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Seasonal Variation of Electrical Conductivity of Groundwater and Its Implication on the Residents of Lafia Municipal Area, Nasarawa State, Nigeria

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Abstract: This study investigated Seasonal Variation of Electrical Conductivity (EC) of Groundwater (Boreholes and Hand-dug Wells) in Lafia Municipal Area, Nasarawa State. A total of seventy (70) samples, consisting of forty (40) and thirty (30) samples were collected from Boreholes and Hand-dug Wells respectively during wet and dry seasons in some major locations, in Lafia Municipal Area. Samples collected were sealed airtight in plastic bottles. The samples were analyzed using the Jenway DDS-307, a standard digital conductivity meter adaptable to temperature variation using a probe. The result analyzed shows that the mean EC value for Hand-dug well water samples ranged from 256.00µS/cm to 1488.00µS/cm during the wet season and 126.00µS/cm to 1416.00µS/cm during the dry season. Similarly, the mean EC for Borehole water samples ranged from 26.70µS/cm to 551.33µS/cm during the wet season and ranges from 28.70µS/cm to 588.00µS/cm during the dry season respectively. Out of thirty (30) Hand-dug wells sampled during the wet and dry seasons, eight (8) had EC values above and approximately to the benchmark value of 1000µS/cm. The results obtained showed that seasonal variation has much effect on the electrical conductivity of Hand-dug wells than Boreholes. The seasonal variation trend revealed that there was increase in the EC of Hand-dug wells during the wet season. However, there was no significant change in EC values of Boreholes. It was therefore recommended that, Hand-dug wells with elavated levels of EC compared with the benchmark should not be used for drinking and cooking.

Keywords: Electrical Conductivity, Borehole, Hand-dug Well, Groundwater, Seasonal Variation

1. Introduction

Environmental Education promotes environmental literacy and develops the skills needed to be environmentally responsible. It refers to educational efforts that increase public awareness, concern, and knowledge about environmental issues and provides the critical thinking, problem-solving and decision-making skills needed to make responsible decisions about the environment and to enhance their appreciation of the environment; resulting in positive environmental behavioural change. [1, 2]

Nigeria is one of the most populous nations constantly facing different issues like overpopulation, migration, improvement of medical care as well as problems connected to environmental pollution such as; air pollution, water pollution, desertification, industrial waste, solid waste, oil spills, deforestation, wind erosion, climate change, soil degradation, floods and erosion [3]. These numerous environmental issues, prompted the researchers to make an investigation into the effect of seasonal variation of electrical conductivity of groundwater considering water as an essential environmental natural resource man and other living organisms cannot do without it, and if not well protected, can affects many lives due to its vitality.

UNESCO [4] estimates that globally, groundwater provides about 50% of current potable water supplies, 40%

of the demand of self-supplied industry and 20% of water use in irrigated agriculture. Over much of Africa, groundwater is the most realistic water supply option for meeting water demand. However, increasing demand and withdrawal, significant changes in land use pattern. Vast industrial and agricultural effluents entering the hydrological cycle as well as seasonal variation, affect the quality and quantity of groundwater [5].

The determination of groundwater quality for human consumption is important for the well-being of the ever increasing population. Groundwater quality depends, to some extent, on its chemical composition [6, 7] which may be affected by natural and anthropogenic factors. Changes in groundwater recharge, due to seasonal variation, also affect the concentration of the water parameters, Makwe & Chup, [8]. Rapid urbanization, especially in developing countries like Nigeria, has affected the availability and quality of groundwater due to waste and effluent disposal practice, especially in urban areas.

Natural waters contain dissolved substances as well as undissolved solids and particles. These are mostly dissolved salts, (electrolytes). The conductivity of the course of rivers subjected to waste water effluents, for example, is therefore regularly monitored. High conductivities can result from in-washes after heavy downpours because of the geography, or may indicate contamination by inorganic salts or, in flowing water, the transport of salts from distant regions [9].

There is high possibility that the effluents from the abattoir and dumpsite will percolate into the ground and pollute the groundwater. This study therefore seeks to evaluate the effect of seasonal variation (changes) of electrical conductivity on groundwater [8]. It also determines the extent of pollution of the groundwater from the abattoir and dumpsite effluents through the qualitative analysis of groundwater samples taken from different existing wells and boreholes at various distances from the abattoir and dumpsites in Lafia Municipal Area.

The Electrical Conductivity (EC) of a solution is the measure of its ability to carry an electric current. The more dissolved ionic solute in the water, the greater its electrical conductivity. Electrical Conductivity (S) is the reciprocal of electrical resistivity (Ω). Conductivity can be regarded as a crude indicator of water quality for many purposes, since it is related to the sum of all ionized solutes or Total Dissolved Solids (TDS) Electrical Conductivity (EC) is widely used for monitoring the mixing of fresh water and saline water, separation stream, hydrographs and geophysical mapping of contaminated groundwater [10].

