IJAAR PUBLISHING®

International Journal of Advanced Academic Research | ISSN: 2488-9849
Vol. 9, Issue 10 (October, 2023) | www.ijaar.org

Determination of Gross Alpha Radioactivity in Underground Water in Bichi

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Abstract: *Twenty (20) samples of water from hand dug wells and boreholes in Bichi Local Government Area were selected using a stratified random sampling. Few drops of concentrated nitric acid were added to each one litre of the sampled water for preservation. The samples were then evaporated and counted for Gross Alpha using MPC 2000 model gas filled proportional counter. Results of alpha activities in water in the assessed area showed a range of 0.080Bq/L to 2.166 Bq/L with a geometric mean of 0.544 Bq/L. This value is slightly above the World Health Organization (WHO) recommended practical screening level of 0.5Bq/L for radioactivity in drinking water, but below the United States Environmental Protection Agency (USEPA) recommended practical screening level of 0.55 Bq/L for radioactivity in drinking water. Adequate discussions and appropriate recommendations are made for further research work in this field.*

Keywords: Determination, Gross Alpha, Radioactivity, Water, Geometric mean.

Published *17/10/2023*
ATSOR, A.J. & Terngu, M.K. (2023). Determination of Gross Alpha Radioactivity in Underground Water in Bichi. *International Journal of Advanced Academic Research*, 9(10), 82-90.

Introduction

Gross alpha is of concern for natural radioactivity in water as it refers to the radioactivity of Thorium (Th), Uranium (U), Radium (Ra) as well as Radon (Rn) and daughter isotopes, (WHO, 2011). The presence of radionuclides in water poses a number of health hazards, especially when these radionuclides are deposited in the human body through drinking. Dissolved radionuclides in water emit particles (alpha and beta) and photons (gamma) which gradually affect living tissues (Gruber et al., 2009).

Generally, the environment where man lives is radioactive. Consequently, human beings are constantly exposed to radionuclides found in air, soil, water and plant. Every day, we ingest/inhale nuclides in the air we breathe, in the food we eat and the water we drink. Radioactivity is common in the rocks and soil that makes up our planet, in the water and oceans and even in our building materials and homes. It is just everywhere, there is no where on earth that one can get away from natural radioactivity soil acts as a source of transfers of radionuclides through the food chain depending on their chemical properties and the uptake process of the root to plants and animals. Hence, it is the basic indicator of the radiological status of the environment. These radionuclides take part in several biogeochemical processes that determine their mobility and availability for biological updates. The major potential hazard from the natural radiation is from external exposure either by direct exposure to soil or as they enter in many building materials. Vegetables may be subjected to direct and indirect contamination of uranium series radionuclides. Use of fertilizers leads to elevation of uranium series, nuclides of thorium and uranium are the significant contributors of ingestion dose and are present in the biotic system of plants, animal, soil, water, air and thus food. Water contains a number of both alpha (such as 238U, 226Ra and 240P) and beta emitters (such as 40K, 228Ra and 210Pb). Natural radioisotopes as 40K and the nuclides from the 228U and 232Th series are the greatest source of internal and external exposure in human beings. Many of these radionuclides exist only in trace amounts in nature, including all cosmogenic nuclides. Secondary radionuclides will occur in proportion to their half-lives, so short-lived ones will be very rare (Abdulkarim, 2020). For example, polonium can be found in uranium ores at about 0.1 mg per metric ton (1 part in 1010). Further radionuclides may occur in nature in virtually undetectable amounts as a result of rare events such as spontaneous fission or uncommon cosmic ray interactions (WHO 2012).

The widespread use of Depleted Uranium (DU) ammunition may have caused ground water and fresh water contamination. Moreover, the risk of terrorism acts involving voluntary radio contamination of water resources or the use of ‘dirty bombs” is considered not negligible by public authorities (Carvalho & Fajgel, 2013). The quality of water is of importance in environmental studies for daily use and as carrier of pollutants. Determining the gross alpha radioactivity will help to estimate the radiological assessment of the underground water in the area of interest which is considered to be an important factor for the natural radiation exposure in human (Aregunjo *et-al*, 2004). Radioactivity in drinking water is not a new phenomenon, having been present to some extent for thousands of years. Nevertheless, exposure to radiation over a long period of time is believed to put one’s life at risk of developing illness and other cancer related health hazards.

