High Field Strength Elements (HFSE) in metamorphic and igneous rocks (Tiepolo et al., 2002; Zhou et al., 2021). Titanite is highly responsive to changes in temperature (Hayden et al., 2008), oxygen and water fugacity, and fluid composition (Manning and Bohlen, 1991; Cao et al., 2015). Previous study has described granodiorite of Wasimi as dark-spotted, coarse-grained, lightcoloured rock which comprises low-lying outcrops and boulders (Oziegbe et al., 2020a). This study uses the textural relationship to determine the origin of titanite in granodiorite and to interpret the coexistence of titainite with ilmenite and biotite.

2. Geological setting

The Nigerian basement complex is part of the Pan-African mobile belt which lies between the West African and Congo Cratons (Figure 1). Wasimi which is the area of study is 12.4 km NE of Ikire. Charnockite, early granitic phases of Older Granite Cycle, and younger granitic phases of Older Granite Cycle, migmatite and amphibolite are the prominent rock units at Wasimi (Figure 2). The units can best be described as Migmatite-Gniess-Granite-Complex (Hubbard, 1975). Early tonalitic and syenitic diapirs and late magmatic, granitic, pegmatitic and aplitic intrusions have been reported within Iwo-Ikire complex of southwestern Nigeria (Hubbard, 1975). 'Older Granite' which is now very common of literature of granite in Nigeria was brought in by Falconer (1911) to differntite the concordant or semi-concordant granites (or deep-seated) of the Basement Complex from the highly discordant (or high-level) tin-bearing granites found in Northern Nigeria.

3. Methodology

Thin sections of granodiorite from Wasimi (7^{o} 26' 7.35"N 4^{o} 15' 53.586"E) were prepared and the labouratory of the Depatment of Geology, Obafemi Awolowo University, Nigeria.

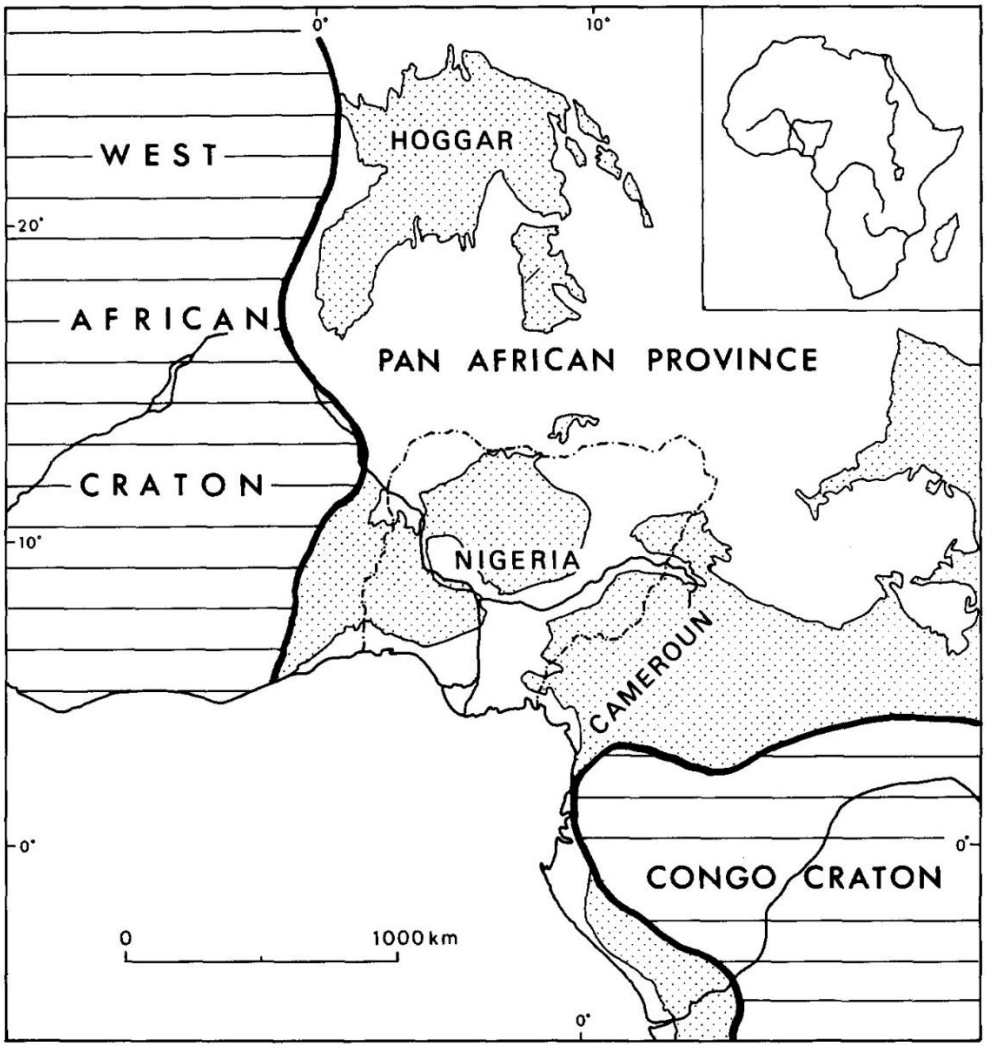

Figure 1: Location Map showing position of Nigerian sector of the Pan-African Province of West Africa (Turner, 1983).

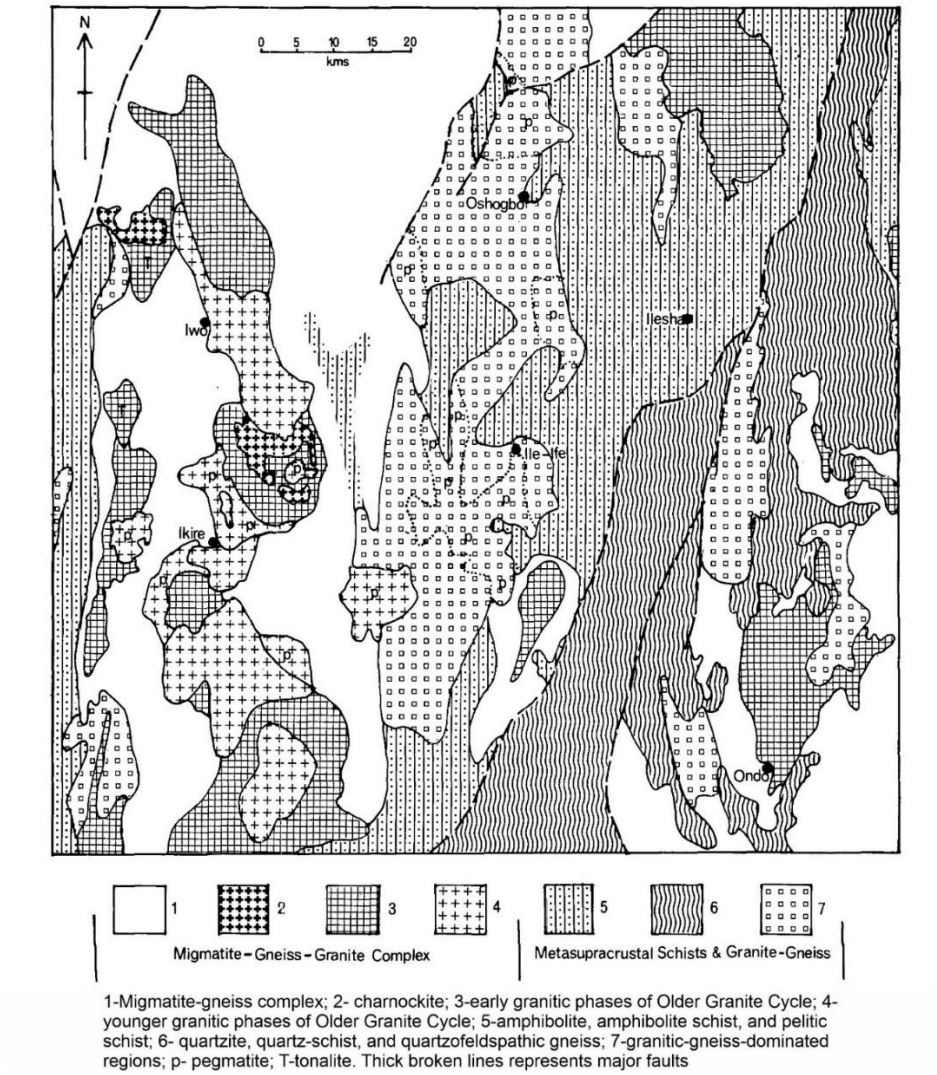

Figure 2: Geologic map of Iwo region of which Ikire-Wasinmi complex is part (Hubbard, 1975).

Detailed petrography of the thin sections was done at the labouratory of the Department of Geosciences, University of Lagos, Nigeria using a polarizing microscope. Photomicrographs of areas of interest were taken with the aid of a digital camera.

4. Results

Petrography

The following minerals were observed, amphibole, biotite, plagioclase, titanite, quartz, ilmenite and apatite. Amphibole is light green to brownish in colour having inclusions of titanite, plagioclase, apatite and ilmenite (Figures 3a - 3d) and can be described to have sieve texture. The

inclusions are more concentrated in the cores of amphibole grains. Biotite grains and brown, green in colour and in close contact with amphibole and in some cases rimmed by amphibole (Figures 3e, 3f, 4a & 4b). Also, deep-brown biotite (altered biotite) were observed, most of which have inclusions of titanite. Amphibole and biotite are both mantled by plagioclase feldspar (Figure 4c & 4d). Titanite are anhedral and forms reaction rim on ilmenite (Figures 4a & 4b). Also, titanite occur at the edges of biotite in the proximity of plagioclase (Figure 4e & 4f), and as inclusions in amphibole (Figure 4a). Two generations of plagioclase feldspars were observed, the first generation (Plagioclase 1) which occur as inclusions in biotite and amphibole and second generation (Plagioclase 2) which mantles both amphibole and biotite (Figure 4d). Anhderal to subehdral quartz occur as interstitial grains in contact with amphibole, biotite and plagioclase (Figures 5). In some cases, anhedral quartz mantles plagioclase feldspars (Figure 5d). Euhedral apatite occur as inclusions mainly in biotite and amphibole, while some grains occur within the matrix (Figures 3c & 3d).

5. Discussion

The textural feature in which titanite reaction rims surround ilmenite has been reported from amphibolite-facies terranes (Harlov and Forster, 2002; Harlov and Hansen, 2005). This texture can be formed from the destruction of minerals such as pyroxenes and hornblende and leaving quartz (Drakoulis et al., 2013). Seive-textured amphibole may be the result of bulk assimilation of xenoliths from the magma during crust-mantle mixing (Beard et al., 2005). Sieve-textured amphibole with inclusions of pyroxene, plagioclase and quartz has previously been described in granodiorite of Wasimi (Oziegbe et al., 2020a). The texture can be used to describe the late-stage formation of biotite and amphibole at expense of orthopyroxene, clinopyroxene, and ilmenite (Beard and Day, 1988; Beard et al., 2005).

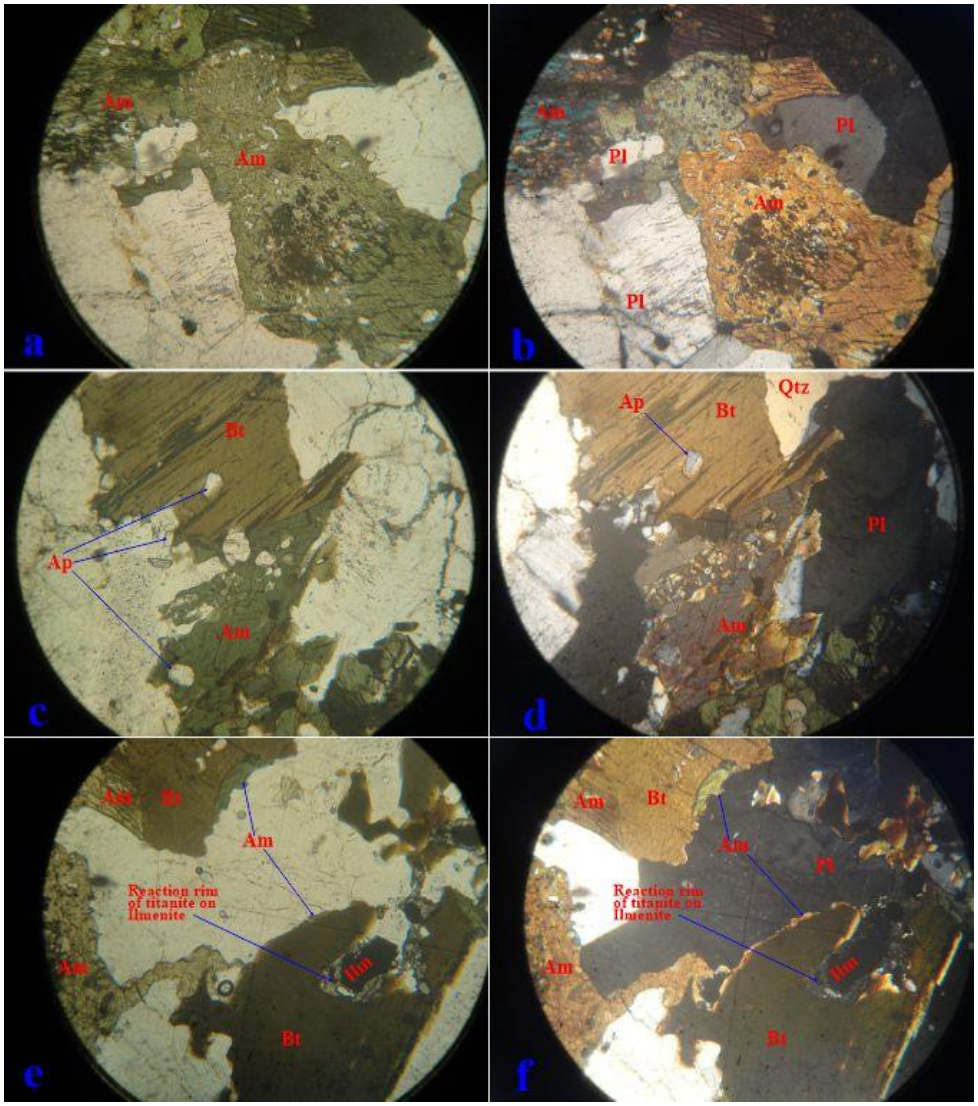

Figure 3: Photomicrographs of granodiorite showing a) Sieve-textured greenish amphibole (Am), PPL b) sieve-textured amphibole (Am) surrounded by plagioclase feldspar (Pl). XPL c) amphibole (Am) in contact with biotite (Bt), amphiboles and biotite both having inclusions of apatite (Ap), PPL d) amphibole (Am) and biotite (Bt) surrounded by plagioclase feldspar (Pl), XPL e) amphibole (Am) forms reaction rim on both biotite (Bt) and titanite (Ttn), while titanite (Ttn) forms reaction rim on ilmenite (ilm), PPL. f) amphibole (Am) forms reaction rim round biotite (Bt), plagioclase feldspar (Pl) and titanite (Ttn), XPL.

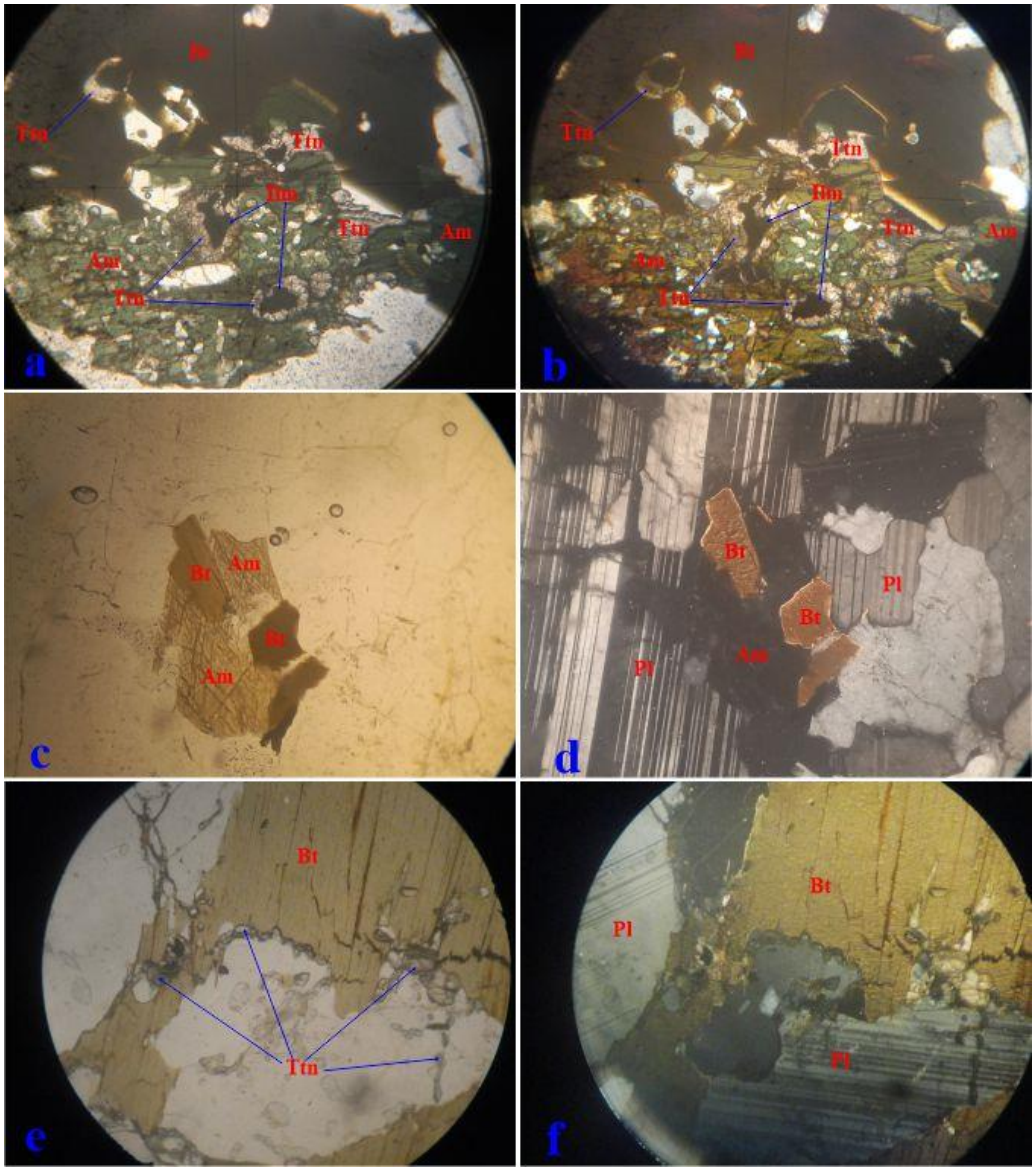

Figure 4: Photomicrographs of granodiorite showing a) sieve-textured amphibole (Am) with inclusions titanite (Ttn) and ilmemite (Ilm), take note of reaction rim of titanite (Ttn) on ilmenite (Ilm), biotite (Bt) in contact with amphibole (Am), PPL b) sieve-textured amphibole (Am) with inclusion of tiranite (Ttn) and ilmenite, XPL c) brownish amphibole (Am) in contact with biotite (Bt), PPL d) amphibole (Am) and biotite (Bt) mantled by plagioclase feldspar, XPL, e) titanite (Ttn) along the edges of biotite (Bt), PPL f) titanite (Ttn) between biotite (Bt) and plagioclase feldspar (Pl), XPL.

