





ORIGINAL RESEARCH ARTICLE

Microbiological and Physicochemical Quality of Effluent and Treated Tap Water in Sokoto Metropolis: Evidence of Post-Treatment Contamination

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ABSTRACT

This study examines the microbiological and physico-chemical properties of influent and treated water sources for municipal use in Sokoto Metropolis, Nigeria. Water samples were collected from Sokoto Mechanic Village, Tudun Wada, Waziri Ward C, Tashar Illela Garage, Sokoto Water Board, Nakasari, Mabera, Tsohuwar Kasuwa, Minanata, and Runjin Sambo areas, then analyzed for temperature, pH, turbidity, total dissolved solids, hardness, biological oxygen demand, bicarbonate, electrical conductivity, dissolved oxygen, and heavy metal concentrations. Microbiological assessments included coliform tests and total bacterial counts of isolated bacterial species. The results showed variations in water quality across sampling locations, with some sources exceeding World Health Organization (WHO) and National Standard Drinking Water Quality (NSDWQ) standards for drinking water. High levels of coliforms and the presence of antibiotic-resistant bacteria in influent and treated water highlight potential public health risks. Despite treatment efforts, some areas still exhibited microbial contamination, underscoring the need for improved water treatment protocols. *S. marcescens* was isolated at Sokoto Mechanic Village and Tashar Illela Garage; *E. coli* was found at Tudun Wada and Runjin Sambo; *S. aureus* at Waziri Ward C; *V. cholerae* at Sokoto Water Board; *K. pneumoniae* at Nakasari; *S. typhi* at Mabera; *Enterobacter* sp. at Tsohuwar Kasuwa; and *C. freundii* at Minanata. This study highlights the importance of continuous monitoring and enhanced treatment strategies to ensure the availability of safe drinking water for the growing population of Sokoto Metropolis.

ARTICLE HISTORY

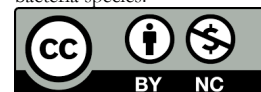
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KEYWORDS

Water quality, microbiological assessment, physico-chemical analysis, Sokoto Metropolis, bacteria species.



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INTRODUCTION

Almost every living organism needs water either directly or indirectly for its survival. Over 70% of the Earth's surface is covered with water. This is the reason why water is the most abundant naturally occurring chemical substance found on the Earth's crust (Mathew & Krishnamurthy, 2017). It is estimated that about ninety-seven percent (97%) of the Earth's population depends on water for survival (Mathew & Krishnamurthy, 2017), while food production heavily depends on water; as such, the minimum standard of quality treatment is required (Mathew & Krishnamurthy, 2017). The quality of water is determined by its physical, chemical, and biological properties. Therefore, water quality should be evaluated before use. Consequently, the most relevant quality parameters that could affect water quality should be assessed (Shah, 2017). Despite advances in water treatment technologies, many communities (such as the study area) struggle to access enough, clean, and safe potable water, leading to a range of health problems and economic burdens (Walker *et al.*, 2012).

Only recently has the environment been recognized for its role in the global spread of antibiotic resistance related to clinical use. Aquatic environments, specifically, may receive water from urban sewage and runoff from agricultural facilities. The occurrence of antibiotic resistance in aquatic environments has been reported since the 1970s, when *Enterobacteriaceae* were observed in rivers in the USA (Feary *et al.*, 1972). Furthermore, it has been demonstrated that rivers and lakes that are contaminated with wastewater effluent also contain ARBs (Iwane *et al.*, 2001; Czekalski *et al.*, 2012). Antimicrobial-resistant microorganisms in water may originate from waste, including human and animal faeces (Burgmann *et al.*, 2018). This is generally due to the fact that the microbes from these organisms had, at some stage, been exposed to antibiotics, either for therapeutic purposes (infection control or as a prophylactic) or as growth promoters in the case of animal-rearing practices (Burgmann *et al.*, 2018).

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Heavy metals contamination in earth dam water bodies also poses significant environmental and public health challenges (Manhas, 2025; Tazri *et al.*, 2025). Heavy metals, such as lead (Pb), mercury (Hg), cadmium (Cd), arsenic (As), chromium (Cr), and nickel (Ni), can enter water bodies through natural geological processes or human activities like industrial discharge, mining, agricultural runoff, and improper waste disposal (Chen *et al.*, 2025; Sultana *et al.*, 2025). Once these metals are introduced into an earth dam, they often remain in the ecosystem because of their non-biodegradable nature (Chen *et al.*, 2025). This persistence leads to the accumulation of heavy metals in sediments, water, and aquatic organisms, resulting in long-term environmental damage and posing risks to both human and ecological health (Datta *et al.*, 2025). Heavy metal contamination is a major global ecological concern; it frequently contaminates soil, sediments, and wastewater, where it stays persistent and becomes toxic to many species once it exceeds certain threshold levels (Bilyaminu *et al.*, 2025). Only recently has the environment been recognized for its role in the global spread of antibiotic resistance related to clinical use. Aquatic environments, in particular, may receive water from urban sewage and runoff from agricultural facilities. The presence of antibiotic resistance in aquatic environments has been reported since the 1970s, when *Enterobacteriaceae* were

observed in rivers in the USA (Feary *et al.*, 1972). Furthermore, it has been shown that rivers and lakes contaminated with wastewater effluent also contain ARBs (Iwane *et al.*, 2001; Czekalski *et al.*, 2012). Antimicrobial-resistant microorganisms in water may originate from waste, including human and animal feces (Burgmann *et al.*, 2018). This is generally because microbes from these sources had, at some point, been exposed to antibiotics—either for therapeutic purposes (infection control or prophylaxis) or as growth promoters in animal-rearing practices (Burgmann *et al.*, 2018).