Materials and Methods

The equipment used for this study are; Gross alpha and beta counter (MPC 2000), Global Positioning system (G.P.S), Digital Hand Held pH meter, Digital TDS meter, Digital Conductivity meter and Thermometer.

Equipment Standard
The alpha standard used for this project work is plutonium- 239 sources. It is a sealed calibration source used to determine efficiency in the proportional counter. The alpha standard is used to calibrate the proportional counter.

Sampling Area
The area under study is Bichi Local Government Area Kano State, Northwest Nigeria and has its headquarters in the town of Bichi. It is bounded by co-ordinates $12^{o}14'$ 03"N, $8^{o}14'28$"E and has eleven council wards. Bichi LGA covers a total area of 612 square kilometers and features two major seasons; the rainy and dry seasons. It has an average temperature of 34 ^{o}C with humidity estimated at 18 percent. Bichi local government area has a fertile land with crops such as rice, beans, groundnut, millet and sorghum grown extensively within the area.

Sample Procedure
A stratified random sampling method will be adopted for this work. The mapped area will be divided in to 30 grids. A sample will be collected from each grid by simple random process.

Sample Collection
Two sets of samples will be collected from each grid; acidified and non-acidified samples.

For the Acidified Sample: A two-litre container each is rinsed three times with water to be collected to minimize contamination from the original content of the sample container. The amount of water collected is such that air space of about 1% of container air capacity is left for thermal expansion. Thermometer is dipped in to each of the samples to measure the temperature. About two (2) drops of concentrated nitric acid are added per 2litres of sample immediately after collection to reduce the pH and to minimize precipitation and absorption on the walls of the container. Sample was tightly covered with the container cover and kept in the laboratory until analysis for alpha activity was carried out. A sample was collected per grid, giving a total of twenty samples.

For Non-Acidified Sample: A one-litre container thoroughly washed was used to collect water from each grid. The samples here were used to measure other physical parameters in water such as pH, Total dissolved solute (TDS), and Conductivity.

Sample Preparation
Acetone was used to clean the apparatus needed for the sample preparation. A known volume of the water was measured and transferred to a beaker. The sample was evaporated carefully on a Binatone temperature adjustable hot plate. The evaporation was done at the temperature less than 100^{0}C until the volume will reduce to about 50ml and allowed to cool. The concentrated solution was transferred to a weighed planchette. The beaker was carefully washed and transferred to the planchette. Few drops of Vinyl acetate was added to the solvent to aid even distribution on the planchette. The sample was heated again to dryness and residue was obtained. The planchette and residue was weighed and by subtraction, the mass m (mg) of the ignited residue was obtained. The residue was dispersed evenly over the planchette by slurring with a few drops of ethanol and was allowed to dry. The planchette was weighed again to ensure that no residue has been lost. This procedure was repeated for all the samples.

The sample preparation efficiency was derived by taking the weight of the empty planchette W_B and the weight of the planchette plus sample after evaporation to 50ml, W_{B+S}. The difference between W_{B+S} and W_B gives the weight of the residue.

The ratio of the difference between the weights of the residue to 0.0770g as specified by ISO multiplied by 100 gives the sample efficiency as shown in equation below;

$$\varepsilon s = \frac{(\text{WB} - \text{WB})}{0.071} \times 100$$

The desired weight of 0.0770g of residue on the planchette was transferred to the sample holder of MPC 2000 detector. The detector was then operated in alpha mode to obtain the count rates of alpha and beta in counts per minutes respectively.

Results and Discussion

The physical parameters of sampled water investigated in this research work with their respective location names, geographical coordinates, type of water sampled and measured values of depth of the water sources are presented in table-1.

The physical parameters are pH, Temperature, Total Dissolved Solids (TDS) and Conductivity. The parameters are also presented in figure-1.

Radioactivity in the Sampled Water: The gross alpha and gross beta concentrations as detected from the entire measurement sites are presented in table-2. The values of gross alpha and gross beta activities are also shown in Figure-2 and figure-3.

Table 1: Physical Parameters in Sampled Water.