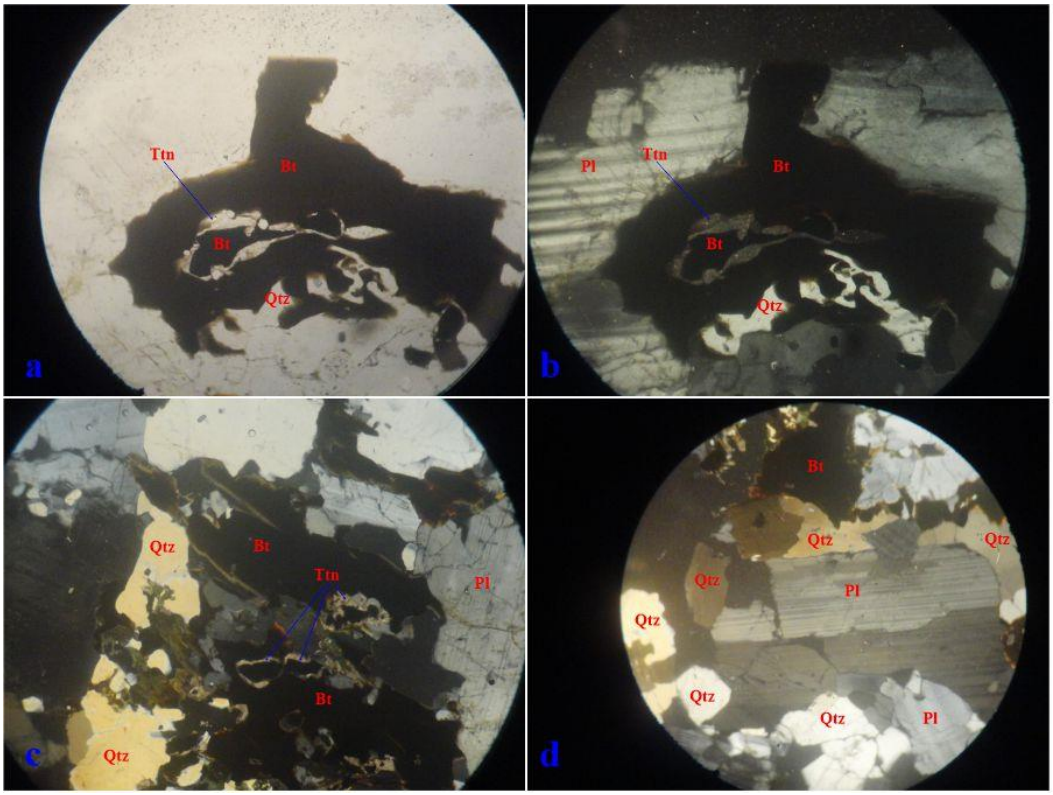

Figure 5: Photomicrographs of granodiorite showing a) reaction rim of titanite (Ttn) on deep-brown biotite (Bt). PPL b) biotite (Bt) surrounded by plagioclase feldspar (Pl) and quartz (Qtz), XPL c) titanite (Ttn) enclosed within biotite (Bt), biotite surrounded by plagioclase feldspar (Pl) and quartz (Qtz), XPL d) plagioclase feldspar (Pl) mantled by quartz (Qtz), XPL.

Such hornblende texture has been ascribed to K- and Si-metasomatism after solidification of the plutonic rocks (Collins, 2003).

Studies have observed that the Ca/Al ratio of a melt influences the presence or absence of titanite in igneous rocks (Frost et al., 2001). Based on the fact that clinopyroxene is absent, the reaction can be represented by Equation (1) (Harlov and Hansen, 2005):

$$\text{Amphibole} + \text{Ilmenite} + O_2 \Longrightarrow \text{Titanite} + \text{Magnetite} + \text{Quartz} + H_2O \qquad (1)$$

This implies that TiO_2 is extracted from ilmenite was used in the formation of titanite. Such reactions have been reported in orthogneisses of the amphibolite facies (Harlov. and Förster, 2002). Titanite forming reaction rim on opaque (ilmenite) has been reported in the tonalitic

samples of Iwo region (Oziegbe et al., 2020b). A study on amphibole-orthogneiss has reported a similar texture (Gutiérrez-Aguilar et al., 2021). Also, study on amphibolites has reported a similar texture (Rene, 2008). Clinopyroxene + ilmenite-bearing assemblages have been reported to transform into amphibole + titanite-bearing assemblages (Frost et al. 2001). Titanite has been reported to commonly form with amphibole in the late stage of crystallization (Xirouchakis et al., 2001).

Titanite along biotite grains (Figures 4e & 4f) is an indication that titanite is a by-product of the reaction in which plagioclase replaces biotite (Wintsch et al 2015). Plagioclase could be the source of Ca for titanite (Imon et al., 2002), while silica could be from the dissolution of quartz. Textural feature show plagioclase feldspar mantled by quartz (Figure 5d). Anhedral titanite has been described as secondary titanite forming as reaction rim around primary magmatic phases (Piccoli et al., 2000). The replacement of ilmenite by titanite in the absence of magnetite is indicative of relatively low oxygen fugacity (Cao et al., 2015). Texture of reaction rim on ilmenite is suggestive of reducing environment for hydrothermal fluid (Cao et al., 2015). Magmatic titanite has been reported to occur in late magmatic stage (Cao et al., 2015). Titanite in interstices/cleavages and enclosed within primary biotite (Figures 4a, 4e, 5a & 5b) can be described as magmatic titanite based on the fact that it was formed before biotite and because the grains occur in the late stage of magmatic process (Cao et al., 2015). The reaction texture in Figures 3a & 4e can be best represented by Equation (2), (Harlov et al., 2006):

$$\underset{\text{Plagioclase 1}}{[XCaAl_2Si_2O_8 + YKAlSi_3O_8 + ZNaAlSi_3O_8]} + \underset{\text{Ilmenite}}{3AlFeTiO_3} + AH_2O =$$

$$[(X-3A)CaAl_2Si_2O_8 + \underset{\text{Plagioclase 2}}{(Y-A)KAlSi_3O_8} + (Z+4A)NaAlSi_3O_8] + \underset{\text{Titanite}}{3ACaTiSiO_5} + AKFe_3Si_3AlO_{10}(OH)_2 \quad (2)$$

Biotite

Plagioclase 1 (Ca-rich plagioclase) supplies Ca, while ilmenite loses its FeO to the formation of titanite rims as well as the formation of biotite (Harlov et al., 2006). Biotite takes K_2O and FeO and Plagioclase 2 is enriched in albitic component. Textures of inclusion of titanite in biotite (Figures 4a, 4b, 5b, 5c & 5d) with the absent of ilmenite in the core can be represented by the reaction in Equation (3), (René, 2019):

Andesine + Ti-rich annite = Titanite + Oligoclase + Quartz (3)

This chemical reaction has been proposed for the titanite of late-magmatic origin in I-type granite and spotted granodiorite (Broska et al., 2007; René, 2019).

6. Conclusion

As shown in the petrography, straight edges of some mineral grains (amphibole, biotite and plagioclase feldspar), coupled with reaction rim of late amphibole on biotite, plagioclase feldspar and quartz are suggestive of igneous origin. Textural observations made on the rock strongly suggest two origins for titanite: 1) reaction of Ca-rich plagioclase with ilmenite to produce titanite, Na-rich plagioclase (albitic plagioclase) and biotite, and 2) Ca-rich plagioclase (andesine) reacting with biotite (Ti-rich annite) to give titanite, albite-rich plagioclase (oligoclase) and quartz. Amphibole can be interpreted as a product of late stage magmatic crystallization.

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OCCURRENCE AND ANTIBIOTICS SUSCEPTIBILITY PATTERNS OF *YERSINIA ENTEROCOLITICA* FROM PIGS AND DIARRHOEIC HUMANS IN SELECTED FARMS AND HOSPITALS IN SHANGO, MINNA, NIGER STATE, NIGERIA

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Abstract

Yersinia enterocolitica is a food-borne enterotoxigenic microorganism associated with human gastroenteritis and septicaemia especially among children. Pigs constitute a major source of infection for man. The increase in pig farms and pork consumption in Shango community of Minna, Niger State North Central, Nigeria; necessitated investigation into the occurrence of *Yersinia enterocolitica* in diarrhoeic pigs and humans in selected farms and hospitals in this region. Three hundred and fifty diarrhoeic samples were collected: 150 from pigs raised in 3 selected farms, 60 from children aged 2-6 years and 140 adults (22-50years) in medical wards of 2 selected hospitals located in the study areas. *Yersinia enterocolitica* was isolated from faecal samples and identified biochemically by standard bacteriological methods. Susceptibility of *Yersinia enterocolitica* to 19 antibiotics was determined by disc diffusion method. Data were analysed using descriptive statistics and ANOVA at $p<0.05$. Forty-five *Yersinia enterocolitica* isolates comprising 15 from humans: 08 and 07 from the 2 selected hospitals and 30 from pigs: 10, 08 and 12 from the 3 selected farms were identified. The antimicrobial susceptibility spectrum from human showed 100% susceptibility to quinolones (ciprofloxacin and pefloxacin). Others includes-gentamicin (86.7%), cefuroxime (86.7%), trimethoprim (80%), sulphamethoxazole (80%), cotrimazole (73.3%), erythromycin (73.3%), cefotaxime (66.7%), ceftriaxone (66.7%), cloxacillin (60%) and amikacin (60%) While highest degree of resistance (100%) were exhibited to ampicillin, cefazolin and amoxicillin, followed by tetracycline (83.3%) and chloramphenicol (83.3%). Similar antimicrobial patterns were demonstrated from the *Y. enterocolitica* strains from the pig's faecal samples. *Y. enterocolitica* showed 100% susceptibility to quinolones (ciprofloxacin and pefloxacin). Others includes-gentamicin (86.7%), cefuroxime (86.7%), trimethoprime (80%), cotrimazole (73.3%), erythromycin (73.3%), cefotaxime (66.7%), furazolidone (66.7%), sulphamethoxazole (52%), and amikacin (60%) While highest degree of resistance (100%) were exhibited to ampicillin, cefazolin and amoxicillin, followed by chloramphenicol (75%), cloxacillin (75%) tetracycline (71.7%). There was significant difference between the occurrence of *Yersinia enterocolitica* in human and pig isolates. These organisms may constitute public health hazard, hence proper piggery hygiene and disposal of waste is advocated to prevent contamination of water and food of humans. Legislation on misuse and abuse of antibiotics should be enforced to prevent drug resistance.

Keywords: *Yersinia enterocolitica*, Diarrhoea, Bacteriology, Pigs, Antibiotic profile.

1. Introduction

Yersinia enterocolitica is an Enteropathogenic, psychotropic, Gram negative, facultative anaerobic zoonotic bacterium belonging to the family Enterobacteriaceae (Bancerz-Kisiel *et al*., 2018). It is a biochemical and serologically heterogeneous species, it has six biotypes (1A, 1B, 2, 3, 4 and 5) (Wauters *et al*., 1987), with approximately 70 serotypes and some serotypes related to human diseases e.g. 0:3, 0:5. 27, 0:8 and 0:9 (Ye *et al*., 2016; Peruzy *et al*., 2017). *Y.enterocolitica* can be bio typed according to their pathogenic properties: the non-pathogenic biotype 1A has involvement in human gastroenteritis (Movafagha *et al*., 2021) especially in children (Bottone 1997), less pathogenic, the biotypes 2–5, and highly pathogenic biotype 1B associated with human infections (Bancerz- Kisiel *et al*., 2018 ; Tavassoli *et al*., 2018). The most frequently responsible biotype for human infections worldwide is biotype 4 (Drummond et *al.,* 2012), which is almost systematically associated with serotype O: 3 (4/O: 3), followed by bioserotype 2/O: 9. Yersiniosis comes after Campylobacteriosis and Salmonellosis as a gastrointestinal infection (Zadernowsks *et al*., 2014) and manifested by acute diarrhoea, abdominal pain, fever, and sometimes vomiting (Rosner *et al*., 2013), septicemia in elderly and immuno-compromized patients (Savin *et al.*, 2012), Reactive arthritis and erythema nodosum are the most frequent secondary complications (Bottone , 1997), mesenteric lymphadenitis, and pseudo appendicitis (Tavassoli *et al*., 2018). Other human infections include terminal ileitis, intestinal intussusception, and arthritis (Imoto *et al.,* 2012). Moreover, *Y. enterocolitica* can occasionally be present as a primary skin and soft tissue abscess from direct inoculation and extend to cause regional suppurative adenitis (Menzies, 2010). *Y. enterocolitica* related pneumonia has also been reported (Wong *et al.*, 2013). *Y. enterocolitica* related pneumonia has also been reported (Wong *et al.,* 2013). The primary pathogenic event of *Y. enterocolitica* is colonization of the intestinal tract where most of the pathologic effects and clinical manifestations occur. Temperature and calcium concentration regulate expression of virulence factors that guide the invading yersinia and allow them to survive and disseminate (Fàbrega and Vila, 2012). For 2019, 29 countries reported 7048 yersiniosis cases in the Europe with an overall notification rate of 1.7 per population remained stable from 2015 to 2019 (ECDC, 2021). Pigs are the main reservoir of bioserotype 4/O: 3 strains (Drummond *et al.,* 2012). These animals are asymptomatic carriers of the bacteria in their tonsils and intestinal tract, and they shed the Enteropathogen in the environment with their stools. Contamination of pork meat often occurs during pig evisceration at slaughter (Liang *et al*., 2012; Ferl *et al.,* 2020). *Y. enterocolitica* had also been isolated from humans, alpine ibex, sheep, birds, rodents, African green monkeys, wild boar, as well as from the environment, such as water and soil (Virtanen *et al*., 2012; Modesto *et al*., 2021). Raw pork meat has been shown to be the most important reservoir for human pathogenic *Y. enterocolitica* (Rosner *et al.,* 2012). Reports indicated that butchers who handled swine throats and intestines had elevated levels (27%) of *Y. enterocolitica* O: 3 antibodies compared to blood donors (10%) (Merilahti-Palo *et al.,* 1991). Studies reported the isolation of pathogenic *Y. enterocolitica* from the stools of patients presenting with enteric infections (Okwori *et al*., 2007). Indirect person-to-

person transmission has apparently occurred in several instances by transfusion of blood product (Mitchell and Brecher, 1999). In these cases, the most likely source of *Yersinia* has been blood donors with subclinical bacteremia (Feng *et al.,* 1992). The significance of food product contamination during processing is underscored by the organism's ability to grow in properly refrigerated food, including raw and cooked meat and milk. Virulence appears to be mediated by a variety of plasmid (YadA: a pYV-encoded adhesion Yop (Yersinia outer proteins) secretion and the Ysc secretion apparatus.) and chromosomally encoded resistance factors (Invasin. Inv (Attachment invasion locus) Ail. Myf fibrillae. (Mucoid *Yersinia* factor), that promote adhesion to and entry into enterocytes, confer resistance to complement-mediated immune responses, and inhibit the antiinvasive effect of interferon (Hartland and Robins-Browne. 1998; Grassl *et al*., 2003). The genome sequencing of a representative of the most epidemiologically successful *Y.enterocolitica* subsp. palearctica strain Y11, serotype O: 3, biotype 4 has been finished and annotated (Batzilla *et al.,* 2011). The incubation periods of *Y. enterocolitica* varies between 4 and 7 days and have affinity for the lymphoid tissue and penetrate into the Ileal mucosa via the M - cells of Peyer's Patches. From the basolateral site they invade the intestinal epithelial cells- resulting in gastroenteritis (Parregaard *et al*., 1991; Murray *et al.,* 2003**).** Records have showed that *Y. enterocolitica* was susceptible to many antimicrobial agents except penicillin, ampicillin, amoxicillin-clavulanic acid, and the first-generation cephalosporins (Bolton *et al*., 2013; Bonardi *et al*., 2018), and the main cause of drug resistant of *Y.enterocolitica* strains in food and the environment is the usage of antibiotics in animal farms and transmission of antibiotic-resistance gene through dissimilar species of bacteria (Özdemir and Arslan, 2015). Moreover, the main cause of the treatment failures is the presence of antimicrobial resistance that lead to need for expensive and/or toxic alternative drugs which may be more expensive in most cases and this spreading of drug resistance for *Y. enterocolitica* is very important for public health appraisal (Pandove *et al*., 2012). Despite the numerous works that has been done on *Yersinia enterocolitica* in the advanced countries, it is still pertinent to have more knowledge on the organism, since new strains showing multi resistance to drugs are emerging particularly in the developing countries like Nigeria. This study determined the carriage of *Y. enterocolitica* in the animal reservoir (pigs) and in human diarrheal diseases and antibiotic susceptibilities patterns of commonly used antibiotic drugs in *Yersinia enterocolitica isolates* in Shango community of Minna, Niger State where the consumption of pork meats are considerably high.

2. Materials and Methods

Materials

Study area: The study was carried out in Shango community in Minna, Niger State, Nigeria between Latitudes 9º336'81'N and Longitudes 6º355.44'E (Fig.1). Stool samples from both apparently healthy and diarrhoeic patients and healthy pigs were collected from Hospitals and Piggery respectively and assessed for their *Y. enterocolitica* species contents from this community.

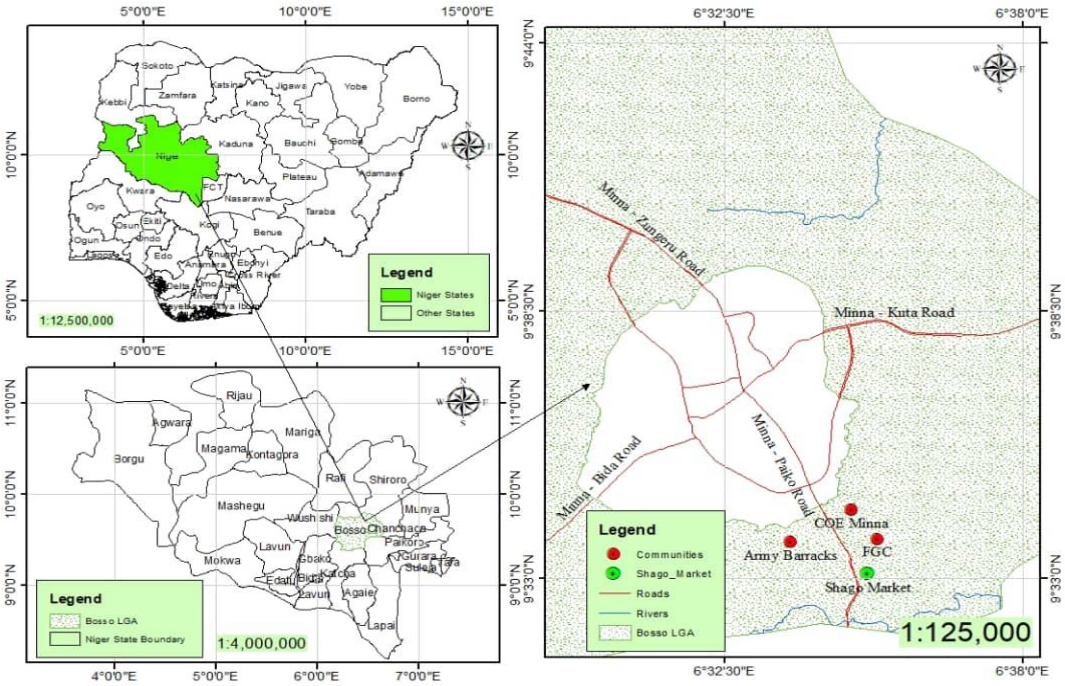

Fig. 1: Map of Study Area (Shango community, Minna) Source: Adapted from Minna Street Map, 2014

Ethical approval:

Ethical approval was obtained from the Ministry of Health, Niger state, before the commencement of sample collection.

Study design:

The research, a cross sectional study, and the sample were collected from both male and female patients. Clinical data for each diarrhoeic patient were collected, such as the age, gender, educational and occupational status, using structured questionnaire, to identify the possible socio-demographic factors that assessed a patient's hospital and community risk for Yersiniae acquisition.

Study participants:

These comprised of patients with clinically diagnosed cases of diarrhoea. Informed consent was obtained from the patients concerned.

Sample Collection from Hospitals (Human source):

A total number of two hundred freshly voided faecal samples from apparently healthy individuals and diarrhoeic patients were collected into sterile sample bottles from Hospitals (Primary Health care Centre, Shango, Minna and General Hospital Minna, Niger State). Sixty faecal samples from the paediatric wards and 140 faecal samples from the Adults males/ females wards.

Sample Collection from Animal Farms (pigs):

A total number of one hundred and fifty faecal samples from healthy pigs (with no history or signs of illness) were collected into sterile sample bottles from the farms. Fifty samples each from designated farms (A, B and C). All faecal samples collected in sterile sample bottles in this study between June and September, 2022, were transported immediately to the Department of Microbiology laboratory and processed within two to three hours of collection/ defaecation for microbial analysis.

Isolation of *Yersinia enterocolitica*

(A). A loop full of fresh faecal samples from pigs and diarrhoeic human patients were prepared respectively as a 10% suspension in 0.067M phosphate buffer (PBS, pH 7.6) in a sterile labelled test tubes and incubated at 4°C for 3-7 days according to methods described previously (FDA/CFSAN, 2001; Okwori *et al.,* 2005; Van Damme *et al.* 2013). The enrichment cultures were then streaked respectively and aseptically onto MacConkey agar and Deoxycholate agar plates and incubated at 37°C for 48 hours according to Standard methods (Weissfeld and Sonnenwirth, 1982). All the non-lactose fermenting colonies from Deoxycholate and MacConkey agar plates were sub-cultured onto freshly prepared MacConkey agar for purity and further identification.