MATERIALS AND METHODS

Study Area

Sokoto State is situated in the North-western part of Nigeria. The State lies between longitudes 5.136040 E to 5.302310 E and latitudes 12.956610 N to 13.083790 N. Shares boundaries with the Niger Republic to the North, Kebbi State to the South, Zamfara State to the East, and the Benin Republic to the West. The normal annual rainfall is about 640mm, with the rainy season lasting between May and October, and the dry season extending between November and April.

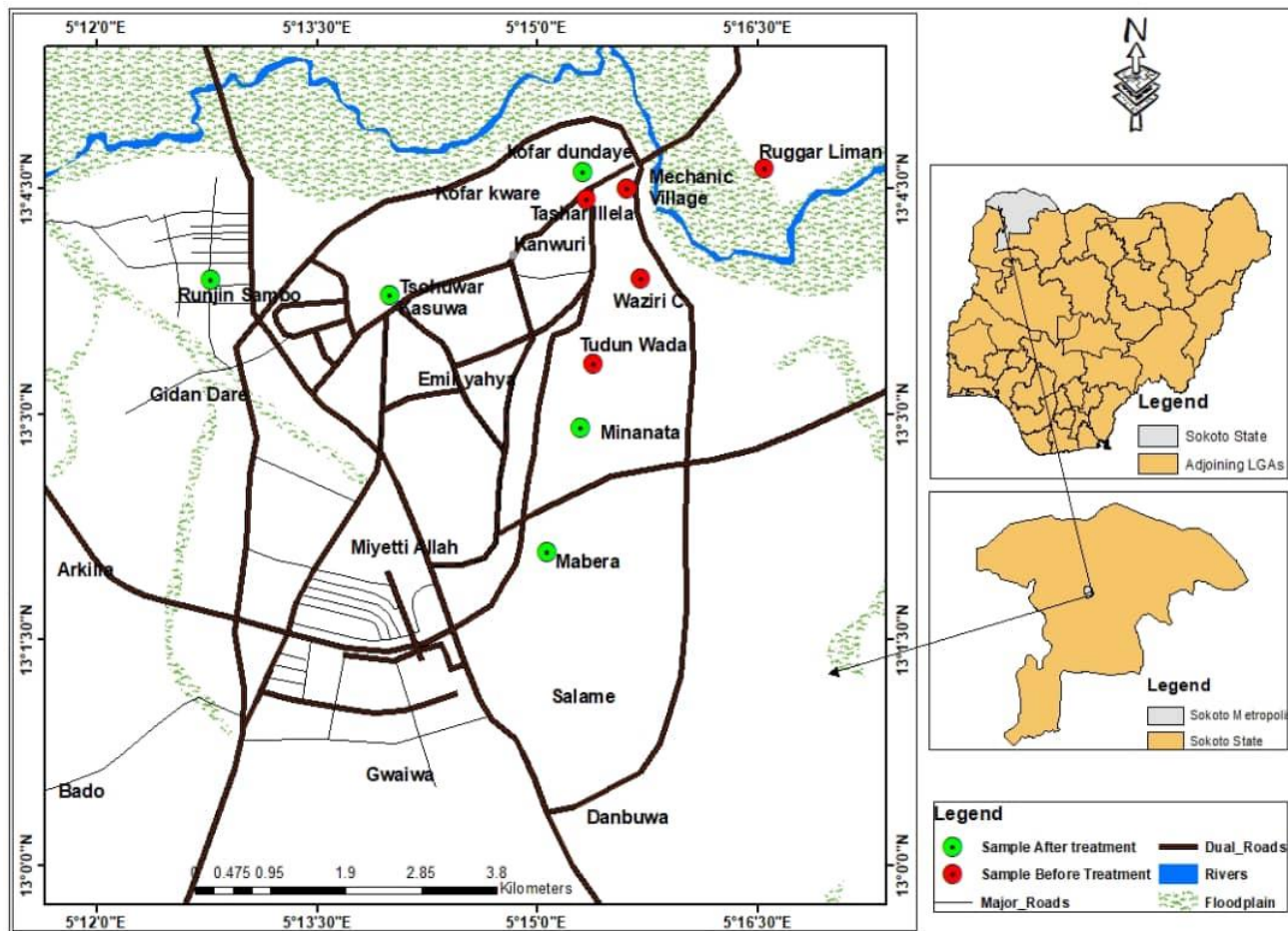


Figure 3.1: Showing the Map of the study area. (Source; GIS) Geography Department

The temperature is as high as 43°C around March/April (middle of the dry season) and as low as 23°C in December/January (middle of the cold season). The Sokoto town area is drained by the westward-flowing

Sokoto-Rima River system, which is responsible for rich alluvial soil suitable for a multitude of crops. The valley has a usual altitude of 240 meters above sea level, representing the lowest level in the study area. The highest

part of the study area has an altitude of about 321 meters above sea level, giving an altitudinal difference of 81 meters. The metropolis has an estimated population of 685000 persons spread over a geographical area of 31041 km² (National Population Commission, 2022).

Water Sample Collection.

All samples were collected for a period of five months between January to May, 2025. A total of 30 water samples were collected from ten (10) different locations, each sample was collected in triplicate, these include: Sokoto Mechanic Village, Tudun Wada Point, Waziri Ward C Point, Tashar Illela Garage Point Sokoto Water Board, Nakasari Area, Mabera, Tsohuwar Kasuwa, Minanata, and Runjin Sambo areas, respectively. The Samples were collected in sterile sample collection bottles from the study areas, 500ml from each water point, sealed, and labeled appropriately. The samples were immediately transported in a cooler with ice packs to the Microbiology laboratory and Agric chemical laboratory for initial processing (Lazarus, 2008).