S/N	Sample Location	Location Code	Geographical Coordinates	Type of Water	Depth (m)	pH	TDS (mg/ L)	Conductivity Ohms/ cm
1	Danzabuwa	DZW	N12°20'42.708'', E8°6'48.384''	WW	3.3	7.60	7	1.6
2	Lamba	LAK	N12°19'58.254'', E8°9'21.066''	WW	5.7	7.86	5	6.8
3	Gidan Maigari-Waire	GMW	N12°20'54.714'' , E8°13'10.068''	BH	34.5	5.90	10	140
4	Damisa-Kaukau	DAK	N12°18'29.862'', E8°12'58.386''	WW	13.5	6.06	10	1210
5	Emir Palace	BCH-01	N12° 14' 16.206'' , E8°14'19.608''	WW	11.4	6.09	8	900
6	General Hospital Bichi	BCH-02	N12°14' 9.036'', E8°14'5.676''	BH	33.0	7.27	8	1350
7	Hayin-Waya	BCH-03	N12°13'38.448'' E8°14'8.43''	WW	2.9	7.66	8	490
8	Agalawa	BCH-04	N12°13'32.52'' E8°13'32.038''	WW	3.8	8.16	11	340
9	FCE(T) Bichi	BCH-05	N12°13'24.192'' E8°12'53.664''	BH	28.0	6.09	11	100
10	Badume Town	BAW-01	N12°11'25.152'', E8°18'42.03''	BH	30.0	7.79	5	190
11	Badume Petroleum Company	BAW-02	N12°11'23.304'', E8°18'42.102''	WW	10.5	8.35	1	100
12	GJSS Badume	BAW-03	N12°11'24.534'', E8°18'44.958''	BH	33.0	5.93	1	190

13	Yantasha-Yallami	YAW	N12°13'40.458'' E8°18'29.664''	WW	11.4	6.91	11	150
14	Ungu-Fogolo	FOG-01	N12°16'24.036'', E8°26'40.44''	WW	6.7	6.73	13	140
15	Ungu Mauta Fogolo	FOG-02	N12°16'36.444'', E8°26'58.866''	BH	42.0	6.71	14	570
16	Arabic GGJSS Saye	SAY-01	N12°16'32.034'', E8°23'33.882''	BH	36.0	7.11	13	200
17	Tuqubi Saye	SAY-02	N12°15'4.278'', E8°22'15.156''	WW	11.4	7.06	14	270
18	Dan-Muntsira	MUN-01	N1211'56.76'' E813'39.582''	WW	9.5	7.88	13	370
19	PHC Muntsira	MUN-02	N12°11'12.952'' E8°13'28.518''	BH	31.5	6.01	12	230
20	Muntsira	MUN -03	N12°11'12.85'' E8°13'28.492''	BH	28.0	6.00	8	200

WW: Well Water & BH: Borehole Water.

