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Determination of Heavy Metals and Bacterial Contaminations from Different Water Sources in Ikwo, Ebonyi State, Nigeria

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ABSTRACT: The occurrence of high levels of heavy metals in drinking water is a significant health concern due to the accompanying health concerns. Hence, the objective of this study was to evaluate the bacterial species and concentration of heavy metals in certain drinking water sources in Ikwo, Ebonyi State. Nigeria. The analysis of metal concentration revealed that the levels of lead, iron, and mercury in the water exceeded the established limits for drinking water quality set by the World Health Organisation (WHO) and Nigeria standard for drinking water quality (NSDWQ). However, the concentrations of copper, zinc, calcium, and sodium in the water were not statistically significant (P >0.05). The bacteriological count results indicated that the average Total Bacterial Count (TBC) in water samples collected from ponds, rivers, and wells were 5.10 x 10-^{4}, 6.10 x 10-^{3}, and 4.10 x 10-^{4}, respectively. During the experiment, there was a notable disparity (p <0.05) in the bacterial quantities seen in all of the samples. *Escherichia coli* was the predominant strain, representing 70% of all isolates, as indicated by prevalence surveys. Salmonella and *Klebsiella* species accounted for 25% and 39% of isolates, respectively. Research on antibiotics discovered that *Salmonella, Klebsiella* species, and *E. coli* exhibited significant resistance to popular antibiotics, albeit showing some vulnerability to some ones. The presence of antibiotic resistant microbes in drinking water samples from the research region is a significant public health concern due to the high probability of contracting waterborne illnesses and the associated health hazards. This is particularly worrisome for the immune-compromised residents of the area.

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Water constitutes almost 71% of the Earth's surface, according to the World Health Organisation (WHO, 2004). Water is a fundamental element in all living organisms, including the smallest cells. It plays a crucial role in the creation and sustenance of life (Obi *et al.*, 2012). Water is essential and considered the most vital component when producing animals like cattle (Odikamnoro *et al.*, 2014). However, obtaining safe drinking water has always been challenging due to the increasing human populations and activities, which negatively affect the chemical and microbiological properties of the accessible water supplies (Webster *et al.,* 2004). The principal cause of pathogen infiltration into aquifers, which has been demonstrated to lead to pandemic outbreaks of waterborne diseases, is usually linked to inadequate management of wastewater disposal (Völker *et al.,* 2010; Biyela *et al.,* 2004). Non-point sources of pollution, including the dumping of manure onto fields and crops, contribute significantly to the introduction of pathogens into soils and water (Ogunnowo 2004). Animal dung, similar to human excrement, can include high concentrations of harmful microorganisms (>106 per gramme of dung). These microorganisms include viruses, bacteria, protozoa, and helminths, which have the potential to cause zoonotic diseases in humans (Biyela *et al*., 2004). This poses a substantial threat to human well-being in rural areas (WHO, 2006), as private wells that are relied upon by farms for their drinking water can include harmful substances. According to the World Health Organisation (WHO), some 3.4 million people die each year from diseases related to water, with children making up the majority of these fatalities (Nweke *et al.*, 2004). Shallow groundwater contamination resulting from flooding episodes that are directly influenced by rainfall often contribute to the occurrence of waterborne diseases in less developed countries (Gambo *et al.*, 2005). Viruses and pathogenic microorganisms pose a current hazard to groundwater, together with increasing human effects (Obi *et al*., 2012). Traditionally, it has been thought that groundwater is entirely devoid of viruses and bacteria due to the extended time it takes for them to move vertically and their limited ability to survive long enough to reach aquifers (Nweke *et al*., 2004). Nevertheless, the dangers of water contamination are apparent when one takes into account the multiple localised and widespread occurrences of disease-causing microorganisms and viruses that have occurred in the past two centuries and may be linked to polluted groundwater and the intake of drinking water (Khapre *et al.,* 2018). In rural parts of low-income nations such as South Asia and Africa, a significant number of people obtain water from wells, rivers, ponds, and streams without being aware of the potential health hazards involved. While a portion of them cleanse themselves in the creek, others utilise it for the purpose of immersing their cassava and other agricultural products. In addition to felines, canines, and various domesticated animals, certain individuals of religious faith also gather at the same body of water to engage in a form of sacred ritual. When these animals decompose, they introduce a multitude of infectious microbes into the river. Research indicates that certain individuals engage in the act of excreting bodily waste, specifically urine and faeces, within bodies of water such as rivers and streams. Human activity introduces a multitude of viruses into rivers and streams, along with harmful elements from industrial, household, chemical, and agricultural waste, as well as improper disposal of garbage. The problem is exacerbated by the insufficient sanitation systems in the area, which increase the risk of outbreaks of water-borne diseases and the emergence of antibiotic resistance in these harmful microorganisms due to irresponsible usage (Singh and Sao, 2015). Therefore, it is imperative for the sake of public health to regularly conduct testing, evaluation, and surveillance of our water sources, specifically in the remote areas of Ebonyi State. Hence, the objective of this paper was to evaluate the metal content and antibiotic resistant bacterial species from selected drinking water sources in Ikwo, Ebonyi State. Nigeria

