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ORIGINAL RESEARCH

Bacteriological Quality Assessment of Municipal Water Supply in Lokoja Metropolis

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ABSTRACT

One of the primary responsibilities of government is the provision of clean drinking water to its population. The major issue with water quality worldwide is the contamination of water supplies by microorganisms resulting in infection. Regardless of the source, water may be contaminated with microorganisms, organic matter, and other pollutants. Drinking water acts as a primary etiological agent for microbial diseases. Drinking contaminated water is mostly known to be the key cause of waterborne diseases. Water is indispensable for life considering the fact that it is an essential part of human nutrition. This study aimed at determining the possible contamination of municipal water in Lokoja metropolis at the source and along the chain of supply to the public for use. Water samples were collected from the source at Greater Lokoja Water Treatment Plant and 19 other samples at random from different locations within Lokoja metropolis reached by the water supply. Aliquots of each water sample was inoculated aseptically on MacConkey agar using the pour-plate method. Bacterial isolates were observed for morphological features and further subjected to Gram staining and various biochemical tests as well as antibiotics susceptibility test. A total of 29 bacterial isolates were recovered from the 20 water samples collected. The bacterial isolates included *Klebsiella spp* (20.6%), *Pseudomonas aeruginosa* (17.2%), *Escherichia coli* (27.8%), *Aeromonas spp* (17.2%) and *Salmonella spp* (17.2%). All isolates were resistant to Cefuroxime and Oxacillin (100%), 45% of the isolates were resistant to both Ciprofloxacin and Nitrofuranton followed by Ofloxacin (31%), Cefixime (24%) while the lowest antibiotic suscepibility pattern was displayed against Pefloxacin (14%). However, all isolates were susceptible to Imipenem. The findings of this study reveals that municipal water supply is contaminated along the chain of supply thereby posing serious threat to the inhabitants particularly those using the water.

Keywords: Drinking, Water, Contamination, Municipal, Bacteriological

Introduction

Water is a substance that can exists in gaseous, liquid, and solid form and is made up of the chemical components hydrogen and oxygen. It is among the most common and necessary substances to man. Given that it is a vital component of human nutrition, water is necessary for life since clean water is essential to human survival, disease prevention and maintenance of personal hygiene (Reader, 2022). Groundwater and surface water are the two sources of water used by community water systems. In addition to recreational, agricultural, and industrial uses, people use surface and ground water on a daily basis for drinking, cooking, and basic hygiene (Gaaloul and Eslamian, 2022). Though more people (68%) are supplied year-round by community water systems that use surface water, the bulk of public water systems (91%) are supplied by ground water, according to the US Environmental Protection Agency (EPA) (Yoder et al., 2008). This is due to the fact that tiny, rural communities typically rely on ground water, while large, densely populated metropolitan areas typically rely on surface water supplies. Water that gathers on the ground or in a lake, reservoir, river, stream, or ocean is referred to as surface water. Precipitation continuously restores surface water, but evaporation and seepage into groundwater supplies depletes it.

According to Vantsawa et al. (2020), taps, boreholes, wells, and rivers are the main sources of water in Lokoja. Lokoja metropolis has a standard municipal water system popularly called ‘Ibro water’, named after the former state Governor (Ibrahim Wada Idris) that supplies water to certain locations within Lokoja metropolis. Water from the confluence of river Benue and Niger majorly is treated and debussed to the community for both industrial and domestic uses in Lokoja Metropolis.

