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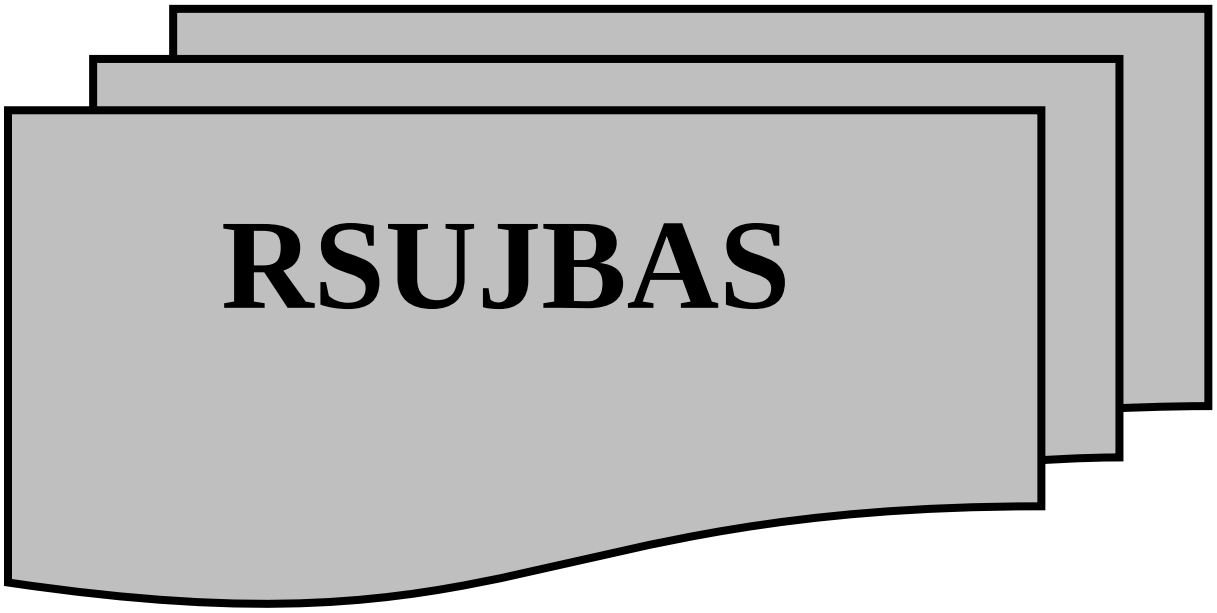

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**Kingsley- Opara, Ngozi**
Research Scholar, Department of Computer Science, Ignatius Ajuru University of Education, rivers State, Nigeria.

**Prof. Asagba, Prince Oghenekaro.**
Visiting Scholar, Department of Computer Science, University of Education (IAUE), Rumolumeni, Port Harcourt, Rivers State Nigeria.
Emial:asagbapince@uniport.edu.ng

**Gabriel.B.C., Gabriel M.N.O.Asagba**
School of Graduate Studies Ignatius AJURU University of Education ((IAUE), Rumolumeni, Port Harcourt, Rivers State Nigeria.
Department of Computer Science
Gabrielbariyira@gmail.com, meegabzgmail.com

**WAIDOR, Tamaramiebi Keith & ASAGBA, Prince Oghenekaro**
Department of Computer Science
Faculty of Natural and Applied Sciences
Ignatius Ajuru University of Education, Port Harcourt
Zalimaxxx@gmail.com

Department of Computer Sciences,
University of Port Harcourt, Rivers State Nigeria.
Prince.asagba@uniport.edu.ng

**Fibersima, Alalibo Ralph**
Visiting Scholar, Department of Computer Science,
University of Port Harcourt, Rivers State Nigeria.
Fiberesima.a.r@outlook.com

**Asagba, Prince Oghenekaro.**
Visiting Scholar, Department of Computer Science,
University of Port Harcourt, Rivers State Nigeria.
Asagba.prince@uniport.edu.ng

**Kingsley- Opara, Ngozi**
Research Scholar, Department of Computer Science,
Ignatius Ajuru University of Education, Rivers State Nigeria.
Email: ngoziopara@g.mail.com

**Prof Asagba, Prince Oghenekaro.**
Visiting Scholar, Department of Computer Science,
University of Port Harcourt, Rivers State Nigeria.