MATERIALS AND METHOD

Description of study area: In Ebonyi State, Ikwo is the largest Local Government Area. It is located in the state's eastern region. With a land area of around 500 square kilometers, the city and local government area borders Cross River State, Abakaliki, Izzi, and Ezza local government areas (Wikipedia) (Fig. 1). The town is home to a number of waterways that meander through the villages and towns. There is absolutely no municipal water supply in the town and settlements that surround it. As a result, the majority of the population turns to manually dug wells, boreholes, and streams for domestic water supplies, including drinking water.. The probability of contamination of the streams is high especially during the rainy seasons, from wastewater contaminations, from urban and rural run offs and agricultural activities as the streams flow through the city and its suburbs.

Sample collection and processing: A total of three water samples were collected from each water source at regular four-hour intervals, starting at 7.00 am and ending at 3.00 pm. This sampling was conducted in the months of December, February, and April. The samples were promptly transported to the Microbiology Laboratory of Ebonyi State University on the same day of collection. Aliquots of the samples were then utilized for the selective isolation of certain bacteria using established microbiological methods. The water samples were obtained from multiple places throughout the Ikwo Local Government Area of Ebonyi State using one-liter jerry cans. The jerry cans were initially rinsed with distilled water and subsequently filled with water samples from wells, rivers, and ponds, prior to being filled with the water for examination.

Isolation, purification, and characterisation of planktonic bacteria: Three volumes of 100 mL were filtered using a Sartorius 16824 water pump and a 0.45 μm pore sized filter from Whatman Laboratory Division in Maidstone, England. Subsequently, the membrane was carefully positioned onto the plate containing nutritional media, ensuring the absence of any trapped air bubbles. The plates were thereafter placed in an incubator set at a temperature of 37 degrees Celsius for a duration of 24 hours in order to monitor the development of microorganisms. After this period, the quantity of colonies was tallied. The colonies were subsequently transferred to appropriate selective media, such as Salmonella - Shigella Agar (SSA) for the purpose of isolating *Salmonella and Shigella species*, Mannitol Salt Agar (MSA) for the purpose of isolating Staphylococci, Eosin Methylene Blue (EMB) and McConkey Agar (MA) for the purpose of isolating *E. coli* and other Enterobacteriaceae. The media were acquired from Biolab, a subsidiary of Merck in South Africa. The agar plates were placed in an incubator and kept at a temperature of 37 degrees Celsius for a period of 18 to 24 hours. The bacterial isolates were identified using various methods including colony morphology, Gram's reaction, catalase test, motility test, and biochemical tests such as oxidase test, citrate test, indole test, Methylred-Voges Proskauer (MRVP) test, urease test, hydrogen sulphide production test, and sugar fermentation.