(B). Direct plating of the faecal samples was equally done onto MacConkey agar and Deoxycholate agar plates and incubated at 37^0C for 24-48 hours. After an initial examination, the colonies were purified by sub-culturing the colonies onto another MacConkey agar and Deoxycholate agar plates, returned to the incubator for another 24-48 hours. After 48 hours of incubation, morphological characteristics of the isolates were recorded. Every culture and subculture was properly labelled. The pure non-lactose fermenting colonies (small 1-2mm diameter), flat, colourless, or pale pink colonies from MacConkey agar plates were sub-cultured onto nutrient agar slants and stored at 4°C. Throughout this study stock cultures were maintained on nutrient agar slants stored at 4°C with periodic subculture to maintain their viability (Barrow and Feltman 1993).

Identification of Isolates

The essential preliminary screening tests include:

Cultural and Morphological Characteristics

The cultural characteristics of the isolates were confirmed on MacConkey agar. Smears were made from typical colonies i.e small non-lactose fermenting colonies by emulsifying the organism in a small drop of normal saline on the glass slide to give an even suspension. This was air-dried and the preparation was fixed by passing through a Bunsen flame and was Gram stained. Those colonies that stained Gram- negative and appeared coccobacillary were further tested by examining a Giemsa stained smear for coccobacillary showing bipolar staining. Biochemical characteristics, (viz : catalase production, urease production, Nitrate reduction, Citrate utilization,

Oxidase production, Phenylalanine deaminase, Ornithine decarboxylase, indole production, hydrogen sulphide production, esculin hydrolysis, Pyrazinamidase, and beta-D-glucosidase), motility and test for metabolism of carbohydrates this includes: Monosaccharides (Glucose, xylose, and sorbose), Disaccharides (Sucrose, lactose and trehalose), polyhydric alcohol (inositol) and Glycoside (Salicin) were carried out as described by Barrow and Feltman (1993)and Garcia and Isenberg (2007).

Antibiotics Susceptibility Testing

Antimicrobial susceptibility test for the confirmed *Yersinia enterocolitica* isolates were determined using disk diffusion method (Kirby Bauer method) on Mueller–Hinton agar plates (HiMedia Laboratory Ltd,India) using calibrated inoculums of the isolates based on McFarland standard with the following antibiotics: Gentamicin (10 µg), Cotrimazole (25 µg), Chlorapmhenicol (10 µg), Ampicillin (25 µg), Cloxacillin (5 µg), Pefloxacin (5 µg), Cefuroxime (30 µg), Cefotaxime (30 µg), Furazolidone (50 µg), Erythromycin (50 µg), Tetracycline (30 µg), Trimethoprim (25 µg), Ciprofloxacin (5 µg), Amikacin (5 µg), Sulphamethoxazole (23.75 µg), Amoxycillin- Clavulanate (25 µg/10 µg), Ceftriaxone (30 µg) and Cefazolin(30µg) as described by CLSI (2018). The antibiotic discs were from BD Diagnostic Systems (Becton Dickinson, Sparks, MD, USA).

3. Results

In this study a total number of 200 faecal samples from diarrhoeic patients were examined for the occurrence of *Y. enterocolitica*. 100 samples each were collected from Primary Health care Centre, Shango, Minna and General Hospital Minna, Niger State while 150 pig's faecal samples were examined for occurrence of *Y. enterocolitica*. 50 samples each was collected from the 3 different farms studied (Farm A, Farm B, and Farm C) all in Shango, Minna, Niger State. The antimicrobial susceptibility spectrum of each of the isolates to nineteen (19) different antibiotics was determined by standardized single disc diffusion method. *Y. enterocolitica* isolates from human showed 100% susceptibility to Quinolones (ciprofloxacin and pefloxacin). Others includes-gentamicin (86.7%), cefuroxime (86.7%), trimethoprim (80%), sulphamethoxazole (80%), cotrimazole (73.3%), erythromycin (73.3%), cefotaxime (66.7%), ceftriaxone (66.7%), cloxacillin (60%) and amikacin (60%) While highest degree of resistance (100%) were exhibited to ampicillin, cefazolin and amoxicillin, followed by tetracycline (83.3%) and chloramphenicol (83.3%). Similar antimicrobial patterns were demonstrated from the *Y. enterocolitica* strains from the pig's faecal samples. *Y. enterocolitica* showed 100% susceptibility to quinolones (ciprofloxacin and pefloxacin). Others includes-gentamicin (86.7%), cefuroxime (86.7%), trimethoprime (80%), cotrimazole (73.3%), erythromycin (73.3%), cefotaxime (66.7%), furazolidone (66.7%), sulphamethoxazole (52%), and amikacin (60%) While highest degree of

resistance (100%) were exhibited to ampicillin, cefazolin and amoxicillin, followed by chloramphenicol (75%), cloxacillin (75%) tetracycline (71.7%).

TABLE 1: Faecal samples collected from Primary Health care Centre, Shango, Minna and General Hospital Minna, Niger State

	Subjects	**Sex**	Primary Health care Centre, Shango, Minna	General Hospital Minna,	**Total**
1	Children	Male	18	12	30
	(2-6yrs)	Female	17	13	30
		Total	35	25	**60**
2	Adults	Male	30	35	65
	(23-50yrs)	Female	35	40	75
			65	75	**140**
		Grand Total	100	100	**200**

Prevalence of *Y. enterocolitica* from Children (Paediatrics wards) and adult patients with diarrhoea (Medical wards) in Primary Health care Centre, Shango, Minna: Five children and three adult were found to be positive for the occurrence of *Y. enterocolitica* in their faecal samples examined. (Fig. 2)

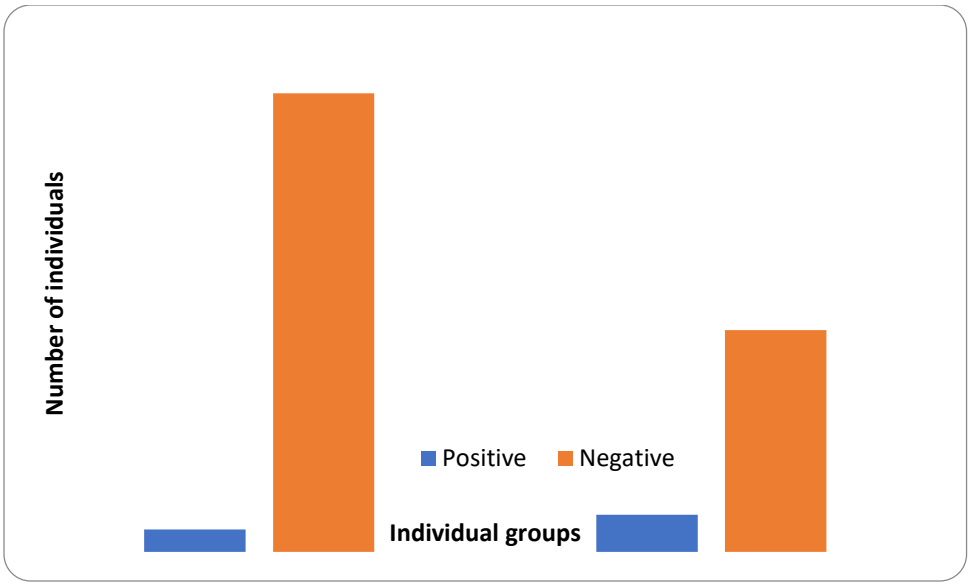

Figure 2: Occurrence of *Y. enterocolitica* from children and adults patient with diarrhoea in Primary Health care Centre, Shango, Minna.

Percentage occurrence: A total of eight (08) patients representing 8% of the sample from Primary Health care Centre, Shango, Minna, were infected with *Y. enterocolitica*. While ninety-two (92) constituting 92% of the patients tested negative to *Y. enterocolitica* infection. Statistically there is significant difference between the patient that had the organism and those that do not have ($p<0.05$).

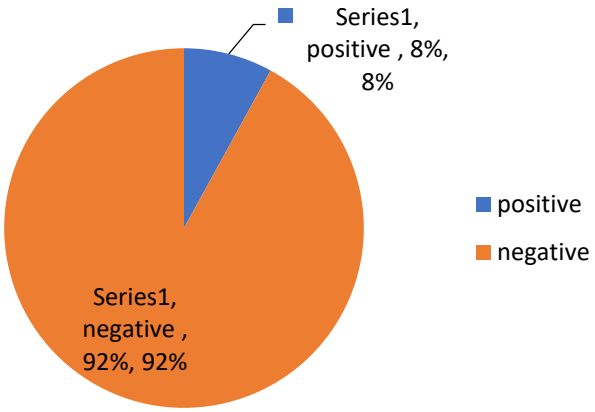

Figure 3: Total percentage occurrence of *Y. enterocolitica* from children and adults patient with diarrhoea in Primary Health care Centre, Shango, Minna

Prevalence of *Y. enterocolitica* in children's (Paediatric ward) and adult patients with diarrhoea in General Hospital Minna, Niger State: Four children were found to carry *Y. enterocolitica* in their faecal samples and 21 children faecal sample test negative for *Y. enterocolitica* in their faecal sample examined in General Hospital Minna, Niger State. Three adults out of 75 patients examined were found to carry *Y. enterocolitica* in their faecal sample examined in General Hospital Minna, Niger State.

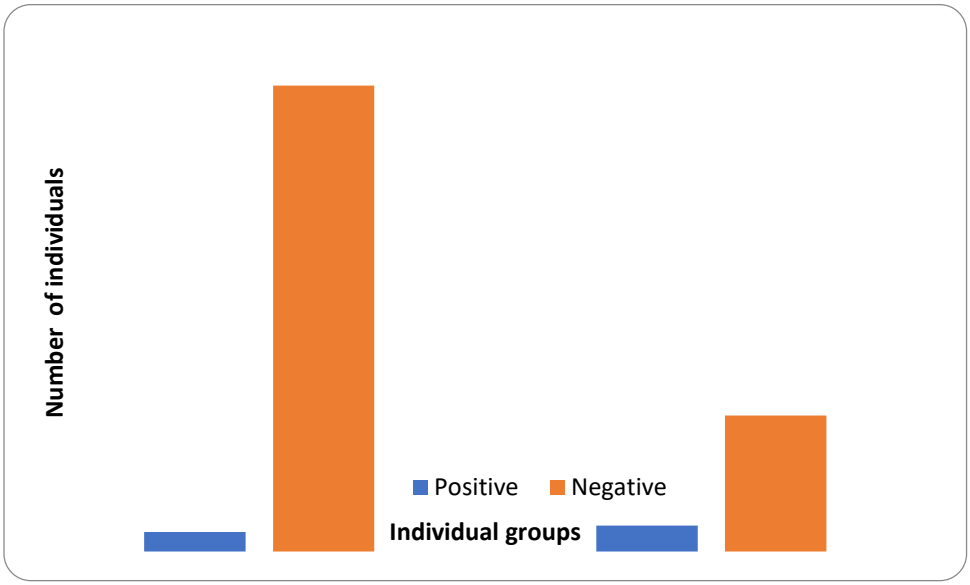

Figure 4: Occurrence of *Y. enterocolitica* from children and adults patient with diarrhoea in General Hospital Minna, Niger State

Percentage occurrence: A total of seven (07) patients representing 7% of the samples from both children and adult faecal sample in General Hospital Minna, Niger State had *Y. enterocolitica* present in their stool while a total of Ninety- three (93) patients constituting 93% of the faecal sample tested negative for *Y. enterocolitica* infection (Fig 5). There is statistical difference between the patient that had the organism and those that do not have ($p < 0.05$).

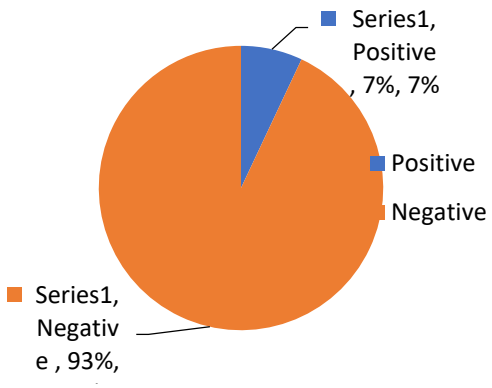

Figure 5: Total percentage occurrence of *Y. enterocolitica* from children and adults patient with diarrhoea in

General Hospital, Minna, Niger State.

Table 2: Total Occurrence of *Y. enterocolitica* in Primary Health care Centre, Shango, Minna and General

Hospital Minna, Niger State

Location	Number Sampled	Number Positive	Number Negative
PRIMARY HEALTH CARE CENTRE	100	08	92
GENERAL HOSPITAL	100	07	93
Total	200	15	185

$\chi^2 = 0.66 < CV = 3.841$; df = 1; p> 0.05

A total of fifteen (15) patients representing 7.5% of *Y. enterocolitica* were isolated from the faecal samples of diarrhoeic patients in both Primary Health care Centre, Shango, Minna and General Hospital Minna, Niger State. The difference in prevalence of the two locations was not statistically significant (P >0.05).

Table 3: Occurrence of *Y. enterocolitica* among pigs in three farms studied

Location (farms)	Number sampled	Number positive	Number negative
A	50	10	40
B	50	08	42
C	50	12	38
Total	150	30	20.0

χ^2 = 0.28 CV = 5.9991; DF =2; P >0.05

No significant difference exist between the three farm areas sampled (p>0.05)

The occurrence of *Y. enterocolitica* in Pigs from different farms studies shows ten pigs were infested with *Y. enterocolitica* in Farm A and 40 pigs faecal sample tested negative for *Y. enterocolitica* infection. In farm B, a total of Eight (08) pigs faecal sample tested positive to *Y. enterocolitica* while 42 pigs tested negative for *Y. enterocolitica* infection in the Farm B. Similarly in farm C, Twelve (12) pigs' faecal samples tested positive for *Y. enterocolitica* while 38 pigs tested negative for *Y. enterocolitica* infection Table 3 and Figure 6.

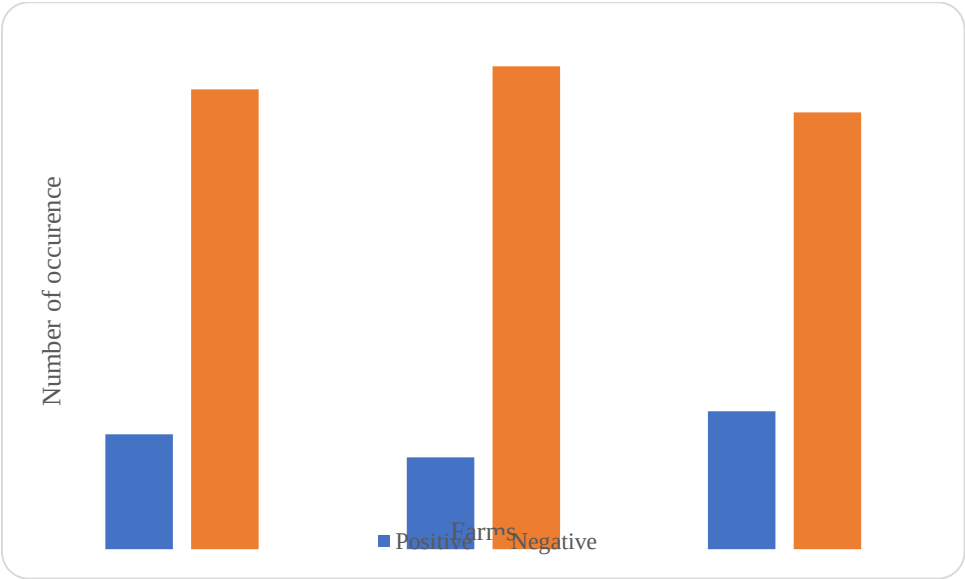

Figure 6: Occurrence of *Y. enterocolitica* among pigs in three different farms studied

Percentage occurrence: A total of thirty (30) pigs faecal sample representing 20% of the total sample size from farm A, B and C had *Y. enterocolitica* present in their faecal sample while a total of one hundred and twenty (120) pigs constituting 80% of the faecal sample tested negative

for *Y. enterocolitica* infection (Fig 7). There is statistical difference between the pigs that had *Y. enterocolitica* present in their faecal sample and those that do not have ($p < 0.05$).

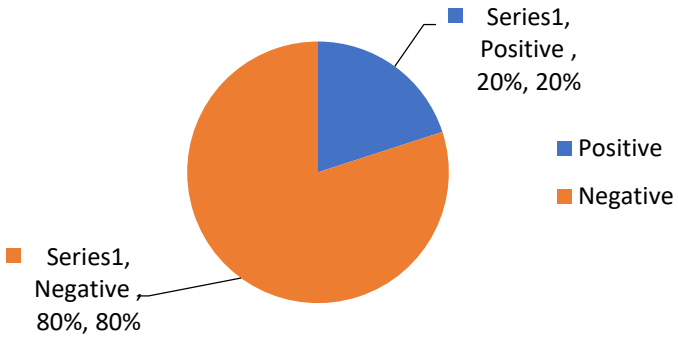

Figure 7: Total percentage occurrence of *Y. enterocolitica* from pigs in three different farms studied

Table 4: *Y. enterocolitica* isolates from pigs and human diarrhoeic faecal samples.

Sources	**Number of samples**	**Number of isolates**	**% Occurrence**
Humans	200	15	7.5
Pigs	150	30	20.0

$\chi^2 = 11.95 > CV = 3.841$; df = 1; $p<0.05$

A total of fifteen (15) *Y. enterocolitica* were isolated from faecal sample of human diarrhoeic faecal samples which account for 7.5% of the sampled size and a total of thirty (30) faecal samples of the pigs had the presence of *Y. enterocolitica* infection which account for 20.0% of the sample size of pigs faecal sample. There is significant difference statistically between the isolation made from human stool samples and pigs faecal samples ($P < 0.05$).

Table 5: Biochemical characteristics of *Y. enterocolitica* isolates from pigs and human diarrhoeic faecal

Samples

Reactions	Results
Cultural properties On MacConkey Agar	Non-lactose fermenting colonies (small 1-2 diameter) flat,colourless or palepink
Gram staining	Gram negative rod
Motility at 25^0C	Actively motile
Motility at 37^0C	Non motile
Fermentation of sugar	
a. Glucose (Acid production)	Positive
b. Sucrose	Positive
c. Trehalose	Positive
d. Salicin	Negative
e. Lactose	Negative
f. Inositol	Positive
g. Xylose	Positive
h. Sorbose	Positive
Catalase test	Positive
Urease production	Positive

Nitrate reduction	Positive
Citrate utilization	Negative
Oxidase test	Negative
Phenylalanine deaminase	Negative
Oxidase test	Negative
Ornithine decarboxylase	Positive
Indole production	Positive

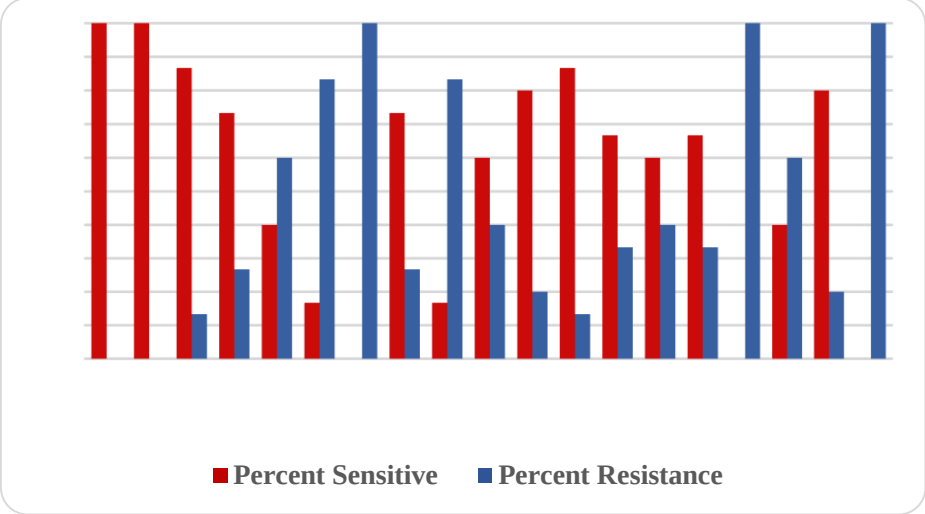

Figure8: Antibiotic susceptibility pattern of *Y. enterocolitica* isolated from diarrhoeic patients (faecal samples) both in Primary Health care Centre, Shango, Minna and General Hospital Minna, Niger State.

