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Evaluation of Drinking Water Quality Using Electrical Conductivity: A Case Study of Nassarawa Local Government Area, Kano State

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ABSTRACT

This research was aimed at determining the electrical conductivity through different water samples, in Nassarawa Local Government Area of Kano. It assesses the quality of different drinking water samples by determining their electrical conductivities. Samples of Borehole, Tap and Well water, were collected so many times from different sampling points and locations. The parameters determined include pH, Temperature, Mean Electrical conductivity and Standard Deviation (SD). The results showed that, well water has the highest conductivity of 0.0065794mhos/m followed by Borehole with 0.003923168mhos/m and lastly, the Tap water which has 0.0017659mhos/m, which means that well water sample conducts more electricity followed by Borehole and Tap water samples. This is as a result of so many impurities and other dissolved ionic solutes found within the well. The research explicitly informed that, well water and borehole have less quality in Nassarawa Local Government Area, as such it is not good for human consumption.

Keywords: *pH, Temperature, Mean Electrical conductivity, Standard Deviation*

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1.0 Introduction

Any substances which allow electricity to flow through them are called conductors. Those which do not allow electricity to flow are called insulators. Examples of conductors are metals salt and inorganic acid solutions and that of Insulators are air, plastic materials, rubber, wood, paper, ebonite, pure water, organic acid solutions, etc. Silver is the best of the metallic conductors; copper is the next best. Pure copper inside flex and plastic materials is widely used as connecting wire for domestic and commercial electricity supplies. When impurities, however small, are mixed with pure copper, an alloy is produced of much lower conductivity or, to put it the other way, of much higher electrical resistance. Nichrome and mangnin are two copper alloys used in circuits as resistance wire. The insulating properties of materials can break down under certain conditions and they became conductors. Air at normal pressure is usually an insulator, but flashes of lighting show their conduction path during electrical storms (Alther, 1983).

Conductivity is a measure of the ability of water to pass an electrical current which is affected by the presence of inorganic dissolved solid such as chloride, nitrates, sulphate and phosphate anions (ions that carry a negative charge) or sodium, magnesium calcium, iron, aluminum cations (ions that carry a positive charge). Organic compounds like oil, phenol, alcohol and sugar do not conduct electrical current very well and therefore have a low conductivity when in water. Conductivity is also affected by temperature: the warmer the water the higher the conductivity, for this reason, conductivity is reported at 25^0C (Battino, 1991).

Also electrical conductivity is the reciprocal of electrical resistivity and measures a materials ability to conduct an electrical current. It is commonly represented by the Greek letter δ (Sigma), but K (Kappa) isespecially used. Its S.I unit is Siemens per meter (S/m) and (GSE) unit is reciprocal second (S^{-1}) (Atakwanaa, et al, 2004). As an example, if a 1M x 1M x 1M solid cube of material has sheet contact on two opposite faces and the resistance between these contact is 1Ω, then the resistivity of the material is 1Ωm.

2.0 Background of the Research

The demand for clean drinking and domestic purposes water for day-to-day and commercial interests/activities has surpassed even the interest in healthy living. As such, Electrical conductivity is widely used to quickly estimate the ions or soluble-salt concentration in solids, water supplies fertilizer solutions, chemical solutions and water deionization systems. It is useful to assess the sources of pollution and often employed to monitor desalination of plants. In coastal regions, conductivity data can be used to decide the extent of intrusion of sea water in to ground water.

2.1 Electrical Conductivity of Solids

One of the defining characteristics of solid is that, its particles were packed extremely close together, and therefore it is not possible for nuclei to move very far from their equilibrium positions. As a result, only electrons carry current in solids and not ions. Electrons are extremely small and can easily move among the atoms without creating holes or fractures in the atomic framework, therefore wires can carry current for a long period without incurring damage. The best conductors are on the left side of the periodic table, since those are the elements with the weakest bond on their outermost electrons (Benjamin, 2002).

