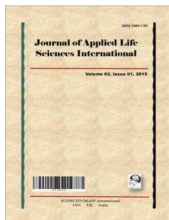

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Bacteriological Profiling and Antibiotic Resistance of Bacteria Isolated From River Niger Lokoja Tributary, Nigeria

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Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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ABSTRACT

A beehive of activities occurs in the River Niger tributary located in Lokoja town, Nigeria which pollutes the water often consumed or used by the indigenes. This study is aimed at investigating the physicochemical and bacteriological quality of the water, whilst also determining the resistance of isolated bacteria to frequently used antibiotics. Water samples were collected along River Niger, Old market Area in Lokoja metropolis at different depths and were analyzed microbiologically and physic-chemically using standard laboratory methods. The antibiogram of bacteria isolated from the water samples was carried out using the disk diffusion technique. The total viable count ranged between 1.0×10^5 - 9.0×10^5 cfu/ml. The predominant bacteria isolated include *Salmonella* sp. (18.6%), *Klebsiella* sp. (11.6%), *Bacillus* sp. (16.3%), *Staphylococcus* sp. (20.9%), *Proteus* sp. (7%) *and Escherichia coli* (25.6%). Temperature, pH, turbidity and salinity values ranged between 27 - 29°C; 7.71 - 8.11; 433.70 - 3898 NTU and 0.04 - 0.06 ppt respectively. Total suspended solids, total dissolved solids and biochemical oxygen demand range of the water samples was between 32.0 - 952.0 mg/l, 66.0 - 92.1 mg/l and 1 - 4 mg/l respectively. *Bacillus* sp. was susceptible to all the tested antibiotics while *Staphylococcus* sp. exhibited resistance to only amoxicillin. *Salmonella* sp.

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and *Klebsiella* sp. were susceptible to almost all the antibiotics. *Proteus* exhibited resistance to only amoxicillin-clavulanic acid while *Escherichia coli* were resistant to chloramphenicol, amoxicillin-clavulanic acid and ciprofloxacin. The presence of pathogenic bacteria in the water from river Niger and their antibiotic resistance traits necessitates the need to enlighten and dissuade the public from drinking this water and also discouraging its use in the washing of ready to eat fruits and vegetables sold in the environs.

Keywords: River Niger; microbial quality; water; antibiotic resistance; bacteria.

1. INTRODUCTION

Water is an essential natural resource for sustainability of life on earth. Humans may survive for several weeks without food, but can barely survive a few days without water because constant supply of water is needed to replenish the fluids lost through normal physiological activities such as respiration, perspiration and urination [1].

The lack of adequate supply of potable water is a critical challenge in developing countries such as Nigeria. Potable water with reference to its intended use is defined as water which is fit for consumption by humans and other animals [2]. Although, we as humans recognize this fact, we disregard it by polluting our rivers, lakes, and oceans [3]. Subsequently, we are slowly but surely harming our planet to the point where organisms are dying at a very alarming rate. Asides from innocent organisms dying off, our drinking water has become greatly affected and so also is our ability to use water for recreational purpose.

Better access to safe drinking water, adequate sanitation and increased water for food production and industry contribute to health, livelihood and broader economic development outcomes. It is also essential for the environment services provided by wetlands and other aquatic ecosystems [3].

The usual source of drinking water is the streams, rivers, wells and boreholes which are mostly untreated and associated with various health risks [4]. Paucity of infrastructure for effective treatment and distribution of water accounts for the incidence of high morbidity and mortality rate associated with water borne diseases in developing countries [1].

The River Niger is the third longest river in Africa extending about 4,180 km (2,600 mi) and has the ninth largest river basin in the world [5]. The River Niger is a major source of portable water for over 100 million people, though in years it has been adversely affected by the menace of drought [5]. Lokoja is one of the cities in which the River Niger passes through. The River Niger in Lokoja is used for many purposes such as fishing, washing, urinating and defecation, dumping of refuse, bathing, fetching of water for drinking and cooking, used as an abattoir, selling and buying, swimming, irrigation, recreation, relaxation, boat ride, molding of blocks and transportation of man and goods with ferry [6].