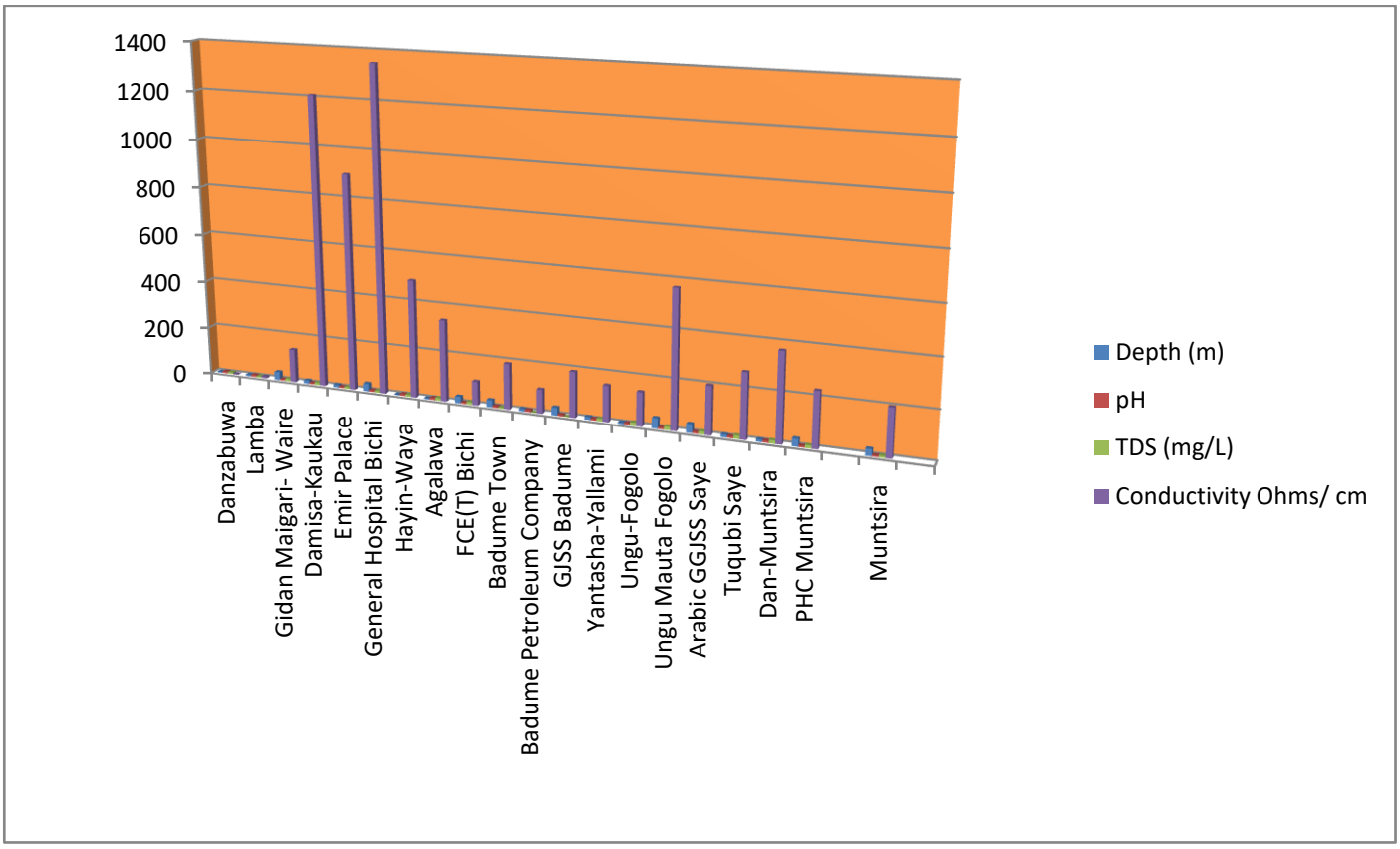


Figure 1: Physical Parameters in Sampled Water.

Table 2: Radioactivity in Sampled Water

S/N	Sample Location	Location Code	Geographical Coordinates	Type of Water	Depth (m)	Alpha Activity Concentration (Bq/L)
1	Danzabuwa	DZW	N12°20'42.708'', E8°6'48.384''	WW	3.3	0.395
2	Lamba	LAK	N12°19'58.254'', E8°9'21.066''	WW	5.7	0.080
3	Gidan Maigari-Waire	GMW	N12°20'54.714'' , E8°13'10.068''	BH	34.5	0.082
4	Damisa-Kaukau	DAK	N12°18'29.862'', E8°12'58.386''	WW	13.5	1.319
5	Emir Palace	BCH-01	N12°14`16.206'' , E8°14'19.608''	WW	11.4	1.220
6	General Hospital Bichi	BCH-02	N12°14`9.036'', E8°14'5.676''	BH	33.0	0.281
7	Hayin-Waya	BCH-03	N12°13'38.448'' E8°14'8.43''	WW	2.9	0.405
8	Agalawa	BCH-04	N12°13'32.52'' E8°13'32.038''	WW	3.8	0.125
9	FCE(T) Bichi	BCH-05	N12°13'24.192'' E8°12'53.664''	WW	28.0	0.222
10	Badume Town	BAW-01	N12°11'25.152'', E8°18'42.03''	BH	30.0	0.112
11	Badume Petroleum Company	BAW-02	N12°11'23.304'', E8°18'42.102''	WW	10.5	0.439
12	GJSS Badume	BAW-03	N12°11'24.534'', E8°18'44.958''	BH	33.0	1.629
13	Yantasha-Yallami	YAW	N12°13'40.458'' E8°18'29.664''	WW	11.4	0.087
14	Ungu-Fogolo	FOG-01	N12°16'24.036'', E8°26'40.44''	WW	6.7	0.209
15	Ungu Mauta Fogolo	FOG-02	N12°16'36.444'', E8°26'58.866''	BH	42.0	0.436
16	Arabic GGJSS Saye	SAY-01	N12°16'32.034'', E8°23'33.882''	BH	36.0	0.206
17	Tuqubi Saye	SAY-02	N12°15'4.278'', E8°22'15.156''	WW	11.4	0.158
18	Dan-Muntsira	MUN-01	N1211'56.76'' E8°13'39.582''	WW	9.5	2.166
19	PHC Muntsira	MUN-02	N12°11`12.952'' E8°13'28.518''	BH	31.5	1.073
20	Muntsira	MUN -03	N12°11`12.85'' E8°13'28.492''	BH	28.0	0.206