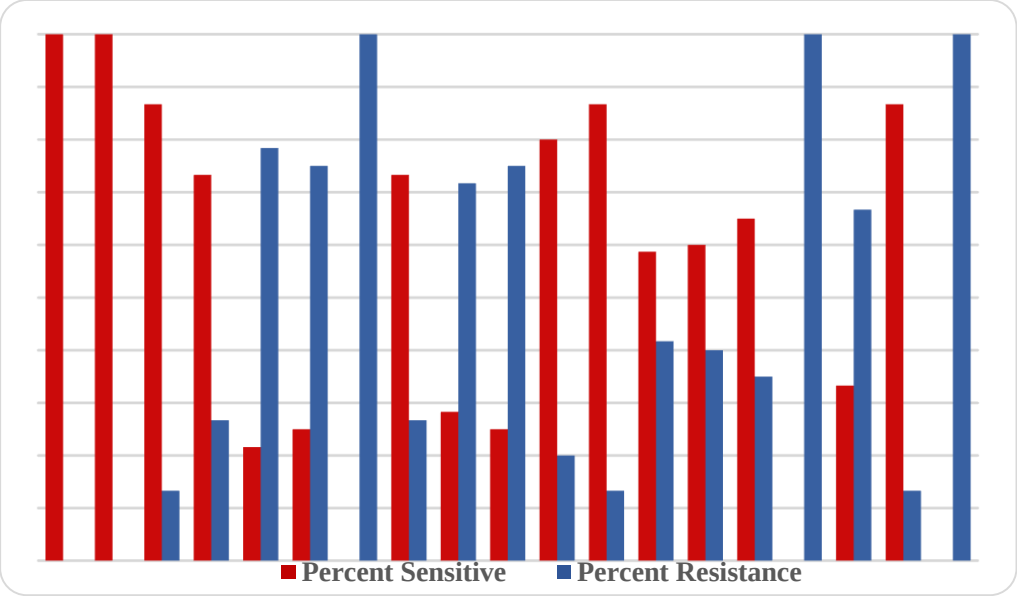

Figure 9: Antibiotic susceptibility pattern of *Y. enterocolitica* isolates from faecal samples of pigs from the three farms studied.

4. Discussion

Yersinia enterocolitica, the cause of human yersiniosis is harboured by healthy pigs (Bottone, 1999; Fredriksson-Ahomaa *et al.*, 2006a; Kuehni-Boghenbor *et al.*, 2006; Rosner *et al.*, 2012). Outbreaks of yersiniosis are commonly associated with food vehicles such as meat (particularly pork), milk, cheese, tofu and raw vegetables (Doyle and Cliver, 1990; Kapperud, 1991; Tavassoli *et al.*, 2019). Diarrhoea is a leading killer of children accounting for approximately 9 percent of all deaths among children under age 5 worldwide in 2019 (WHO and UNICEF, 2021). In this investigation sixty and one hundred and forty diarrhoeic faecal samples from children and adults were screened for the presence of *Y.enterocolitica* from the two Hospitals sampled. Five and three *Y. enterocolitica* were isolated from the diarrhoeic faecal samples of the children and the adult's in Primary Health Care Centre, Shango, in Minna, Niger State respectively; with total prevalence of 08(08%). Statistically there is significant difference between the patients that had the organism and those that did not have it ($p<0.05$).Whereas four *Y. enterocolitica* were isolated from the diarrhoiec faecal samples of the children and three *Y. enterocolitica* strains from the adults diarrhoeic faecal samples in General Hospital, Minna, Niger State; with the total prevalence of 07(07%). Statistically there is significant difference between the patients that had the organism and those that did not have it ($p<0.05$). Fifteen (7.5%) *Y. enterocolitica* were isolated from diarrhoeic human faecal samples in the study. The difference in prevalence of *Y.enterocolitica* of the two locations was not statistically significant ($p>0.05$). Nine of *Y. enterocolitica* isolates

(which represents 15% of the isolates obtained from the faecal sample of the diarrhoeic children) were from children's faecal samples of age range 2-7years.Six of *Y. enterocolitica* isolates (representing 4.3% of isolates obtained from diarrhoeic adults' faecal samples) were from the diarrhoeic faecal samples of young adults and adults of age range 23-34 years both in Primary Health Care Centre, Shango, in Minna, Niger State and General Hospital, Minna, Niger State. Infections due to *Y. enterocolitica* have been reported by several workers, indicating children, young adults and adults as victims (Onyemelukwe, 1993*;* Nahed *et al.,* 2000; Riahi *et al.*, 2021). In this study about Nine(60%) of the *Y. enterocolitica* isolated from diarrhoeic human samples were from the infant's faecal samples compared with young adults and adults., this correlates with the findings which confirms that *Y enterocolitica* infections are more common among children, mostly aged 2-7years and up to 15 years (Okwori *et al.*,2007; Riahi *et al.*, 2021). Most of the children screened for *Y. enterocolitica* in this study were associated with poor culinary practices, low level of personal and environmental hygiene. Data derived from most hospitalized diarrhoeic children who tested positive for *Y. enterocolitica* showed that they were cared for by less educated nannies, private day care centres which were not properly equipped with standard facilities such as good toilets and clean water. This is in agreement with the previous findings by Adegunloye (2006). According to previous studies, the highest frequency of *Y. enterocolitica* was in cool weather rural areas (Martinez, 2011; Markey *et al*., 2013**),** based on the presence of the most important sources of contamination such as pigs, cows, rabbits and dogs contaminating surfaces and environment with their faeces (Thibodeau *et al.*, 1999; Virtanen *et al.,* 2012). This is similar to our finding since most of the children who tested positive for *Y. enterocolitica* were being taken care of in homes where they had direct contact with dust, wastes and faeces of pet animals such as dogs and cats roaming within the premises. The main risk factors for the morbidity and mortality of diarrhoea are well known and relate to a poor quality of life, lack of sanitation and clean water supply for most of the population living in poor areas of developing countries (Gonul and Karapinar, 1991). *Y. enterocolitica* is an important cause of diarrhoea in some European and Scandinavian countries with cold climate; this study has emphasized the clinical importance of *Y. enterocolitica* and also indicated its presence in North Central Nigeria. The transmission of the organism had been associated with consumption of contaminated food, water and raw milk and milk products (Lee *et al.*, 1990; Ackers, *et al.,* 2001). The diseases due to *Y. enterocolitica* such as enteritis, enterocolitis, acute mesenteric, lymphadenitis, multiple liver abscesses, terminal ileitis, cellulitis, endocarditis, mycotic aneurysms, cerebrospinal fluid shunt infection have been documented (Chandler, *et al.,* 1994; Robins-Browne, 1997; Bottone, 1999). These findings support the concept that contamination of the infant's food or formula by an adult who prepared chitterlings is a source of *Yersinia* infection. Neonates have been found to develop pnuematosis intestinalis indicating that *Y. enterocolitica* can penetrate the intestinal mucosa and cause bacteremia and possibly metastatic infection in neonates (Bottone, 1999). The finding in this study of 15(7.5%) was low compared to the earlier works reported by Mackinen and co-workers (1998) and Sherbini *et al.,* (1999) who isolated *Y. enterocolitica* from 3 patients out of 6 patients faecal samples presented for collagenous colitis infection, 42 nursery School Children

(23.1%) were infected with *Y.enterocolitica* from 182 Children sampled for food poisoning in Japan and 8.6% *Y. enterocolitica* from cases of acute appendicitis which got higher prevalence rates respectively. The differences observed in the isolation might be due to the fact that *Y. enterocolitica* infection is considerably low or not well documented in the area sampled in this study. Whereas very low prevalence were recorded in China where 0.59% of *Y enterocolitica* was isolated in Children with diarrhoea between 2010-2015 (Duan, *et al*., (2017); in Palestine, with 600 cases of Children documented with diarrhoea, 16 were infected with *Y. enterocolitica* giving a prevalence rate of 2.7%

(El Qouqa *et al.*,2011**)**; in India, 3% of *Y enterocolitica* were isolated from stool samples of paediatric diarrhoeic patients (Singh,*et al.*,2003), however in Bavaria, Southern Germany the isolation rate of pathogenic *Y. enterocolitica* in human faecal samples was quite low, only 46 of the 22,835 samples (0.2%) yielded *Y. enterocolitica* (Bucher, *et al.*,2008), and in Greece *Y. enterocolitica* was isolated from 46 (0.6%) out of 7090 human faecal samples (Maraki *et al.,* 2003). This indicated that the infection rate in adult is much lower than in children. A little lower isolation rate was reported in children in Seattle in the U.S.A; where 2 (0.1%) out of 1626 faecal samples yielded *Y. enterocolitica*, this difference might be attributed to the fact that there is awareness of the infections due to *Y. enterocolitica* and precautions in the food industries in developed Countries compared to developing Countries where little is known about the public health problems associated with the organism. In Jos, Nigeria out of 150 stool samples from diarrhoeic children screened 6(15%) were positive for *Y. enterocolitica* (Okwori *et al.,* 2007). The high prevalence rate was due to the climatic condition in Jos compared to Minna, Niger State because *Y. enterocolitica* infection is more commonly isolated in cooler climates, and its prevalence peaks from November to January, coupled with high consumption of pork and dog (reservoir hosts) meat within this environment which may have been processed poorly or undercooked as previously documented (Ostroff *et al.,* 1994). No significant difference was obtained in the prevalence of *Y. enterocolitica* in Primary Health Care Centre, Shango, in Minna, Niger State and General Hospital, Minna, Niger State. ($p > 0.05$). This might be due to the same geographical location of the two sampled area. This study recorded improved frequency of 7.5% of *Y.enterocolitica* due to diarrhoea compared to earlier reported studies of 13-15% frequency in Africa (Ostroff *et al.,* 1994; Okwori *et al*., 2007). This study revealed that females were mostly infected with *Y.enterocolitica* than males. This disagrees with the work of Koehler *et al.* (2006) who presented male-to-female ratio of 2:1. The reason might be due to the fact that female's works more in abbatoir and in pig farms in the studied areas and are therefore exposed to contamination by *Y. enterocolitica* compared to the studied areas conducted by Koehler *et al.* (2006). Extra-intestinal infections like cellulitis, conjunctivitis, meningitis, UTI, pyomyositis, pneumonia etc are more likely to occur in the studied areas as females infected with *Y.enterocolitica* have been indicted to be mostly affected with these infections, as reported by Menzies (2010), Imoto *et al.* (2012) and Wong (2013). Ten, eight and twelve *Y. enterocolitica* isolates were recovered from the diarrhoeic faecal sample of pigs in Farm A, Farm B and Farm C respectively. A total number of thirty (30) 20% isolates of *Yersinia enterocolitica* were isolated

from 3 different farms studied in Shango community, Minna, Niger state. This result is in harmony with the variously reported prevalence of *Yersinia enterocolitica* in pigs as between 0% and 65% (Funk *et al.,* 1998; Letellier *et al.,* 1999; Gurtler, *et al.,* 2005; Vilar *et al*. 2013; Younis *et al.,* 2019; Koskinen *et al*., 2019). These findings were however lower than what were obtained by Virtanen *et al.* (2012) in Europe, 88% of *Y enterocolitica* was obtained from pig farms studied. The higher frequency of occurrence of *Y. enterocolitica* in the study conducted by Virtanen *et al.* (2012) might be due to the seasonal variation for the isolation of *Y. enterocolitica* as the organism were more frequently isolated during cold months as previously reported (Virtanen *et al.,* 2011). Simonova *et al*. (2008) obtained 3.3% *Y. enterocolitica* from faecal samples obtained from a farm in Czecks Republic and in the United States of America pathogenic *Y. enterocolitica* was isolated from 106 (4%) of 2793 pig faecal samples, which is in accordance with European results (Bhaduri and Wesley, 2006). The present investigation almost correlates with Jens, (1988) and Bonardi *et al*. (2003) studies, they found about 24.7% and 18.7% *Y. enterocolitica* as faecal contamination from pigs sampled respectively. The similarity might be due to time and period of sample collection as the organism (*Y. enterocolitica*) were excreted more in the faeces of 8 to 15 week-old pigs within 1-3 weeks of entering pens which were thought to be contaminated with *Y. enterocolitica* in this investigation (Vilar *et al.,* 2013). Forty-five *Y.enterocolitica* strains were isolated from both diarrhoeic faecal samples of children and adults in this study. The incidence of *Y. enterocolitica* from the diarrhoeic human samples and *Y. enterocolitica* from the three farms studied was compared by Chi square method. Significant difference (P= <0.05) was however obtained in the isolation of *Y. enterocolitica* in stool samples of human with diarrhoea and faecal samples of the pigs. This is not surprising as pigs had been strongly indicted to be the highest carrier of *Y. enterocolitica*, and a major source of infection to human (Adesiyun *et al.,* 1986; Nesbakken *et al.,* 1991; Andersen 1998 and Bottone, 1999; Virtanen *et al.,* 2012; Van Damme *et al.,* 2013; Laukkanen-Ninios *et al.,* 2014., Vilar *et al.,* 2015; Ferl *et al.,* 2020). No significant difference existed between the three piggery farms sampled (P=>0.05). The antibiotics susceptibility patterns of *Y.enterocolitica* isolates of humans and pigs were determined in this study. Nineteen antimicrobial agents were employed. *Yersinia enterocolitica* recovered from the patients with diarrhoea were highly susceptible to floroquinolones such as ciprofloxacin and pefloxacin showing 100% susceptibility. These two antimicrobials were previously shown to be most active agents against *Y. enterocolitica* (Pharm *et al.,* 1991; Preston *et al.,* 1994). Ogunleye *et al.* (2010) however found high fluoroquinolones resistance in *Salmonella enterica* isolates in Nigeria. Gentamicin (86.7%), cefuroxime (86.7%), sulphamethoxazole 80.0% and trimethoprin 80.0% were also found to have very strong bactericidal effect as earlier reported (Funk *et al.,* 2000; Rastawicki *et al.,* 2000). However, Stolk-Engelaar *et al.* (1995) and Lyons *et al.* (1991) reported 10% and 27% of *Yersinia enterocolitica* strains to be resistant to cefuroxime respectively. Cotrimazole (73.3%), erythromycin (73.3%), ceftriaxone (66.7%), furazolidone (66.7%), cefotaxime (66.7%), amikacin (60.0%) and cloxacillin (60.0%) shown mild susceptibility to the *Y. enterocolitica* isolates; this correlates with the work of Homstein *et al.* (1985). The systemic extraintestinal infections and enterocolitis caused by *Yersinia enterocolitica*

in immune-compromised patients require prompt antibiotics therapy, and the agent used most correlates with some of the above antibiotics used in this study as reported by earlier workers, this include gentamicin, cotrimaxole and ciprofloxacin (Hoogkamp-Korstanje, 1987; Butler,1990; Pai *et al.,* 1994).The organisms were resistant to ampicillin (100%), cefazolin (100%),amoxycillin (100%), chloramphenicol (83.3%) and tetracycline (83.3%) in human isolates and ampicillin (100%), cefazolin (100%), amoxicillin (100%), chloramphenicol (75%) and tetracycline (71%) resistant patterns demonstrated in the pigs isolates (Bonardi *et al.,* 2013), all these antimicrobial susceptibilities results were in keepings with findings reported in studies conducted in Europe on the in-vitro susceptibilities to antibiotics of clinical isolates of *Y. enterocolitica* (Hornstein, 1985; Hoogkamp-Korstanje, 1987),and pigs isolates (Kwaga and Ivesen,1992; Bonardi *et al.,* 2013). However this is in contrast with the study conducted by Preston *et al.* (1994) on the antibiograms of *Y. enterocolitica* in Canada from 1972-1990, high percentages of *Y.enterocolitica* strains were susceptible to ampicillin, chloramphenicol, tetracycline and amoxicillin. Previous investigators of *Y. enterocolitica* susceptibilities also found that most isolates were susceptible to these various classes of antibiotics (Kanazawa *et al.,* 1987; Pharm *et al.,* 1991). *Y. enterocolitica* is naturally resistant to ampicillin (Aarestrup *et al.,* 1998a) and the resistance is due to production of β-lactamases production by the *Y. enterocolitica*, Prats *et al.* (2000) ; Lyons *et al.* (1991) and Martins *et al.* (2018) reported 100% resistance to oxytetracycline chloramphenicol and cefazolin, all these were in consistence with the findings in this study. The resistance pattern of amoxicillin described in this study is in accordance with the previously reported study of Baumgartner *et al.* (2007); they determined the antimicrobial resistance of *Y. enterocolitica* strains from human patients, pigs and retail pork in Switzerland. From this study, about 59% of the clinical isolates were found to be susceptible to all the antimicrobial used and 41% were resistant, indicating that most infections that results from *Y. enterocolitica* can be treated with the commonly available antimicrobial agents; and about 57% of the *Y. enterocolitica* isolates from the pigs were found to be sensitive to all the antimicrobial used and 43% were resistant, no clear difference could be detected between the susceptibility patterns of human and pigs *Y. enterocolitica* isolates from the study.

5. Conclusions

There was high occurrence of virulent *Y. enterocolitica* in the two hospitals and the pig farms studied. *Y. enterocolitica* isolates from the study; showed the ability to cause diarrhoea diseases especially in children and young adults and many of these isolates were susceptible to commonly used antibiotics in the community studied.

Safe disposal of the piggery waste products is recommended to avoid contamination of the water bodies, farm products and other materials meant for human consumption and the use of antibiotics should be regulated so that it can only be used under the prescription and supervision of trained medical personnel to avoid resistance. Adequate cooking of pork meat and consumption of

pasteurized milk or milk products is postulated; these would assist in the control of the spread of the organism. Good hygienic practices should be observed by farm handlers and other personnel handling raw meat. Government should set up National Yersinial Suivellance Laboratory Centre because of the increasing levels of prevalence of virulent strains of *Y.enterocolitica* and Yersinial infections as recorded in this study.

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ANTIBACTERIAL ACTIVITY OF COFFEE SENNA (*Senna Occidentalis*) SEED

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Abstract

Chloroform, ethyl acetate, and aqueous extracts of *S. occidentalis* seed were evaluated for antibacterial potential by agar well diffusion and broth dilution techniques. Ethyl acetate extract exhibited the highest antibacterial activity by inhibiting the growth of *S. aureus; S. pyogenes; Enterococcus spp; L. monocytogenes; E. coli; K. pneumonia;* and *S. dysentria* with Minimum Inhibitory Concentration (MIC) and Minimum Bactericidal Concentration (MBC) ranging from 5 to 10 mg/mL and 10 to 20 mg/mL respectively. It was however inactive against *B. subtilis P.aeruginosa* and *S. typhi*. Components of the ethyl acetate extract were separated by column chromatography and subjected to antibacterial and phytochemical analysis. Fractions F7 and F11 had the highest antibacterial activities. Fractions F7 had a MIC range of 0. 62 to 1.25 mg/mL and an MBC range of 1.25 to 2.5 mg/mL while fractions F11 also had a MIC range of 0.62 to 1.25mg/mL and an MBC range of 2.5 to 5 mg/mL.

Keywords: Antibacterial activity, Chromatography, Coffee senna seed, Infectious diseases, Phytochemicals

1. Introduction

Despite the tremendous progress in human medicine, infectious diseases remain one of the greatest health challenges of our time (WHO, 2018). The emergence and rapid spread of multi- and pan-drug-resistant bacteria, combined with the drying up of the antibiotic pipeline in the pharmaceutical industry has significantly worsened the situation in recent years (WHO. 2020). As a result, novel antibacterial agents with different mechanisms of action are urgently needed.

Like other living organisms, plants have their fair share of bacterial invasion and are capable of producing compounds that act as a defense against infectious bacteria (Franco et al., 2006; Kovalskaya et al., 2011). Some of these compounds have been identified to belong to different classes of phytochemicals and has inspired a renewed interest in the development of new classes of antibiotic with a different mechanism of action from those in current use. *Senna occidentalis* (L.) Link formally known as *Cassia occidentalis* (GBIF, 2011), commonly called Coffee Senna, Negro-Coffee, Stinking Weed (Joy et al., 2001) or Septic Weed is a small annual or biennial shrub that is a member of the *Senna* genus and belongs to the family Fabaceae (Leguminosae). It is a wild flowering plant found in many tropical countries. In Nigeria, it is very common along roadsides and in uncultivated lands. Different parts of the *S. occidentalis* plant have been used in folk medicine as an excellent broad-spectrum internal and external antibacterial herb (Sadiq et al., 2012). The leaves are used to heal infected wounds (Taylor, 1996), while the seeds are dried, beaten up, and used as a coffee substitute. Hence, they are referred to as coffee Senna. Drink prepared from coffee Senna has a reputation for usefulness in the treatment of dermatitis infection, malaria, fevers, kidney, and bladder troubles, as well as general pains (Globinmed, 2014). Despite these uses, there is little research information on the antibacterial properties of *S. occidentalis* seed. hence this research was aimed at isolating and investigating the bioactive components of *S. occidentalis* seed as a potential source of novel antibacterial agent(s)

Fig 1 *Senna occidentalis* (L.) Link Plant with Flower and Matured Fruit

2. Materials and methods

2.1 Bacterial isolates

Clinical bacterial isolates made up of five Gram-positive bacterial isolates; *Enterococcus spp, Bacillus subtilis, Listeria monocytogene, Staphylococcus aureus,* and *Streptococcus pyogenes;* and five Gram-negative bacterial isolates; *Escherichia coli, Klebsiella pneumonia, Pseudomonas aeruginosa, Salmonella typhi,* and *Shigella dysentria* were obtained from the Department of Medical Microbiology, Ahmadu Bello University Teaching Hospital (ABUTH), Zaria and the Department of Veterinary Public Health and Preventive Medicine, Ahmadu Bello University, Zaria. All the bacteria were checked for purity and maintained at 4^0C in a nutrient agar slant.