2.2 Electrical Conductivity of Liquid

In a liquid, the situation is again different. The molecules in this case can slide past each other, so both ions and electrons can carry currents. Pure water is a poor conductor because

the water molecules tend to keep a strong bond on their electrons and few electrons or ions are available to move. However, with the addition of even a small amount of certain substances called electrolytes, typically salts or bases, water can become quite a good conductor. When table salt NaCl, is added to water, the NaCl molecules dissolve into Na^+ and Cl^- ions, which can then move and create currents. This explains why electric currents flow through the cells in our body. Cellular as well as extracellular fluids are quite salty. When we sweat, however, not just water but also electrolytes are lost, with the result that dehydration strongly impacts on our cells electrical systems. For this reason, electrolytes are included in sports drinks and formulas for rehydrating infants who have diarrhea. Since current flow in liquids involves entire ions, physical signs of its occurrence can frequently be seen. For example, the H_2SO_4 battery acid in a heavily used car battery gradually loses hydrogen ions that are the main charge carriers completing the circuit inside the battery. The sulfate SO_4 is then deposited as a blue crust on the battery posts. Many resistors and conductors have a uniform cross section with a uniform flow of electric current, and are made of one material. In this case, the electrical resistivity ρ is defined as,

$$\rho = R\frac{A}{L} \tag{1}$$

Here,
R – the electrical resistance of a uniform specimen of the material,
L – the length of the piece of material and
A – the cross sectional area of the specimen.

Conductivity δ is define as the inverse of resistivity,

$$\delta = \frac{1}{\rho} \tag{2}$$

Electrical conductivity strongly depends on temperature, as such, electrical conductivity of water samples measured at various temperatures need to be corrected to values corresponding to a standard temperature for meaningful data interpretation. In geophysical investigation, verification of resistivity images may require laboratory measurement of core samples at a common room temperature, which need to be adjusted to the subsurface temperature at sampling locations, which may have seasonal variability.

As temperature increases, molecules velocity also increases. Kinetic energy of molecules is in square law proportional to the velocity of the molecules,

$$(E_k = \frac{MV^2}{2}) \tag{3}$$

So, when temperature increases, more molecules have higher kinetic energy, thus the fraction of molecules that have high enough kinetic energy to exceed the activation energy also increases, therefore, more molecules dissolve in to ions. (Benedek & Villars, 2000).

2.3 Electrical Conductivity of Gas

Gas molecules are normally widely separated from each other and therefore cannot conduct electricity by passing electrons from atom to atom as solids do. Not surprisingly, gases are therefore good insulators. Lightning is a good example of opposite charges gradually build up in a storm cloud and on the ground, thereby creating a stronger and voltage differences. However, there is almost no current flow until finally the voltage attains a certain threshold

and triggers and is the impressive example of what is known as a spark or electrical discharge (Brown et al., 1999).

3.0 Materials and Method

3.1 Materials

Glass tube, connecting wires, battery (0 – 12V), ammeter (0 – 200mA), voltmeter (0 – 20V), rheostat, different water samples (borehole, tap and well water), distilled water, pH meter, thermometer and Geographical Positioning System (GPS).