# MICROBIOLOGICAL AND PHYSICOCHEMICAL PROPERTIES OF EKPAN RIVER AND ANTIBIOTICS RESISTANCE PROFILE OF BACTERIAL ISOLATES IN NIGERIA

**IDISE, OKIEMUTE EMMANUEL**
Department of Microbiology, Delta State University, Abraka, Delta State, Nigeria
E-mail: emmaidise@yahoo.com
Tel: +2348136506553
**&**
**ODUM, EDWARD IKENNA**
Department of Microbiology, Delta State University, Abraka, Delta State, Nigeria
Tel: +2348057592441

## ABSTRACT

*Physicochemical and microbiological properties of Ekpan creek in Warri, Delta State, and antibiotics resistance of bacterial isolates were carried out using standard methods from March to August, 2020. Mean Temperature ($^oC$) was 27.38±0.24; Color (Pt-Co), Depth (m), Speed of flow (m/s) increased from Location 1- 4; pH value 6.27±0.09, Electrical conductivity 109.21±74.94µs/cm, calcium <0.001ppm and lead <0.001-0.002ppm and TDS 56.22±18.44ppm were within the WHO set standards. Turbidity (NTU), Total Dissolved Solids, Dissolved Oxygen, Calcium, Potassium, Manganese, Sulphates and Total nitrogen (ppm), Heterotrophic Bacterial, coliform and fungal counts (Log $_{10}$cfu/ml) decreased from Locations 1 and 2, increased in 3 and decreased again in 4; Water quality index (WDI) values of 46.1, 48.1 (Good quality water) 56.9, 63.2 (poor water quality) were observed for Locations 1 to 4 respectively. Mean Biological Oxygen Demand$^5$ 3.55±1.03 and Dissolved Oxygen 5.59±0.85 reduced from Location 1 to 4 and were above WHO set Standards. The coliform counts were above the WHO set standard of 0/100ml in all the samples. Bacillus sp was isolated from locations 1- 4, Escherichia sp 1 – 3 and Staphylococcus sp in 4; Mucor sp was isolated in Locations 1, 2 and 4; Aspergillus sp 2, 4 while Penicillium sp and Rhizopus sp in Location 2. Strong correlations were observed amongst tested parameters, there was no statistically significant difference in parameters of the stations at 95% confidence level. Bacillus sp, Staphylococcus sp and Escherichia sp were resistant to 8, 3 and 7 of the tested antibiotics with mean multi-Antibiotic Resistance Index (MARI) of 0.4, 0.3 and 0.5 respectively. The observed high coilform counts and presence of multi drug resistance among isolates are of great public health concern. Thus, the Ekpan creek water should be subjected to different treatments prior to use for domestic purposes to avert outbreak of water-borne diseases.*

**Key words:** Microbiological. Physicochemical, Properties, Ekpan River, Antibiotics, Resistance, Bacteria.

## Introduction

The Ekpan creek is a brackish, deep and flowing river used for domestic purposes and fishing. It is located in Effurun-Warri of Delta State on longitude 5.54$^o$E and 5.7$^o$W and latitude 5.31$^o$N and 5.6$^o$S. The creek is about 12km long with its origin in Effurun-Warri. It stretches from

Sokoh Estate area through the then Bendel Estate (Now Delta Property and Development Area (DPDA)), Ijaw quarters and Ugboroke (which generate rural/urban wastes that are discharged into it) and flows through the western side of Warri City into Tori Creek at the Nigeria National Petroleum Corporation (NNPC) jetty and empties into the Warri River at the Bennet Island (Goodie, 2001; Olomukoro and Azubuike, 2009). The upstream of the creek is unidirectional fresh water with dense forest vegetation while downstream is tidal, brackish water and consist of mangroves. The area experiences a mean annual rainfall of 3,000mm (Alakpodia, 2001) and tropical humidity of the semi-hot equatorial type. Its wet season spans from April to October and dry season from November to March. The communities settled along its bank obtain drinking water from it. These include Ugbirikoko, Ugboroke and Edjeba communities.