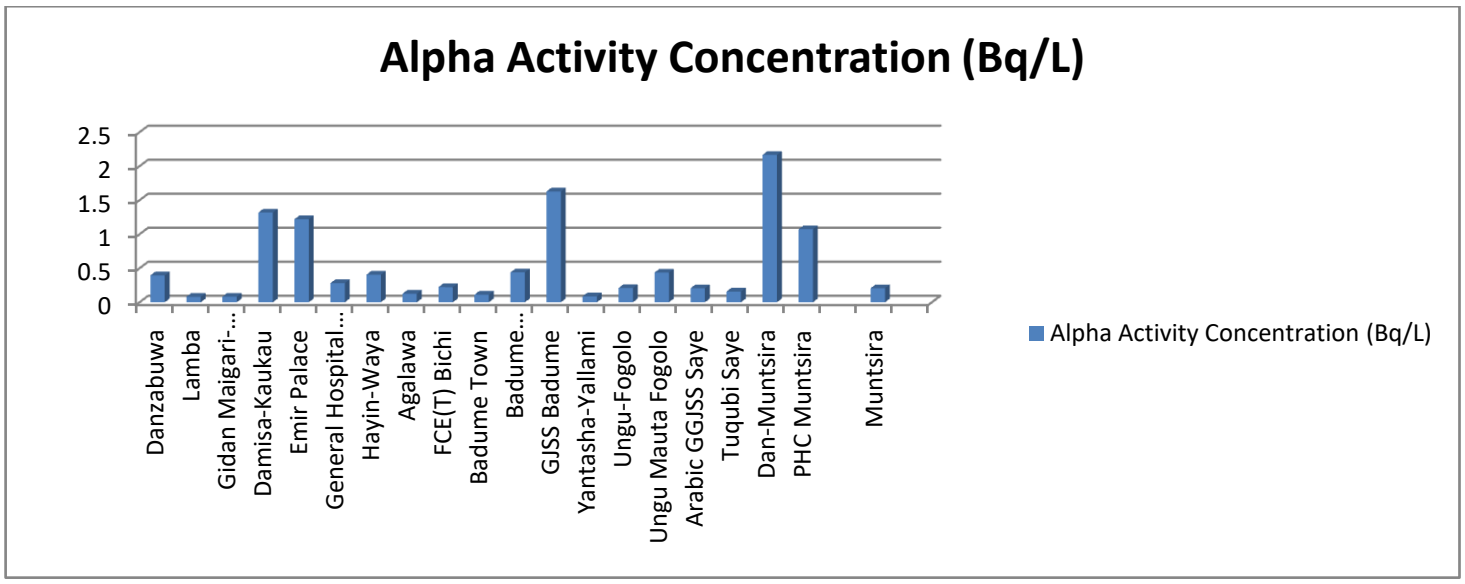


Figure 2: Alpha Activity across the Sampled Points

Table3: Comparison of Gross Activity Levels Between Wells and Boreholes at Bichi and its environs.

Sample Description	Alpha Activity (Bq/L)	
	Maximum Value	Minimum Value
Borehole water	1.629	0.082
Well water	2.166	0.080

Table 4: Comparison of Measured Gross Activities in Bichi with WHO and USEPA Standards and with Results Obtained from Other Places

Location	Range of Alpha (Bq/L)	Sources of Data
Belgium	0.006-0.028	CEC, 1982
Netherlands	0.028-0.064	CEC,1982
UK	0.030-0.150	CEC, 1982
Venezuela	0.070-0.540	Sajo-Bohus *et al*,1982
Zaria	0.001-0.043	Onoja, 2004
Kano	0.002-0.011	Tajudeen, 2006
Gboko	0.309-14.488	Atsor, 2015
Bichi	0.080-2.166	This work
	≤0.5	WHO, 2008
	≤0.55	USEPA, 1996

Determination of the Effective Dose Equivalent: The following equation was used to determine the yearly Effective Dose Equivalent

$$DR_w = A_w \times IR_w \times ID_F$$

Where DR_w the Effective Dose Equivalent (Sv) is, A_w is the activity (Bq/L), ID_F is the intake of water for a person in a year (730 litres) and IDF the ingestion effective dose equivalent factor ($3.58 \times 10^{-7} Sv/yr$).