3.2 Methodology

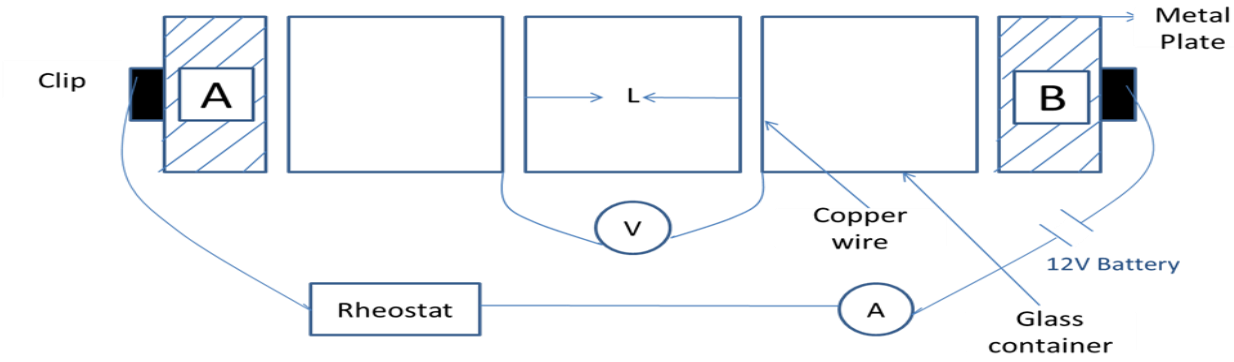


Figure 1. Circuit diagram of Determination of electrical conductivity

The apparatus was set up as shown in figure 1. Starting with the circuit, the power supply was set to read 12V, the glass cylinder was washed with distilled water to avoid contamination with other chemicals. After that, the water sample was poured into the glass cylinder to certain volume. The power supply was switched on and the rheostat was also positioned at the initial point, and so the readings were observed carefully and recorded for both the two meters (Ammeter and Voltmeter), continuously. The rheostat was positioned at the initial point to the center point and from center to the end point of the rheostat and each time, the reading was observed and recorded for several times before replacing another water sample. The volume of the water was also measured and recorded. In continuation, water samples were replaced one after the other and at the same time recording the readings. The reading was taken at least nine times (9 times) for each of the water sample.

After tabulating the readings of the voltage and current, the average/mean conductivity and standard deviation were calculated.

3.2.1 Sampling and Identification

The water samples were collected from three different sources of water which includes Borehole, Tap and Well water at Nassarawa Local Government Area of Kano State. During the sampling process, each water sample was collected in a clean well labeled colorless container, usually bottle.

The samples were identified with reference to the source using certain alphabet and numbering. Borehole water samples were represented by B, well water by W and tap water by T, this was explained in section 3.2.3.

3.2.2 Data Collection and Analysis

The data collected within the study area were presented in table 1.Noting that, the temperature and pH of the samples were recorded at the instant of collection.

Table 3.1 Showing the water samples and their location.