The observed presence of water hyacinth (*Eichhornia crassipes)*, which has been severally reported as an indicator of water pollution (Opande *et al.*, 2004) made it imperative to undertake this study of the River water to ascertain its suitability for use for domestic and/or industrial purposes. The choice of the locations was based on proximity to facilities, structures or human activities that could potentially affect the water quality of the River.

The aim of this study was to determine the microbial quality and physicochemical properties of water obtained from the Ekpan creek and the resistance profile of bacteria isolated from the water.

## 2.0 Materials and methods

**2.1**. **Study Area:** The study area was Ekpan River which flows from the Bendel Estate (Now Delta Property and Development Area (DPDA)) (behind PhD Hotel) through Ijaw quarters, Ugboroke and Ekpan Bridge (by NNPC Housing Estate) in Warri, Nigeria. The four study locations were chosen based on different activities going on along the River.

**2.2**. **Collection of Water Samples**: Water samples were collected in accordance with standard procedures (Cheesebrough, 2004). The water samples for physicochemical parameters were collected with newly purchased 2-Liter plastic containers, previously sterilized by rinsing with 95% ethanol and allowing them to dry, while the water samples for microbiological analyses were collected with sterile bottles. The samples were transported in ice-packed container to the Microbiology Laboratory, Delta State University, Abraka for analyses within 2 hours of collection.

**2.3 Isolation and Enumeration of Microorganisms:** The water samples were serially diluted and spread-plated onto the surface of nutrient agar (NA), Sabouraud dextrose agar (SDA) and MacConkey agar (MA) according to Cheesebrough (2004). NA and MA plates were incubated at $37^0$C for 24h while the SDA plates were incubated at room temperature (28±2°C) for 48h. Microbial counts were determined after incubation and pure cultures of the isolates obtained by subculturing and stored at $4^0$C until required.

**2.4 Characterization and Identification of Bacterial Isolates**: Purified bacterial cultures were characterized and identified based on colonial/morphological characteristics, Gram reaction and biochemical tests with the procedures described by Cheesebrough (2004).

**2.5 Characterization and Identification of Fungal Isolates:** Purified fungal cultures were characterized and identified according to the methods of Harrigan and McCance (2001). The pure isolates were subjected to macroscopic and microscopic identification procedures.

**2.6 Determination of Physicochemical Parameters of the Water Samples:** The physicochemical parameters of the water samples were determined using the procedures described in ASTM (2002).

**2.7 Determination of Water Quality Index:** These were determined using procedures described in WHO (2012).

**2.8 Antibiotic Susceptibility Test:** The disc diffusion technique according to Bauer *et al*. (1996) was used to determine the antibiotic susceptibility pattern of isolates. Firstly, one colony of overnight bacterial culture was inoculated into normal saline and standardized to 0.5 McFarland. Then, previously prepared sterile Mueller Hinton agar (MHA) plates were inoculated, carefully spread over the entire surface of the agar using sterile swab and allowed for 5 min to dry. Using a sterile forceps, the following antibiotic discs – pefloxacin (10µg), gentamycin (30µg), ampiclox (30µg), zinnacef (30µg), Amoxicillin (30µg), rocephin (10µg), ciprofloxacin (10 µg), streptomycin (30µg), septrin (30µg) and erythromycin (10µg) were placed onto the surface of the MHA plates, and incubated at 35±2°C for 18–24 h. The zone of inhibition was read post-incubation and recorded following the Clinical and Laboratory Standards Institute guidelines (CLSI, 2014).