The estimations of total dissolved solid (TDS) content are based on electrical conductivity (EC) measurements. The spatial distribution of electrical conductivity (EC) is controlled by several factors and practices which may cause salinity variation. Some of these factors are, the collected samples concentration and type of concentration, mobility of groundwater valence, temperature of water, type of soil rock leaching, the long term flow with high rates of discharge and the distance between recharge and discharge area.

Higher electrical conductivity of groundwater has bad effect on the quality of water and human health. The effect of electrical conductivity (EC) of groundwater cannot be over emphasized for the fact that, man and other animals need good quality water to live healthy. Water is very essential to life. Water is an invaluable resource to man and living things essentially, for the sustenance of life [11], on earth as exemplified by its diversified uses such as drinking, cooking, washing, irrigation, farming, [12].

The quality of drinking water is therefore, universally recognized as a basic human need and one of the most essential factors of civilization. Millions of people in developing countries do not have access to adequate and safe water supply. Increasing population and urbanization make it difficult for governments around the world to meet the increasing demand for portable drinking water. In a survey by Majuru, Makoena, Jagals & Hunter, [13] it is estimated that, 6.5 million Nigerians had no access to safe drinking water.

Access to clean water is a fundamental human need of every society and ultimately, it is the responsibility of government. According to the World Health Organization (WHO) and the United Nations Children's Fund (UNICEF) Joint Monitoring Programme for water supply and sanitation estimated that, 1.1 billion people live without improve water sources. While water demand increases with rapid population growth, surface water is considered unreliable and unsustainable due to vulnerability to adverse weather condition, pollution and presence of pathogens necessitating the need to explore groundwater resources an alternative for reliable, quality and sustainable water supply [14, 15].

Many human communities around the world are increasingly turning to groundwater for their water needs. Groundwater is water that exist underground [16]. It represents all the water present in the soils, voids and fissures within geological formations which comes from natural precipitation either directly by infiltration or indirectly from rivers [17]. Without safe water near dwellings, the health and livelihood of families can be severely affected [18, 19]. However, the quality is under intense stress from increasing demand and withdrawal, significant change and pollution arising geological and geochemistry of the environment [20]. Although, groundwater in its natural state is relatively free of contaminants and traditionally regarded as having good natural quality [19]. Human activities may consequently pollute this water sources overtime and make it unsafe for use without prior treatment [21].

The continued consumption of untreated, possibly contaminated and higher electrical conductivity (EC) groundwater should be expected to pose short or long term (or even both) health implications to the people. Therefore, the evaluation of groundwater quality is essential for the development of civilization and establishment of database for future water resources strategic planning and development [22].

Several researches have been conducted on groundwater quality, but there is no comprehensive study conducted on the determination of the seasonal variation of electrical conductivity (EC) of groundwater quality in Lafia Municipal Area of Nasarawa State.

Environmental education and protection have become inevitable in Nigeria if actually our country wants to achieve environmental sustainability for self-reliance and positive development. This is consequent upon the fact that our environment suffers unwanted abuse from man which leads to its degradation.

Groundwater sources are being increasingly used as drinking water, but no one questions the quality of the water that goes into the body. According to [23], about 1.1 billion people lack access to good drinking water supply. In most cities, towns and villages in Nigeria, valuable man-hours are spent on seeking and fetching water, often of doubt quality from distant sources [24]. The effect of water pollution can be catastrophic, depending on the kind of chemical concentration of the pollutants and swage in many water bodies near urban areas (cities and towns) can have detrimental effect of the populace that consume such water source.

Groundwater from Hand-dug wells or Boreholes is expected to adequately meet human demand. However, high concentration of ions, heavy metals and other pollutants has tremendously affect the quality of water, making it unsafe for human consumption. The inorganic chemicals hold a greater portion as contaminants in drinking water in comparison to organic chemicals. A part of inorganic chemicals are heavy metals. Heavy metals tend to accumulate in human organs and nervous system and interfere with their normal function. Hence, there is need to access the quality of groundwater in all Nigerian towns including Lafia municipal.