S/N	Location	pH	Latitude	Longitude	Elevation	Sample	Temperature
1	Hotoro Tsamiyar Boka Bus-stop	5.35	N11^{0}58	E008^{0}29	483m	Well	32^{0}c
2	Hotoro Tsamiyar Boka Bus-stop	5.65	N11^{0}58	E008^{0}35	486m	Borehole	30^{0}c
3	Hotoro Kukar Dillalai	5.97	N11^{0}58	E008^{0}35	482m	Borehole	33^{0}c
4	Hotoro Layin Muntari Paris	6.36	N11^{0}58	E008^{0}35	482m	Borehole	33^{0}c
5	Kawon Lambu	6.69	N11^{0}59	E008^{0}34	470m	Borehole	33^{0}c
6	Kawon Lambu	6.19	N11^{0}59	E008^{0}34	466m	Tap	31^{0}c
7	Kawo Bakin Lambu	5.90	N11^{0}59	E008^{0}34	471m	Borehole	32^{0}c
8	Matan Fada	6.78	N11^{0}59	E008^{0}32	482m	Well	34^{0}c
9	Hotoro Masallacin Juma'a	6.52	N11^{0}58	E008^{0}34	497m	Borehole	30^{0}c
10	Hotoro Cikin Gari	6.37	N11^{0}58	E008^{0}34	503m	Borehole	30^{0}c
11	Unguwar Jarkasa	5.55	N11^{0}58	E008^{0}34	495m	Borehole	32^{0}c
12	Unguwar Jarkasa	5.71	N11^{0}58	E008^{0}34	505m	Borehole	31^{0}c
13	Layin Shehu Na Allah	7.15	N12^{0}00	E008^{0}34	467m	Tap	31^{0}c
14	Kawaji Cikin Gari	5.35	N12^{0}00	E008^{0}34	477m	Tap	29^{0}c
15	Kawaji Cikin Gari	6.67	N12^{0}00	E008^{0}34	476m	Tap	30^{0}c
16	Layin Mohd Goni	7.35	N12^{0}00	E008^{0}34	478m	Tap	30^{0}c
17	Layin Shehu Aliyu Hadeja	6.19	N12^{0}01	E008^{0}34	480m	Borehole	30^{0}c
18	Layin Alh. Tukur Buhari	6.63	N12^{0}01	E008^{0}34	477m	Borehole	33^{0}c
19	Maimalari	5.68	N12^{0}01	E008^{0}34	475m	Borehole	31^{0}c
20	Maimalari	6.39	N12^{0}01	E008^{0}34	475m	Borehole	30^{0}c
21	Layin Dirimi	6.01	N12^{0}01	E008^{0}33	453m	Borehole	32^{0}c
22	Layin Dirimi	7.65	N12^{0}01	E008^{0}33	451m	Borehole	30^{0}c
23	Yan Balangu	6.43	N12^{0}01	E008^{0}33	461m	Borehole	32^{0}c
24	Yan Balangu	6.30	N12^{0}01	E008^{0}33	458m	Borehole	33^{0}c
25	Unguwar Gabas	5.92	N12^{0}01	E008^{0}33	464m	Borehole	30^{0}c
26	Unguwar Gabas	7.30	N12^{0}01	E008^{0}33	463m	Borehole	33^{0}c
27	Kwanar 'Yan Gana	6.83	N12^{0}01	E008^{0}33	460m	Borehole	32^{0}c
28	Kwanar 'Yan Gana	6.46	N12^{0}01	E008^{0}33	469m	Borehole	31^{0}c
29	Layin Mai Unguwa	6.10	N12^{0}01	E008^{0}33	460m	Borehole	33^{0}c
30	Layin Kasuwa	6.41	N12^{0}01	E008^{0}33	463m	Borehole	30^{0}c
31	Layin Kasuwa	6.33	N12^{0}01	E008^{0}33	459m	Borehole	32^{0}c
32	Layin Walahau Sare	6.24	N12^{0}01	E008^{0}33	464m	Borehole	30^{0}c
33	Layin Gidan Jakai	6.48	N12^{0}01	E008^{0}33	459m	Borehole	32^{0}c
34	Layin Gidan Jakai	6.24	N12^{0}01	E008^{0}33	469m	Borehole	30^{0}c
35	Layin Dogo Me Rake	6.21	N12^{0}01	E008^{0}33	460m	Borehole	32^{0}c
36	Layin Umaru Me Biredi	5.85	N12^{0}01	E008^{0}33	460m	Borehole	33^{0}c
37	Ganga	5.88	N12^{0}01	E008^{0}33	460m	Borehole	32^{0}c
38	Layin Fanfo	7.32	N12^{0}01	E008^{0}33	466m	Borehole	30^{0}c
39	Layin Fanfo	6.00	N12^{0}01	E008^{0}33	466m	Borehole	32^{0}c
40	Tagwayen Layi	6.56	N12^{0}01	E008^{0}33	486m	Borehole	33^{0}c
41	Kwana Hudu	5.37	N12^{0}01	E008^{0}31	467m	Borehole	33^{0}c

42	Kwana Hudu	6.40	$N12^{0}01$	$E008^{0}31$	462m	Borehole	$32^{0}c$
43	Kwana Uku	6.21	$N12^{0}01$	$E008^{0}31$	463m	Borehole	$30^{0}c$
44	Gaman Kwari	6.62	$N12^{0}01$	$E008^{0}31$	463m	Borehole	$30^{0}c$

3.2.3 Identification of Water Samples

The samples were identified with reference to the source using certain alphabet and numbers. Noting that borehole water samples were represented by B_n, the well water samples by W_n and the tap water samples by T_n (Wood, 1976)

A total number of 44 samples, S_n were collected from different sources, comprising of 37 from borehole, 5 from tap and 2 from well. Similarly, the samples were marked and identified in tables 3.2, 3.3 and 3.4 respectively.

Table 3.2 Table of sample identification for Borehole water (B)