Physico-chemical Analysis of Water Samples

Measurement of Temperature

This was carried out by using a mercury-in-glass thermometer.

Determination of pH

The pH of the water was determined using pH meter. 10 ml of each of the samples was poured into a sterile beaker, and the anode of the pH meter was dipped into it, and the readings were obtained (Burgmann *et al.*, 2018).

Turbidity

The joined tube was held over a white paper, while slowly pouring the water sample into the tube until the black cross at the bottom was no longer visible. At this point, the reading was taken from the site of the tube, as the turbidity value of the water sample.

Turbidity was measured by using a 2100 turbidity meter (Burgmann *et al.*, 2018).

Determination of Bicarbonate

Twenty-five milliliters (25 ml) of the water sample were measured into a conical flask, and a few drops of phenolphthalein indicator were added to the water sample. The pink coloration indicated the presence of carbonates (EA., 2012).

Calcium and Magnesium

Inductively coupled plasma-Atomic Emission Spectroscopy (ICP-ES) was used to determined mineral components. The unit of measurement is mg/ℓ (Apha, 2015).

Chloride

Ion chromatography (Metrohm 761 Compact IC-system A) Verification standards were run after every 10th sample (Apha, 2015).

Biological Oxygen Demand (BOD)

Three hundred 300ml of BOD bottles with 10ml of water sample were incubated at 20 °C for five (5) days, and the bottles were sealed without air bubbles, followed by measuring the difference in oxygen content before and after incubation. Then, day five 5 reading was subtracted from day one (1) reading to determine the BOD level (Lechevallier *et. al.*, 2023).

Dissolved Oxygen Demand (DOD)

Ten (10) ml of Manganous sulphate solution was added to 50ml of the water sample using a pipette, along with five (5)ml of alkali-iodide reagent. The solution was kept for 2 min to allow the reaction to dissolve. After the precipitates were formed, two (2) ml of sulphuric acid was added to dissolve the precipitate. Then titrated with sodium thiosulfate solution using starch indicator till the blue hue fades (Lechevallier and Kwok-keung., 2018).

Total Dissolved Solids (TDS)

The water sample is filtered and the filtrate evaporated in a tarred dish on a steam bath. The residue after evaporation is dried to constant mass at 103-105°C or 179-181°C.

Bacteriological Analysis

Coliform Test

Presumptive Test

The first set of three tubes contained 10ml of sterile Double Strength Lactose Broth (DSL_B), and Durham tubes were inserted before sterilization. In each of the tubes, 10 mL of water samples was added using sterile pipettes. Similarly, 1 ml of water to 3 tubes containing 10ml of single-strength medium and 0.1ml of water to the remaining 3 tubes containing 10 ml of single-strength medium were incubated at 37 °C for 24-48 hours. The presence of faecal coliforms was observed, and gas production was also observed. Acid production was determined by colour change in all the tubes from reddish purple to yellow, and gas production was determined by the entrapment of gas in the Durham tubes (Eckner, 2022).

Confirmed Test for Coliforms

Confirmed test was carried out by transferring a loopful of culture from a positive tube from the presumptive test

into a tube of sterile Brilliant Green Lactose Bile (BGLB) and incubating at 37 °C for 24-48 hours. Gas production and total coliforms were observed (Adetunde and Glover, 2010).

Completed Test for Coliforms

A complete test for coliforms was carried out by streaking a loopful of broth from a confirmed test onto Eosine methylene Blue (EMB) agar plates. The plates were incubated at 37 °C for 24-48 hours. Colonies were observed on EMB agar, which were identified as faecal coliforms. Colonies with green metallic sheen were confirmed to be faecal coliform bacteria (Adetunde and Glover, 2010).

Isolation and enumeration of Bacteria

Spread plate method. A hundred microliter (100 µl) of each dilution factor 4 and 5 of the samples were inoculated into already prepared sterile nutrient agar, Eosine methylene blue agar, and MacConkey agar plates. The inocula were spread evenly with a sterile spreader, left on the bench for 30 minutes to diffuse, inverted, and incubated at 37 °C for 24 hours and 42 °C for 24-42 hours for fecal coliforms on MacConkey agar. The Most Probable Number (MPN) method was employed using multiple-tube fermentation, and a presumptive test for coliform bacteria was performed on MacConkey broth. After incubation at 37°C for 48 hours, the tubes with acid and gas were considered positive for coliforms. Positive tubes from MPN were determined following the standard probability table as described by Dhawale and LaMaster (2003). In addition, the presence of *Escherichia coli* was confirmed by streaking a loopful of broth onto Eosine Methylene Blue (EMB) agar and evaluating for the formation of metallic green sheen colour, a positive test for the presence of *E. coli* (Adetunde and Glover, 2010).

Identification and characterization of bacterial isolates.

Viable counts of the bacteria were determined after incubation. Distinct colonies from each nutrient agar, Thiosulfate-citrate-bile salts-sucrose agar, Eosine methylene blue agar, and MacConkey agar plates were counted and recorded in CFU/ml. Discrete colonies were picked for subculturing onto prepared agar plates aseptically to get distinct colonies and stocked in agar slants for further experiments. Isolates were presumptively identified based on cultural (shape, color, opacity, elevation, colony size), morphological Gram staining test, and biochemical tests i. e catalase, oxidase, citrate utilization test, indole, sugar fermentation, and triple sugar iron tests (Manga and Oyeleke, 2008).