2.2 Plant Collection and Identification

S. occidentalis plants with dried seeds were collected from uncultivated farmland opposite the Institute of Agricultural Research, $11^0$09'40.8" N $7^0$38'38.5" E, Ahmadu Bello University, Zaria. The plant was identified and authenticated with a voucher; 1611 at the Herbarium in the Department of Biological Science, Ahmadu Bello University, Zaria. The seeds were air-dried and stored in polythene bags until use.

2.3 Extraction of S. occidentalis Seed with Different Solvents

S. occidentalis seed extraction was carried out by cold maceration according to the method of Mahdi and Altikriti (2010). The seeds were milled into fine powder. 200g of the pulverized seeds was defatted by adding two liters of N-Hexane and allowed to stand for two hours. The N-Hexane extract was decanted and the residue was exposed to air to enable the remaining N-Hexane to evaporate. 50g of the de-fatted seed powder was extracted separately with 500 mL of distilled water, ethyl acetate, and chloroform by separately soaking different 50g portions of the de-fatted seed powdered in each solvent for 24 hours. The solvents were decanted and filtered using Whatman filter paper No .1. The extracts were evaporated to dryness in a water bath at 40^0C.

2.4 Antibacterial Activity of Crude Solvent Extracts of S. occidentalis Seed

2.4.1 Standardization of Bacteria

Clinical samples of bacterial isolates were subcultured on selective media according to the sample types and incubated for 24 hours. The Bacterial isolates were inoculated in 10mL sterile normal saline solution and incubated at 37^0C for six hours. After the incubation period, sterile normal saline solution was added to the growth medium to adjust its turbidity (by visual

comparison) to match the turbidity of 0.5 McFarland turbidity standard (0.5 mL 1.75% (w/v) Barium Chloride dihydrate 99.5 mL1% (v/v) Sulphuric acid). This gave an approximate cell density of 1.5×10^8 colony-forming units per milliliter (CFU/mL) of growth medium.

2.4.2 Antibacterial Activity

Susceptibility of the bacterial isolates to the crude aqueous, ethyl acetate, and chloroform extracts of *S. occidentalis* seed was carried out on Muller Hilton Agar by agar well diffusion method as described by Hugo and Russel (1992). One gram of each extract was separately dissolved in 5 mL of 40% Dimethyl sulfoxide (DMSO) to obtain a stock concentration of 200mg/mL. Extract concentrations of 50mg/mL and 100mg/mL were prepared from the stock concentration. Muller Hilton Agar was prepared and sterilized according to the manufacturer's instructions. The media was allowed to cool to 45^0C. 20mL of the media was poured into sterile Petri dishes and allowed to cool and solidify. The sterile agar plates were seeded with 0.1mL of standardized bacteria. The inoculums were spread evenly over the surface of the agar with a sterile swab. A sterile standard cork borer of 4mm diameter was used to bore holes on the inoculated agar plates. 100µl of each extract concentration was added separately to the agar wells. Wells containing 40% DMSO instead of plant extract served as the negative control while Ciprofloxacin and Sparfloxacin standard antibacterial discs placed on the surface of the agar served as the positive control. The inoculated plates were kept at room temperature for one hour to enable the extract to diffuse across the surface. The plates were then incubated at 37^0C for 24 hours after which they were observed for zones of inhibition of bacterial growth around the agar well. The zones were measured with a transparent ruler and the results obtained were recorded in millimeters.

2.5 Extraction of S. occidentalis Seed with Ethyl Acetate

About 600g of pulverized S. occidentalis seed was defatted with five liters of N-Hexane as previously described and extracted with six liters of ethyl acetate for 24 hours. The ethyl acetate extract was filtered and concentrated at 40^oC using a rotary evaporator. The recovered solvent was re-introduced into the seed residue and re-extracted for 24 hours. The extract was filtered and concentrated at 40^oC. The solvent recovered was again re-introduced into the residue for the third time and re-extracted for another 24 hours. The extract was filtered and again concentrated at 40^oC. The concentrated extracts from the three extraction steps were combined and dried to a constant weight in a water bath at 40^oC. Susceptibility of the bacterial isolates to 100 mg/mL of the crude ethyl acetate extract of S. occidentalis seed was carried out as earlier described.

2.6 Minimum Inhibitory Concentration of Ethyl Acetate Extract of S. occidentalis Seed

Minimum Inhibitory concentrations (MIC) of the ethyl acetate extract against susceptible bacteria isolates were determined using the broth dilution method as described by Egharevba et al. (2010). 10mL of Muller Hilton broth (prepared according to manufacturer's instruction) were dispensed into separate test tubes, sterilized at 121^0C for 15 minutes, and allowed to cool. Bacterial isolates that were susceptible to the ethyl acetate extract were sub-cultured on selective media, incubated for 24 hours, inoculated in 10mLsterile normal saline solution, and incubated at 37^0C for six hours. After the incubation period, sterile normal saline solution was added to the growth medium to adjust its turbidity (by visual comparison) to match the turbidity of 0.5 McFarland turbidity standard. A stock concentration of 80mg/mL of the ethyl acetate extract in sterile broth was prepared by dissolving 0.8g of the extract in a few drops of 40% DMSO and making up the mixture to10 mL with sterile broth. Twofold serial dilutions of the stock with sterile broth were prepared to obtain a working concentration of 40mg/mL, 20mg/mL, 10mg/mL, 5mg/mL, and 2.5mg/mL. 0.1mL of standardized inoculums were inoculated in the different concentrations of extract and incubated at 37^oC for 24 hours. A test tube containing the extract which was not inoculated with bacteria was incubated alongside to serve as a negative control. After the incubation period, the test tubes were observed for the presence or absence of turbidity as an indication of bacterial growth. The lowest concentration of the extract in the broth which showed no turbidity in the test tube was recorded as the MIC.

2.7 Minimum Bactericidal Concentration of Ethyl Acetate Extract of S. occidentalis Seed

Minimum Bactericidal Concentration (MBC) of the ethyl acetate extract of S. occidentalis seed was carried out as described by Egharevba et al. (2010), the contents of the MIC test tubes were sub-cultured on nutrient agar plates and incubated at 37^0C for 24 hours. After the incubation period, the plates were observed for the presence of bacterial colonies. Plates with the lowest concentration of extract and without bacterial colonies were recorded as the MBC.

2.8 Isolation of Antibacterial Agent from Ethyl Acetate Extract of S. occidentalis Seed by Column Chromatography

A solvent combination that best separates the various components of the extract was determined by Thin Layer Chromatography (TLC). A glass column (75cm by 3.5cm) was packed with 120g of silica gel (mesh size 60-120). Five grams of the ethyl acetate extract was dissolved in a minimum amount of ethyl acetate then mixed with a small amount of silica gel and allowed to dry. The dried mixture was gently loaded on the packed column; the column was eluted with absolute N-hexane as the mobile phase. The Polarity of the mobile phase was gradually

increased by making it comprised of 5% absolute ethyl acetate and 95% absolute N-hexane. Upon getting to 100% ethyl acetate, 10% methanol was introduced up to 100% methanol. 100 fractions were collected in 50mLaliquots at a flow rate of 3mL/min. The contents of the fractions were monitored by TLC and fractions with similar TLC patterns were pulled together. 20mg/mL of each isolated fraction was screened for antibacterial activity. MIC and MBC were carried out.

2.9 Phytochemical Analysis of Crude and Fractions of Ethyl Acetate Extract of S. occidentalis Seed

The crude ethyl acetate extract of *S. occidentalis* seed as well as each fraction isolated from the crude extract were separately dissolved in ethyl acetate and spotted on several TLC plates. The spotted plates were developed in a solvent containing 7:3 N-hexane: ethyl acetate. The chromatograms were tested for the presence of phenols, tannins, alkaloids, flavonoids, anthraquinone, cardiac glycosides, sterol, and triterpenes as described by Jork et al. (1990)

3. Results

3.1 Antibacterial Activities of Extracts of S. occidentalis Seed against Gram-Positive Bacteria

Antibacterial activities of crude aqueous, ethyl acetate and chloroform extracts of *S.occidentalis* seed against Gram- positive bacteria are presented in Table 1. The antibacterial activities (which are represented by zones of inhibition of bacterial growth) indicate that the aqueous extract produced significantly higher ($P < 0.05$) zones of inhibition against *B. subtilis* than it did against *S. aureus, L. monocytogenes,* and *Enterococcus. Sp.* The aqueous extract, however, was inactive against *S. Pyogenes*. Ethyl acetate extract was significantly more effective ($p < 0.05$) against *S. aureus,* and *S. pyogenes,* than *L. monocytogenes,* and *Enterococcus spp* but was inactive against *B. Subtilis.* While the chloroform extract was significantly more effective ($p < 0.05$) against *S. Pyogenes* than *S. aureus* and *L. monocytogenes,* but was inactive against *B. Subtilis* and *Enterococcus spp*. All the five Gram- positive bacteria used were inhibited by Sparfloxacin, while Ciprofloxacin inhibited the growth of *S. aureus, S. Pyogenes,* and *B. Subtilis* but was inactive against *L. monocytogenes,* and *Enterococcus spp.*

Table 1 Inhibition (mm) of Gram-positive Bacteria by Extracts of *S. occidentalis* Seed and Standard Antibacterial Drugs

		Test Organisms				
Extract	mg/mL	*Staphylococcus aureus*	*Bacillus subtilis*	*Streptococcus pyogenes*	*Listeria monocytogenes*	*Enterococcus spp*
Aqueous	50	21.00±0.00^{b}	22.67±0.58^{c}	-	20.00±0.00^{b}	18.00±1.0^{a}
	100	23.33±0.58^{a}	24.00±0.00^{b}	-	23.00±0.00^{a}	23.00±0.00^{a}
	200	23.67±0.58^{a}	30.67±0.58^{c}	-	23.67±0.58^{ab}	25.33±0.58^{ab}
Ethyl acetate	50	24.00±0.00^{d}	-	22.33±0.58^{c}	21.33±0.58^{b}	19.00±0.00^{a}
	100	25.00±0.00^{c}	-	26.00±0.00^{d}	23.33±0.58^{a}	24.00±0.00^{b}
	200	26.33±0.58^{b}	-	26.33±0.58^{b}	25.33±0.58^{a}	25.00±0.00^{a}
Chloroform	50	10.33±0.58^{a}	-	13.00±0.00^{c}	12.00±0.00^{b}	-
	100	14.00±0.00^{b}	-	15.33±0.58^{c}	12.00±0.00^{a}	-
	200	15.00±1.0^{a}	-	19.00±0.00^{b}	14.67±0.58^{a}	-
Ciprofloxacin	10(µg)	37.00	45.00	35.00	-	-
Sparfloxacin	10(µg)	35.00	40.00	32.00	35.00	37.00

- No inhibition. Values are expressed as means ± SD, (n = 3).

a,b,c,d,e Values with different superscripts in the same row are significantly different from each other at $P < 0.05$.

3.2 Antibacterial Activities of Extracts of S. occidentalis Seed against Gram-Negative Bacteria

Table 2 shows the antibacterial activities of crude aqueous, ethyl acetate, and chloroform extracts of *S. occidentalis* seed against Gram-negative bacteria. At 200mg/mL, the aqueous extract was most effective against *E. coli* but was not effective against *K. pneumonia* and *P. aeruginosa a*t 100mg/mL, the aqueous extract of the seed could only inhibit the growth of *E. coli* and *S*. *dysenteriae* but was inactive against *K. pneumonia, P. aeruginosa* and *S. dysenteriae.* While at 50mg/ mL, it only slightly inhibited the growth of *E. coli.* Ethyl acetate extract of the seed was significantly ($p < 0.05$) most effective against *S. dysenteriae* while Chloroform extract was most effective against *E. coli*. All five Gram-negative bacteria were inhibited by Sparfloxacin while ciprofloxacin inhibited the growth of *E. coli, K. pneumonia, S. typhi*, and *S. dysenteriae* but was inactive towards *P. aeruginosa.*

Table 2 Inhibition (mm) of Gram-Negative Bacteria by Extracts of *S. occidentalis* Seed and Standard Antibacterial Drugs

		Test Organisms				
Extracts	mg/mL	*Escherichia coli*	*Klebsiella pneumonia*	*Pseudomonas aeruginosa*	*Salmonella typhi*	*Shigella dysenteriae*
Aqueous	50	09. 67±0.58	-	-	-	-
	100	16.00±0.00	-	-	12.67±0.58	-
	200	21.00±0.00^{c}	-	-	15.00±0.00^{b}	12.67±0.58^{a}
Ethyl acetate	50	20. 33±0.58^{a}	20.00±0.00^{a}	-	-	25.00±0.00^{b}
	100	23.33±0.58^{a}	27.00±1.0^{b}	-	-	28.00±0.00^{b}
	200	27.33±0.58^{a}	30.00±0.00^{b}	-	-	32.67±0.58^{c}
Chloroform	50	20.33±0.58^{c}	18.00±0.00^{b}	-	-	14.33±0.58^{a}
	100	21.00±0.00^{c}	20.00±0.00^{b}	-	-	15. 33±0.58^{a}
	200	23.67±0.58^{c}	22. 33±0.58^{b}	-	-	20.00±0.00^{a}
Ciprofloxacin	10(µg)	37.00	45.00	35.00	-	-
Sparfloxacin	10(µg)	35.00	40.00	32.00	35.00	37.00

- No inhibition. Values are expressed as means ± SD, (n = 3).

^{a,b,c,d,e} Values with different superscripts in the same row are significantly different from each other at $p < 0.05$.

All the tested extracts were effective against both Gram-positive and Gram-negative bacteria. Ethyl acetate extract, however, was most effective in inhibiting bacterial growth and was therefore extracted in a larger quantity, subjected to MIC and MBC analysis and further purification.

3.3 Antibacterial Activity of Ethyl Acetate Extract of S. occidentalis Seed

Antibacterial analysis of the bulk ethyl acetate extract of S. occidentalis seed carried out to determine its potency gave results (Table 3) that were similar to the results previously obtained for the ethyl acetate extract of the seed.

Table 3 Inhibition (mm) of Bacteria by 100 mg/mL Ethyl Acetate Extract of *S. occidentalis* Seed

Test Organisms	Zones of Inhibition (mm)
Gram Positive	
Staphylococcus aureus	28.67 ± 0.58^{e}
Bacillus subtilis	-
Streptococcus pyogenes	26.00 ± 0.00^{bc}
Listeria monocytogenes	24.00 ± 0.00^{a}
Enterococcus spp	25.33 ± 0.58^{b}
Gram Negative	
Escherichia coli	26.33 ± 0.58^{cd}
Klebsiella pneumonia	27.00 ± 1.00^{d}
Pseudomonas aeruginosa	-
Salmonella typhi	-
Shigella dysenteriae	28.00 ± 0.00^{e}

- No inhibition. Values are expressed as means ± SD, (n = 3).

^{a,b,c,d,e} Values with different superscripts down the column are significantly different from each other at $p < 0.05$.

3.4 Minimum Inhibitory Concentration and Minimum Bactericidal Concentration of Ethyl Acetate Extract of S. occidentalis Seed

Table 4 shows that a minimum concentration of 5mg/mL of ethyl acetate extract of the Seed is sufficient to inhibit the growth of *S. aureus, S. pyogenes, E. coli, K. pneumoni,* and *S.dysenteriae* while a minimum concentration of 10mg/mL was required to inhibit the growth of *L.monocytogenes* and *Enterococcus spp*. While Table 5 shows that the extract was bactericidal against *S. aureus, K. pneumonia,* and *S. dysenteriae* at a minimum concentration of 10mg/mL and bactericidal against *S. pyogenes, L. monocytogenes, Enterococcus spp.,* and *E. coli* at a minimum concentration of 20mg/Ml.

Table 4 Minimum Inhibitory Concentration of Ethyl Acetate Extract of *S. occidentalis* Seed

Test Organisms	MIC (mg/mL)
Staphylococcus aureus	5
Streptococcus pyogenes	5
Listeria monocytogenes	10
Enterococcus spp	10
Escherichia coli	5
Klebsiella pneumonia	5
Shigella dysenteriae	5

Table 5: Minimum Bactericidal Concentration of Ethyl Acetate Extract of *S. occidentalis* Seed

Test Organisms	MBC (mg/mL)
Staphylococcus aureus	10
Streptococcus pyogenes	20
Listeria monocytogenes	20
Enterococcus spp	20
Escherichia coli	20
Klebsiella pneumonia	10
Shigella dysenteriae	10

3.5 Antibacterial Activity of Fractions of Ethyl Acetate Extract of S. occidentalis Seed

The components of the ethyl acetate extract of *S. occidentalis* seed were isolated on a chromatographic column based on their polarity. The solvent mixture that best separated the components of the extracts on a TLC plate was N-Hexane/ethyl acetate in a ratio of 3:7. This ratio of the solvent mixture was used to monitor the fraction eluted from the column using TLC plates. One hundred (100) fractions in 50 mL aliquots were collected from the column and combined into 11 fractions based on the similarities of their Rf values. After evaporation of the solvents, fractions one to four were oily. They were therefore considered to be part of the de-fatting process and were not used for further analysis. Fractions 5 to 11 were solids of different physical appearances and were subjected to phytochemical screening and further antibacterial activity.

Antibacterial activities of 20mg/mL of fractions of ethyl acetate extract of *S. occidentalis* seed against Gram-positive and Gram-negative bacteria are presented in Table 6. The results show that fractions 6, 7, 8, 9, and 11 demonstrated excellent broad-spectrum anti-bacterial activity against *S. aureus, S. pyogenes, L. monocytogenes, Enterococcus spp, E. coli, K. pneumonia,* and *S. dysenteriae* but were inactive against *B. subtilis, P. aeruginosa,* and *S. typhi.* This pattern of antibacterial activity is similar to those exhibited by the crude extract (Table 1) while fractions seven and eleven exhibited significantly higher ($p < 0.05$) antibacterial activity compared to the others, fractions five and ten were inactive against all the bacteria isolates used.

Table 6 Zones Inhibition (mm) of Bacteria by Fractions of Ethyl Acetate Extract of *S. occidentalis* Seed

	Fractions (20mg/mL)						
Test Organisms	5	6	7	8	9	10	11
Gram Positive							
Staphylococcus aureus	-	22.00±0.00^{b}	25.67±0.58^{d}	24.00±0.00^{c}	20.67±0.58^{a}	-	24.00±0.00^{c}
Bacillus subtilis	-	-	-	-	-	-	-
Streptococcus pyogenes	-	21.00±0.00^{b}	23.33±0.58^{c}	20.00±0.00^{a}	22.67±0.58^{c}	-	23.33±0.58^{c}
Listeria monocytogenes	-	24.00±1.00^{d}	27.00±0.00^{e}	22.00±0.00^{b}	20.00±0.00^{a}	-	23.00±0.00^{c}
Enterococcus spp	-	28.00±0.00^{e}	28.00±0.00^{e}	20.00±0.00^{a}	21.00±0.00^{b}	-	23.67±0.58^{c}
Gram Negative							
Escherichia coli	-	22.00±0.00^{b}	26.00±0.00^{e}	23.33±0.58^{d}	22.67±0.58^{b}	-	20.00±0.00^{a}
Klebsiella pneumonia	-	25.67±0.58^{c}	30.00±0.00^{d}	24.00±0.00^{a}	24.67±0.58^{b}	-	25.00±0.00^{b}
Pseudomonas aeruginosa	-	-	-	-	-	-	-
Salmonella typhi	-	-	-	-	-	-	-
Shigella dysenteriae	-	24.00±0.00^{c}	28.00±0.00 ^{d}	22.33±0.58 ^{b}	21.00±0.00 ^{a}	-	21.00±0.00 ^{a}

- No inhibition. Values are expressed as means ± SD, (n = 3).

^{a,b,c,d,e} Values with different superscripts across the row are significantly different from each other at $p < 0.05$.