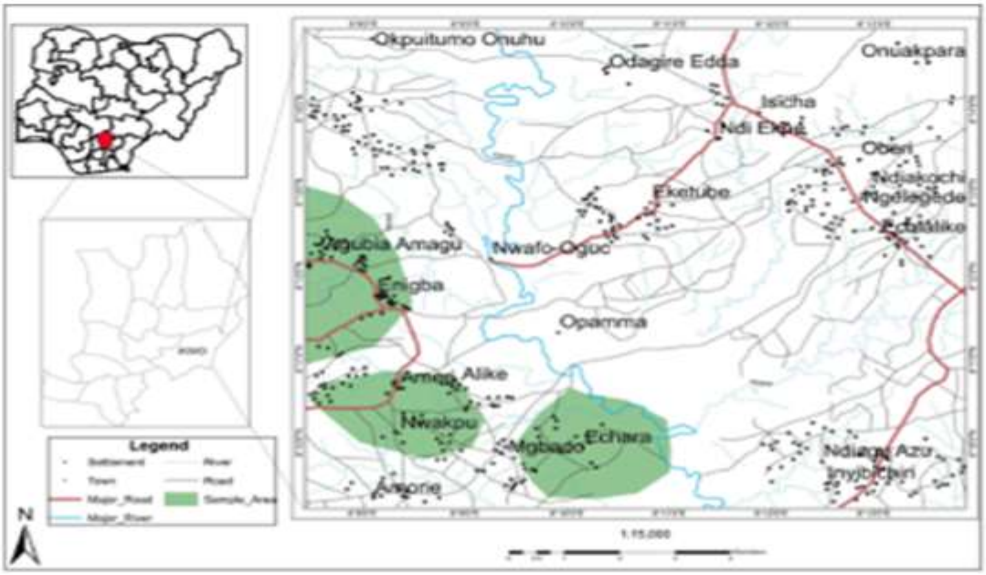

Fig 1: Map of Ikwo L.G.A (Using Geographical Information System).

Determination of heavy metals concentrations in the water samples from different water sources in Ikwo, Ebonyi State. Digestion of sample water: The standard procedure by Engwa, *et al* (2015) can be used to prepare water samples for metal ion analysis by atomic absorption spectrophotometer by digestion. In summary, three sets of 100 mL water samples were collected and transferred into 50 mL Erlenmeyer flasks. These samples were then treated with a mixture of nitric acid and hydrochloric acid in a 3:1 ratio. Subsequently, the samples were subjected to heat on a hot plate in order to decrease the volume to a certain amount of 25 mL. Ultimately, the residual portion of the samples was subjected to a cooling process and subsequently filtered using a Whatman paper filter. Subsequently, the samples were diluted to 100 mL volumetric flasks in preparation for analysis using an Atomic absorption spectrophotometer.

Analysis of Heavy Metal Content: Following the completion of digestion, the AAS equipment was utilised to ascertain the presence and concentration of the metal analyte in the sample. The determined concentrations of the heavy metals were verified using commercially generated standards of the respective metals as a quality control measure (Marcus and Edori, 2016). Each metal analysis was performed with three replicates, and the instrument provides the average of the results.

Statistical Analysis: The results of replicates were pooled and expressed as Mean ± Standard error of mean. Data obtained were subjected to a one-way analysis of variance with the aid of IBM Statistical Package for Social Sciences (SPSS) version 22 and Microsoft Excel 2013 software.