**2.9 Statistical Analysis**: F-test to determine statistical differences in parameters obtained from the locations and Pearson moment correlation of physico-chemical parameters were determined using Microsoft Excel 2003.

**3.0 Results**

The physicochemical parameters of the water samples are presented in Table 1. Mean values for temperature, depth, color, speed, conductivity, TDS (ppm), and COD (ppm) increased from Location 1 - 27$^{o}$C, 3.2m, 44co-pt,1.37m/s, 85.3µs/cm, 48.11ppm and 8.3ppm, to Location 4 – 28$^{o}$C, 4.1m, 170co-pt,1.49m/s, 155.28µs/cm, 78ppm, and 11.6ppm with ranges of 27-28$^{o}$C, 3.3-4.6m, 44-170co-pt, 1.37-1.49m/s, 14.79-181.16µs/cm and 5.6-14.66ppm respectively. Ca, K, Mn, $SO_4$ and Pb increased from Location 1 to 4. Values of pH, turbidity, DO and $BOD^5$ reduced from location 1 (6.2, 31NTU, 7.4ppm and 6.6ppm) to location 4 (6.15, 28NTU, 3.75ppm and 2.0ppm) with ranges of 6.15-6.54, 28-34NTU, 3.75-7.40ppm and 5.60-14.66ppm respectively. $TN_2$ reduced from Location 1-4. Water quality index increased from Location 1 (46.1 Good quality water) to Location4 (63.2 Poor quality water) indicating good quality water in Location 1 and poor quality water in Location 4. Of the tested parameters, turbidity, DO, $BOD^5$and COD were above WHO set standards for drinking water (WHO, 2012).

Values of the means and ranges were 27.38±0.24 (27-28$^{o}$C), 135.5±30.63 (44-170 Pt-Co), 3.68±0.19 (3.3-4.1m), 1.42±0.03 (1.37-1.49m/s) for temperature, color, depth and velocity respectively; 6.27±0.09 (6.15-6.54), 109.21±74.94 (14.75-181.60 µs/cm), 30.50±2.65 (28-34NTU), 56.22±18.44 (7.88-90.88ppm) respectively for pH, EC, turbidity and TDS; 5.59±0.85 (3.75-7.40ppm), 3.55±1.03 (2.00-6.60ppm), 10.04±1.97 (5.60-14.66ppm), 6.86±2.90 (0.88-13.14ppm) for DO, $BOD^5$, COD and Ca respectively; 11.93±4.57 (0.98-22.47ppm), 4.95±1.85 (1.14-9.25ppm), 12.75±4.07 (3.00-22.00ppm), 0.67±0.34 (0.11-1.59ppm) respectively for K, Mn, $SO_4$ and $TN_2$. Values for Cr and Pb were <0.001ppm and <0.001-0.02ppm respectively. Water quality index were 46.1, 48.1 (good water quality) and 56.9, 63.2 (poor water quality) respectively for Locations 1- 4.

The microbial load of the water samples are presented in Table 2. Results showed that the mean values were 4.5, 3.85 and 4.43x$10^3$cfu/ml while the ranges were 5.3 – 8.0, 3.5 – 7.0 and 1.5 – 5.45x$10^3$cfu/ml respectively for heterotrophic bacterial, coliform and fungal counts. Heterotrophic bacterial counts and Coliform counts reduced from Location 1 (8x$10^3$cfu/ml and 7x$10^3$cfu/ml) to Location 4 (5.3x$10^3$cfu/ml and 3.5x$10^3$cfu/ml) while FC increased from 1.5x$10^3$cfu/ml in Location 1 to 3.0x$10^3$cfu/ml in Location 4 which followed the same trend with changes in pH.

The bacterial and fungal types isolated from the water samples are presented in Table 3. The bacterial isolates were *Bacillus* sp, *Escherichia* sp and *Staphylococcus* sp while the fungal isolates were *Mucor* sp, *Aspergillus* sp, *Penicillium* sp and *Rhizopus* sp.