RESULTS AND DISCUSSION

Table 1: Relative weight of Physicochemical Parameters of Water Board after treatment compared with Standard Water Quality Index

S/N	Parameter	Relative Weight	WHO and NSDWQ Standard Value
1	pH	0.16	0.12-8.
2	TEM	20	0.0-37
3	EC	11.1	0.0-1000
4	TDS	10.0	0.0-500
5	Turbidity	1.0	0.0-1.5
6	Hardness	6	0.0-150 ⁰
7	Nitrate	0.4	0.0-50
8	Calcium	3.0	0.0-22
9	Bicarbonate	8.0	0.0-100
10	Magnesium	1.2	0.0-30
11	BOD	16.1	00
12	DO	7.5	0.0-100
13	Taste	Tasteless	00
15	Color	Colorless	00
16	Cl	0.2	0.0-0.5

$WQI = \sum_i^n = Wi = 84.66$

Table 2: Relative weight of Physicochemical Parameters of Minanata area Compared with Standard Water Quality Index

S/N	Parameter	Relative Weight	WHO and NSDWQ Standard Value
1	pH	6.0	0.12-8.5
2	TEM	19	0.0-37
3	EC	30	0.0-1000
4	TDS	3.0	0.0-500
5	Turbidity	0.9	0.0-1.5
6	Hardness	1.0	0.0-150 ⁰
7	Nitrate	0.2	0.0-50
8	Calcium	1.0	0.0-22
9	Bicarbonate	0.01	0.0-100
10	Magnesium	16.0	0.0-30
11	BOD	13.2	00
12	DO	7.8	0.0-100
13	Taste	Tasteless	00
15	Color	Colorless	00
16	Cl	0.3	0.0-0.5

$WQI = \sum_i^n = Wi = 98.21$

Table 3: Relative weight of Physicochemical Parameters of Tsohuwar Kasuwa area, Sokoto, Compared with Standard Water Quality Index

S/N	Parameter	Relative Weight	WHO and NSDWQ Standard Value
1	pH	6.88	0.12-8.5
2	TEM	22	0-37
3	EC	17.4	0.0-1000
4	TDS	0.09	0.0-500
5	Turbidity	1.3	0.0-1.5
6	Hardness	12	0.0-150 ⁰

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Table 3 continued

S/N	Parameter	Relative Weight	WHO and NSDWQ Standard Value
7	Nitrate	3	0.0-50
8	Calcium	11.0	0.0-22
9	Bicarbonate	4.0	0.0-100
10	Magnesium	2.0	0.0-30
11	BOD	13.2	00
12	DO	8.8	0.0-100
13	Taste	Tasteless	00
15	Color	Colorless	00
16	Cl	0.4	0.0-0.5

Table 4: Relative weight of Physicochemical Parameters of Runjin Sambo area Sokoto, Compared with the Standard Water Quality Index

S/N	Parameter	Relative Weight	WHO and NSDWQ Standard Value
1	pH	6.0	0.12-8.5
2	TEM	12	0.0-37
3	EC	0.00	0.0-1000
4	TDS	2.0	0.0-500
5	Turbidity	1.4	0.0-1.5
6	Hardness	10	0.0-150 ⁰
7	Nitrate	3	0.0-50
8	Calcium	0.6	0.0-22
9	Bicarbonate	9.0	0.0-100
10	Magnesium	26.0	0.0-30
11	BOD	16	00
12	DO	7.0	0.0-100
13	Taste	Tasteless	00
15	Color	Colorless	00
16	Cl	0.2	0.0-0.5

$WQI = \sum_i^n = Wi = 93.2$

Table 5: Relative weight of Physicochemical Parameters of Mabera area Sokoto Compared with Standard Water Quality Index

S/N	Parameter	Relative Weight	WHO and NSDWQ Standard Value
1	pH	6.9	0.12-8.5
2	TEM	26	0.0-37
3	EC	13	0.0-1000
4	TDS	1.0	0.0-500
5	Turbidity	1.3	0.0-1.5
6	Hardness	10	0.0-150 ⁰
7	Nitrate	3.0	0.0-50
8	Calcium	2.0	0.0-22
9	Bicarbonate	6.0	0.0-100
10	Magnesium	11.0	0.0-30
11	BOD	17	00
12	DO	7.0	0.0-100
13	Taste	Tasteless	00
15	Color	Colorless	00
16	Cl	0.3	0.0-0.5

$WQI = \sum_i^n = Wi = 104.5$

Table 6: Relative weight of Physicochemical Parameters of Water Board before treatment compared with the Standard Water Quality Index

S/N	Parameter	Relative Weight	WHO and NSDWQ Standard Value
1	pH	7.8	0.12-8.5
2	TEM	34	0.0-37
3	EC	201	0.0-1000
4	TDS	41.0	0.0-500
5	Turbidity	1.0	0.0-1.5
6	Hardness	50	0.0-150 ⁰
7	Nitrate	32	0.0-50
8	Calcium	38	0.0-22
9	Bicarbonate	65.0	0.0-100
10	Magnesium	40.0	0.0-30
11	BOD	25	00
12	DO	7.9	0.0-100
13	Taste	Tasteless	00
15	Color	Colorless	00
16	Cl	0.3	0.0-0.5

$WQI = \sum_i^n = Wi = 139$

Table 7: Relative weight of Physicochemical Parameters of Mechanic Village Compared with Standard Water Quality Index

S/N	Parameter	Relative Weight	WHO and NSDWQ Standard Value
1	pH	6.72	0.12-8.5
2	TEM	27	0.0-37
3	EC	113.5	0.0-1000
4	TDS	30	0.0-500
5	Turbidity	5	0.0-1.5
6	Hardness	10	0.0-150 ⁰
7	Nitrate	20	0.0-50
8	Calcium	36	0.0-22
9	Bicarbonate	20	0.0-100
10	Magnesium	57	0.0-30
11	BOD	35	00
12	DO	10	0.0-100
13	Taste	Moldy Tasteless	00
15	Color	Color	00
16	Cl	1.3	0.0-0.5