Depending on the contaminants, drinking contaminated water can result in several of illnesses, including cholera, typhoid, dysentery, and skin and mental conditions (Onyedikachi and Mukah, 2024). The natural physico-chemical properties of the catchment areas and the way human waste is managed both affect the quality of groundwater resources (Lalumbe et al., 2022). An essential component of disease prevention and life quality enhancement is the availability of clean water. Events involving water pollution are frequently caused by waste products that end up in residential and commercial sewage, overflowing sanitary sewer systems, discharges from waste water treatment facilities, and animal faeces that run off during storms (Botturi et al., 2021). The gastro intestinal tract infections are mainly spread through the intake of contaminated water (Adhikary et al., 2022). The development of the communities is seriously threatened by a shortage of safe drinking water, which can also have an adverse effect on inhabitants' health. Families and communities who rely on non-public water supply systems are extremely concerned about the serious and urgent issue of water availability in many developing nations (Reader, 2022).

The Lokoja municipal water supply is susceptible to bacterial contamination during supply to various households due to leakages in the pipes and passage of the pipes through gutters. Hence, the aim of this study was to ascertain the purity of “ibro” water used by significant inhabitants of Lokoja metropolis.

Materials and Methods

Study Area

This study was carried out in Lokoja metropolis, Kogi State of North Central Nigeria. Lokoja is located between latitude 7°49' N, longitude 6°44' E and altitude of 45 - 125m. Kogi State is bordered by the Federal Capital Territory (FCT) Abuja, Nasarawa, Niger and Kwara to the North, Ondo and Ekiti to the South, Anambra, Edo and Enugu to the west and then Benue to the East. The state is the confluence of the two major rivers in Nigeria (River Niger and River Benue).

Figure 1: Map of Kogi State showing the Location of Lokoja (source: https://images.app.goo.gl/94ybKiJC8jz3LhhR6)

Collection of Samples

A total number of 20 water samples were collected first at the source (Greater Lokoja Water Treatment Plant) and then at 19 other different locations within Lokoja Metropolis reached by the municipal water supply chain. The samples were collected at random within an estimated distance of 350 to 400 meters along the chain of supply. The water samples were collected using sterile sample bottles which were coded accordingly indicating the different point of collection.

Inoculation

One milliliter aliquot of each of the water samples collected were aseptically inoculated on Nutrient agar, MacConkey agar, Mannitol Salt agar and Eosin Methylene Blue agar using the pour-plate method. The media were prepared according to the manufacturer's instructions. Plates were then incubated at 37°C for 18 to 24hours.

Identification of Isolates

Colony Morphology

Bacterial isolates were observed for visible characteristics of the colonies such as color, texture, shape and size on agar plate serving as a guide for identification of the isolates. This was done with the help of Bergey's Manual of Determinative Bacteriology.

Gram Staining

A colony of bacterial isolate used was placed on a clean, grease-free microscopic slide with the aid of sterile inoculating loop. The smear was allowed to dry completely in the air and fixed by passing rapidly through flame. Staining was done with iodine solution as a mordant for one minute. The iodine was then washed off and rinsed with distilled water. The smear was decolorized with alcohol until no color was seen. The excess alcohol was drained off, and slides were covered with 1% safranin for 30 seconds before rinsing off with distilled water and the smear was then allowed to dry in the air. The Gram reaction and cell shapes were determined under X100 objective lens of the light microscope. Gram positive cells retained the color of the primary stain (purple) while for the Gram negative cells, the primary stain was decolorized and picked up the color of the secondary stain (red) (Cheesbrough, 2006).

Biochemical Test

The biochemical tests carried out on the isolates includes the following; Oxidase test and Indole test, Urease Test, Methyl Red Test Starch Hydrolysis Test and Lactose Fermentation Test. The standard procedures were followed when carrying out the biochemical test (Cheesbrough, 2006).