Contaminated water bodies often serve as natural habitat for pathogenic coliforms, thereby playing a role in disease process [7]. The aquatic environment for living organisms can be affected and bioaccumulation of harmful substances in the water-dependent food chain can occur [8]. In developing countries, high population growth has led to increased human activities. These activities accounts for indiscriminate dumping of refuse and waste disposal in water bodies hence, making accessibility and availability of clean and uncontaminated water difficult [9,10,11].

Contaminants such as bacteria, viruses, heavy metals, nitrates and salt have polluted water supplies as a result of inadequate treatment and disposal of waste from humans and livestock, industrial discharges, and over-use of limited water resources [12]. Antibiotic resistance then sets in as a result of insurgent sub-therapeutic concentration of antibodies in waste water discharged into natural bodies [13].

This aim of this study is to identify bacteria (especially pathogenic species) present in River Niger Lokoja tributary and to determine their susceptibility to routinely used antibiotics.

2. MATERIALS AND METHODS

2.1 Study Area

The study area is the River Niger tributary around old market, Lokoja and is situated at 7.11^{o} North latitude, 6.12^{o} East longitude. Old

market is located at Kabbawa in Lokoja, Kogi State.

2.2 Sample Collection

Water samples were collected aseptically from River Niger opposite old market, Lokoja. The river was divided into three sampling points (the bank, the middle and the end) at different depths of the river (the surface, 8 m deep, 16 m deep and 32 m deep). These samples were collected into different sample bottles, labeled accordingly as A^{i} = Water sample from the river Bank's surface, A^{ii} = Water Sample from the river bank at the depth of 8 m, A^{iii} = Water Sample from the river bank at the depth of 16 m, A^{iv}=Water Sample from the river bank at the depth of 32 m, B^{i}= Water Sample from the river Middle's surface, B^{ii}=Water Sample from the river middle at the depth of 8 m, B^{iii}=Water Sample from the river middle at the depth of 16 m, B^{iv}=Water Sample from the river middle at the depth of 32 m, C^{i}=Water sample from the river End's surface, C^{ii}=Water Sample from the river end at the depth of 8 m, C^{iii}=Water Sample from the river end at the depth of 16 m, C^{iv}=Water Sample from the river end at the depth of 32 m and taken to the laboratory for immediate analysis.

2.3 Physicochemical Analysis of Water Samples

2.3.1 Determination of Total Dissolved Solids (TDS)

The total dissolved solid was determined using the method described by Chinedu et al. [14]. One hundred milliliters (100 mL) of the water sample was filtered and ten milliliters (10 mL) of the filtrate was measured into a pre-weighed evaporating dish. Following the procedure below, the total dissolved solids content of the water was calculated.

Total dissolved solids (mg/L) =

$$\frac{(W_2-W_1) \times 1000}{\text{Volume of filtrate used}}$$

Where W_1 = initial weight of evaporating dish
W_2 = Final weight of the dish (evaporating dish + residue).

2.3.2 Determination of Total Suspended Solids (TSS)

The gravimetric method according to APHA [15] was employed. Ten milliliters (10 mL) of water sample was filtered through a pre-weighed filter paper. The filter paper was then dried at 103-105°C for 2 h. Total suspended solids was determined by using the following formula:

$$TSS= \frac{(Wpost_{(g)} – Wpre_{(g)}) \times 1000}{V (L)}$$

Where Wpost= Final weight of filter paper
Wpre= Initial weight of filter paper
V= Volume of sample

2.3.3 Determination of the pH of Water Samples

The method of Chinedu et al. [14] was used to determine the pH of the water samples. The pH of the water samples was determined in-situ at the site of sample collection using a portable pH meter. The pH of the water samples was determined using the Oakton™ Waterproof pH 150 Portable Meter.

2.3.4Determination of temperature of water samples

The method of Chinedu et al. [14] was used to determine the temperature of the water samples. The temperature of the water samples was determined in-situ at the site of sample collection using the Oakton™ Waterproof pH 150 Portable Meter. This was done by inserting the probe of the meter into the sample and a stable reading was recorded.

2.3.5 Determination of the turbidity of water samples

The method of Chinedu et al. [14] was used to determine the turbidity of the water samples. The turbidity of the water samples was determined by using a standardized Thermo Scientific™ Orion™ AQ4500 turbidimeter. Five milliliters (5 mL) of the samples was pipetted into the turbidimeter cell and the surface of the cell was wiped with silicon oil. The cell was inserted into the turbidimeter and the reading was obtained.