3.6 Minimum Inhibitory Concentration and Minimum Bactericidal Concentration of Fractions of Ethyl Acetate Extract of S. occidentalis Seed

A minimum of 1.25mg/mL of fractions 6, 8, 9, and 11 were required to inhibit the growth of all susceptible bacterial isolates. A minimum of 0.62mg/mL of fraction seven was required to inhibit L. monocytogenes, Enterococcus spp, K. pneumonia, and S. dysenteriae while a minimum of 1. 25mg/mL of fraction F7 was required to inhibit S. aureus, S. pyogenes, and E. coli. (Table 7)

Table 7 Minimum Inhibitory Concentration (MIC) of Fractions of Ethyl Acetate Extracts of *S. occidentalis* Seed

Test Organisms	Fractions				
	6	7	8	9	11
	MIC (mg/ml)				
Staphylococcus aureus	1.25	1.25	1.25	1.25	1.25
Streptococcus pyogenes	1.25	1.25	1.25	1.25	1.25
Listeria monocytogenes	1.25	0.62	1.25	1.25	1.25
Enterococcus spp	1.25	0.62	1.25	1.25	1.25
Escherichia coli	1.25	1.25	1.25	1.25	1.25
Klebsiella pneumonia	1.25	0.62	1.25	1.25	1.25
Shigella dysenteriae	1.25	0.62	1.25	1.25	1.25

Table 8 Minimum Bactericidal Concentration (MBC) of Fractions of Ethyl Acetate Extracts of *S. occidentalis* Seed

Test Organisms	Fractions				
	6	7	8	9	11
	MBC (mg/ml)				
Staphylococcus aureus	5	2.5	2.5	5	2.5
Streptococcus pyogenes	5	2.5	5	5	2.5
Listeria monocytogenes	2.5	1.25	5	5	2.5
Enterococcus spp	2.5	1.25	2.5	5	5
Escherichia coli	5	2.5	5	5	2.5
Klebsiella pneumonia	2.5	1.25	2.5	5	2.5
Shigella dysenteriae	2.5	1.25	5	5	5

Comparing the MIC and MBC results (Tables 7 and 8) of the fraction and their zones of inhibition of bacteria growth (Table 6) indicate that fractions F7 and F11 exhibited the highest bactericidal activities.

3.7 Qualitative Phytochemical Analysis of Crude and Fractions of Ethyl Acetate Extract of S. occidentalis Seed

The presence of phenols, tannins, flavonoids, anthraquinone, cardiac glycosides, sterol, triterpenes, and Steroids were detected in the crude ethyl acetate extract of S. occidentalis seed (Table 9)

Table 9 Qualitative Phytochemical Analysis of Crude and Fractions of Ethyl Acetate Extract *S.occidentalis* Seed

Phytochemical	Crude	5	6	7	8	9	10	11
Phenol	+	-	+	+	+	-	-	+
Tannins	+	+	-	-	-	+	+	+
Alkaloids	-	-	-	-	-	-	+	+
Flavonoids	+	+	+	-	+	+	+	+
Anthraquinone	+	-	-	-	+	+	+	-
Cardiac glycosides	+	+	-	-	-	+	+	+
Sterols	+	+	+	-	-	-	-	-
Triterpenes	+	-	-	+	+	+	+	-
Steroids	+	+	+	-	-	-	+	+

+ = present**;** - = absent

4. Discussion

The three solvent extracts used inhibited more Gram-positive bacteria than Gram-negative bacteria, confirming the report by Lin et al. (1999) that plant extracts are usually more active against Gram-positive bacteria than Gram-negative bacteria. Seven out of the 10 bacterial isolates which were classified as susceptible to the ethyl acetate extracts based on Performance Standards for Antimicrobial Susceptibility Testing of the Clinical and Laboratory Standards Institute (2017) are of serious public health concerns. *S. aureus, K. pneumonia, and Enterococcus spp*. are known to cause the majority of nosocomial infections and have been identified as particular threats. (Rice, 2008; Boucher et al., 2009). *L. Monocytogenes, S. aureus, S. dysenteriae,* and *E. coli* are known to cause food-related infections that not only cause diarrhea and discomfort but can be life-threatening. Most significantly, five out of the seven susceptible bacterial (*E. coli, K. pneumonia, S. dysenteriae, S. aureus, S. pyogenes,* and *Enterococcus Spp*) are included in the World Health Organizations list of antibiotic-resistant "priority pathogens" that pose the greatest threat to human health and for which new antibiotics are urgently needed (WHO, 2017).

The presence of phenol in all five fractions with antibacterial activity and its absence in the two fractions without antibacterial activity is an indication that the major antibacterial component in the extract is most likely a phenolic compound. Phenols have multiple functions in plants; the most important of which is plant defense against pathogens and herbivore predators. Phenols are also well known for their antibacterial activities (Rauha et al., 2000) and have been applied in the control of human pathogenic infections (Doughari, 2012), The mechanisms of antibacterial action of the phenolic compound include enzyme inhibition possibly through reaction with sulfhydryl groups or through more nonspecific interactions with proteins (Cowan, 1999). The site(s) and the number of hydroxyl groups on the phenol group are thought to be related to their toxicity to bacteria due to evidence that increased hydroxylation results in increased toxicity and more highly oxidized phenols are more inhibitory towards bacteria (Scalbert, 1991; Cowan, 1999).

Alkaloids which rank among the most efficient and therapeutically significant plant substance (Okwu, 2005) were detected in fraction 10 and 11 but was not detectable in the crude extract by the method employed in the study. Alkaloids are known to intercalate with the cell wall and/or DNA (Cowan, 1999) and also inhibit bacterial cell respiration and bacterial enzymes such as esterase, DNA, and RNA-polymerases (Kovacevic, 2004).

Antibacterial properties of other compounds detected in the crude and the isolated fractions, like flavonoids and Tannins have been established by various researchers. Flavones glycosides with broad-spectrum antibacterial activity were isolated from the methanol extract of *S. occidentalis* seed by Yandava and Satnami (2011). Flavonoids are known to be synthesized by plants in response to microbial infection and are said to inhibit bacterial growth by complexing with extracellular soluble proteins and cell walls and also by binding to adhesins (Prashant et al., 2011). Tannins are synthesized and accumulate in plant tissue after a microbial attack (Bobbarala, 2012). Tannins are known to bind to adhesins, cause enzyme inhibition, substrate deprivation, and membrane disruption as well as form complexs with cell walls and metal ions (Cowan 1999). They are also known to cause bacterial colonies to disintegrate probably due to their interference with the bacterial cell wall thereby inhibiting bacterial growth (Cowan 1999).

Conflict of Interest

The authors declare no conflict of interest.

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DATABASE ACCESSIBILITY BY POST GRADUATE LIBRARY USERS: A CASE STUDY OF IBRAHIM BADAMASI BABANGIDA UNIVERSITY LAPAI

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ABSTRACT:

This research investigated the accessibility of database management system by post graduate library users. The study is aimed at finding out the extend of accessibility of electronic database for postgraduate learning, teaching and research in Ibrahim Badamasi Babangida University, Lapai, Niger State. The study was conducted among the post graduate library users of Ibrahim Badamasi Babangida University. It utilized the survey research design. The sample size was 419 with 100% response rate. The results of the findings showed that awareness level varied across the categories of respondents while 135 (32.5%) of the library users access the library out of the total of 419 respondent. The research concluded that there should be increased awareness which is expected to lead to more access to the library database. Finally, due to the positive correlation between awareness and access to library database among the post graduate library users, it is logical to allure from the formulated hypothesis that there is strong correlation between creating awareness to increased library database access which led to the rejection of the formulated hypothesis. The research then recommended that current awareness services and selective dissemination of information should be used to scale accessibility to library database by post graduate library users.

Keywords: Database, Access, Postgraduate, Awareness, Library users, University libraries

1. Introduction

Libraries play vital role in development of individuals in our society. The quality of library resources both print and electronic determines quality of graduates produced and research development. Libraries are agents of educational, social and economic development. The purpose of setting up libraries is to acquire, process, store, preserve and make available current and relevant print and electronic materials that will meet the need of its user at appropriate time. Ternenge and Kashimana (2019) have reported that the accessibility and availability of information has increased remarkably due to the digitization of information. The growing supply of literature in libraries that is available in digital format facilitates effective searching for the material needed by scholars. This development has rapidly increased the scholars' exposure to a wider range of literature than would otherwise be available. There are some indications that scholars' ways of accessing literature for their work has changed in the electronic information environment (Angello 2010). There are larger volumes of information than ever before, new ways of collecting information, new information containers and new tools for working for information (Egberongbe 2011). Researchers can access electronic information through a variety of technologies. These include: Compact Disk Read Only Memory (CD-ROMs), Compact Disk Read Only Memory (OPACs), e-journals, while the internet provides a broad range of information via search engines, subject gateways, subject directories and other web-based resources. Electronic resources facilitate research and play a complimentary role to print library resources. Based on this important contribution to academic world, the University under study subscribed to number of eresources. Some of them are free while others are been paid for. If the University has invested much money on e-resources, it is expected that those resources are fully utilized. It was on this note the researcher investigates if lecturers in the Babcock Business School are aware of these electronic resources and if they are accessible and to what extends are these resources been used.

The results indicate that, while most indexes and databases are now largely compliant with common accessibility standards and permit the performance of common search tasks, their actual user-friendliness for people with disabilities tends to be low. (Emwanta and Nwalo 2013).

Statement of Research Problem: Among many similar researches, Ankrah & Atuase (2018) conducted a study on the access of databases by postgraduate students of University of Cape Coast. The findings of the earlier researches posed the following concerns:

1. The level of library database awareness could be linked to the level of access to the databases
2. Access to database is directly proportional to efficient research output

The research problem under investigation is therefore to determine the level of access of the university library database as a prelude to knowing the level of awareness and taking necessary decition by concerned stakeholders on scalabiltity for more effective library services.

Objectives of the study: The following objectives guided the study:

1. To determine the level of awareness on library databases in Ibrahim badamasi Babangida university lapai
2. To determine the level of access of library database among post graduate library users of Ibrahim Badamasi Babangida university, lapai.

Research Question: The following research questions guided the study:

1. What is the level of awareness on library databases among the post graduate library users?
2. What is the level of data base access among the post graduate library users of Ibrahim badamasi Babangida University, Lapai?

Hypothesis: The following research hypothesis guided the study.

H01: there is no significant difference between library awareness and access among post graduate library users.

Significance of the study: This study is significant in the sense that, its findings can provide library management, government and stake holders guided information on level of awareness and access of post graduate users so as to decide on scalability and growth of database availability for effective research output

2. Literature Review

Aina, Mutula and Tiamiyu (2008) recorded that electronic resources are information resources that are available in computer processable form. Examples of electronic resources databases subscribed to by some University libraries include: Academic Journal, AJOL, BOOKBOON, Dissertation and Theses, HINARI, EBISOHOST, Koha, SAGE etc. Awareness of electronic resources means users of the library have information and knowledge of e-resources been subscribed to. When users of a library have adequate information on what resources available in the library, they are encouraged to use them as the need arises. Angello (2010) revealed that the rate of awareness of electronic resources among livestock researchers in Tanzania was very low. Only 11 researchers (24.4%) were aware of AGORA and 5 researchers (11.1%) were aware of HINARI databases. INFORM and OARE were known to 3 researchers (6.7%) respectively and each of the remaining databases were known by 2 researchers (4.4%) only. The findings of Velmurugan (nd) showed positive response of awareness of faculty members of Engineering College Chennai, Tamilmdu India with almost 66 respondents (62.8 %) are aware of online resources but whereas only 39 respondents (37.2 %) are not aware of them. Aina (2011) stated that accessibility determines the speed at which an information output in any formats is obtained.

Therefore, good information resources should be received and retrieved to meet the desired need. University libraries support Universities in discharging their responsibilities by acquiring all the relevant information resources necessary for sustaining the teaching, learning, research and the public service functions of their universities (Aniebiet, 2009) cited in Emwanta and Nwalo (2013). Electronic resources have the potential for enhancing student's learning, as the resources provide teachers and students with vast quantities of information in an easily accessible non-sequential format. Electronic resources provide access to information that might be restricted to the user because of geographical location or finances. Electronic resources also provide access to current information as these are often updated frequently. n the Nigerian context, Oduwole and Akpati (2003) in Egberongbe (2011) investigated the accessibility and retrieval of electronic information at the University of Agriculture Library, Abeokuta, Nigeria. The 425 participants responded out of a survey population of 1,000, giving a response rate of 53.87 percent. The study revealed that electronic information cuts across all members of the University community that it was to a greater extent easy to use and were satisfied with their search outputs. The constraints identified included insufficient number of terminals available for use despite high demand and inadequate electricity supply.

Effective use of library materials in both print and electronic resources is expected to enhance the quality of teaching and research by academic staff of any institution. In Nigeria, the use of computer terminals in information searching is gradually gaining popularity and so the students need to be computer literate. Thus, many Nigerian university libraries are striving to be fully automated while some are still in the process of computerization. To derive maximum benefit from the increasingly electronic library use environment, the user of Nigerian university libraries needs to be computer literate. (Emwanta and Nwalo, 2013) Electronic resources provide a number of benefits over print resources. These benefits include the fact that electronic resources are often faster to consult than print indexes especially when searching retrospectively, and they are straight forward when wishing to use combination of keywords. They open up the possibility of searching multiple files at a time. Electronic resources can be printed, searched and saved to be repeated or consulted at a later date. They are updated more often than printed resources. Commenting on the advantages of electronic resources, Dadzie (2007) cited in Egberongbe (2011) writes that electronic resources are invaluable research tools that complement the print – based resources in a traditional library setting. Their advantages, according to her include: access to information that might be restricted to the user due to geographical location or finances, access to more current information, and provision of extensive links to additional resources related contents. The study carried out by Bhukuvhani, Chiparausha and Zuvalinyenga (2012) revealed that 86.7% indicated that they used at least one or more electronic information resources to find information for use for their teaching and/or research. Only 13.3% lecturers indicated non-usage of electronic information sources. Of the lecturers participated in this study, 66.67% indicated that they had attended the EIRST workshops provided by the University library while 33.33% did not attend. Aina (2009) also revealed that the highest usage point of any databases among academic staff of Babcock University was less than 17%. Despite the fact that electronic

resources have a lot of benefits, there are some hindrances and challenges to its effective use. Velmurugan (nd) found in his study that one common problem faced by the users of electronic resources is that a greater number of respondents complained of slow internet access. The slow speed results in to wastage of time required to retrieve relevant information. Other may include lack of constant electricity supply and access to electronic resources.

3. Methodology

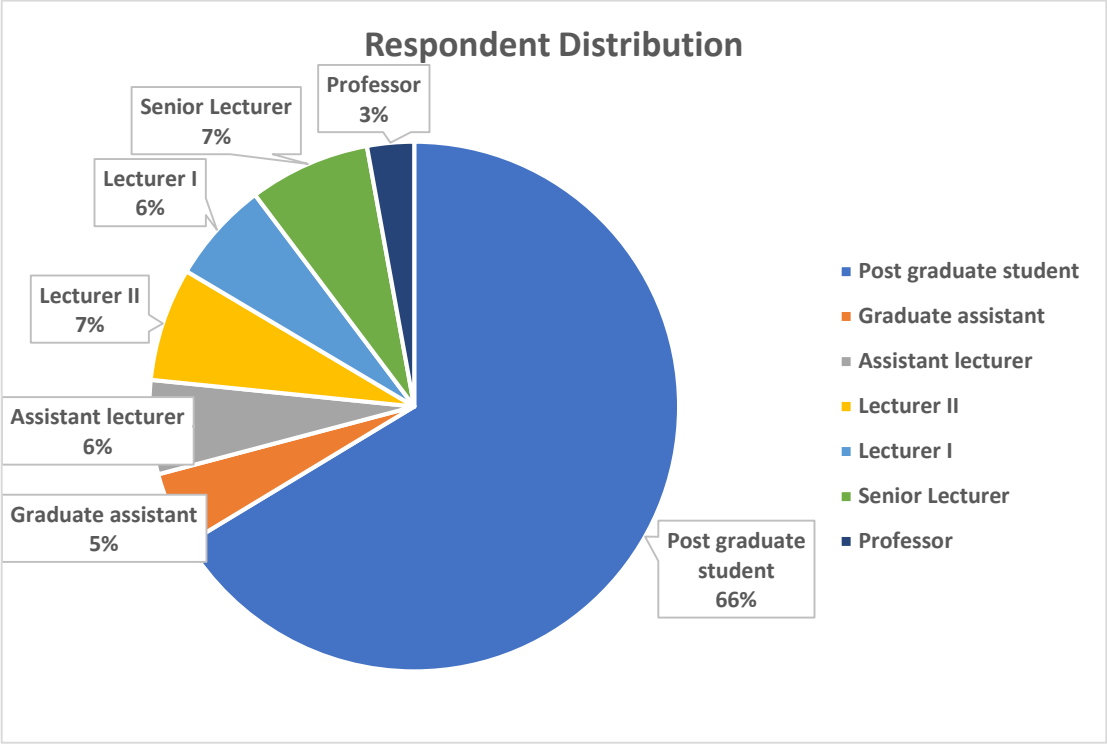
The study was conducted among the post graduate library users of Ibrahim Badamasi Babangida University. It utilized the survey research design. The entire population of study is 419. Simple random technique was adopted. Questionnaire was the instrument used for data collection. One hundred (419) copies of Questionnaire were administered among the respondents from the PG school with 95% return rate. The data collected were analyzed by Statistical Package for Social Sciences (SPSS).

4. Results and Discussion

The data collected showed that there are more male respondents (58.2 %) than female respondents (41.8%). This implies that there are more males in the PG school than female in IBB University PG School. The respondents were categorized into Post Graduate students, graduate assistants, assistant lecturer, lecturer II, Lecturer I, Senior Lecturer and Professor. Respondent statistic Distribution is as follows:

S/No.	Category of respondent	Population	Percentage
1	Post graduate student	278	65.1%
2	Graduate assistant	19	4.5%
3	Assistant lecturer	24	5.6%
4	Lecturer II	29	6.8%
5	Lecturer I	26	6.1%
6	Senior Lecturer	31	7.3%

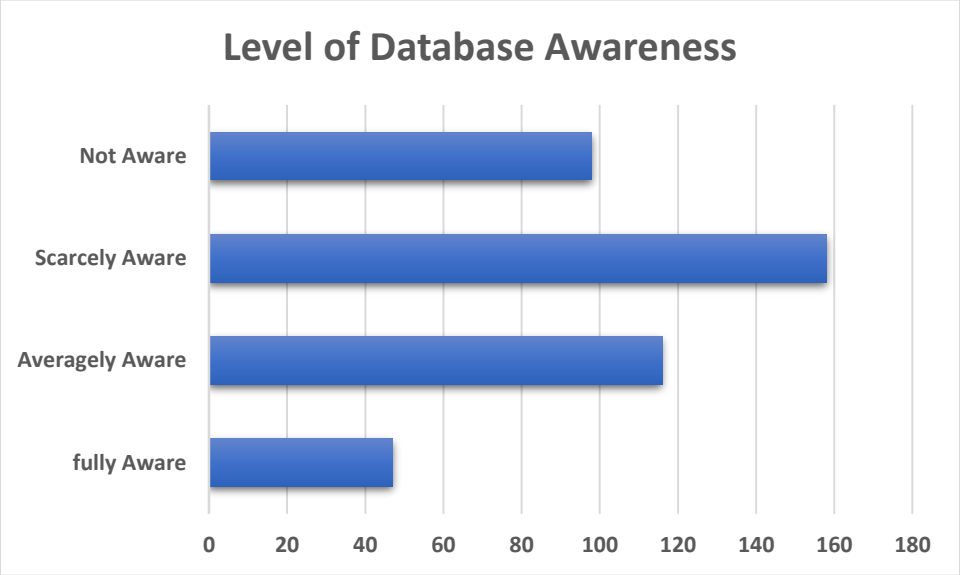
7	Professor	12	2.8%
8	Total	419	100%



The above figure revealed that the majority of respondents 278 (66%) were post graduates students. Senior lecturer 7% and lecturer II was 6% as shown in the figure. Assistant lecturer made 6% of the respondent population followed by graduate assistant with 5% population. Lectuerer I is 6% followed by the Professor cadre wich made 3% of the respondednts among the Post graduate users of the university library.

S/No.	Response categories	Responses	Percentage
1	fully Aware	47	11%

2	Averagely Aware	116	28%
3	Scarcely Aware	158	38%
4	Not Aware	98	23%
5	Total	419	100



The data below shows that the level of awareness of databases among the post graduate library users varies significantly. For instance, majority of respondents were scarcely aware of databases in the library totaling up to 158 respondents out of 419 (38%). Also, 116 (28%) were averagely aware. 98 (23%) were not aware and just 47 (11%) were fully aware of the existing database in the library.

Level of accessibility of database in IBBUL

The table below summarises the findings on accessibility of database among the post graduate library users of Ibrahim Badamasi Babangida University Lapai.