Antibiotic Susceptibility Testing (Disc diffusion test)

The isolates were sub-cultured on MacConkey agar using the streak method to obtain discrete and pure colonies. The antibiotic susceptibility testing was performed using Bauer-Kirby Disc Diffusion method as modified by the Clinical and Laboratory Standards Institute (CLSI, 2020). Suspension of each bacteria colony was made by emulsifying a loopful of the confluent growth of the pure culture of the isolates in 5 ml of sterile distilled water and standardized to 0.5 McFarland Standard. This standard contains approximately 10^7 cfu/ml. 1 to 2mls of the standardized inoculum was aseptically introduced to Mueller Hinton agar plate using the pour plate method. Excess inoculum was carefully decanted. Antibiotic discs were carefully placed on each of the inoculated Mueller Hinton agar plates containing the different isolates, which were then incubated at 37^0C for 18 to 24 hours. The diameters of zones of inhibition were measured to the nearest millimeter using a meter rule. Approved CLSI (2020) susceptibility zone diameter interpretative standards was used in determining the resistance and susceptibility of the different isolates. The following antibiotic disks (Oxoid Ltd, Basingstoke, Hampshire, UK) were used: Cefuroxime (CXM) (30µg), Ciprofloxacin (CIP) (5µg), Cefixime (CXM) (5µg), Oflaxacin (OFX) (5µg), Imipenem (IPM) (10µg), Nitrofuratoin (NIT) (300µg) Oxacilin (OX) (10µg), Pefloxacin (PEF) (5µg).

Results

Prevalence of bacterial isolates present from the water samples

A total of 29 bacterial isolates were recovered from 20 water samples collected. The bacterial isolates include *Klebsiella spp* (20.6%), *Pseudomonas aeruginosa* (17.2%), *Escherichia coli* (27.8%), *Aeromonas spp* (17.2%) and *Salmonella spp* (17.2%). Table 1 and Table 2 show biochemical tests for identification of the isolates and the rate of bacterial isolation from the different water samples respectively.

Table 1: Biochemical characterization of bacteria isolated from the Treated water samples

Sample Tags	G.R	C.T	O.T	I.T	U.T	M.R	S.H	L.F	Identified Organisms
GLWTP – 1	−	+	+	−	−	−	−	−	*Pseudomonas aeruginosa*
KT – 1	−	+	−	+	−	+	−	+	*Escherichia coli*
FT – 1	−	+	−	−	+	−	−	+	*Klebsiella spp*
FT – 2	−	+	+	+	−	NR	−	+	*Aeromonas spp*
ANL – 1	−	+	−	−	−	+	−	−	*Salmonella spp*
ANL – 2	−	+	−	+	−	+	−	+	*Escherichia coli*
AD – 1	−	+	+	−	−	−	−	−	*Pseudomonas aeruginosa*
AD – 2	−	+	+	+	−	NR	−	+	*Aeromonas spp*
2U – 1	−	+	−	−	−	+	−	−	*Salmonella spp*
2U – 2	−	+	−	−	+	−	−	+	*Klebsiella spp*
OPQ -1	−	+	+	−	−	−	−	−	*Pseudomonas aeruginosa*
OPQ – 2	−	+	+	+	−	NR	−	+	*Aeromonas spp*
KT – 1	−	+	−	−	−	+	−	−	*Salmonella spp*
KT – 2	−	+	−	+	−	+	−	+	*Escherichia coli*
NT – 1	−	+	+	+	−	NR	−	+	*Aeromonas spp*
NT – 2	−	+	−	−	+	−	−	+	*Klebsiella spp*
LK – 1	−	+	−	+	−	+	−	+	*Escherichia coli*
LK – 2	−	+	−	−	−	+	−	−	*Salmonella spp*
AS – 1	−	+	+	−	−	−	−	−	*Pseudomonas aeruginosa*
AS – 2	−	+	−	−	+	−	−	+	*Klebsiella spp*
KT – 2	−	+	−	+	−	+	−	+	*Escherichia coli*
FT – 2	−	+	+	−	−	−	−	−	*Pseudomonas aeruginosa*
KT – 1	−	+	−	−	−	+	−	−	*Salmonella spp*
FT – 1	−	+	−	+	−	+	−	+	*Escherichia coli*
AD – 2	−	+	+	+	−	NR	−	+	*Aeromonas spp*