2.3.6 Determination of the Biochemical Oxygen Demand (BOD) of water samples

The BOD of the samples was determined using the Winkler method [16]. Four glass stoppered BOD bottles (300 mL) was used. Ten milliliters (10 mL) of the samples was pipetted into two of

the BOD bottles and the bottle was filled with the dilution water (50 mL) and labeled as the sample solution bottle. The remaining two BOD bottles were filled with only the dilution water (25 mL) and were labeled as the blank solution bottle. Each of the blank and sample solution was placed in the BOD incubator for 5 days at temperature of 20ºC. To each of the remaining blank and sample solution, Manganese sulfate (2 mL) was pipetted and introduced to the bottom of the liquid. Potassium hydroxide sodium axide solution (2 mL) was also added. The mixture was allowed to settle after which it was shaken thoroughly and a precipitate was formed. Concentrated sulfuric acid (2 mL) was added until the precipitate dissolved. The resulting solution was poured into a conical flask and the solution was titrated with sodium thiosulphate till a pale yellow colour was obtained and 1 mL of starch was added. Titration continued until the blue colour of the starch changed to colourless. The volume of sodium thiosulphate used was recorded as DO_1. Manganese sulfate (2 mL) was pipetted and introduced to the bottom of the blank and sample solution incubated for 5 days. Potassium hydroxide sodium axide solution (2 mL) was also added. The mixture was allowed to settle after which it was shaken thoroughly and a precipitate was formed. Concentrated sulfuric acid (2 mL) was added until the precipitate dissolved. The resulting solution was poured into a conical flask and the solution was titrated with sodium thiosulphate till a pale yellow colour was obtained and 1 mL of starch was added. Titration continued until the blue colour of the starch changed to colourless. The volume of sodium thiosulphate used was recorded as DO_2.

BOD was calculated using the formula below:

$$BOD = \frac{(DO_1-DO_2)\ (\text{volume of diluted sample})}{\text{Volume of sample taken}}$$

2.3.7 Determination of salinity of water samples

The salinity of the samples was determined using Thermo Scientific Orion® 013005MD Duraprobe conductivity meter in-situ. The conductivity probe of the meter was standardized using 111 mS/cm standard. The probe was inserted into twenty milliliters (20 mL) of the water samples until a stable reading was obtained and recorded.

2.3.8 Isolation and identification of bacteria

Serial four-fold dilution was carried out on the water samples using the standard microbiological techniques until the required dilution was obtained. Nutrient agar was inoculated with 0.1 mL of the aliquot of the dilution. The plates were incubated at 37°C for 18 - 24 h and the colonies were observed and sub-cultured. Discrete colonies were sub-cultured into freshly prepared nutrient agar and incubated at 37°C for 24 - 48h. The pure cultures of bacterial isolates were subjected to various morphological and biochemical characterization tests such as Gram staining, spore staining, oxidase test, coagulase test, catalase test, indole test, citrate utilization test, starch hydrolysis, gelatin liquefaction and carbohydrate fermentation test for the identification of the bacteria isolates with reference to Bergey's manual of determinative bacteriology.

2.3.9 Enumeration of bacteria in water samples

Standard plate count (SPC) method was used to determine the total bacterial load of each water sample. Tenfold serial dilution of each sample was prepared. The aliquot (1mL) of the fourth dilution was used to inoculate plate count agar. The plates were incubated at 37°C for 24 h. After 24 h incubation, the colonies that developed on the plates were counted using the colony counter and the values were multiplied by the dilution factor to get the total bacterial count. The values were recorded in cfu/mL [17].

2.4.0 Detection and enumeration of coliform in water samples

Eosin Methylene Blue (EMB) agar plates was inoculated with 1 mL of the fourth dilution. The plates were incubated at 37°C for 24 h. After 24 h of incubation, colonies with green, metallic sheen on the plates were counted [18].