The main aim of this study was to assess the quality of groundwater in Lafia Municipal Area with the following objectives; To

(i) measure the electrical conductivity (EC) of Boreholes and Hand-dug Well water for wet and dry Seasons in Lafia Municipal Area.
(ii) determine the seasonal trend of EC for Boreholes and Hand-dug well waters from the measure EC values.
(iii) compare the measured values of EC in Lafia Municipal Area with that of Local and International benchmark for drinking water.
(iv) educate the residents on the implication of the results obtained in this study
(v) establish data base line reference material for future studies in the area

2. Materials and Methods

Lafia, town Nasarawa State, North-Central Nigeria, is the capital city of Nasarawa State, Nigeria. lies on latitude 8° 29’30”N and Longitude 8° 31’ 0”E with an altitude of 290 meters elevation above sea level. The map of lafia is shown in figure 1. The water samples were collected from Boreholes and Hand–dug wells in the peak of the wet season (September) and dry seasons (January) with sterilized plastic bottles. A total of seventy (70) consisting of Thirty-five (35) samples each in the wet and dry seasons samples was collected from Bukan-Sidi (A), Angwan-Maina (B), Tudun-Gwandara (C) Sabon-Pegi (D). In each location, five (5) water samples were collected from Borehole and Wells respectively except at Sabon Pegi where only Boreholes sources were found. Sample points were determined using a Global Positioning System (GPS) shown in table 1. The samples collected were hermetically sealed in clean plastic containers. These were clearly marked for easy identification, and transported to the laboratory for analysis. Each of the samples was carefully opened to avoid contaminating the water. The water was carefully poured in a beaker properly rinsed with deionized water. The samples were then analyzed using the Jenway conductivity meter DDS-307 ranging from 0 to 20 $mScm^{-1}$, a standard digital conductivity meter adaptable to temperature probe. The electrode (Platinum black-model DJS-1C) of the conductivity meter was first calibrated to its cell constant $k = 0.991$. After calibration, the knob of the conductivity meter was switched to the measurement range. The electrode and the probe of the meter were then immersed in each of the water samples in the beaker. The conductivity value was read and recorded for each of the water sample. The probe was washed with distilled water in each case to prevent cross contamination of the sample. The procedure was repeated three times using the same sample after which the mean value was obtained.

Table 1. *Sample laocations in Lafia Municipal.*

Sample Area	Borehole Samples			Well Samples		
	Label	Latitude	Longitude	Label	Latitude	Longitude
Bukan- Sidi	AB_1	8° 31’ 33.58”	8° 31’ 28.44”	AW_1	8°31’ 34.84”	8° 31’ 32.93”
	AB_2	8° 31’ 39.04”	8° 31’ 34.16”	AW_2	8° 31’ 45.55”	8° 31’ 17.54”
	AB_3	8° 31’ 43.18”	8° 31’ 20.2”	AW_3	8° 31’ 47.88”	8° 31’ 12.91”
	AB_4	8° 31’ 42.89”	8° 31’ 22.54”	AW_4	8° 31’ 44.68”	8° 31’ 14.18”
	AB_5	8° 31’ 49.94”	8° 31’ 19.6”	AW_5	8° 31’ 44.67”	8° 31’ 19.14”
Agwan- Maina	BB_1	8° 30’ 25.83”	8° 30’ 21.22”	BW_1	8° 30’ 25.67”	8° 30’ 19.54”
	BB_2	8° 30’ 24.04”	8° 30’ 16.9”	BW_2	8° 30’ 24.59”	8° 30’ 14.45”
	BB_3	8° 30’ 25.02”	8° 30’ 14.36”	BW_3	8° 30’ 19.89”	8° 30’ 8”
	BB_4	8° 30’ 18.85”	8° 30’ 5.11”	BW_4	8° 30’ 19.53”	8° 30’ 7.21”
	BB_5	8° 30’ 6.68”	8° 30’ 15.23”	BW_5	8° 30’ 19.09”	8° 30’ 5.93”
Tudun Gwandara	CB_1	8° 29’ 49.15”	8° 30’ 6.58”	CW_1	8° 29’ 51.11”	8° 30’ 5.05”
	CB_2	8° 29’ 45.49”	8° 30’ 7.1”	CW_2	8° 29’ 52.6”	8° 30’ 1.32”
	CB_3	8° 29’ 47.03”	8° 30’ 30.34”	CW_3	8° 29’ 48.22”	8° 30’ 6.55”

Sample Area	Borehole Samples			Well Samples		
	Label	Latitude	Longitude	Label	Latitude	Longitude
Sabon Pegi	CB_4	8° 29’ 51.57”	8° 30’ 36.06”	CW_4	8° 29’ 45.85”	8° 30’ 13.89”
	CB_5	8° 29’ 52.42”	8° 30’ 35.11”	CW_5	8° 29’ 45.12”	8° 30’15”
	DB_1	8° 30’ 25.83”	8° 30’ 21.22”			
	DB_2	8° 30’ 24.04”	8° 30’ 16.9”			
	DB_3	8° 30’ 25.02”	8° 30’ 14.36”			
	DB_4	8° 30’ 18.85”	8° 30’ 5.11”			
	DB_5	8° 30’ 6.68”	8° 30’ 15.23”			