RESULTS AND DISCUSSION

The analysis of the samples revealed that there was no statistically significant change ($P > 0.05$) in the content of heavy metals, specifically copper, zinc, calcium, and sodium. This work corroborates the findings of Mbaenyi-Nwaoha and Egbuche (2012), Iroha *et al*. (2016), and Obi *et al.* (2012), who also observed comparable levels of concentration in water samples collected from Nsukka, Abakaliki, and Abraka, respectively. Copper is a vital element for living species, including humans, and is required in modest quantities in our diet to maintain optimum health. When copper is dissolved in drinking water, it can give the water a pale blue or blue-green colour and a metallic, bitter taste. This can be harmful to health and can cause different health issues if individuals are exposed to it at levels higher than what is considered safe (Akubuenyi *et al*. 2013). Brief instances of contact can result in gastrointestinal disruption, such as feelings of nausea, diarrhoea, dizziness, and vomiting. Prolonged use of water with copper levels over the established limit over an extended period of time can lead to liver or kidney impairment. EPA. (2011). The use of an excessive amount of copper leads to extensive damage to the capillaries, irritation of the gastrointestinal tract, and harm to the surrounding tissues (WHO, 2006). Zinc plays a crucial role in the composition of insulin and is required for protein synthesis (Mbaenyi-Nwaoha and Egbuche, 2012). Jidauna *et al*. (2014) shown that it aids in the control of vitamin A levels in the bloodstream. Elevated levels of zinc can result in the formation of a bitter and oily residue, particularly when subjected to boiling (Gambo *et al,* 2015). The NSDWQ (2007) and WHO (2011) suggest the following limits for aluminium, iron, mercury, magnesium, and lead in water: 0.20 mg/L, 0.3 mg/L, 0.001 mg/L, 0.2 mg/L, and 0.1 mg/L, respectively. There was a notable disparity ($P < 0.05$) in the concentration of the water samples throughout the research period. The outcome aligns with the findings of Peter-Ikechukwu *et al* (2015), who discovered that the average aluminium concentration in water samples from Owerri, Imo State, Nigeria, was 0.07 ± 0.01 mgL-1. Elevated levels of aluminium in water can cause changes in the central nervous system, as well as microcytic anaemia that is resistant to both vitamin D and erythropoietin. Aluminium, when consumed in large amounts, is linked to changes in the functioning of the blood-brain barrier (Bingham and Cohrssen, 2012). The findings also support the research conducted by Adiotomre and Agbale (2015) in Benin City, Edo State. Lead is widely recognised for its toxicity to animals, and there is concern that even low levels of lead exposure, below the threshold for clinical symptoms of lead toxicity, could result in cognitive impairment in early infants (Eze *et al.,* 2015). The presence of iron, magnesium, and lead in water suggests potential contamination from geological sources, the sorts of minerals in the surrounding rocks, and the introduction of garbage into the water system. According to Agbaire and Obi (2009), an elevated level of iron in water can result in the development of blue baby syndrome in infants and goitre in adults. Therefore, consuming water with a high concentration of iron can have adverse health effects, as excessive iron levels are linked to polycythemia (Peter-Ikechukwu *et al.* 2015). The bacteriological analysis of drinking water sources in various sites within the Ikwo local government area showed that the average Total Bacteria Count (TBC) for water samples obtained from ponds, rivers, and wells was 5.10x10-4, 6.10 x 10-3, and 4.10 x10-4 accordingly.

There was a statistically significant difference ($P < 0.05$) in the bacteria load levels of water samples from all research locations during the study period. All the values for total bacteria counts exceeded the WHO threshold of zero per 100 ml. The study corroborates the findings of Noble *et al*. (2003), who observed a substantial bacterial load ranging from 5.10x10-4 to 7.10x10-4 in Ocean Recreational Water Quality. The variation in bacteria count may be attributed to disparities in the sanitary conditions of the study areas. Additionally, the differences in sample locations and varying levels of development in each locality, as well as the enumeration techniques used, can account for the variations in bacteria count rates. The significant presence of bacteria in the water samples analysed in this study is of great concern to public health due to their association with many waterborne illnesses that affect the general population. (World Health Organisation 2006). The prevalence investigation revealed that *Escherichia coli* was the most commonly found bacteria in the water sources, suggesting the presence of enteric pathogens in the water samples. According to a report by WHO in 2006, the absence of proper sanitation facilities, the use of pit latrines, the discharge of untreated wastewater, and the indiscriminate dumping of waste all contribute to the contamination of drinking water in areas where open defecation is practiced, leading to the spread of illnesses. Utilizing water that is contaminated with *Escherichia coli, Klebsiella species*, and *Salmonella* species can lead to the development of illnesses such as pneumonia, lethargy, nausea, stomach cramps, and bloody diarrhoea (Efuntoye and Apanpa, 2010).