S/No.	Category of respondent	Total Population	Population that Accesses database	Percentage
1	Post graduate student	278	87	31.3%
2	Graduate assistant	19	7	37.0%
3	Assistant lecturer	24	9	37.5%
4	Lecturer II	29	11	38.0
5	Lecturer I	26	6	33.3%
6	Senior Lecturer	31	10	32.3%
7	Professor	12	5	41.7%
8	Total	419	135	32.2%

The chart above presents the level of database access of post graduate library users of IBBUL. It shows that out of 419 people, 135 (32.2%) access the university library database. It further derived from the findings, that 87 out of 278 (31%) of Post graduate student access the library, 7 out of 19 (37%) of Graduate assistant access the library. Nine (9) out of 24 assistant lecturers that constitute 37.5% access the library among their post graduate users. Furthermore, out of 29 Lecturer II category, 11 (38%) access the database of the academic library in their institution. Out of 26 lecturer I in the category of respondents, 6 (33.3%) access the database. In addition, 31 senior lecturers responded while 10 (32.3%) of them claimed they access the database. Similarly, 12 Professors responded and 5 (41.7%) of the professors access the library database among post graduate library users. Below is a chart that further illustrates the findings.

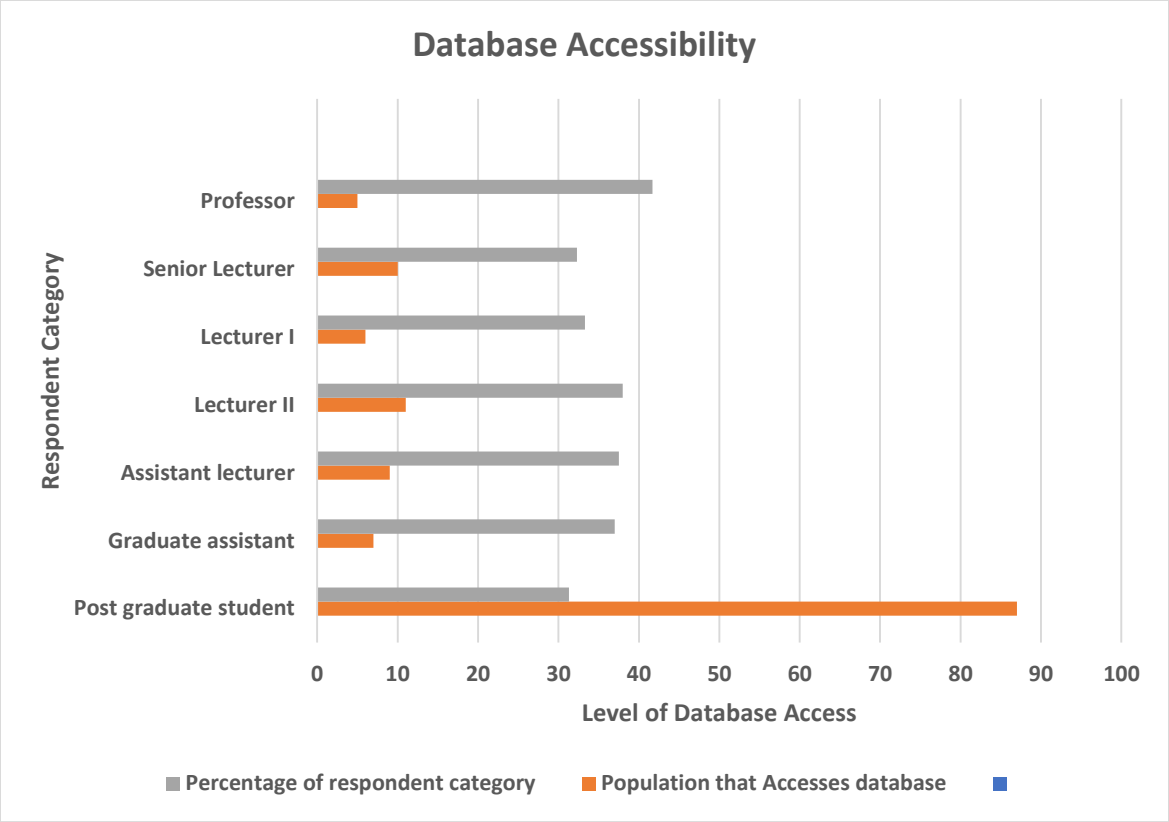


Table 4: Relationship between Awareness and Accessibility of databases

Variables	Mean	Std.Deviation	N	r	D.f	Sig.P	Remarks
Awareness	97.3	16.75	212				
Accessibility	74.2	20.22	135				

Significant *significant at $p < .05$

From Table, there is positive, very strong and significant relationship between Awareness and accessibility of library database in IBBUL library ($r = .766$; $df = 2254$; $p < .05$). Hence, awareness and accessibility of library databases among post graduate library users have no significant difference. Consequently, research and academic output will improve with an improvement in the variables. The hypothesis was, therefore, rejected.

5. Conclusion

The research revealed that: Majority of respondents 278 (66%) were post graduates students not neccesarily working with the university. The level of awareness of library database among the post graduate library users varies significantly. For instance, majority of respondents were scarcely aware of databases in the library totaling up to 158 respondents out of 419 (38%). Also, 116 (28%) were averagely aware. 98 (23%) were not aware and just 47 (11%) were fully aware of the existing database in the library.Out of 419 respondents, 135 (32.2%) access the university library database. It is further derived from the findings, that 87 out of 278 (31%) of Post graduate student access the library, 7 out of 19 (37%) of Graduate assistant access the library. Nine (9) out of 24 assistant lecturers that constitute 37.5% access the library among their post graduate users. Furthermore, out of 29 Lecturer II category, 11 (38%) access the database of the academic library in their institution. Out of 26 lecturer I in the category of respondents, 6 (33.3%) access the database. In addition, 31 senior lecturers responded while 10 (32.3%) of them claimed they access the database. Similarly, 12 Professors responded and 5 (41.7%) of the professors access the library database among post graduate library users. Hypothesis h01 was formulated to test between awareness and accessibility to library databases. It was found out that, there is positive, very strong and significant relationship between Awareness and accessibility of library database in IBBUL library ($r = .766$; $df = 2254$; $p < .05$). Hence, awareness and accessibility of library databases among post graduate library users have no significant difference. Consequently, research and academic output will improve with an improvement in the variables. The hypothesis was, therefore, rejected.

For an institution of higher learning of the 21st century, database accessibility is expected to be an inculcated culture among the postgraduates who should be role models to the undergraduates. Unfortunately, the findings revealed that only 32.2% of the sampled size were accessing the library database while level of awareness on database existence in the library remains a thing of serious concern. Finally, due to the positive correlation between awareness and access to library database among the post graduate library users, it is logical to allure that there is strong correlation between creating awareness to increased library database access which led to the rejection of the formulated hypothesis. Similar findings may be obtainable in academic universities where poor library access could be as low as 32% of the entire postgraduate library users in Nigeria which necessitates awareness on library database access with tools like Current Awareness Services (CAS) and Selective Dissemination of Information (SDI) as well as library education to further boost access and in use of database in order to meet up with the research academia pace of the 21st century.

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RADON GAS EMANATION FROM SOIL AND BUILDING MATERIALS OF LAPAI NORTH-CENTRAL NIGERIA

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ABSTRACT

Radon gas emanates from soil and various building materials due to naturally occurring radioactive isotopes in them and hence contributes significantly to radon gas indoor air content in dwellings and poses a major health risk. A major health risk associated with prolonged exposure to radon gas is lung cancer. In this work, radon emission from soil samples collected from different locations in Lapai town of Niger state, North-Central Nigeria, and some commonly used building materials were measured using a Rad7 detector. The building materials considered include; ceramic tile, black cement, white cement, granite, sand, cement brick, and clay brick. The radon concentration in the soil and building material samples was found to vary in the range of 245.0±9.3 Bqm^{-3} to 157.0±7.3 Bqm^{-3}. The calculated mass and area exhalation rates of the samples were found to vary in the range of 0.155±0.009 $Bqkg^{-1}hr^{-1}$ to 0.240±0.013 $Bqkg^{-1}hr^{-1}$and 0.540±0.031 $Bqm^{-2}hr^{-1}$ to 1.883±0.107 $Bqm^{-2}hr^{-1}$ respectively. Also, the indoor contributions of all the samples were evaluated and it was observed that the samples do not contribute significantly to the indoor air radon levels in a well-ventilated room setting and as such do not pose health risks associated with radon exposure.

Keywords: Surface exhalation rate, Rad7, NORM, soil gas, indoor radon concentration.

1.0 Introduction

Radon is a colorless, odorless, tasteless, and radioactive gas that is a product of a natural uranium decay series and is found in all soils and rocks due to the presence of naturally occurring radioactive material (NORM) such as uranium or thorium or both. The indoor radon content in dwellings has its sources from the influx of outside air and emissions from building and decorating materials. However, a major contributor to the indoor radon gas content is due to emission from the soil or rocks underground and beneath the floor of the dwelling (Gunby et al., 1993). Soil gas finds its way into dwellings through gaps and joints in building structures, and cracks in the foundation due to the lower air pressure indoors with respect to the outside air pressure of the dwelling. Radon is a progeny of the Uranium decay series which may occur in soil and building materials such as Cement, Sand, Tile, Granite, Cement bricks, Mud bricks, etc. and hence resulting in radon indoor activity. Radon-222, though short-lived, has a half-life of 3.85 days which is enough time for it to penetrate through cracks by diffusion and find its way into the ambient air (Ishimori et al., 2013). Radon is an inert gas but highly radioactive and when allowed to buildup in a house due to poor ventilation and for some selection of building materials in such dwellings, and when inhaled they decay and release radioactive particles which get deposited on the bronchial epithelium, thus exposing the lungs to irradiation and could pose a serious potential health risk. Radon exposure is strongly associated with lung cancer (Darby et al., 2004). It is the second leading cause of cancer after smoking (ICRP, 2014). The International Commission on Radiological Protection (ICRP) recommends radon concentration levels in the range of 100-300 Bqm^{-3} for dwellings. This is consistent with the radon concentration referenced by the world health organization (WHO) for dwellings.

Several factors enable radon emanation from building materials; they include but are not limited to; moisture, and temperature. Radon emanations from the soil are dependent on soil porosity and permeability and differ from country to country due to geological and climatic differences. The difference in radon concentration value between countries differs making the determination of local radon concentration levels a necessity. There is no national average level of radon exposure in Nigeria. However, there have been local research reports from some parts of Nigeria (Afolabi et al., 2015; Asuku et al., 2019; Lawal et al., 2022; Sesay et al., 2019) but no report has been made on the radon concentration levels of Lapai town. And, the local assessment of radon exposure is justifiable since houses built over granite and uranium-rich soil can have high radon concentrations if poorly ventilated even if in a country or region with low radon levels. Soil porosity and permeability is a major factor that affects indoor radon contents in dwellings (Ishimori et al., 2013). It is quantified by the exhalation rate which is the number of radon gas emanating from the soil per unit surface area per unit time from the ground. Hence, the exhalation rates from a building material can serve as a guide toward the selection of such material for construction purposes.

Despite the quantum of research that has been conducted, no previous research reference could be found on the radon gas concentrations of dwellings of the Lapai region of Niger state, Nigeria. In the current study, soil samples were randomly obtained from specific locations in lapai town and some commonly used building materials such as; granite, sand, ceramic tiles, cement, concrete brick, and clay brick. The research is important from a radiation protection point of view because the data obtained in this work would contribute to literature data on NORMS for environmental radiation monitoring which should help keep the radiation risks of Lapai residents

as low as reasonably achievable (ALARA Principle) and in line with the international recommendations. It could also serve as a baseline report for future studies in this region.

2.0 Material and Methods

2.1 Geology of the Study Area

Lapai is a town located in Niger State, North-Central Region of Nigeria, West Africa. It is located in the latitudinal range of 4°16'22.83" to 13^{0}53'39.91" North and longitudinal range of 2°40'22" to 14°40'43.74" East. Lapai town shares similar geology with the entire Bida basin. There exist two formations: the sedimentary rocks which constitute about 10 percent and the basement complex formation which is about 90 percent of Lapai (Fig. 1). The basement complex is composed of petro-lithological units namely: Migmatite – gneisses, schists, and older granites. The sedimentary rocks comprise the Bida Sandstone and the Enagi Formation (which is made up mainly of sandstones, siltstones, and claystones) form the bedrock to the west (Obaje et al., 2020; Tersoo et al., 2021). The sedimentary rocks belong to the larger sedimentary sequences that form the Bida Basin. Lapai Town has a minimum mean annual temperature of 21 ^{0}C and is recorded around July – December. The maximum temperature is about 34 ^{0}C between March and April. And mean annual temperature ranges between 27 – 30 ^{0}C. It has elevations in the range of 35 to 574 m above sea level.

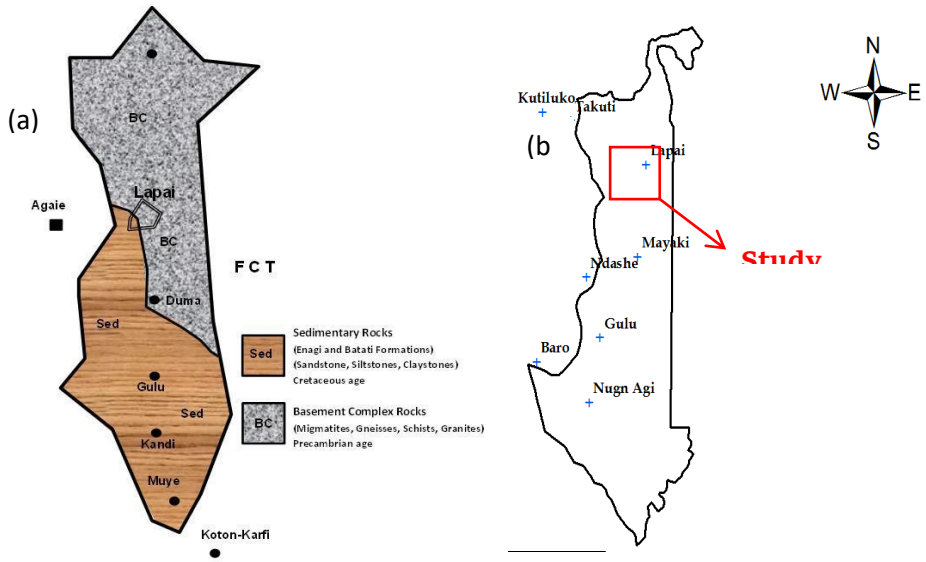

Fig. 1. A Map showing the study area (a) Formation of Lapai LGA showing the study area (Tersoo et al., 2021) (b) map showing the study area and neighbouring town

2.2. Sample Collection

Soil samples: Holes of about 0.5 m deep were dug to collect soil samples from five (5) randomly chosen points of the study area. The soil samples collected from the holes were separately placed

in five (5) neat plastic containers. They were dried in an oven at a temperature of 100 °C for 2 hrs to remove moisture and then the samples were placed in an air-tight container and allowed to remain in the container for 30 days to allow for equilibrium radon activity and the radon measurements were then made with the Rad7 monitor.

Building material samples: Three different Sand sample types commonly used in Lapai town for building construction were collected (plastering sand, sharp sand, and red sand). Building materials collected include; a sample of granite rock; two cement samples (white cement and black cement); the cement used was from different manufacturing brands in Nigeria; five (5) ceramic tiles from different manufacturers; a sample of cement brick and two samples of clay bricks were collected. All samples were processed into a fine powder by crushing and sieving with a molecule sieve and then dried in an oven at a temperature of 100 °C for 2 hrs. The samples were kept in a clean and air-tight plastic container for about 30 days before analysis with a Rad7 Radon monitor. Each sample was collected in two separate containers and well-labeled and the average of the two results was considered for accuracy.

2.3 Measurement of Radon Concentration with Rad7 Detector

The radon concentration measurements were made using a Rad 7 detector (Duridge 0716) available at the center for energy research and training, Zaria, Nigeria. The Rad7 monitor is a continuous and short-time radon measuring device. Radon is pumped into the detector through pipes connected to an "accumulator chamber". The accumulator chamber is a plastic container that hosts the sample whose concentration is to be measured and it is attached to the detector through two one-way inlet and outlet pipes connected at the top and base of the chamber. The chamber was purged before measurements were made to avoid contamination. The Rad7 is a solid-state type detector and detects only alpha radiation from the decay of radon in the closed chamber and converts the radiation count in its electrical signals and displays on a screen as radon concentration in unit Bqm^{-3}. The gas was sucked into the detector for two (2) hours of pumping phase and for twelve (12) rounds to give a 24 hours counting cycle.

3.0 Results and Discussion

3.1 Radon concentration

The concentration of the samples is shown in table 1. Radon concentrations in the samples vary in the range of 245.0±9.3 Bqm^{-3} to 157.0±7.3 Bqm^{-3}. And, radon concentrations for all the samples were within the range of 100 Bqm^{-3} to 300 Bqm^{-3} (Fig. 2) recommended by the International Commission on Radiological Protection (ICRP) and consistent with the recommendations of the World Health Organisation (WHO) (ICRP, 2014). Granite has the highest radon concentration and cement possess the least radon concentration and corresponding low radium content. The high radon concentration in granite is attributed to its high radium content. There is a good correlation between radium content in the samples and their radon concentration as shown in Fig. 3. Granite is an intrusive igneous rock that has a coarse texture and is composed mainly of quartz and feldspar. It is a common plutonic rock of the earth's crust, formed by the cooling and solidification of magma at a certain depth of the crust. The observed

radon concentration in granite can be attributed to the relatively high uranium content in its natural formation.

The soil sample shows a relatively significant radon concentration. However, the radium activity for the soil sample is less than the world average of 35 Bqm^{-3} (UNSCEAR, 2000). And, the observed value of radium content in the soil could be characteristic of the rock formation beneath the Lapai town (Fig. 1a).

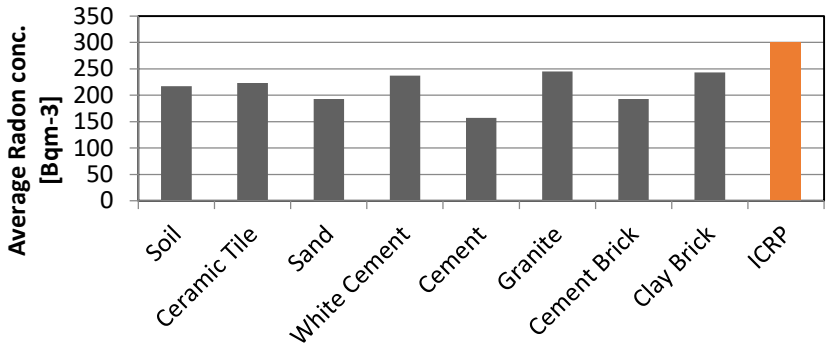

Fig. 2. Radon concentration in the samples and how they compare with the ICRP radon concentration standard safety recommendation limit 2014

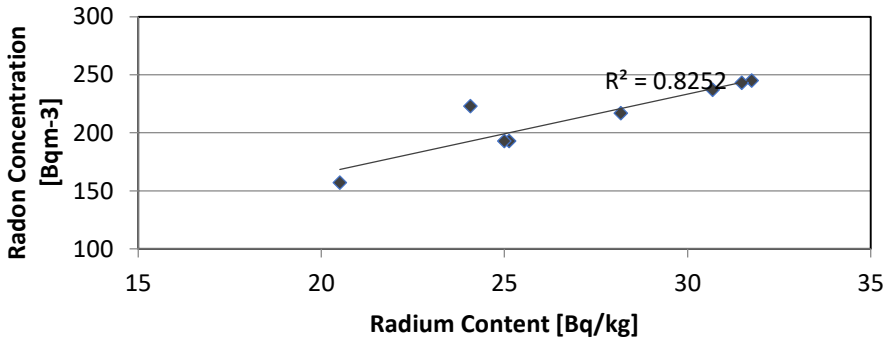

Fig. 3. Correlation between the radon concentration and radium content of the samples

3.2 Mass and Surface exhalation rates

The radon exhaled from the samples was evaluated from the Surface and Mass Exhalation rates, E_S and E_M in Becquerel per meter square per hour ($Bqm^{-2}hr^{-1}$) and Becquerel per meter per hour ($Bqkg^{-1}hr^{-1}$) respectively from the following expressions;

$$E_S = \frac{C\lambda V}{A[t-\left(\frac{1-e^{-\lambda t}}{\lambda}\right)]} \quad (1)$$

$$E_m = \frac{C\lambda V}{M[t-\left(\frac{1-e^{-\lambda t}}{\lambda}\right)]} \quad (2)$$

where A is the total surface area of the sample surface in meter square, C is the integrated radon gas exposure in Bqhm^{-3} and is obtained from the radon concentration C_{Rn} and the exposure time, t (in unit hr); C = C_{Rn}t, V is the volume of the radon chamber in unit m^{-3}, t is the time of exposure in hrs (24 hrs), M is mass of the samples (0.025kg) in kg and λ is the radon decay constant which is calculated from the expression $\lambda = ln2/t_{1/2}$ (7.56×10^{-3}hr^{-1}) where $t_{1/2}$ is the half-life of radon gas in unit h^{-1}.