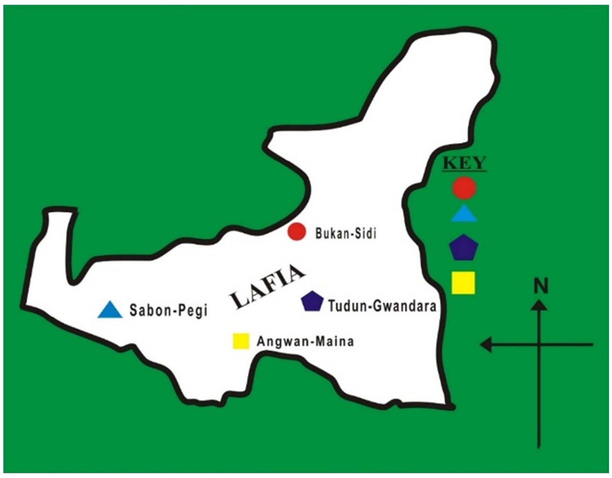

Figure 1. *Map of Lafia Local Government Area.*

Table 2. *Mean EC of Boreholes and Hand-dug well water Samples at Bukan-Sidi.*

Wet Season			Dry Season		
Samples	σ±SD (µS/cm)	S_e	Samples	σ±SD (µS/cm)	S_e
AB_{1wet}	52.40±2.62	1.51	AB_{1dry}	52.37±1.53	0.88
AB_{2wet}	104.70±2.84	1.64	AB_{2dry}	113.53±0.62	0.36
AB_{3wet}	100.30±0.81	0.46	AB_{3dry}	77.07±0.66	0.38
AB_{4wet}	52.23±0.32	0.18	AB_{4dry}	116.63±1.24	0.72
AB_{5wet}	119.10±0.75	0.43	AB_{5dry}	80.10±0.88	0.51
AW_{1wet}	259.00±1.00	0.58	AW_{1dry}	126.00±0.78	0.45
AW_{2wet}	384.00±5.43	3.14	AW_{2dry}	404.00±4.36	2.52
AW_{3wet}	994.00±6.67*	3.86	AW_{3dry}	681.00±7.04	4.07
AW_{4wet}	640.00±1.58	0.91	AW_{4dry}	533.00±7.04	4.07
AW_{5wet}	615.00±4.06	2.35	AW_{5dry}	502.00±4.74	2.74
WHO	1000.0			1000.00	

SD- Standard Deviation, S_e–Standard Error, * Values ≅1000µS/cm.

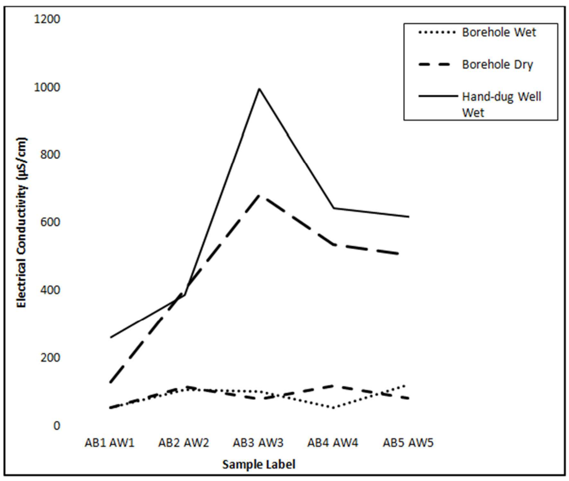

Figure 2. *Seasonal variation of EC of Boreholes and Hand-dug wells at Bukan-Sidi.*

3. Results and Discussion

3.1. Results

Data collected at Bukan–Sidi from Hand-dug wells and Boreholes in the wet and dry seasons were analyzed and the results are presented in Table 2 and figure 2. The seasonal variation of the mean values of electrical conductivity in wet and dry seasons is shown in figure 3.

The locations AB_{5wet} (119.10±0.75) and AB_{4wet} (52.23±0.32) had the highest and lowest value of EC for borehole water and AW_{3wet} (994.00±6.67) and AW_{1wet} (259.00±1.00) had the highest and lowest values for EC of well water respectively. In general, EC values for borehole in Bukan-Sidi, Lafia were relatively lower than those of well water during the wet season. Although, the EC values for both borehole and well water were measured below the recommended EC value.

Drinking water is expected to have EC values below 1000µS/cm for it to be good for public consumption [25, 26, 27]. In this research, borehole and well water surveyed in Bukan-Sidi had EC values <1000µS/cm, However, AW_{3wet} had a value very close to the benchmark hence may not be recommended for drinking. In general, most of the boreholes and Hand-dug Wells assessed can be used for drinking and cooking in the area.

During the dry season, locations AB_{4dry} (116.63±1.24) and AB_{1dry} (52.37±1.53) had the highest and the lowest value of EC for Borehole while the location AW_{3dry} (681.00±7.04) and AW_{1dry} (126.00±0.78) had the highest and lowest value of EC for Hand-dug Wells respectively.