2.4.1 Antibiotic sensitivity test

Antibiotic sensitivity test of the bacterial isolates was determined using the disc diffusion technique described by Cheesbrough [19]. A swab stick was dipped into a 4 h old broth culture of the test organism. The swab stick was used to swab the surface of the Mueller Hinton agar plates. The test antibiotic discs were placed on the surface of the agar plates equidistantly and then allowed to stand for 1 h. The plates were incubated at 37ºC for 18 - 24 h after which the zones of inhibition were determined. The susceptibility of Gram-positive to the following antibiotics; Pefloxacin, Gentamycin, Ampicillin-

sulbactam, Cefuroxime, Amoxicillin, Ceftriaxone, Ciprofloxacin, Streptomycin, Trimethoprim-sulfamethoxazole, and Erythromycin was tested. The susceptibility of Gram – negative bacteria to the following antibiotics; Trimethoprim-sulfomethoxazole, Clarithromycin, Ciprofloxacin, Amoxicillin, Amoxicillin-clavulanic acid, Gentamycin, Pefloxacin, Ofloxacin and Streptomycin was also determined. The antibiotic discs were placed equidistantly on the agar plates and incubated at 37ºC for 18 – 24 h.

2.4.2 Determination of the minimum inhibitory concentration (MIC)

The MIC was determined according to the method of Wiegand et al. [20]. Different concentrations of the antibiotic: 0.25, 0.5, 1, 2, 4, 8, 16 and 32 were prepared and pipetted into nutrient broth which was then inoculated with 1 mL of the standardized test organism and incubated at 37°C for 4 - 6 h. After incubation, the turbidity of each test tube were determined using a turbidometer and the test tube with low level of turbidity due to suppression of microbial growth indicated the presence of active antibiotic at the concentration corresponding to MIC.

The sensitivity of test organisms to the antibiotics was determined by the CLSI guidelines [21].

3. RESULTS

The temperature of water samples ranged between 27 - 29°C while the pH ranged between 7.71 – 8.11 as shown in Table 1. The highest pH value of 8.11 was recorded for the water sample obtained from the 8 m depth and the lowest pH value of 7.71 was obtained from water sample taken 32 m depth into the water.

The highest temperature value of 29°C was obtained for the water sample from the middle of the river at 32 m depth while the lowest temperature value of 27°C was obtained for water sample from the end of river at the surface, 8 m, 16 m and 32 m into the water.

The water samples collected from the bank at the river surface and with 16m depth had the highest bacterial count of 5.9 $\log_{10}$ cfu/mL as shown in Fig. 1. The water samples collected from the middle of the river with a depth of 16 m had the lowest bacterial count of 5 $\log_{10}$ cfu/mL.

A total of six bacterial species were isolated and identified as *Klebsiella* sp., *Bacillus* sp., *Proteus* sp., *Salmonella* sp., *Staphylococcus* sp. and *E. coli* from the water samples. *Escherichia coli, Staphylococcus* and *Bacillus* species had the highest occurrence in the water samples as shown in Table 2. Table 3 shows that *E. coli* occurred in all the water samples irrespective of the depth and the location of the river it was taken. However, only water samples obtained from the middle of the river at 8 m depth did not indicate the presence of the organism. Table 4 shows the antibiogram patterns of *Staphylococcus* sp. and *Bacillus* sp. while Table 5 shows the antibiogram for Gram Negative organism; *Klebsiella* sp., *Proteus* sp., *Salmonella* sp. *and E. coli*.

Table 1. Physicochemical properties of water samples in comparison with WHO standard

Water samples	Temperature (°C)	pH	TDS (mg/l)	Salinity (ppt)	Turbidity (NTU)	TSS (mg/l)	BOD (mg/l)
WHO Standards	-	6.5-8.5	500	0.5	5	40-80	0.6
A^{i}	28	7.97	92.1	0.05	853.41	368	3
A^{ii}	28	7.91	72.3	0.05	754.66	382	3
A^{iii}	28	7.87	69.2	0.05	688.82	354	3
A^{iv}	27	7.83	73.1	0.05	775.23	256	2
B^{i}	28	7.86	66.4	0.04	1269.01	348	2
B^{ii}	28	8.11	67.5	0.05	1145.56	350	1
B^{iii}	28	7.88	66.0	0.04	145.66	32	4
B^{iv}	29	7.93	79.1	0.05	1034.46	460	3
C^{i}	27	7.90	67.0	0.05	808.15	350	3
C^{ii}	27	7.83	81.4	0.06	1182.60	628	2
C^{iii}	27	7.81	73.4	0.06	433.70	56	4
C^{iv}	27	7.71	81.8	0.06	3898.38	952	3