$WQI = \sum_i^n = Wi = 371.52$

Table 8: Relative weight of Physicochemical Parameters of Waziri Ward C area, Sokoto, Compared with Standard Water Quality Index

S/N	Parameter	Relative Weight	WHO and NSDWQ Standard Value
1	pH	6.72	0.12-8.5

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Table 8 Continued

S/N	Parameter	Relative Weight	WHO and NSDWQ Standard Value
2	TEM	20	0.0-37
3	EC	100	0.0-1000
4	TDS	120	0.0-500
5	Turbidity	7	0.0-1.5
6	Hardness	15	0.0-150 ⁰
7	Nitrate	10	0.0-50
8	Calcium	12	0.0-22
9	Bicarbonate	203	0.0-100
10	Magnesium	65	0.0-30
11	BOD	40	00
12	DO	11	0.0-100
13	Taste	Moldy Tasteless	00
15	Color	Color	00
16	Cl	1.6	0.0-0.5

$$WQI = \sum_i^n = Wi = 611.32$$

Table 9: Relative weight of Physicochemical Parameters of Tudun Wada area Sokoto, Compared with the Standard Water Quality Index

S/N	Parameter	Relative Weight	WHO and NSDWQ Standard Value
1	pH	4.3	0.0-8.5
2	TEM	20	0.0-37
3	EC	98	0.0-1000
4	TDS	110	0.0-500
5	Turbidity	4	0.0-1.5
6	Hardness	20	0.0-150 ⁰
7	Nitrate	24	0.0-50
8	Calcium	27	0.0-22
9	Bicarbonate	201	0.0-100
10	Magnesium	50	0.0-30
11	BOD	30	00
12	DO	13	0.0-100
13	Taste	Moldy Tasteless	00
15	Color	Color	00
16	Cl	0.00	0.0-0.5

$$WQI = \sum_i^n = Wi = 189$$

Table 10: Relative weight of Physicochemical Parameters of Tashar Illela Garage area Sokoto Compared with Standard Water Quality Index

S/N	Parameter	Relative Weight	WHO and NSDWQ Standard Value
1	pH	6.62	0.12-8.5
2	TEM	26	0.0-37
3	EC	179.1	0.0-1000
4	TDS	40	0.0-500
5	Turbidity	3	0.0-1.5
6	Hardness	12	0.0-150 ⁰
7	Nitrate	22	0.0-50
8	Calcium	30	0.0-22
9	Bicarbonate	150	0.0-100
10	Magnesium	45	0.0-30
11	BOD	39.0	00
12	DO	6.8	0.0-100
13	Taste	Moldy Tasteless	00
15	Color	Color	00
16	Cl	1.3	0.0-0.5

$$WQI = \sum_i^n = Wi = 189$$

Table 11: Water Quality Classification based on WQI value

Samples	WQI Values	WQ Class
Water Board	88.66	Good
Minanata	98.21	Good
Tsohuwar Kasuwa	102	Poor
Runjin Sambo	93.2	Good
Mabera	104.5	Poor
SKTMV	371.52	Unsuitable for drinking
Wazirir C	611.32	Unsuitable for drinking
Tudun wada	311	Unsuitable for drinking
Tashar Illela Garage	402	Unsuitable for drinking
Nakasari	189	Poor

Table 12: Presents the Statistical Analysis of Effluent and Treated Water Sources in Sokoto Municipal by using pair t- test.

Parameters	Influent Water	Treated Water	I-T	T-Value	Remark
pH	32	25.94	6.06	4.20	SD
TEM	127	99	28	3.50	SD
EC	691	71.5	619	2.00	SD
TDS	341	7.09	333	5.10	SD
Turbidity	20	5.9	14.1	5.21	SD
Hardness	107	53	54	3.56	DS
Nitrate	108	6.6	101.4	6.10	SD
Calcium	143	17.6	125.4	2.34	SD
Bicarbonate	639	27.01	611	5.21	SD
Magnesium	257	56.2	200.8	4.11	SD
BOD	169	75.4	93.6	3.25	SD
DO	48.7	38.1	10.6	1.23	SD
Taste	0	0	0	3.11	SD
Color	0	0	0	1.00	SD
Cl	16.2	1.4	14.8	0.10	SD

Keys: TEM: Temperature, EC: Exchangeable catch ions, TDS: Total Dissolved Solid, BOD: Biological Oxygen Demand, DO: Dissolved Oxygen and SD: Significant Difference among the Variable. **Noted:** Significant differences are said to be exist when the calculated t value is greater than the tabular value at the degree of freedom at $\leq 0.5\%$ confidence limit

Table 13: Most Probable Number (MPN) Analysis of the Influent Water Samples

Sample	Number of tubes giving positive results			MPN index per 100ml	95% confidence limit	
	3 of 10ml	3 of 1ml	3 of 0.1ml		Lower	Upper
MNNA	3	3	1	460	<0.5	9
MNNB	3	2	2	210	<0.5	13
MNNC	3	2	1	150	<0.5	20
BKA	3	3	2	1100	<0.5	21
BKB	2	1	1	20	1	23
BKC	3	3	2	1100	1	36
RSA	3	2	2	210	3	36
RSB	2	1	1	20	3	36
RSC	3	3	2	1100	1	37
MBA	3	3	3	2400	3	44
MBB	3	2	2	210	3	89
MBC	3	2	1	150	7	47
GMJA	1	1	0	7	4	150
GMJB	1	0	0	4	10	120
GMJC	0	1	0	3	4	130

(CLSI, 2022)