S/N	Identification Name	General Sampling Mark	Identity Mark
1	Hotoro Tsamiyar Boka Bus-stop	S2	B1
2	Hotoro Kukar Dillalai	S3	B2
3	Hotoro Layin Muntari Paris	S4	B3
4	Kawon Lambu	S5	B4
5	Kawo Bakin Lambu	S7	B5
6	Hotoro Massalacin Juma'a	S9	B6
7	Hotoro Cikin Gari	S10	B7
8	Unguwar Jarkasa	S11	B8
9	Unguwar Jarkasa	S12	B9
10	Layin Shehu Aliyu Hadejia	S17	B10
11	Layin Alhaji Tukur Buhari	S18	B11
12	Maimalari	S19	B12
13	Maimalari	S20	B13
14	Layin Dirimi	S21	B14
15	Layin Dirimi	S22	B15
16	'Yan Balangu	S23	B16
17	'Yan Balangu	S24	B17
18	Unguwar Gabas	S25	B18
19	Unguwar Gabas	S26	B19
20	Kwanar 'Yan Gana	S27	B20
21	Kwana 'Yan Gana	S28	B21
22	Layin Mai Unguwa	S29	B22
23	Layin Kasuwa	S30	B23
24	Layin Kasuwa	S31	B24
25	Layin Wala Hausare	S32	B25
26	Layin Gidan Jakai	S33	B26
27	Layin Gidan Jakai	S34	B27
28	Layin Dogo Me rake	S35	B28
29	Layin Umaru Me Biredi	S36	B29
30	Ganga	S37	B30
31	Layin Fanfo	S38	B31
32	Layin Fanfo	S39	B32
33	Tagwayen Layi	S40	B33
34	Kwana Hudu	S41	B34

35	Kwana Hudu	S42	B35
36	Kwana Hudu	S43	B36
37	Gaman Kwari	S44	B37

Table 3.3 Table of sample identifications for Tap water (T)

S/N	Identification Name	General Sampling Mark	Identity Mark
1	Layin Shehu Na Allah	S13	T1
2	Kawaji Cikin Gari	S14	T2
3	Kawaji Cikin Gari	S15	T3
4	Layin Mohd Goni	S16	T4
5	Kawon Lambu	S6	T5

Table 3.4 Table of sample identifications for Well water (W)

S/N	Identification Name	General Sampling Mark	Identity Mark
1	Hotoro Tsamiyar Boka Bus-stop	S1	W1
2	Matan Fada	S8	W2

4.0 Data Presentation, Results Analysis and Discussion

Knowing fully that, the current (I) and the voltage (V) varies from each other at a distance of 7.4cm between the metal plates.

The Spacing L between the metal plate is L = $\frac{7.4cm}{1000}$cm = 0.07m

The resistance (R) can be calculated from Ohm's Law

$$R = \frac{V}{I} \tag{4}$$

The resistivity (ρ) was obtained from equation (1) while the conductivity (δ) is the reciprocal of resistivity and is obtained from equation (2)

4.1 Area of the Metal Plates

The sides of the metal plate were observed to be equal and as such the dimension were taken from both sides of each plate.