The seasonal variation trend in figure 2 reveals that the values of EC for Hand-dug Wells were higher than the values of EC for Boreholes in this area.

The mean values of the Electrical conductivity of ground water at Angwan-Maina were computed and presented in table 3. Seasonal variations of the measured conductivities for boreholes and Hand-dug Wells in the area is graphically presented in figure 3.

Table 3. *Mean EC of Boreholes and Hand-dug well water samples, Angwan-Maina.*

Wet Season			**Dry Season**		
Samples	**σ±SD (µS/cm)**	**S_e**	**Samples**	**σ±SD (µS/cm)**	**S_e**
BB_{1wet}	91.03±2.92	0.02	BB_{1dry}	92.50±0.40	0.23
BB_{2wet}	132.53±2.80	1.62	BB_{2dry}	126.77±0.37	0.21
BB_{3wet}	137.87±1.90	1.10	BB_{3dry}	141.80±1.82	1.05
BB_{4wet}	161.07±2.50	1.45	BB_{4dry}	175.50±2.78	1.61
BB_{5wet}	172.07±1.62	0.94	BB_{5dry}	171.33±2.12	1.23
BW_{1wet}	509.00±8.51	4.92	BW_{1dry}	1239.00±23.29*	13.46
BW_{2wet}	777.00±7.81	4.51	BW_{2dry}	146.33±5.90	3.41
BW_{3wet}	878.00±1.00	0.58	BW_{3dry}	759.00±4.06	2.35
BW_{4wet}	1488.00±23.86*	13.79	BW_{4dry}	1358.00±6.93*	4.01
BW_{5wet}	1154.00±4.64*	2.68	BW_{5dry}	1110.00±6.44*	3.72
WHO	1000.00			1000.00	

SD- Standard Deviation, S_e–Standard Error, σ-Mean,* Values ≥1000µS/cm.

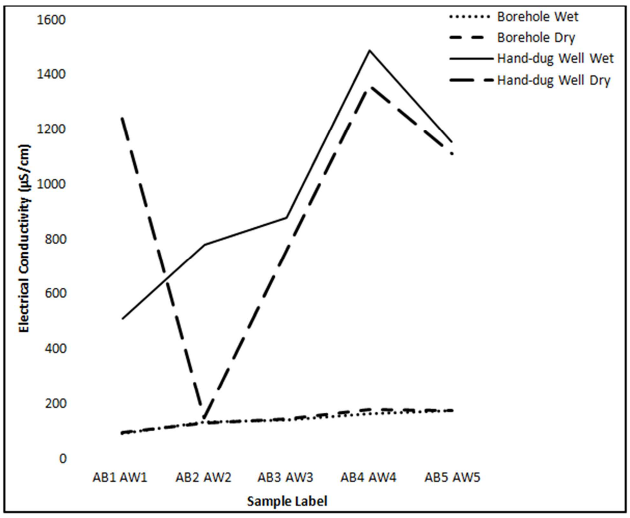

Figure 3. *Seasonal variation of EC of Boreholes and Hand-dug Wells in Angwan-Maina.*

The Electrical Conductivity (EC) of Angwan-Maina during the wet season was measured and recorded in the table 3. The seasonal variation of EC mean values for Boreholes and Hand-dug wells for both wet and dry seasons is represented in figure 3. The sample locations BB_{5wet} (172.07±1.62) and BB_{1wet} (91.03±2.92) had the highest and lowest values of EC for Boreholes. Similarly; BW_{3wet} (1154.00±4.64) andBW_{4wet} (504.00±8.51) had the highest and lowest values for EC of Hand-dug well water in this study area.

In general, EC values of Borehole water in this area were relatively lower than those of Hand-dug well waters in this season. The Borehole and Hand-dug well water in this area were measured below the recommended except for the locations BW_{4wet} (1488.00±23.29) and BW_{5wet} (1154.00±4.64) which had significant high values of EC >1000µS/cm as recommended by United States Environmental Protection Agency (USEPA), Standard Organization of Nigeria (SON) and World Health Organization (WHO) [25-27] for good drinking water.

During the dry season, the locations BB_{4dry} (175.50±2.78) and BB_{1dry} (92.50±0.40) had the highest and the lowest value of EC for Borehole while the locations AW_{4dry} (1358.00±6.93) and AW_{3dry} (759.00±4.07) had the highest and lowest value of EC for well water respectively.

In general, the value for EC of Borehole were measured and found to be lower than the Hand-dug well water in this region. The EC value for these locations; BW_{1dry}, BW_{4dry} and BW_{5dry} were greater than 1000µS/cm. Therefore, they are not recommended for consumption by the people living in this area.