Table 14: Most Probable Number (MPN) Analysis of the Treated Water Samples

Samples	Number of tubes giving positive results			MPN index per 100ml	95% confidence limit	
	3 of 10ml	3 of 1ml	3 of 0.1ml		Lower	Upper
MNNA	1	1	0	7	<0.5	9
MNNB	2	1	1	20	<0.5	13
MNNC	1	2	0	11	<0.5	20
BKA	1	1	1	11	<0.5	21
BKB	2	2	0	21	1	23
BKC	3	0	1	39	1	36
RSA	1	1	0	7	3	36
RSB	1	1	1	11	3	36
RSC	2	0	0	9	1	37
MBA	3	1	1	75	3	44
MBB	1	1	1	11	3	89
MBC	2	0	1	14	7	47
GMJA	2	1	0	15	4	150
GMJB	3	2	0	93	10	120
GMJC	2	0	1	14	4	130

(CLSI, 2022)

Table 15: Biochemical characteristics of Bacteria Isolated from water Samples

Isolates	Microscop	Cit	Ur	Cat	In	MR	VP	Mot	H2S	Gas	Glu	Suc	Lac	Coa	Organisms
TWA1	+ chain	+	+	+	-	-	+	+	+	+	+	+	+	+	<i>S. aureus</i>
TWA2	- rod	+	+	-	-	+	-	+	-	-	+	+	+	+	<i>S. marcescens</i>
TWA3	- rod	+	+	+	-	-	+	-	-	+	+	+	+	-	<i>K. pneumoniae</i>
TWB1	- rod	+	-	+	+	-	+	+	-	-	+	+	+	-	<i>V. cholerae</i>
TWB2	- rod	-	-	+	+	+	-	+	-	+	+	+	+		<i>E. coli</i>
TWB3	- rod	+	-	-	-	+	-	+	-	+	+	+	-		<i>S. typhi</i>
TWB4	- rod	-	+	-	+	-	+	-	-	-	+	+	+		<i>Shigella</i>
SKTMA1	- rod	-	-	+	-	+	-	+	-	+	+	+	+		<i>Enterobacter sp</i>
SKTMA2	+ pairs	-	-	+	+	+	-	+	-	+	+	+	+		<i>E. coli</i>
SKTMA3	+ rod	+	-	-	-	+	-	+	-	+	+	+	-	+	<i>S. typhi</i>
SKTMA4	- rod	+	+	+	-	-	+	+	+	+	+	+	+		<i>S. aureus</i>
SKTMB1	- rod	+	+	+	-	+	-	+	-	+	+	+	+	+	<i>C. freundii</i>
SKTMB2	- rod	+	+	-	-	+	-	+	-	-	+	+	+	+	<i>S. marcescens</i>
SKTMB3	- rod	-	-	+	+	+	-	+	-	-	+	+	+		<i>E. coli</i>
SKTMB4	- rod	+	-	+	+	-	+	+	-	-	+	+	+	-	<i>V. cholera</i>
WBA4	- rod	+	-	+	+	-	+	+	-	-	+	+	+	-	<i>V. cholera</i>
WBB3	- rod	-	+	+	-	+	-	+	+	+	+	+	+	+	<i>C. freundii</i>
WZA2	- rod	-	-	+	-	+	-	+	+	+	+	+	+		<i>Enterobacter sp</i>
WZB2	+ pairs	+	+	+	-	-	+	+	+	+	+	+	+	+	<i>S. aureus</i>
WZB4	+ cluster	-	-	+	-	+	-	+	+	+	+	+	+		<i>E. coli</i>
IGB1	+ chain	+	+	+	-	-	+	+	+	+	+	+	+	+	<i>S. aureus</i>
IGA2	+ pairs	-	-	+	+	+	-	+	-	+	+	+	+		<i>E. coli</i>
IGB3	- rod	+	-	+	+	-	+	+	-	-	+	+	+	-	<i>V. cholera</i>
MNNA1	- rod	+	+	-	-	+	-	+	-	-	+	+	+	+	<i>S. marcescens</i>
BKA1	- rod	+	+	+	-	-	+	+	-	+	+	+	+		<i>C. freundii</i>
BKA3	- rod	+	-	+	+	-	+	+	-	-	+	+	+	-	<i>V. cholera</i>
RJA2	+ chain	+	+	+	-	-	+	+	+	+	+	+	+	+	<i>S. aureus</i>