Escherichia coli can pose a serious risk to those with weakened immune systems, particularly children and the elderly (Efuntoye and Apanpa, 2010)..

Table 1. Metal concentration of water samples from Wells in different location in Ikwo area as compared with NSDWQ and WHO Recommended Limits.

		Location of Water Sources								
S/N	Metal mgL^{-1}	Amagu	Ekaawoke	Echialike	Etam	Ndufu	Enyibichiri	Inyimagu	NSDWQ	WHO
1	Al	0.02± 0.03^{b}	0.05 ± 0.02^{a}	0.04 ± 0.17^{a}	0.01 ± 0.02^{b}	0.08 ± 0.16^{a}	0.04 ± 0.11^{a}	0.06 ± 0.08^{a}	0.20	0.20
2	Ca	29.51 ± 0.04	35.15 ± 0.02^{a}	33.32 ± 0.04	45.21± 0.00^{a}	34.32 ± 0.01^{a}	34.76 ± 0.04^{a}	27.21 ± 0.01^{a}	65-70	75
3	Cu	0.56 ± 0.06^{a}	0.73 ± 0.10^{a}	0.61 ± 0.09^{a}	0.65 ± 0.12^{a}	0.62 ± 0.04^{a}	0.58 ± 0.02^{a}	0.54 ± 0.00^{a}	NS	1.00-2.00
4	Fe	0.78 ± 0.05^{a}	0.67 ± 0.13^{a}	0.83 ± 0.11^{a}	0.62 ± 0.08^{a}	0.34 ± 0.12^{a}	0.40 ± 0.06^{a}	0.46 ± 0.15^{a}	0.3	NS
5	Pb	0.16 ± 0.07^{a}	0.16± 0.06^{a}	0.17 ± 0.10^{a}	0.13 ± 0.17^{a}	0.15 ± 0.140	0.18 ± 0.08^{a}	0.15 ± 0.06^{a}	0.01	0.01
6	Mg	19.10 ± 0.21^{a}	14.63± 0.12^{a}	15.60 ± 0.14^{a}	19.62 ± 0.04^{a}	17.76 ± 0.07^{a}	18.47 ± 0.11^{a}	8.64 ± 0.04^{b}	0.2	50
7	Hg	0.17 ± 0.07^{b}	0.32 ± 0.10^{a}	0.18 ± 0.14^{b}	0.28± 0.10^{a}	0.19 ± 0.07^{b}	0.15 ± 0.10^{b}	0.15 ± 0.02^{b}	0.001	-
8	K	1.67 ± 0.09^{b}	3.31 ± 0.11^{a}	1.93 ± 0.06	3.67± 0.12^{a}	1.51 ± 0.11^{b}	1.56 ± 0.23^{b}	2.56 ± 0.21^{a}	NS	30
9	Na	2.98 ± 0.04^{a}	3.76 ± 0.04^{a}	3.53 ± 0.02^{a}	2.66 ± 0.01	3.72 ± 0.02^{a}	3.67 ± 0.01^{a}	2.56 ± 0.00^{a}	100-200	NS
10	Zn	1.53 ± 0.02^{a}	0.72 ± 0.01^{b}	0.86 ± 0.08^{b}	0.67 ± 0.12^{b}	1.58 ± 0.05^{a}	1.89 ± 0.07^{a}	1.56 ± 0.09^{a}	3.0	5.0

The results are mean ± SD of well water samples from Amagu, Ekaawoke, Echialike, Etam, Ndufu, Enyibichiri and Inyimagu. Values with different alphabets differed significantly ($p<0.05$) across the row. Key: NR= NO Rivers and BDL= Below Detectable Lim

Table 2. Metal concentration in Rivers from different location of Ikwo compared with NSDWQ and WHO recommended limits.