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AD – 1	−	+	−	−	+	−	−	+	*Klebsiella spp*
AD – 1	−	+	−	+	−	+	−	+	*Escherichia coli*
AD – 2	−	+	−	−	+	−	−	+	*Klebsiella spp*
LK – 2	−	+	−	+	−	+	−	+	*Escherichia coli*

Keys: GR= Gram Staining, **CT**= Catalase Test, **OT**= Oxidase Test, **LT**= Lactose Test, **UT**= Urase Test, **MR**= Methyl Red Test, **SH**= Starch Hydrolysis **LF** = Lactose Fermentation, **GLWTP**= Greater Lokoja Water Treatment Plant, **FT** = Fehintolu, **ANL** = Adankolo New Layout, **AD** = Adankolo, **2U** = 200 Housing Unit, **OPQ** = Old Poly Quarters, **KT** = Kpata Market, **NT**= Nostalgia, **LK** = Lokongoma, **AS** = Army Signal, **NR**= No Reaction

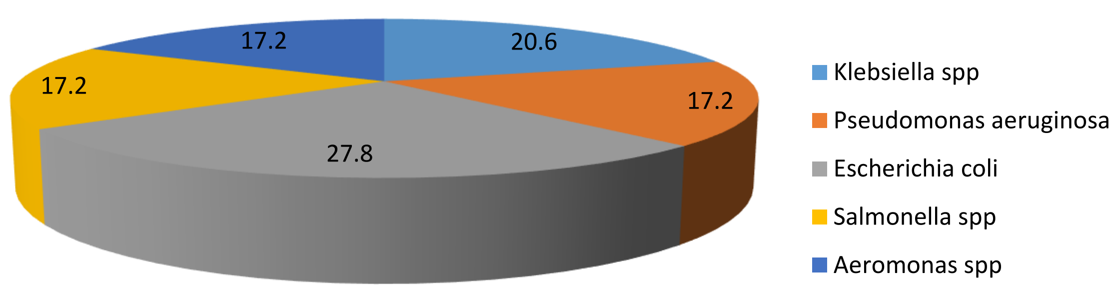

Figure 1: Percentage Prevalence of Isolates

Antibiotics resistance pattern of bacteria isolates

All the isolates were resistant to Cefuroxime and Oxacillin (100%), 45% of the isolates were resistant to both Ciprofloxacin and Nitrofurantoin followed by Ofloxacin (31%), Cefixime (24%) while the lowest antibiotic resistance pattern was displayed against Pefloxacin (14%). However, all isolates were susceptible to Imipenem (Table 2).

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Table 2: Antibiotic Susceptibility Patterns of Isolates Recovered from Treated Water Samples

Bacteria isolates	OFX No. (%)	CXM No. (%)	0X No. (%)	IPM No. (%)	CFM No. (%)	F No. (%)	PEF No. (%)	CIP No. (%)
Klebsiella spp (6)	2(33)	6(100)	6(100)	0.00	2(33)	4(67)	2(33)	4(67)
P. aeruginosa (5)	2(40)	5(100)	5(100)	0.00	2(40)	3(60)	0.00	2(40)
Escherichia coli (8)	2(25)	8(100)	8(100)	0.00	3(38)	6(75)	0.00	5(63)
Salmonella spp (5)	1(20)	5(100)	5(100)	0.00	0.00	0.00	0.00	0.00
Aeromonas spp (5)	1(20)	5(100)	5(100)	0.00	0.00	0.00	2(40)	2(40)
Total (29)	**8(31)**	**29(100)**	**29(100)**	**0.00**	**7(24)**	**13(145)**	**4(14)**	**13(45)**

Keys: OFX = Ofloxacin; **CXM** = Cefuroxime; **OX** = Oxacilin; **IPM** = Imipinem; **CFM** = Cefixime; **F** = Nitrofuran; **PEF** = Pefloxacin; **CIP** = Ciprofloxacin