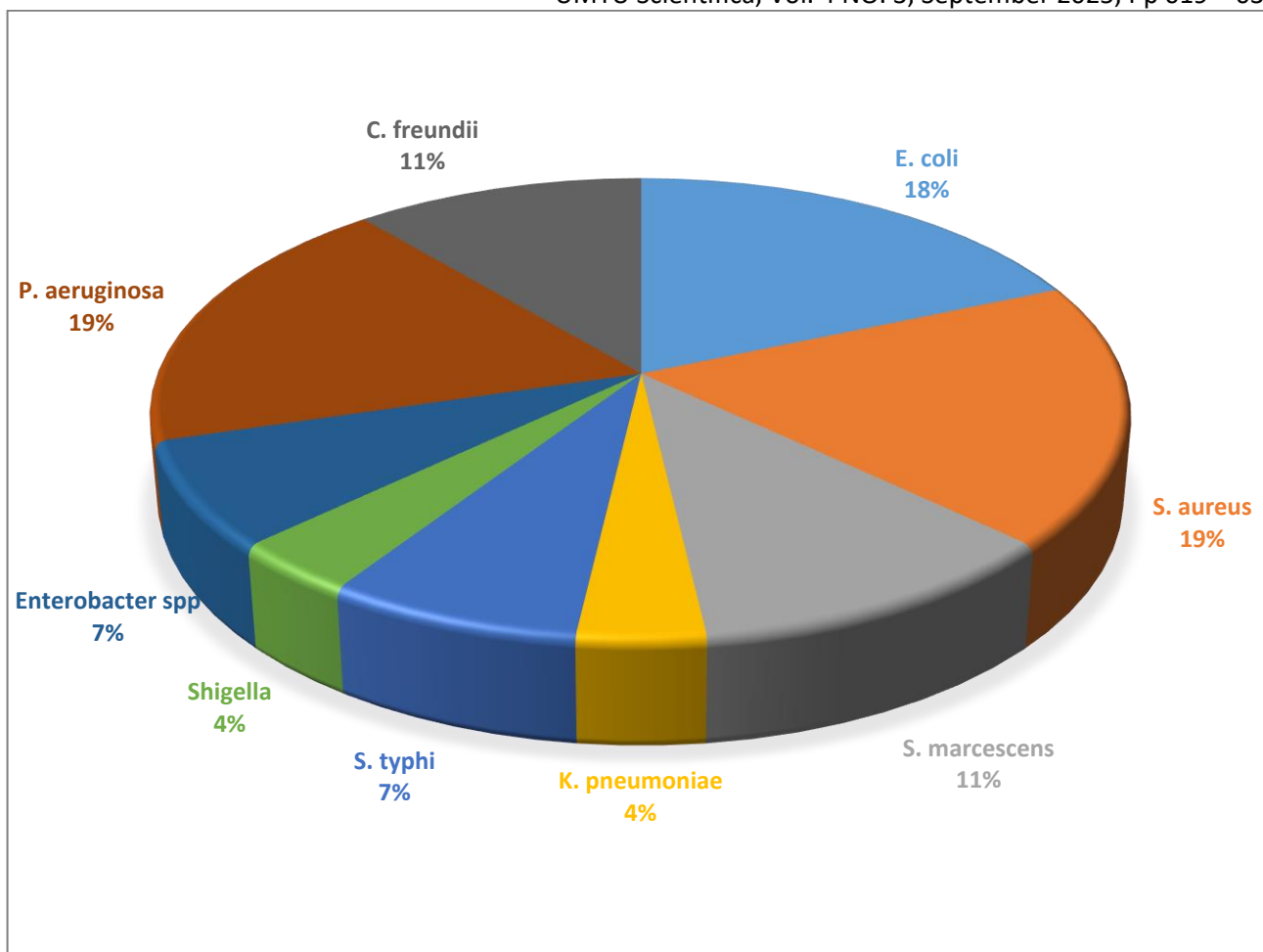


Figure 4.1: Representation of Frequency and Percentage of Occurrence of Bacteria Isolated from Influent Water Sample

Table 16: Biochemical characteristic of Bacteria Isolated from Treated water Samples

Isolates	Microscopy	Biochemical Characteristics													Organisms
		Cit	Ur	Cat	In	MR	VP	Mot	H ₂ S	Gas	Glu	Suc	Lac	Coa	
MBA1	+ chain	+	+	+	-	-	+	+	+	+	+	+	+	+	<i>S. aureus</i>
MBB2	- rod	-	-	+	+	+	-	+	-	+	+	+	+		<i>E. coli</i>
MBB3	- rod	+	-	-	-	+	-	+	-	+	+	+	-		<i>S. typhi</i>
MBB4	- rod	-	+	-	+	-	+	-	-	-	+	+	+	+	<i>Shigella</i>
MNNB3	- rod	+	+	+	+	+	-	+	-	-	-	-	-		<i>P. aeruginosa</i>
TKB3	+ cluster	+	-	+	+	-	+	+	-	-	+	+	+	-	<i>Bacillus sp</i>
TKA1	- rod	+	+	+	-	+	-	+	-	+	+	+	+		<i>Protetus sp</i>

Key: Cit=Citrate, Ur=Urase, Cat= Catalase, In=Indole, Mot=Mortality, Glu=Glucose, Suc= Sucrose, Lac=Lactose, Coa=Coagulase, MB=Mabera, MNN=Minannata and TK=Tsohuwar Kasuwa.

DISCUSSION

Table 1 Show the physico-chemical parameters conducted in this study namely; color, taste, ordor, temperature (27.7-31.7°C), alkalinity (15-100mg/1), pH (0.16-8.0), total hardness (1.0-100gm/1), calcium (1.0-36mg/1), magnesium (2.0-57mg/1), chloride (00.2-0.5mg/1), total

dissolve solid (1.00-120mg/1), total suspended solid (nil), turbidity (1.00-7.0mg/1), nitrate (0.4-24.00mg/1), copper (0.00-0.10), chromium (0.00-0.06), lead (nil), biological oxygen demand (16.00-39.0mg/1), dissolved oxygen (7.00-13.00mg/1), bicarbonate (0.01-12.00mg/1) and exchangeable actions (.00-17.00mg/1). It could be deduced that the water samples were high in total

dissolved solids, biological oxygen demand, magnesium, total hardness, alkalinity, and temperature, while chromium and copper were observed to be low. However, this study is similar to the work of Idehen, 2020 and Singh *et al.*, 2019, report the following physico-chemical parameters; hardness (32-114mg/1), calcium (18.0-59.0mg/1), magnesium (18.0-57.0mg/1), chloride (32.0-48.0mg/1), total dissolved solid (60.0-130), alkalinity (17.9-59.0), nitrate (0.15-0.30mg/1), pH (5.15-7.23), temperature (26.2-29.2), turbidity (4.00-7.00) and conductivity (38.7-84.5 \mathcal{M} s/cm) from wells situated in Ille-Oluji popularly known for cocoa plantation. Similarly, this study is different from the report of Yasin *et al.*, 2015 and Sesugh *et al.*, 2019, report the physico-chemical parameters from shallow wells around cement factories which also a vital point of water contamination in the society; turbidity (17.5-51.5), pH (4.10-5.0), total dissolved solid (270-959mg/1), total suspended solid (53.0-70.0mg/1), conductivity (4.30-893 \mathcal{M} s/cm), irons (0.25-1.16mg/1), manganese (0.33-0.92mg/1), zinc (0.075-0.127) and no activity was recorded on biological oxygen demand, temperature and copper.