The mean values of the EC of ground water at Tudun-Gwandara were measured and presented in table 4. Seasonal variations of the measured electrical conductivities for Boreholes and Hand-dug wells in the area is graphically presented in figure 4.

Table 4. *Mean EC of Boreholes and Hand-dug well water Samples Tudun-Gwandra.*

Wet Season			Dry Season		
Samples	**σ±SD (μS/cm)**	**S_e**	**Samples**	**σ±SD (μS/cm)**	**S_e**
CB_{1wet}	45.53±0.24	0.14	CB_{1dry}	445.00±5.79	3.35
CB_{2wet}	63.70±1.00	0.58	CB_{2dry}	59.00±3.81	2.20
CB_{3wet}	26.70±0.69	0.40	CB_{3dry}	65.60±1.00	0.58
CB_{4wet}	278.00±4.95	2.86	CB_{4dry}	70.23±0.42	0.24
CB_{5wet}	432.00±7.11	4.11	CB_{5dry}	384.00±5.29	3.06
CW_{1wet}	1335.00±19.66*	11.36	CW_{1dry}	974.00±7.65	4.42
CW_{2wet}	465.00±0.72	0.42	CW_{2dry}	548.00±4.06	2.35
CW_{3wet}	533.00±1.00	0.58	CW_{3dry}	1416.00±11.85*	6.85
CW_{4wet}	256.00±1.73	1.00	CW_{4dry}	386.00±1.00	0.58
CW_{5wet}	420.00±4.36	2.52	CW_{5dry}	535.00±6.67	3.86
WHO	1000			1000	

SD- Standard Deviation, S_e–Standard Error, σ-Mean, * Values >1000μS/cm.

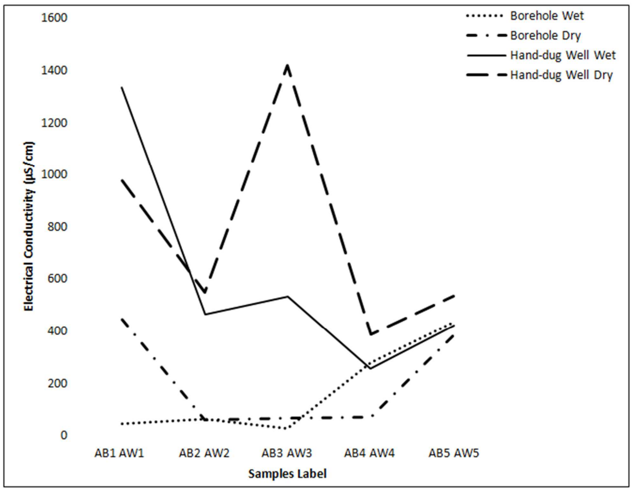

Figure 4. *Seasonal variation of EC of Boreholes and Hand-dug wells.*

The electrical conductivity EC was measured and recorded in table 3. A seasonal variation of the data obtained is shown in figure 5 for both wet and dry seasons. The locations CB_{5wet} (432.00±7.11) and CB_{3wet} (26.70±0.69) had the highest and the lowest values of EC for Boreholes meanwhile, CW_{1wet} (1335.00±19.66) and CW_{4wet} (256.00±1.73) had the highest and the lowest values of EC for Hand-dug wells respectively.

In general, the values of EC for both Borehole and Well water in this area in this season were within the recommended value except, for the location CW_{1wet} which had EC value of 1335.00μS/cm greater than 1000μS/cm. This implies that, this well water is not safe for drinking.

During the dry season, the electrical conductivity of this area was also measured and recorded in the table 4. The locations CB_{1dry} (445.00±5.79) and CB_{2dry} (59.00±3.81) had the highest and the lowest values of EC for Borehole water while the location CW_{3dry} (1416.00±11.85) and CW_{4dry} (386.00±1.00) had the highest and lowest values of EC for Well water respectively.

In general, the values of EC for Boreholes were measured were found to be lower than the Hand-dug well waters in this region. The EC value in this location CW_{3dry} was greater than the benchmark of 1000μS/cm. Therefore, it is not safe for consumption by the residents.

The mean values of the Electrical conductivity of ground water at Sabon-Pegi were measured and reported in table 5. Seasonal variations of the measured electrical conductivities for Boreholes and Hand-dug wells in the area is graphically presented in figure 5.