Discussion

Surface and ground water are the major sources of drinking water in Lokoja metropolis. Urban drinking water was readily available at the start of the 19th century and required little to no filtration; nevertheless, as cities and industries grew, pollution levels rose then fecal-borne illnesses became more common (Helgertz and Önnerfor, 2019). As the ecology and routes of transmission of faecal microorganisms have been better understood, water cleaning methods like filtration and chlorination was developed (Gwenzi, 2021). Water purification has developed over time with new methods like aeration and ultra-filtration been added. Chlorine is still the most commonly used chemical disinfection agent, and it also has a residual effect (Al-Abri et al., 2019).

The Greater Lokoja Water Treatment Plant, which is the main source of treated water appear to be relatively clean than all other water outlets within the sampled area. This is due to the level of treatment carried out at the plant prior to the release for mass utilization. However, *Pseudomonas aeruginosa* was isolated from this point. This contamination can be attributed to the fact that the tanks used in the treatment of the water are not frequently decontaminated as expected. The result of this study demonstrated the quality of water at the various sampled sources was compromised as bacteria were isolated in all samples.

The high percentage isolation of *Escherichia coli* is in agreement with a similar study by Khan et al. (2020) who reported higher *Escherichia coli* isolate in a study conducted to assess the quality of drinking water in urban areas of Peshawar District, Pakistan. The findings of this study result concur with the findings reported by Bonso et al., (2023) and Odonkor and Addo, (2018) which all pointed to the very high prevalence of *E. coli* in drinking water sources due to poor neighborhood sanitation and hygiene practices around the water sources and failure to protect water sources. Acute gastroenteritis and urinary tract infections are amongst the most common diseases caused by these bacteria, posing a great threat to human health. The effects of bacterial infection vary depending on the amount of water consumed and the immune status of the individual, with children and the elderly being the most vulnerable (Khabo-Mmekoa et al., 2022).

Globally and locally, microbial antibiotic resistance is becoming a serious threat to public health. The antibiotic susceptibility testing showed that all isolates were resistant to Cefuroxime and Oxacillin (100%). The multiple antibiotic resistances of *E. coli* established in this study agrees with the findings Liu and Qin*,* (2022). Study by Meem et al., (2024) equally demonstrated the pattern of *E. coli*, *Pseudomonas aeruginosa* and *Klebsiella spp* to Oxacillin and Cefuroxime. The high resistance rate of cefuroxime and oxacillin in the current study among the isolates may be due to the indiscriminate use of inexpensive antibiotics in the community and the production of betalactamase enzymes by the isolates. However, all isolates were susceptible to Imipenem due to its broad-spectrum nature and thus imipenem can be used to effectively treat infections caused by the isolates.

Conclusion

From this study, it was discovered that the major contaminant of the municipal water in Lokoja metropolis are the coliforms thereby making the water fall short of WHO standards for drinking water. The presence of pathogenic bacteria in this study may be due to lack of adequate treatment at the plant, the storage tanks not cleaned regularly, passage of leaky pipes through drainages, poor conditions of the pipes among other factors. Water with such level of contamination is not safe for human consumption. Regrettably the inhabitants of this area have no way of knowing which of these points is safe and which one is not. It is therefore the responsibility of the regulatory authorities to employ adequate measures to protect the inhabitants of Lokoja metropolis by ensuring clean drinking water get to their homes. Also, this study indicated that the various microbial contaminants of treated water in the study area are resistant to certain antibiotics.

Authors' Contributions

LIM conceptualized and design the studies and prepared the draft manuscript. OOO, GE and OAJ participated in the collection and processing of the samples. AF and IOA reviewed the manuscript. All the authors contributed in developing the final manuscript and consent given for submission.

Conflict of Interest

None

Ethics Approval and Informed Consent

This study did not involve human or animal subjects. Therefore, ethical consideration was not applicable.

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