The results in Table 2 revealed that Sokoto Water Board, Minanata, and Runjin Sambo had good water for drinking based on the water quality index (WQI) rating. In contrast, the Tsohuwar Kasuwa, Mabera, and Nakasari areas were rated to have poor water quality. Finally, Waziri C, Tudun Wada, Tashar Illela, and Sokoto Mechanic Village were unsuitable for drinking based on the water quality index, which could be a result of the very old pipe system. Most of the pipes are in poor condition. There are leakages and breakages through which contaminants from outside the pipe might enter and mix with the supplied water, or due to a lack of adequate water, these pipes often lose pressure. Moreover, due to the inadequate layout of water supply lines, there may be crossing between them. This may cause fecal contamination. Thus, it is very much possible that even if there is water, upon entering the pipes, it might no longer be suitable for drinking and pose a public health threat to the end users.

The total bacterial count, total coliform count, and total fecal count obtained from this research ranged from 10.2×10^{-8} - 1.5×10^{-9} CFU/ml, 8.2×10^{-4} - 1.5×10^5 CFU/ml, and 7.2×10^4 - 2.6×10^4 CFU/ml, respectively, which is higher than that up Yasin *et al.*, 2015 and Sesugh *et al.*, 2019 that report on *Enterobacteriaceae* isolated in well water ranged from 2.79×10^8 - 9.66×10^8 CFU/ml.

Based on this study Twenty Seven (27) bacterial species were isolated namely; *E. coli* (5), *S. marcescens* (3), *S. aureus* (5), *K. pneumoniae* (1) *S. typhi* (2) *Shigella* (1) *Enterobacter* sp (2) *V. cholerae* (5) and *C. freundii* (3) which is in line with the work of Adebawore *et al.*, 2016 documented the species of bacteria isolated from necrosols collected from urban cemeteries in Poland to be: *B. cereus*, *B. megaterium*, *Enterococcus faecalis*, *Escherichia coli*, *Serratia megaterium*, *Staphylococcus epidermidis* and coagulase negative staphylococci (CNS). This is in line with some of the bacterial organisms isolated in this work. Previous reports also documented the isolation of similar organisms from

water sources situated close to grave sites. Rodrigues and Pacheco (2010) and Kutlu *et al.* (2015) also documented the isolation of *E. coli*, *Enterococcus* sp., *Staphylococcus* sp., and *Glycomyces* sp. from funeral decomposed artifacts such as jewelry, metal dental fillings, and caskets. In addition, Adesakin *et al.* (2020) predominantly identified *Enterobacteriaceae* such as: *Pseudomonas* sp., *E. coli*, *Enterococcus* sp, *Vibrio* sp, and *Bacillus* sp. in domestic water samples situated close to burial grounds. This is in line with some of the organisms isolated from this study. These pathogenic organisms are associated with the gut and skin microbiome, which can consequently be released into the environment through the decomposition of humans or animals.

The presence of pathogenic bacteria such as *Escherichia coli*, *Serratia marcescens*, *Staphylococcus aureus*, *Klebsiella pneumoniae*, *Salmonella typhi*, *Vibrio cholerae*, *Citrobacter freundii*, and *Enterobacter* sp. in both influent and, alarmingly, some treated water samples indicates a serious public health risk. These organisms are known etiological agents of gastrointestinal and waterborne diseases. Their presence in treated water suggests potential post-treatment contamination or inadequate disinfection protocols.

CONCLUSION

Out of 30 water samples collected, physicochemical properties were determined from each water sample and yielded a significant result. This represents a total relative weight of each water sample; water board after treatment 84.66%, Minanata area 98.21%, Tsohuwar Kasuwa 102.07%, Runjin Sambo 93.2%, Mabera 104.5%, Sokoto water board before treatment 139%, Sokoto mechanic village 371.52%, Waziri ward C 611.32%, Tudun wada 189% and Tashar Illela Garage 139% respectively. From the result of the coliform count sample TWA of the effluent water source indicates the highest number of coliforms with MPN 2400/100ml, and WBC has the least number of coliform with MPN 3/100ml. Similarly, the sample MBA of the treated water source has the highest number of coliform with MPN 75/100ml, and sample MNN has the lowest number of coliform with MPN 7/100ml. Based on the analysis of the drinking water sources available in Sokoto communities, the coliform counts, as evident from the analysis, revealed a gross population exceeding the World Health Organization standard of 10 coliforms per 100ml of water. However, from the result of biochemical identification of both effluent and treated water sources, 27 bacterial isolates were identified from the effluent water. The name and frequency of occurrence are; *E. coli* 5(18.5%), *S. aureus* 5(18.5%), *S. marcescens* 3(11.1%), *K. pneumoniae* 1(3.7%), *S. typhi* 2(7.4%), *Enterobacter* sp 2(7.4%), *Shigella flexineri* 1(3.7%), *P. aeruginosa* 5(18.5%), *C. freundii* 3(11.1%) and 16 bacterial isolates were identified from treated water, the name and frequency of occurrence are; *E. coli* 4(24%), *S. aureus* 3(18.7%), *S. typhi* 3(18.7%), *Shigella flexineri* 1(6.25%), *Bacillus* sp 2(12.5%), *Proteus* sp 1(6.25%) and *P. aeruginosa* 2(12.5%).

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