		Location of Water Sources							*Standard Limits*	
S/N	Metal mgL^{-1}	Amagu	Ekaawoke	Echialike	Etam	Ndufu	Enyibichiri	Inyimagu	NSDWQ	WHO
1	Al	03 ± 0.00^{b}	NR	NR	0.03 ± 0.00^{b}	NR	0.6 ± 0.02^{a}	0.02± 0.00^{b}	0.20	0.20
2	Ca	42.10 ± 0.04^{a}	NR	NR	40.45 ± 0.04^{a}	NR	23.45 ± 0.01^{b}	26.14 ± 0.00^{b}	65-70	75
3	Cu	0.71 ± 0.01^{a}	NR	NR	0.62 ± 0.00^{a}	NR	0.51 ± 0.00^{a}	0.52 ± 0.02^{a}	NS	1.00-2.00
4	Fe	0.63 ± 0.02^{a}	NR	NR	0.35 ± 0.03^{b}	NR	0.43 ± 0.00^{a}	0.42± 0.02^{a}	0.3	NS
5	Pb	0.16 ± 0.00^{a}	NR	NR	0.18 ± 0.00^{a}	NR	0.16 ± 0.00^{a}	0.14 ± 0.02^{a}	0.01	0.01
6	Mg	12.54 ± 0.02^{a}	NR	NR	18.50 ± 0.04^{a}	NR	20.34 ± 0.04^{a}	6.98 ± 0.06^{b}	0.2	50
7	Hg	0.15 ± 0.04^{a}	NR	NR	0.14 ± 0.00^{a}	NR	0.16 ± 0.00^{a}	0.12 ± 0.04^{a}	0.001	-
8	K	2.54 ± 0.01^{a}	NR	NR	3.78 ± 0.00^{a}	NR	3.54± 0.00^{a}	2.12 ± 0.02^{a}	NS	30
9	Na	3.42 ± 0.01^{a}	NR	NR	4.72 ± 0.00^{a}	NR	2.61 ± 0.04^{a}	3.20 ± 0.02^{a}	100-200	NS
10	Zn	0.94 ± 0.00^{b}	NR	NR	0.65 ± 0.01^{b}	NR	0.31 ± 0.02^{b}	1.74 ± 0.04^{a}	3.0	5.0

The results are mean ± SD of four pond water samples from Amagu, Ekaawoke, Echialike, Etam, Ndufu, Enyibichiri and Inyimagu. Values with different alphabets differed significantly ($p<0.05$) across the row. Key: NR= NO Rivers and BDL= Below Detectable Limits

Table 3. Metal Concentration of water samples collected from Ponds in different location in Ikwo Local Government area compared with NSDWQ and WHO Recommended Limits