- **For Metal Plates (A) and (B)**

$L_1 = 8.0\text{cm} = 8.0\text{x}10^{-2}\text{m}$

$L_2 = 9.0\text{cm} = 9.0\text{x}10^{-2}\text{m}$

$$L(A) = \frac{8.0\text{x}10^{-2}\text{m} + 9.0\text{x}10^{-2}\text{m}}{2}$$

$$L(A) = \frac{17.0\text{x}10^{-2}\text{m}}{2}$$

$$L(A) = 8.5\text{x}10^{-2}\text{m} = L(B) \tag{5}$$

The width was also find to be equal, therefore,

$W_1 = W_2 = 5.0\text{cm} = 5.0\text{x}10^{-2}\text{m}$

$$W(A) = \frac{5.0\text{ x}10^{-2}\text{m} + 5.0\text{ x}10^{-2}\text{m}}{2}$$

$$W(A) = 5.0\text{x}10^{-2}\text{m} = W(B) \tag{6}$$

But Area,

$$A = LxW \tag{7}$$

And

$$L = \frac{L(A)+L(B)}{2} \text{ and } W = \frac{W(A)+W(B)}{2} \quad (8)$$

$$L = \frac{8.5x10^{-2}m+8.5x10^{-2}m}{2} = 8.5x10^{-2}m \quad (9)$$

With,

$$W = \frac{5.0x10^{-2}m+5.0x10^{-2}m}{2} = 5.0x10^{-2}m \quad (10)$$

From Equation (7),

$$A = 8.5x10^{-2}m \text{ x } 5.0x10^{-2}m$$

$$A = 4.25x10^{-3}m \quad (11)$$

The mean conductivity was calculated from,

$$\overline{\delta_X} = \frac{\sum \delta X_n}{n} \quad (12)$$

While the standard deviation was derived from,

$$\sigma^2 = \frac{\sum(\delta X_n - \overline{\delta_X})^2}{n} \quad (13)$$

Where the Electrical Conductivity is given by,

$$S.D = \sqrt{\frac{\sum(\delta X_n - \overline{\delta_X})^2}{n}} \quad (14)$$

4.2 Electrical Conductivity Calculations

4.2.1 Mean conductivity and Standard Deviation for Borehole Water

For borehole water, the number of samples, n = 37

From equation (12), the mean/average conductivity for borehole water was calculated from,

$$\overline{\delta_B} = \frac{\sum \delta B_n}{n} \quad (15)$$

And it was calculated to be,

$$\overline{\delta_B} = 0.003923168 mhos/m \quad (16)$$

While the Standard Deviation was calculated using equation (14),

$$S.D = \sqrt{\frac{\sum(\delta B_n - \overline{\delta_B})^2}{n}} \quad (17)$$

Which was found to be,

$$S.D_B = 0.00236925 mhos/m \quad (18)$$

4.2.2 Mean conductivity and Standard Deviation for Tap Water

For tap water, the number of samples, n = 5

From equation (12), the mean/average conductivity for tap water was calculated from,

$$\overline{\delta_T} = \frac{\sum \delta T_n}{n} \quad (19)$$

And it was calculated to be,

$$\overline{\delta_T} = 0.0017659 mhos/m \quad (20)$$

While the Standard Deviation was calculated using equation (14),

$$S.D = \sqrt{\frac{\sum(\delta T_n - \overline{\delta_T})^2}{n}} \quad (21)$$

Which was found to be,

$$S.D_T = 0.0015259 mhos/m \quad (22)$$

4.2.3 Mean conductivity and Standard Deviation for Well Water

For well water, the number of samples, n = 2

Also, from equation (12), the mean/average conductivity for well water was calculated from,

$$\overline{\delta_W} = \frac{\sum \delta W_n}{n} \quad (23)$$

And it was calculated to be,

$$\overline{\delta_W} = 0.0065794 mhos/m \quad (24)$$

While the Standard Deviation was calculated using equation (14),

$$S.D = \sqrt{\frac{\sum(\delta W_n - \overline{\delta_W})^2}{n}} \quad (25)$$

Which was found to be,

$$S.D_W = 0.0047874 mhos/m \quad (26)$$

4.3 Summary of the Findings

Tables 4.1 and 4.2 present explicitly the summary of the findings and the range of the measured/observed quantities from equations (16), (18), (20), (22), (24) and (26) respectively.

Table 4.1: Summary of the table below presents the observed results

S/N	Parameters	Borehole Water	Tap Water	Well Water
1	Average Temperature (^{0}C)	31.4	30.2	33
2	Average pH	6.27	6.54	6.06
3	Average conductivity ($mhos/m$)	0.003923168	0.0017659	0.0065794
4	Standard Deviation ($mhos/m$)	0.00236925	0.0015259	0.0047874

Table 4.2: Range of Measured Quantities (Data)

S/N	Measured Quantities	Borehole Water	Tap Water	Well Water
1	Temperature (^{0}C)	30 – 33	29 – 31	32 – 34
2	Conductivity ($mhos/m$)	$0.003923168 \pm 0.00236925$	0.0017659 ± 0.0015259	0.0065794 ± 0.0047874

4.4 Discussion

The results in table 4.2 represent the mean value $\pm$ standard deviation obtained from the calculations. This electrical conductivity showed that well water has higher value than borehole, followed by tap water.

5.0 Conclusion

In conclusion, after the experiment, different results were obtained. The higher conductivity value is due to the high dissolved ions in the water sample. This implies that, the ability of an

electric current to pass through the water is proportional to the concentration of ionic solutes dissolved in the water.

6.0 Recommendations

It was recommended that:

1. People should be educated on the use of treated tap water as its pH is almost neutral, and suitable for human consumptions and other domestic purposes.
2. Further research should be conducted on this topic to determine other physicochemical parameters in order to make timely informed decisions.

7.0 Acknowledgement

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