Key: The water samples A^{1} – C^{iv} are defined in the Materials and Methods section

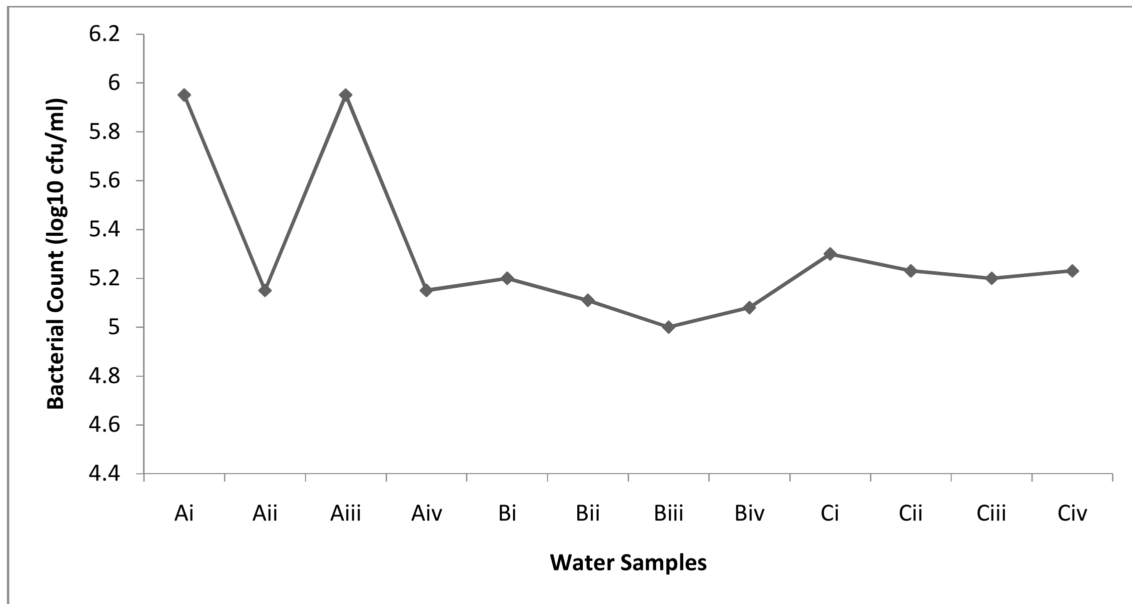

Fig. 1. Total bacterial count of the water samples (log_{10} cfu/ml)
Key: The water samples A^1 – C^{iv} are defined in the Materials and Methods section

Table 2. Occurrence of bacterial isolates in water samples

Isolates	Water samples	Occurrence	Frequency of occurrence (%)
Klebsiella sp.	12	5	11.6
Salmonella sp.	12	8	18.6
Proteus sp.	12	3	7.0
E. coli	12	11	25.6
Staphylococcus sp.	12	9	20.9
Bacillus sp.	12	7	16.3

Table 3. Occurrence of bacterial isolates at different depths

Bacterial isolates	A^I	A^{II}	A^{III}	A^{IV}	B^I	B^{II}	B^{III}	B^{IV}	C^I	C^{II}	C^{III}	C^{IV}
Staphylococcus sp.	+	+	+	+	+	+	-	-	+	+	+	-
Bacillus sp.	+	-	+	+	-	+	+	-	+	+	-	-
Klebsiella sp.	+	+	+	-	-	-	-	-	-	+	+	-
Salmonella sp.	+	+	+	+	+	+	+	-	+	-	-	-
Proteus sp.	+	+	-	-	+	-	-	-	-	-	-	-
E. coli	+	+	+	+	+	-	+	+	+	+	+	+

Keys: + = Present, - = Absent

4. DISCUSSION

The pH range of the samples indicate a decline with corresponding depth, this was however exclusive to samples A and C. Sample B portrayed pH variability likely from an uneven distribution of contaminating particulate matter. The variation in the pH of water samples may also be due to the presence of varying amount and types of mineral matter [6]. This also influenced the distribution of microorganisms at different depths. Temperature ranged from 27 - 29°C. This finding is in agreement with the study of [22] and the high temperature was attributed to discharge of waste into the water. Most bacteria isolated from water have been reported to be

mesophiles [23]. The temperature range for the water samples is suitable for the proliferation of mesophiles and also the most salient factor influencing microbial growth in drinking water [24]. Temperature of water reservoir can also affect the receiving water. Whether a water system serves a single home or entire community, proper treatment must be ensured also the physical appearance of the water environment must be kept clean.