S/N	**Metal mgL^{-1}**	**Amagu**	**Ekaawoke**	**Echialike**	**Etam**	**Ndufu**	**Enyibichiri**	**Inyimagu**	**NSDWQ**	**WHO**
1	Al	0.03 ± 0.06^{b}	0.02 ± 0.03^{b}	0.06 ± 0.10^{a}	0.02 ± 0.08^{b}	0.08 ± 0.12^{a}	0.04 ± 0.01^{b}	0.02± 0.04^{b}	0.20	0.20
2	Ca	20.23 ± 0.21^{b}	33.41 ± 0.06^{a}	32.61 ± 0.04^{a}	20.24 ± 0.04^{b}	46.50 ± 0.02^{a}	51.10 ± 0.25^{a}	29.42 ± 0.04	65-70	75
3	Cu	0.72 ± 0.08^{a}	0.43 ± 0.06^{a}	0.54 ± 0.05^{a}	0.38 ± 0.02^{a}	0.41 ± 0.03^{a}	0.50 ± 0.01^{a}	0.51 ± 0.01^{a}	NS	1.00-2.00
4	Fe	0.74 ± 0.13^{a}	0.76 ± 0.00^{a}	0.63 ± 0.04^{a}	0.42 ± 0.04^{a}	0.61 ± 0.06a	0.61 ± 0.02^{a}	0.75 ± 0.02^{a}	0.3	NS
5	Pb	0.15 ± 0.023^{a}	0.14 ± 0.06^{a}	0.16 ± 0.15	0.17 ± 0.02^{a}	0.15 ± 0.23^{a}	0.17 ± 0.00^{a}	0.16 ± 0.00^{a}	0.01	0.01
6	Mg	17.56 ± 0.04^{a}	25.67± 0.04^{a}	10.64± 0.01	18.42 ± 0.11	14.64 ± 0.02	18.72 ± 0.01	24.18 ± 0.01	0.2	50
7	Hg	0.16 ± 0.24^{a}	0.14 ± 0.02^{b}	0.15 ± 0.13^{a}	0.18 ± 0.12^{a}	0.16 ± 0.08^{a}	0.18 ± 0.17^{a}	0.17 ± 0.02^{a}	0.001	-
8	K	1.17 ± 0.02^{b}	1.16 ± 0.12^{b}	1.98 ± 0.02^{b}	2.21 ± 0.10^{b}	4.76 ± 0.05^{a}	4.54 ± 0.11^{a}	3.62 ± 0.02^{a}	NS	30
9	Na	4.46 ± 0.07^{a}	3.84 ± 0.05^{a}	3.67 ± 0.10^{a}	3.71 ± 0.01^{a}	4.46 ± 0.02^{a}	3.76 ± 0.00^{a}	3.72 ± 0.01^{a}	100-200	NS
10	Zn	1.38 ± 0.08^{a}	2.15 ± 0.10^{a}	0.67 ± 0.13^{b}	0.78 ± 0.04^{b}	1.45 ± 0.09^{a}	1.67 ± 0.04^{a}	1.53 ± 0.00	3.0	5.0

Table 4. Mean total bacterial count (CFU/ mL) of water samples collected from different water sources

S/N	**Sample Sources**	**Mean number of colonies**
1	Pond water	5.10 x 10^{-4}
2	River water	6.10 x 10^{-3}
3	Well water	4.10 x 10^{-4}

Table 5. Percentage distribution of bacterial species isolated from water samples from different water sources

Isolates	**Pond water (%)**	**River water (%)**	**Well water (%)**	**Total (%)**
E. coli	28(40)	22(31.4)	20(28.6)	70(52.2)
Salmonella spp	8(32)	7(28)	10(40)	25(18.65
Klebsiella spp	14(35.9)	15(38.5)	10(25.6)	39(29.1)
Total Isolates	50(37.3)	44(32.8)	40(29.9)	134(100)

Table 6. Antibiotic resistance pattern of bacterial *species* isolated from different drinking water sources in Ikwo communities.