**Table 1: Physicochemical parameters of water samples**

| | Location | | | | Mean ± SD | WHO standards |
|---|---|---|---|---|---|---|
| Parameters | 1 | 2 | 3 | 4 | Range | |
| Temperature ($^{o}$C) | 27 | 27 | 27.5 | 28 | 27.38 ± 0.24<br>27 - 28 | NA |
| Color (Pt-Co) | 44 | 158 | 170 | 170 | 135.5 ± 30.63<br>44 – 170 | NA |
| Depth (m) | 3.2 | 3.6 | 3.8 | 4.1 | 3.68 ± 0.19<br>3.3 – 4.1 | NA |
| Speed (m/sec) | 1.37 | 1.39 | 1.41 | 1.49 | 1.42 ± 0.03<br>1.37 – 1.49 | NA |
| pH | 6.2 | 6.54 | 6.2 | 6.15 | 6.27 ± 0.09<br>6.15 – 6.54 | 6.5 – 8.5 |
| EC (µs/cm) | 85.3 | 14.75 | 181.60 | 155.20 | 109.21 ± 74.94<br>14.75 – 181.60 | 50 – 1500 |
| Turbidity (NTU) | 31 | 29 | 34 | 28 | 30.50 ± 2.65<br>28 - 34 | 0.5 |
| TDS (ppm) | 48.11 | 7.88 | 90.88 | 78 | 56.22 ± 18.44<br>7.88 – 90.88 | 500 |
| DO (ppm) | 7.4 | 6.6 | 4.6 | 3.75 | 5.59 ± 0.85<br>3.75 – 7.40 | 5 |
| $BOD_5$(ppm) | 6.6 | 2.8 | 2.8 | 2.0 | 3.55 ± 1.03<br>2.00 – 6.60 | 5 |
| COD (ppm) | 8.3 | 5.6 | 14.66 | 11.6 | 10.04 ± 1.97<br>5.60 – 14.66 | 10 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Ca (ppm) | 3.12 | 0.88 | 13.14 | 10.28 | 6.86 ± 2.90<br>0.88 – 13.14 | NA |
| K (ppm) | 8.99 | 0.98 | 22.47 | 15.26 | 11.93 ± 4.57<br>0.98 – 22.47 | NA |
| Mn (ppm) | 2.7 | 1.14 | 9.25 | 6.7 | 4.95 ± 1.85<br>1.14 – 9.25 | < 150 |
| $SO_4$ (ppm) | 10 | 3 | 22 | 16 | 12.75 ± 4.07<br>3.00 – 22.00 | NA |
| $TN_2$ (ppm) | 0.2 | 0.11 | 1.59 | 0.79 | 0.67 ± 0.34<br>0.11 – 1.59 | NA |
| Cr (VI) (ppm) | < 0.001 | < 0.001 | < 0.001 | < 0.001 | ND | 36 |
| Pb (ppm) | < 0.001 | 0.001 | 0.002 | 0.02 | ND | 35 – 110 |
| Water Quality Index | 46.1 | 48.1 | 56.9 | 63.2 | ND | |

Key: 1 = Behind PhD Hotel, 2 = Ijaw Quarters, 3 = Ugboroke, 4 = Ekpan Bridge, NA = Not available, ND = Not determined

**Table 2: Microbial load of water samples**

| Location | 1 | 2 | 3 | 4 | Mean | Range |
|---|---|---|---|---|---|---|
| HBC (x $10^3$ cfu/ml) | 8.00 | 5.7 | 5.85 | 5.3 | 4.5 | 5.3 – 8.0 |
| CC (x $10^3$ cfu/ml) | 7.00 | 4.9 | 5.70 | 3.5 | 3.85 | 3.5 – 7.0 |
| FC (x $10^3$ cfu/ml) | 1.50 | 5.15 | 5.45 | 3 | 4.43 | 1.5 – 5.45 |

Key: HBC = Heterotrophic bacterial counts, CC = Coliform counts, FC = Fungal counts