Turbidity ranged from 433.70 - 3898 NTU which is higher than the WHO permissible limits 5.0NTU. Turbidity measures the physical or visual observable dirtiness of a water resource and is an indicator of water pollution. The high values could be attributed to direct emptying of waste materials into the water source, a phenomenon that is common in Nigeria and Africa at large [25].

Salinity ranged from 0.04 - 0.06 ppt, total suspended solid ranged between 32.0 to 952.0 mg/l, total dissolved solid ranged between 66.0 - 92.1 mg/l. The total suspended solids are composed of carbonates, bicarbonates, chlorides, phosphates and nitrates of Ca, Mg, Na, K, Mn organic matter, salts and may also include mud, algae, detritus, and fecal material [26]. The effect of presence of total suspended solids is the turbidity due to silt and organic matter. When the concentration of suspended solids is high it may be aesthetically unsatisfactory for bathing [27], while biochemical oxygen demand ranged from 1 to 4 mg/l which is within WHO permissible limit. BOD below 3 mg/l or less is required for the best use [28].

Coliform tests are useful for determining if water is adequately treated and whether the water quality is suitable for drinking and recreation. As coliform bacteria are very abundant in human wastes, they are much easier to locate and identify in fecal polluted water than other pathogens that cause severe diseases. Therefore, coliforms are used as indicator organisms for detecting the presence of other pathogens. Some coliforms are found in soil, test for fecal coliforms are considered to be the most reliable [29]. The presence of coliforms indicates faecal contamination. The occurrence of coliforms in the water is an indication that other pathogens are also present. Whether a water system serves a single or an entire community, proper treatment must be ensured also the physical appearance of the water environment must be kept clean.

In a similar study by Okonko et al. [30], *S. aureus*, *Salmonella* sp., *E. coli*, *Proteus* sp., *Bacillus* sp. were isolated from water samples from Abeokuta and Ojota in Nigeria. Similarly, [31] isolated these organisms from Orogodo river in Agbor, Nigeria. The presence of these organisms in the examined water samples may be attributed to the excessive waste that is disposed into the river and is responsible for the high temperature, turbidity and high BOD values of the water. *Micrococcus* and *Pseudomonas* are natural water inhabitants. *Bacillus subtilis* and

Table 4. Antibiotic sensitivity test for gram positive bacterial isolates

Antibiotics	Concentration	*Staphylococcus* sp.			*Bacillus* sp.		
		Zones of inhibition (mm)	MIC	Interpretation	Zones of inhibition (mm)	MIC	Interpretation
PEF	10 µg	31.0	0.25	S	30.0	0.5	S
CN	10 µg	28.0	0.5	S	27.0	0.5	S
A/S	30 µg	21.0	2	I	19.0	0.5	S
CXM	20 µg	27.0	0.25	S	25.0	0.25	S
AMX	30 µg	17.0	4	R	20.0	0.5	S
CTR	25 µg	25.0	0.25	S	27.0	0.25	S
CIP	10 µg	28.0	0.5	S	24.0	0.25	S
S	30 µg	21.0	2	I	24.0	0.25	S
SXT	30 µg	26.0	0.5	S	22.0	0.5	S
E	10 µg	30.0	0.25	S	26.0	0.5	S

Key: PEF: Pefloxacin, CN: Gentamycin, A/S: Ampicillin-sulbactam, CXM: Cefuroxime, AMX: Amoxicillin, CTR: Ceftriaxone, CIP: Ciprofloxacin, S: Streptomycin, SXT: Trimethoprim-sulfamethoxazole, E: Erythromycin