Isolates	Total Isolates	AMC (%)	CIP (%)	CN (%)	CRO (%)	E (%)	MEM (%)	NA (%)	OFX (%)	S (%)	TE (%)	VA (%)
E.coli	70	61(87)	9(7)	23(33)	49(70)	30(43)	58(63)	34(49)	24(34)	59(84)	31(44)	28(40)
Salmonella spp	25	18(62)	4(14)	11(38)	16(55)	14(48)	20(69)	18(62)	13(45)	17(59)	12(41)	11(38)
Klebsiella spp	39	29(74)	7(18)	20(51)	26(67)	27(69)	30(67)	22(56)	18(46)	28(72)	18(46)	19(49)

Allamin *et al.* (2015) and Bello *et al.* (2016) both found that *Escherichia coli* was the most often identified species in their respective research, supporting the findings of this study. The study on antibiotics involved the use of twelve commonly used antibiotics: amoxicillin-clavulanic acid, ciprofloxacin, gentamicin, ceftiaxone, erythromycin, meropenem, nalidixic acid, norfloxacin, ofloxacin, streptomycin, tetracycline, and vancomycin.

The results indicated a generally high rate of resistance among the organisms that were isolated. The findings of this study align with the research conducted by Ekhosuehi *et al*. (2018) in Benin City, Nigeria, Choudhry *et al.* (2016) in India, and Kinge *et al*. (2010). However, they contradict the findings of Saba *et al.* (2013) in Ghana, who discovered *Escherichia coli*, *Pseudomonas aeruginosa*, *Klebsiella species*, and *Salmonella species* in streams and rivers without any resistance to the antibiotics tested. The *Salmonella species* analysed in this study exhibited significant resistance to meropenem, amoxicillin-clavulanic acid, nalidixic acid, streptomycin, and ceftriaxone, with resistance rates of 69%, 62%, 62%, 62%, and 59% respectively. However, they showed high susceptibility to ciprofloxacin, gentamicin, vancomycin, tetracycline, and ofloxacin, with susceptibility rates of 86%, 62%, 62%, 59%, and 55% respectively. The findings align with the previous research conducted by Afuntoye and Apnapa (2010), which indicated that *Escherichia coli, Salmonella, Pseudomonas, Shigella, and Klebsiella* species exhibited significant resistance to amoxicillin-clavulanic acid, penicillin, and ceftriaxone. Conversely, ciprofloxacin, ofloxacin, and nalidixic acid demonstrated high susceptibility against these bacterial strains. The *Klebsiella species* that were identified exhibited the highest resistance percentages to Amoxicillin-clavulanic acid (74%), streptomycin (72%), ceftiaxone (67%), and meropenem (67%). The isolates exhibited susceptibility rates of 82% to ciprofloxacin, 69% to erythromycin, 54% to tetracycline, 54% to ofloxacin, and 51% to vancomycin. In contrast, *Escherichia coli* demonstrated resistance to over 55% of the tested antibiotics, including streptomycin, amoxicillin-clavulanic acid, ceftiaxone, and meropenem. *Escherichia coli* isolates exhibited a high susceptibility to ciprofloxacin, erythromycin, vancomycin, tetracycline, and ofloxacin. In line with Dufour *et al*. (2006), the study found that *Klebsiella and Shigella species* exhibited a susceptibility rate of 50% to gentamicin, ciprofloxacin, vancomycin, erythromycin, and ofloxacin, while they showed a resistance rate of 50% to amoxicillin/clavulanic acid, ampicillin, ceftriaxone, oxacillin, and cefltazidime.

Conclusion: The investigation has discovered that certain metal concentrations exceed the permissible limits set by NSDWQ and WHO. In addition, the bacteriological results, including the total bacterial count, did not comply with the international norm, as they exceeded the WHO guideline of zero per 100ml. This indicates a possible concern for both human and animal health. The presence of several antibiotic-resistant organisms in drinking water samples from the examined area is a significant health concern. This is because it increases the risk of contracting waterborne infections, especially for individuals with weakened immune systems who live in the area. Antibiotic resistance in bacteria is a significant issue in society, and one of the main causes is the excessive or incorrect use of antibiotics in humans. To address this problem, it is crucial to establish a comprehensive programme for monitoring the usage of antimicrobials and the development of resistance in bacteria found in surface and drinking water sources within the study area.

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Data Availability Statement: Data are available upon request from the corresponding author.

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