Table 5. *Mean EC values of Borehole samples, Sabon-Pegi during the wet and dry season.*

Wet Season			Dry Season		
Samples	**σ±SD (μS/cm)**	**S_e**	**Samples**	**σ±SD (μS/cm)**	**S_e**
DB_{1wet}	95.53±1.26	0.74	DB_{1dry}	132.17±1.79	1.03
DB_{2wet}	165.63±2.29	1.32	DB_{2dry}	165.47±4.03	2.33
DB_{3wet}	104.70±0.84	0.49	DB_{3dry}	28.70±0.68	0.39
DB_{4wet}	46.17±0.21	0.12	DB_{4dry}	43.70±1.00	0.58
DB_{5wet}	551.33±2.89	1.67	DB_{5dry}	588.00±4.18	2.42

SD- Standard Deviation, S_e–Standard Error, σ-Mean, * Values >1000μS/cm.

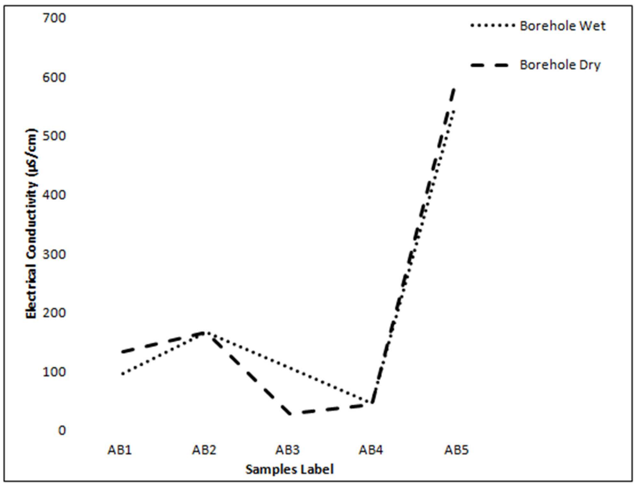

Figure 5. *Seasonal variation of electrical conductivity of Boreholes and Hand-dug Wells.*

The electrical conductivity EC was measured and recorded in the table 5. A graphical presentation of the seasonal variation of EC is shown in figure 5 for both wet and dry seasons. There were no Hand-dug wells found in this region. The major source of water is Borehole. The locations DB_{5wet} (551.33±2.89) and DB_{4wet} (46.17±0.21) had the highest and the lowest values of EC for the sampled boreholes. In general, the borehole water in this region had the value of EC below the benchmark value of 1000µS/cm as recommended by USEPA, SON and WHO, for a good water quality. These boreholes are therefore safe for public consumption.

During the dry season, the electrical conductivity EC was measured and reported in the table 4. The locations DB_{5dry} (588.00±4.18) and DB_{4dry} (28.70±0.68) had the highest and the lowest values of EC for the sampled boreholes water. In general, the borehole water in this area had the values of EC below the maximum value of 1000µS/cm as recommended for a good water quality. These boreholes are therefore safe for public consumption.

3.2. Discussion of Findings

One of the basic or fundamentals to wellbeing as an essential human right and a part of effective policy for public health assurance is access to safe drinking water. Environmental Education EE plays an important role to bring to the general public, privileged information about the safety of their drinking water.

This ought to be truly the undertaking of the monitoring agencies, tertiary and research institute set up together as an imperative part of their social and coordinate duty to each Nigerian. A consumer may just be made mindful of potential issues related with drinking water, through media inclusion or access to inquire about distribution. This study assessed the quality of drinking water sources such as Boreholes and Hand-dug wells in Lafia Municipal Area, based on the Electrical Conductivity (EC) as a standard for surveillance.

During the research undertaking, the following results were evident. The mean EC for Borehole water samples ranged from 26.70µS/cm for CB_{3wet} Tudun-Gwandara to 551.33µS/cm for DB_{5wet} Sabon-Pegi during the wet season and 28.70µS/cm for DB_{3dry} Sabon-Pegi to 588.00µS/cm for DB_{5dry} Sabon-Pegi during the dry season. While the mean EC value for Hand-dug wells ranged from 256.00µS/cm for CW_{4wet} Tudun-Gwandara to 1488.00µS/cm for BW_{4wet} Angwan-Maina during the wet season also ranges from 126.00µS/cm for AW_{1dry} Bukan-Sidi to 1416.00µS/cm for CW_{3dry} Tudun-Gwandara during the dry season respectively.

From the Seasonal variation of electrical conductivity of Boreholes and Hand-dug wells it shows that seasonal variation has less effect on the Boreholes than the Hand-dug wells. The results obtained in this study also suggest that, electrical conductivity of Boreholes and Hand-dug wells in this area does not follow a particular pattern but rather depends wholly on human activities and natural geographical formation of a specific location.

High level of EC mean values of Hand-dug wells were as a result of run-off, infiltration, percolation from dumpsite, Agricultural activities, abattoir, domestic waste, industrial waste, leachates etc. located near the wells and rivers, also, natural phenomena such as; erosion, flood, high temperature, soil type etc. This is possible because of the shallow nature of the Hand-dug wells.

A comparison of EC values obtained in this research and other researchers is giving in table 6 below in different researches.