The statistical analysis of the tested parameters revealed that there were strong correlations (r) between Speed of flow and depth, coliform counts, total dissolved solids (TDS), color, chemical oxygen demand (COD), Calcium, Magnesium, sulphate ($SO_4$), total nitrogen ($TN_2$); pH and fungal count (FC), $SO_4$, $TN_2$; Electrical conductivity and depth, speed, TDS, turbidity, COD, Ca, potassium, Mn, $SO_4$, $TN_2$; Depth and electrical conductivity (EC), TDS, turbidity, color, COD, Ca, Mn, $TN_2$, total aerobic counts (TAC), coliform counts (CC); dissolved oxygen (DO) and biological oxygen demand ($BOD^5$); Color and Ca, $TN_2$, fugal counts (FC), depth, speed; Total dissolved solids (TDS) and EC, turbidity, Ca, K, Mn, $SO_4$, $TN_2$; Turbidity and EC, TDS, Ca, K, Mn. $SO_4$, $TN_2$; $BOD^5$and DO, THC, CC; COD and depth, speed, EC, Ca, K, Mn, $SO_4$, $TN_2$, FC; FC and pH, color, COD; TAC and BOD; CC and $BOD^5$.

**Table 3: Bacterial and fungal types isolated from the water samples**

| | Location | | | |
|---|---|---|---|---|
| Organism | 1 | 2 | 3 | 4 |
| *Bacillus* sp | + | + | + | + |
| *Escherichia* sp | + | + | + | - |
| *Staphylococcus* sp | - | - | - | + |
| *Mucor* sp | + | + | - | + |
| *Penicillium* sp | - | + | - | - |
| *Aspergillus* sp | - | + | - | + |
| *Rhizopus* sp | - | + | - | - |

Key: + = Positive, - = Negative

The f-value determined using ANOVA (Single factor) at 95% confidence level showed that f-crit (2.798061) was greater than f-cal (1.221731) while t-test values for sampled locations showed that t-crit (2.178813) was greater than the t-cal values. Thus, there were no statistically significant differences in parameters of sampled locations at P = <0.05.

Results of the antibiotic sensitivity test presented in Table 4 showed resistance of *Bacillus* sp, *Escherichia coli* and *Staphylococcus* sp to 8, 6 and 3 of the ten tested antibiotics respectively. *Bacillus* sp was resistant to pefloxacin (10µg), gentamycin (30µg), ampiclox (30µg), zinnacef (30µg), Amoxicillin (30µg), rocephin (10µg), ciprofloxacin (10 µg), streptomycin (30µg), septrin (30µg) and erythromycin (10µg).

MAR index of the bacterial isolates presented in Table 5 showed that mean values were 0.4, 0.3 and 0.5 respectively for *Bacillus* sp, *Staphylococcus* sp and *Escherichia* sp.

**Table 4: Antibiotic sensitivity profile of bacterial isolates**

| Antibiotic | 1 | | 2 | | 3 | | 4 | |
|---|---|---|---|---|---|---|---|---|
| | Bac | Escher | Bac | Escher | Bac | Escher | Bac | Staph |
| Pefloxacin (10µg) | S | S | S | S | S | R | S | S |
| Gentamycin (30µg) | S | R | S | S | S | R | R | S |
| Ampliclox (30µg) | R | R | S | S | S | R | R | R |
| Zinnacef (30µg) | S | R | R | S | R | S | S | S |
| Amoxicillin (30µg) | R | R | S | R | R | S | R | R |
| Rocephin (10µg) | R | S | S | S | R | S | R | R |
| Ciprofloxacin (10µg) | S | S | S | R | S | R | S | S |
| Streptomycin (30µg) | S | S | S | S | S | S | R | S |
| Septrin (30µg) | S | S | S | S | R | S | S | S |
| Erythromycin (10µg) | S | S | S | S | R | S | S | S |
| | 3R 7S | 4R 6S | 1R 9S | 2R 8S | 5R 5S | 4R 6S | 5R 5S | 3R 7S |