Table 5. Antibiotic sensitivity test for gram negative bacterial isolates

Antibiotics	Concentration	***Klebsiella* sp.**			***Salmonella* sp.**			***E. coli***			***Proteus* sp.**		
		Zones of Inhibition (mm)	**MIC (µg)**	**Interpretation**	**Zones of Inhibition (mm)**	**MIC (µg)**	**Interpretation**	**Zones of Inhibition (mm)**	**MIC (µg)**	**Interpretation**	**Zones of Inhibition (mm)**	**MIC (µg)**	**Interpretation**
SXT	30ug	28.0	0.25	S	23.0	0.5	S	25.0	0.5	S	20.0	2	S
CH	30ug	18.0	1	I	25.0	0.5	S	0.0	1	R	28.0	0.5	S
CIP	10ug	22.0	0.5	S	31.0	0.5	S	0.0	2	R	28.0	0.25	S
AMC	30ug	19.0	1	I	21.0	0.25	S	22.0	0.25	S	22.0	2	S
AMX	30ug	18.0	1	I	19.0	1	I	0.0	1	R	0.0	4	R
CN	10ug	25.0	0.25	S	39.0	0.5	S	20.0	0.25	S	25.0	0.5	S
PEF	30ug	33.0	0.25	S	25.0	0.5	S	33.0	0.25	S	29.0	0.25	S
OFX	10ug	28.0	0.5	S	27.0	0.25	S	33.0	0.5	S	24.0	0.25	S
S	30ug	25.0	0.25	S	26.0		S	25.0	0.5	S	26.0	0.25	S

Key: SXT: Trimethoprim- sulfomethoxazole, AMC: Amoxicillin-clavulanic acid, CN: Gentamycin, PEF: Pefloxacin, CH: Clarithromycin, CIP: Ciprofloxacin, OFX: Ofloxacin, AMX: Amoxicillin, S: Streptomycin

Enterobacter aerogenes are soil bacteria, so not normal inhabitants of water. *E. coli, Streptococcus faecalis* and *Salmonella Typhi* inhabit the intestine of man and animal [24]. The implications of the bacteria isolated from the water samples are diarrhea, dysentery, and typhoid. Diarrhea is the condition of having frequent loose or liquid bowel movement. Acute diarrhea is a common cause of death in developing countries and the second most common cause of infant deaths worldwide [32].

Generally, chemical micro-pollutants in drinking water are considered as a minor problem in comparison to possible risks of microbial contamination and exposure balances indicate that the contribution of drinking water to the total dietary exposure from most chemicals is very low [33].

Bacillus sp., *Staphylococcus* sp., *Escherichia coli*, *Proteus* sp., *Salmonella* sp. and *Klebsiella* sp. are important human pathogens associated with a variety of infectious diseases such as gastroenteritis, typhoid fever, dysentery, cholera, urinary tract infections [34,35]. Their presence raises serious public health concern because they are known causative agents of many water borne diseases. Their entry into water sources could be attributed to seepages from nearby septic tanks, as opined by Nguendo-Tongsi [36] or through deliberate and indiscriminate deposition of animal waste and human faeces into streams as commonly observed in some riverine areas. Petridis et al. [37] opined that the presence of *Escherichia coli* which is the most common indicator of faecal pollution in a water sample is an indication of the presence of other enteric pathogens and a few strains can cause serious illness including severe diarrhea and kidney failure.

Almost all the tested organisms were susceptible to the antibiotics used in this study however, *Staphylococcus* sp., *E. coli* and *Proteus* sp. exhibited resistance to amoxicillin. The variation in susceptibility and resistance of the isolates to different antibiotics could be attributed to the difference in the concentration of antibiotics, source of the isolate and drug resistance transfer [38,39,40]. The resistance of *Escherichia coli* to majority of antibiotics used is of great health concern. Susceptibility of bacteria to antibiotics could also be altered by the impact of environmental and human activities on such isolates which possibly results in the development and selection of antibiotic resistant strains [41,42,43]. This is a health risk as infections caused by these resistant strains are more difficult to treat.

5. CONCLUSION

The River Niger Old market area, Lokoja was found to have been polluted with pathogenic microorganisms and it indicated a high level of resistance to widely used antibiotics. Thus, there should be public awareness on the need for proper treatment of the River Niger Lokoja Tributary water before its consumption and commercial use. Also, activities such as bathing, washing of clothes and cows, defecating close to the bank of the river should be stopped as these activities contribute to increasing pathogenic microbial flora in the river.

Also regulatory agencies should intensify their effort towards providing clean and portable water to the public and also engage in a campaign for cleanliness of the environment, good refuge and sewage disposal systems since their potential impact on the ecosystem may be much greater than its effect on human life.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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