And, the radium content in the soil and building materials can be estimated from the mass exhalation rate of the various samples using the following equation (3) (Lawal et al., 2022)

$$C_{Ra} \approx \frac{E_m}{\lambda} \quad (3)$$

where C_{Ra} is the radium activity in unit Bqkg^{-1}, λ is the radon decay constant, and E_m is the radon mass exhalation rate of the samples.

The surface and mass exhalation rates of the soil and building material samples are shown in table 1. The mass exhalation and surface exhalation rate vary from 0.155±0.009 Bqkg^{-1}hr^{-1} to 0.240±0.013 Bqkg^{-1}hr^{-1} and 0.540±0.031 Bqm^{-2}hr^{-1} to 1.883±0.107 Bqm^{-2}hr^{-1} respectively. Granite has the highest mass exhalation rate and cement have the least mass exhalation rate. However, white cement showed the highest surface exhalation rate, and the sand samples show the least surface exhalation rates. This result shows that radon exhalation into the atmosphere is more in white cement than in every other sample tested with sand having the least.

The mass and surface exhalation values obtained for cement are similar to values obtained by Sesay et al. (2019) for cement samples from Nigeria (Table 2). However, as shown in table 2, the values for the exhalation rates for cement samples from Sudan, Turkey, and Saudi Arabia(Abo-elmagd et al., 2018; Ahmad et al., 2014) vary from those of the present study. They are less. The observed difference could be a result of the composition of the cement and climate difference.

The surface exhalation rate of the soil sample is comparable to values from those obtained in research by Abo-elmagd et al. (2018) and Saad et al. (2014). However, the mass exhalation rate is less than those obtained in those works which could be a result of the difference in composition due to the process of formation and measurement techniques used. The comparison of results obtained for exhalation rates for research in different countries is shown in Table 2. And some values compare with those of the current study and there are values that do not compare well enough. A number of factors could be responsible for the difference in observed values namely; the porosity of the sample, moisture content, etc (Elzain, 2015; Ishimori et al., 2013).

Table 1

Radon concentration, exhalation rates, and Radium content of the study samples

Samples (sample number)	**Average concentration [Bqm^{-3}]**	**Mass Exhalation [Bqkg^{-1}hr^{-1}]**	**Surface Exhalation [Bqm^{-2}hr^{-1}]**	**Radium Content [Bqkg^{-1}]**
Soil (5)	217.0±5.3	0.213±0.010	0.606±0.028	28.17±1.32
Ceramic Tile(5)	223.0±9.6	0.182±0.012	0.798±0.049	24.07±1.59
Sand(3)	193.0±8.0	0.190±0.011	0.540±0.031	25.13±1.46
White Cement(1)	237.0±6.9	0.232±0.011	1.883±0.107	30.69±1.46
Black Cement(2)	157.0±7.3	0.155±0.009	1.251±0.084	20.50±1.19
Granite(1)	245.0±9.3	0.240±0.013	0.626±0.034	31.75±1.72
Cement Brick(1)	193.0±6.3	0.189±0.009	0.590±0.031	25.00±1.19
Clay Brick(2)	243.0±3.3	0.238±0.010	1.018±0.043	31.48±1.32

Note: The values are all represented with their respective standard uncertainties, and all samples are dry.

Table 2

Comparison of present Radon Exhalation Rates data with values reported for Nigeria and other Countries of the world

Sample	**Country**	**Surface Exhalation**	**Mass Exhalation**	**Reference**
Soil	Nigeria	0.606±0.028	0.213±0.010	Present Study
	Libya	0.890±0.031	0.034±0.001	Saad et al., 2014
	India	0.528	0.0248	Chauhan, 2011
	KSA	0.394–1.683	-	Abo-elmagd et al., 2018

Tile	Nigeria	0.798±0.049	0.182±0.012	Present Study
	Nigeria	1.630±0.540	0.110±0.040	Sesay et al., 2019
	Spain	0.323±0.011	0.041±0.001	Saad et al.,2014
Granite	Nigeria	0.626±0.034	0.240±0.013	Present Study
	Nigeria	1.820±0.440	0.180±0.040	Sesay et al., 2019
	Nigeria	0.111±0.012	0.013±0.001	Lawal et al., 2022
	Egypt	0.653±0.023	0.068±0.002	Saad et al., 2014
	Yemen	0.930±0.020	-	Saleh et al., 2021
Black Cement	Nigeria	1.251±0.084	0.155±0.009	Present Study
	Nigeria	1.86 ± 1.19	0.12 ± 0.07	Sasay et al., 2019
	Sudan	0.379±0.051	0.005±0.001	Elzain, 2015
	KSA	0.454–0.487	-	Abo-elmagd et al., 2018
	Turkey	0.457 ± 0.21	-	Ahmad et al., 2014
White Cement	Nigeria	1.883±0.107	0.232±0.011	Present study
	Nigeria	1.52 ± 0.88	0.08 ± 0.05	Sasey et al., 2019
	Morocco	0.311+0.009	0.012±	Mugahed & Bentayeb, 2019
Cement Brick	Nigeria	0.590±0.031	0.189±0.009	Present study
	Nigeria	3.15 ± 1.52	0.23 ± 0.15	Sasey et al., 2019
	KSA	0.265 ±0.0 11	-	Abo-elmagd et al. 2018
	Yemen	0.299 ± 0.006	-	Saleh et al., 2021
Clay Brick	Nigeria	1.018±0.043	0.238±0.010	Present study
	Yemen	0.101 ± 0.002	-	Saleh et al., 2021
Sand	Nigeria	0.540±0.031	0.190±0.011	Present study
	Nigeria	1.470 ± 1.100	0.120 ± 0.11	Sasey et al. 2019

India	0.258	0.119	Nain et al., 2006
Libya	0.722±0.025	0.027±0.001	Saad et al., (2013)

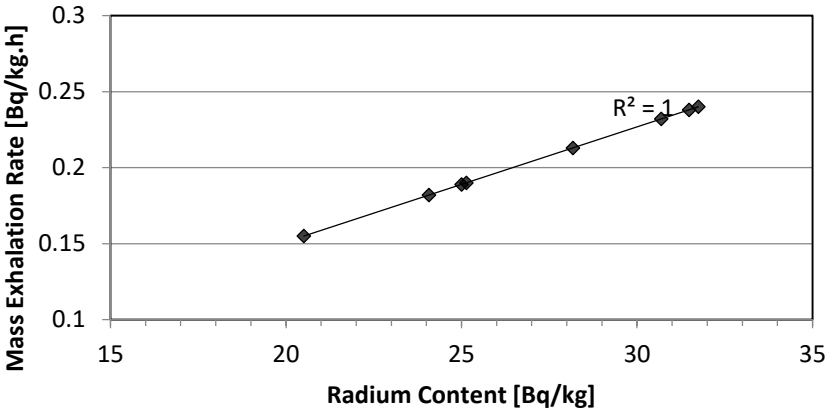

Fig. 2. Correlation between Mass Exhalation and the Radium content

3.3 Indoor radon concentration

The contribution of indoor radon concentration from building materials and soil for dwellings of Lapai town was estimated from the surface exhalation rate using the following equation

$$C_{in} = \frac{E_s A}{(\lambda + h_a)V} \quad (4)$$

Where λ is the radon decay constant in hr^{-1}, ha is the rate of air removal due to ventilation in hr^{-1} (0.1 hr^{-1} and 0.5 hr^{-1} for poor and good ventilation respectively), V is the air volume of the room in unit m^3 (Assuming an average of 4.0 m × 4.0 m area and 2.8 m high for rooms in Lapai). A is the internal surface area of the room

Table 3

Indoor Radon contribution

Samples	**Indoor Radon Contribution[Bq/m^3]**	
	Good Ventilation	Poor Ventilation
Soil	2.05	09.66

Ceramic Tile	2.70	12.72
Sand	1.82	08.61
White Cement	6.36	30.01
Black Cement	4.23	19.94
Granite	2.11	09.98
Cement Brick	2.00	09.40
Clay Brick	3.44	16.22

The indoor contribution of radon from the samples is high for poorly ventilated rooms (Table 3). White cement would contribute the most to indoor radon levels and sand contributes the least. The contribution is in the range of 2.05 Bqm^{-3} to 6.36 Bqm^{-3} for a well-ventilated room. Considering the standard safety limit of 300 Bqm^{-3} for indoor concentration for dwellings, the observed indoor radon contribution of the samples considered is not significant and poses no health risk for a room with good ventilation. This implies good ventilation is an important measure for mitigating the health hazard posed by radon to residents of Lapai town.

4.0 Conclusion

This paper provides data on radon concentration and exhalation rates for soils and some materials used for building and decoration purposes in Lapai town, Nigeria for which there was previously no available report. Hence, the result could contribute to data sets that would help in the determination of a national average value for radon concentration in dwellings in Nigeria. Although radon poses a significant public health hazard, in this study, however, radon concentrations in all the samples measured were within the range of 100 Bqm^{-3} to 300 Bqm^{-3} which is the range recommended for radon concentration in dwellings by the ICRP (ICRP, 2014). The soil and building materials used for building and interior home decoration considered in this work make no significant contribution to indoor radon for houses with adequate air exchange. The research could serve as a baseline for future studies.

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Declaration of competing interest

All authors declare no competing interests of both financial and personal relationships that could have influenced the research work

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EVALUATION OF RADON CONCENTRATION LEVELS IN SELECTED OFFICES OF IBRAHIM BADAMASI BABANGIDA UNIVERSITY, LAPAI, NIGER STATE, NIGERIA AND CONCOMITANT HEALTH HAZARDS

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Abstract
Environmental level of radioactive radon was measured in selected offices of two prominent buildings of Ibrahim Badamasi Babangida University, Lapai, Niger State. The measurement was done using a standardized RAD7 continuous radon monitor. Radon concentration levels for the offices in the administrative building varied between 13.1±3.1 and 44.1±5.6 Bqm^{-3} with a mean value of 22.8 ± 4.0 Bqm^{-3}, while the variation in concentration for the offices in the FMSS building was from 8.6 ± 3.6 to 25.3 ± 5.6 Bqm^{-3} with an average value of 15.3±4.2 Bqm^{-3}. These values were below the world average value of 40 Bqm^{-3}. Computed mean annual effective dose to the lungs for the admin building and FMSS building were 0.55 and 0.46 $mSvy^{-1}$ respectively. Although the radon levels obtained in all the offices evaluated were found to be below the permissible reference levels, there is need for accurate consciousness of the danger of radon accumulation in apartments. Adequate ventilation and other necessary mitigation measures should be put in place to keep the radon concentration levels as low as reasonably achievable.

Keywords: Radon concentration, RAD7 monitor, IBBU, annual effective dose, Niger state

1. Introduction

Radon (^{222}Rn) is the most predominantly found radioisotope in human dwelling environment. It is a naturally occurring tasteless, odourless and colourless radioactive gas which emanates from uranium present in rocks, soils and many ground formations (Afolabi et al., 2015).

Radon gas is ubiquitous in human environment, with increased concentrations indoors in homes and workplaces where most exposure of the general population occurs (Kpordzro et al., 2022). Pervin et al (2022), reported that meteorological parameters, topography, types of building materials and nature of ventilation has great influence on the concentration of indoor radon. Molecular and gaseous diffusion of radon through pore spaces, convection via cracks and

openings, off-gassing of waterborne radon into the indoor environment and radon entrance from air outdoor are additional mechanisms that can enhance the level of indoor radon (Pervin et al., 2018; Lee et al., 2020). Gunby (1993) also reported that building materials especially quartz and cement can significantly influence the level of natural radioactivity in closed places. Most residential homes and workplaces especially in developing countries like Nigeria are often built without any radon resistant facilities, which can result in high level of exposure to indoor radon (Afolabi et al., 2015).

The most prominent cause of lung cancer aside tobacco smoking, according to world health organization report, is human exposure to indoor radon (WHO, 2009). Epidemiological studies have long-established the prevalence of lung cancer due to radon exposure at homes and in work places. Long-time exposure to radon can result in enough damage to the pulmonary mucosa leading to cancer. Studies in Europe, North America, and China have confirmed that a low concentration of radon such as those commonly found in residential settings poses a health risk and contributes to the occurrences of lung cancers worldwide (Darby et al., 2005; Kpordzro et al., 2022). Serious attention must therefore be given to indoor radon from the perspective of human health.

Information on radon gas and its deleterious effect on the health of human population is very scarce especially in the northern part of Nigeria. It is therefore of utmost importance that the human susceptibility to radon exposure especially in residential homes and work environments be investigated. This research is thus aimed at assessing the indoor radon levels in selected offices of IBBU and evaluating the effective dose to human population as a result of their exposure.

2. Materials and method

Ibrahim Badamasi Babangida University (IBBU) is a state owned institution which was founded in 2005. It is located in Lapai town, Lapai local government are of Niger state (Figure 1). This institution, which is run and managed by the Niger state government, has about seven faculties.

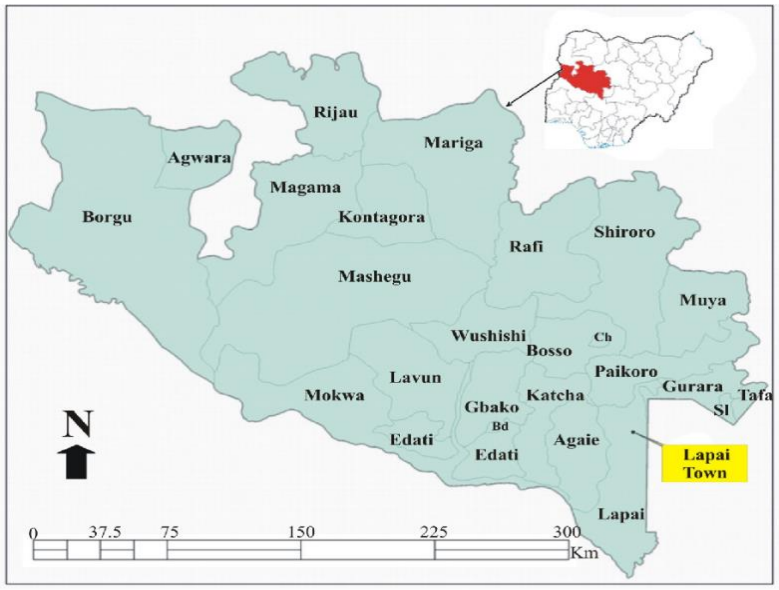

Figure 1 Map of Nigeria showing Lapai town, Niger State

Ten (10) offices in two most prominent buildings of the University: the Administrative (Admin) building and FMSS building, were randomly selected for preliminary indoor radon concentration measurement using a standardized RAD7 continuous radon monitor manufactured by Durridge Company, USA. The setup was such that the monitor was placed about 1 m above ground and only radon gas (^{222}Rn) was allowed by diffusion, to enter through the glass filter into the ionization chamber. Average radon concentration for each office within the period of measurement was computed by an in-built personal computer (PC) Software called CAPTURE.

The annual effective dose (D_R) due to indoor radon in the offices was evaluated using the equation (UNSCEAR, 2000):

$$D_R\ (mSv\ y^{-1}) = C_{Rn} \times D_c \times OF \times I_f \times T \quad (1)$$

where the radon concentration, C_{Rn} is measured in Bqm^{-3}, the dose conversion factor D_c is taken as 9×10^{-6} $mSvh^{-1}$ $(Bqm^{-3})^{-1}$, OF and I_f are the indoor occupancy factor (0.4) and radon equilibrium factor indoors (0.4) respectively, and T is the hours in the year (7008) (ICRP, 2010). Furthermore, the resulting annual effective dose (ED) to the lungs incurred by the occupants due to exposure to indoor radon was estimated using the equation:

$$ED\ (mSvy^{-1}) = D_R \times W_R \times W_T \quad (2)$$

where D_R is the annual effective dose in mSv y^{-1}, W_R is the radiation weighting factor for alpha particles (20) and W_T is the tissue weighting factor (0.12) for the lungs (ICRP, 1993)

3. Results and discussion

Indoor radon concentration along with the temperature and relative humidity of all the offices investigated are presented in table 1. Also presented in table 1 are the computed annual absorbed dose (D_R) and annual effective dose (ED) due to the measured radon level. The six offices of admin building investigated are on the ground floor while the remaining four investigated offices are on the first floor of the FMSS building. Average temperature of the offices in the two buildings at the time of investigation was 29^{o}C, with the FMSS building recording higher mean relative humidity of 71.2%.

Radon Concentration

As seen in table 1, radon concentration on the ground floor offices ranged from 13.1±3.1 to 44.1±5.6 Bqm^{-3}, with a mean value of 22.8 ± 4.0 Bqm^{-3}, while the average radon concentration on the first floor was 15.3±4.2 Bqm^{-3}. Radon level at the ground floor was about 33% higher than at the first floor, which according to Ptiček et al. (2020), may be due to the fact that most

radon comes from the ground which is directly in contact with the ground floor. The temperature variations on the two floors (ground floor and first floor) appears to be uniform which suggests that the effect of temperature on radon levels at the two floors is negligible.

Table 1 Indoor Radon Concentration with temperature, humidity, annual absorbed dose and annual effective dose of Admin and FMSS office buildings in IBB University

LOCATION	CODE	FLOOR	VENTILATION	T (◦C)	RH (%)	C_{Rn} (Bqm^{-3})	D_R (mSv/y)	ED (mSv/y)
ADMIN BUILDING	GF1	Ground floor	Normal	28	55.3	23.9±3.9	0.24	0.58
	GF2	Ground floor	Normal	28.4	65.5	13.1±3.1	0.13	0.32
	GF3	Ground floor	Normal	29.3	68.5	13.1±3.4	0.13	0.32
	GF4	Ground floor	Normal	30.4	64.6	18.0±3.6	0.18	0.44
	GF5	Ground floor	Normal	28.7	64.3	24.7±4.1	0.25	0.60
	GF6	Ground floor	Normal	29	70.3	44.1±5.6	0.45	1.07
	Mean			29.0	64.8	22.8±4.0	0.23	0.55
FMSS BUILDING	FF1	First floor	Normal	29.4	70.9	12.3±3.0	0.16	0.37
	FF2	First floor	Normal	29.9	70.3	14.9±4.7	0.19	0.45
	FF3	First floor	Normal	28.2	71.9	8.6±3.6	0.11	0.26
	FF4	First floor	Normal	29.7	71.5	25.3±5.6	0.32	0.77
	Mean			29.3	71.2	15.3±4.2	0.19	0.46

Mean radon concentration values for the offices on the two floors were lower than the world average value of 40 Bqm^{-3} (Ali et al., 2013; UNSCEAR, 2000). The values were also below the reference level of 100 Bqm^{-3} proposed by the world Health Organization to reduce radiation health incidence as a result of exposure to indoor radon (WHO, 2009). Furthermore, the level of ventilation across all the offices investigated is appreciably normal which might have contributed to the low level of radon in all the offices.

Annual absorbed dose (D_R) and Annual effective dose (ED)

Columns 8 and 9 of table 1 shows the computed D_R and ED for all the investigated offices. D_R for the admin building varied from 0.13 to 0.45 $mSvy^{-1}$ with a mean of 0.23 $mSvy^{-1}$, while that for the FMSS building ranged between 0.11 to 0.32 $mSvy^{-1}$, with an average value of 0.19 $mSvy^{-}$

[1]. The corresponding average ED for the two buildings were 0.55 and 0.46 $mSvy^{-1}$ respectively. Although the mean ED value for the admin building (ground floor) is slightly higher than that for the FMSS building (first floor), the mean ED for the two buildings are below the world average of 1 $mSvy^{-1}$ for normal radiation background. The likelihood of any radiation incidence that may demand urgent intervention is therefore insignificant.

4. Conclusion

This research presents the results of a preliminary and baseline survey of radon concentration levels in offices on the administrative (admin) and FMSS buildings of Ibrahim Badamasi Babangida University Lapai, Niger State. Average radon levels for the two buildings were 22.8±4.0 and 15.3±4.2 Bqm^{-3} respectively, with corresponding mean AED of 0.23 and 0.19 $mSvy^{-1}$ in sequence. Although the values were below the recommended threshold for public safety, proper ventilation in all the office buildings is recommended to keep the radon level as low as reasonably achievable.

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