Table 6. *Comparison of EC mean values Obtained from different places.*

Study	Area	Boreholes EC (µS/cm)	Hand-dug wells EC (µS/cm)
Oki & Ombu, [28]	Yenagoa, Bayelsa	1156.00 -1625.00	
Oyelami *et al*.[29]	Osogbo, Nigeria		70–364
Kudu [30]	Bida, Niger State, Nigeria	1224.67–1485.00	1034.33-1335.00
Shigut *et al*.[31]	Robe Town, Ethiopia	567.67–627.33	
Temaugee et al [32]	Kontagora, Niger State	233.20–346.20	150.20–348.40
Kazeem & Christopher [33]		150–720 wet 190–810 dry	
Shafiu *et al*. [34]	Benue, Nigeria		53.5–985 wet 47.4–1398 dry
Makwe & Chup [8]	Karu Abattoir, Nasarawa State		333.56–358.33
Present work	Lafia Nasarawa State	26.70–551.33wet 28.70–588.00 dry	256–1488 wet 126–1416 dry
WHO		1000.00	1000.00

From table 6, the mean EC values of Boreholes in this study area is lower than the values obtained by other researches. This is because, the basement complex in this area does not have ions that will contribute to high electrical conductivity of Boreholes.

The primary purpose of this study was to give the residents of Lafia Municipal Area a quality education on the seasonal variation of electrical conductivity of groundwater and its implication on the residents. The samples of water collected were tested, the result showed high electrical conductivity in some of the Hand-dug wells while that of Boreholes were far below the benchmark of 1000µS/cm. Those wells that their conductivity was high in the dry season, was as a result of percolation from the dumpsites. The leachate flows with heavy metals into the wells and this leads to an increase in the electrical conductivity which impose a threat on the health of the consumers of these water sources.

In view of the health threat of using this contaminated water, the researchers visited those areas which their Hand-dug wells had higher electrical conductivity and explained the results to them telling them the implications of consuming waters from these wells. The residents were highly educated and well informed on the risks and dangers of making use of these waters.

The residents were also advised to avoid creating dumpsite within the town settlement because leachates from the dumpsite located near their residence are the major sources of contaminants of Hand-dug wells. The boreholes EC were low because of their deep depth. The level of inflow or percolation into borehole water is low as compare to hand-dug wells which is shallow and surface inorganic matter can easily percolate into them.

The researcher encouraged the residents to strictly use Borehole water for drinking and cooking as the electrical conductivities of the Borehole water were very low as been measured. Hand-dug wells should use for other domestic chores such as washing, bathing, flushing etc. The researcher also promised residents to publish the research work in order to help Government and other Environmental Monitoring Agencies to take necessary measures that will enhance environmental safety and their well water safe for drinking.

4. Conclusion

This research work reported the Electrical Conductivities EC of groundwater in Lafia Municipal Area, Nasarawa State. From the results obtained in this study, the values of Electrical Conductivity out of thirty (30) Well water samples collected during the Wet and Dry Seasons, seven (7) Hand-Dug Wells sampled were higher than the benchmark while seven (7) Hand-Dug Wells sampled were near the benchmark of 1000µS/cm respectively as recommended by the Local and International Monitoring Agencies as a result of the seasonal variation.

Out of thirty (30) Hand-dug wells sampled both during the wet and dry seasons. The ones with EC values above or near the benchmark were therefore not recommended by the researcher as safe for drinking and cooking but can be used for other purposes. Accordingly, forty (40) Boreholes electrical conductivity values were far below the benchmark (<<1000µS/cm) for both wet and dry seasons. Hence, were therefore, recommended by the researcher as good for drinking, cooking and other purposes.

5. Recommendations

Based on the results obtained in this study, the following recommendations are made.

i. Since the values of EC are proportional to the amount of inorganic constituents dissolved in form of ions in water, it will be informative to know the quality and quantity of these dissolved solids in the ground water in the area. Hence, further research preferably a physiochemical analysis using Atomic Absorption Spectra (AAS) of Wells and groundwater should be carried out to ascertain the quality and quantity of dissolved inorganic constituents in the area.

ii. Radionuclide constituents of water in Lafia Municipal Area should also be examined. This will give information completely about the safety of drinking water in the area.

iii. Efficient system for garbage collection and its disposal outside the city area should be enhanced by the government agencies and all citizens.

iv. Recycling of waste into useful products, should be encouraged among citizens and government at all levels, since this will reduce the amount of waste that will infiltrate or percolate into Hand-dug wells and Boreholes.

v. Education of people through media about the protection of environment should be carried out by all and sundry or individuals.

vi. Environmental Education (EE) should be given great attention at all levels of learning such as; primary, secondary and tertiary institutions and should be highly included in the school curriculum.

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