Therefore, the mean annual Effective Dose for gross alpha is 0.0028mSv/yr. This value is lower than world permissible value of 0.3mSv/yr for Alpha.

Discussion:

The physical parameters of the sampled water are presented in figure-1. It was observed that, TDS values were low in all the measured sites. Water containing TDS concentrations below 1000 mg/litre (1000ppm) is usually acceptable to consumers, although acceptability may vary according to circumstances. However, the presence of high levels of TDS in water may be objectionable to consumers owing to the resulting taste and to excessive scaling in water pipes, heaters, boilers, and household appliances

The pH values in most of the measurement sites are either above or the neutral point of 7 while the values of conductivity were high in some sites, mostly in those sites that recorded high values of alpha radioactivity i.e. Emir Palace, Damisa- Kaukau etc. However, the values do not show any particular trend for generalization. They are above WHO acceptable value of 0.03 S/m for drinking water.

The variation of alpha activity across all sampled points is shown in figure 2. Dan-Muntsira (well water) recorded the highest value of 2.166 Bq/L for alpha, followed by GJSS Badume (Borehole water) which has a value of 1.629 Bq/L. Others were Damisa-Kaukau (well water) with a value of 1.319 Bq/L, and Emir Palace (well water) with a value of 1.220 Bq/L and PHC Muntsira (Borehole water) recorded a value of 1.073 Bq/L for gross alpha activity. These values are alarming compared to WHO and USEPA recommended values of 0.5 Bq/L and 0.55Bq/L respectively for good water quality. The high Alpha activities in the above areas are stressed to organic fertilizers used by farmers in the area which washes from the surface of the land in to these water bodies. Nonetheless, alpha activities at Agalawa, G.H. Bichi, Badume Town, Gidan Maigeri Waire, Ungo Fagolo, FCE(T) Bichi, Yantasha-Yanllami, Tuquibi Saye, Danzabuwa, Lamba, Ungo-Manta Fagolo, Muntsira, Hayin waya, Arabic GGJSS Saye and Badume Petroleum Company were all within the WHO and USEPA acceptable limits for drinking water bodies.

Theoretically, ground water with high total dissolved solids is the most radioactive and high Alpha is usually associated with granite areas (Meindinyo, 2011). The gross Alpha activities in Bichi are high compared to those of similar sources in Zaria and Kano but lower than that at Gboko. The activities are also higher than that of similar sources in other countries i.e. Belgium, Netherlands, UK and Venezuela. However the mean alpha activity in Bichi is within the WHO and USEPA recommended safety values for good quality drinking water of 0.5Bq/L and 0.55 Bq/L for gross alpha (IAEA, 1996). These water bodies therefore do not pose immediate risk of exposing the human beings with in the area to serious health hazards.

Conclusion:

The gross alpha activity concentration in underground water samples collected from Bichi and its environs were measured using MPC 2000 DP proportional counter. The results obtained were within the reference level of 0.544 BqL^{-1}. The annual effective doses, estimated from the gross alpha emitting radionuclide were all below the world permissible value of 0.3mSv/yr for Alpha. The result of this study shows that all the water resources sampled pose no immediate health risk to the populace though, there is potential of high activity in some locations within the sampled area.

Recommendation

The results of the values obtained are below the 0.55 Bq/L for gross alpha recommended by USEPA practical screening levels of radioactivity in drinking water. However, they are slightly above the WHO value of 0.5 Bq/L for practical screening levels of radioactivity in

drinking water. Therefore, there should be regular screening and monitoring of alpha activities in the assessed area.

Acknowledgement
We would like to express our sincere gratitude to **TETFUND** in funding this Institutional Based Research (IBR) for the encouragement and advancement of research and knowledge.

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