Key: Bac = *Bacillus* sp, Staph = *Staphylococcus* sp, Escher = *Escherichia* sp,

R Resistant, S = Sensitive

## Discussion

The variations in physicochemical properties of water samples obtained from Ekpan River can be linked to the different forms of anthropogenic activities that take place at the different sampling locations (Sajitha and Vijayamma, 2016). Although the temperature of the water samples obtained are optimum for aquatic life, the slightly high concentration of hydrogen ions at locations 1, 3 and 4 may present harmful conditions as low water pH may allow for the mobility and dissolution of toxic elements and compounds (Solomon *et al*, 2016). Furthermore, the low DO values obtained at Ugboroke and Ekpan Bridge are indicative of pollution. Pollution of aquatic environments usually brings about a decreased solubility of oxygen. According to Sajitha and Vijayamma (2016), the presence of dissolved oxygen is essential to maintain proper balance of various pollutants in a water-body. Also, a high BOD value obtained behind PHD hotel could be as a result of water pollution from sewage/runoffs from the activities that take place in the hotel. This pollution may have encouraged the presence and proliferation of coliform bacteria. Yogendra and Puttaiah (2008) stated that BOD is an indicator of biodegradable organic matter in a water body. Also, Etim *et al.* (2013) referred to BOD as a representation of the rate at which microorganisms, principally bacteria, utilize oxygen during breakdown of organic pollutants. According to Olukunle (2013), normal COD range for good water quality is 6-10 mg/l. He further suggested that higher values are indicative of pollution with considerable amounts of chemical pollutants. Therefore, COD values of water samples from Ugboroke and Ekpan Bridge suggest high contamination with chemical pollutants. In addition, values above 15 color units and high turbidity (above 5NTU) aesthetically disqualify the usage of this water for domestic purposes. The high WQI values recorded at some points of the

**Table 5: Multi Antibiotics Resistance Index (MARI) of bacterial isolates**

| Isolate | Antibiotics resistant to | Number of antibiotics Resistant to | Number of antibiotics Sensitive to | Total number of antibiotics tested | MARI | Mean MARI |
|---|---|---|---|---|---|---|
| *Bacillus* sp 1 | Ampiclox, Amoxicillin, Rocephin | 3 | 7 | 10 | 0.3 | |
| *Bacillus* sp 2 | Zinnacef | 1 | 9 | 10 | 0.1 | |
| *Bacillus* sp 3 | Zinnacef, Amoxicillin, Rocephin, Septrin, Erythromycin | 5 | 5 | 10 | 0.5 | |
| *Bacillus* sp 4 | Gentamycin, Ampiclox, Amoxicillin, Rocephin, Streptomycin | 5 | 5 | 10 | 0.5 | **0.4** |
| *Staphylococcus* sp | Ampiclox, Amoxicillin,Rocephin | 3 | 7 | 10 | 0.3 | **0.3** |
| *Escherichia* sp 1 | Gentamicin, Ampiclox, Zinnacef, Amoxicillin | 4 | 6 | 10 | 0.4 | |
| *Escherichia* sp 2 | Amoxicillin, Ciprofloxacin | 2 | 8 | 10 | 0.2 | |
| *Escherichia* sp 3 | Pefloxacin, Gentamycin, Ampiclox, Ciprofloxacin | 4 | 6 | 10 | 0.4 | **0.5** |

Ekpan River is also suggestive of water pollution. Similar findings were made by Ishaku (2011) from Jimeta-Yola area of North Eastern Nigeria and Etim *et al.* (2013) from different water sources in the Niger Delta region of Nigeria. The latter discovered that stream water samples from the Niger Delta Region of Nigeria had poor water quality based on the WQI standards applied in their study. Both researches suggested that poor water quality could be attributed to anthropogenic activities such as defecation and disposal of untreated wastes into the environment. This supports the findings of this study as low DO values and high coliform counts obtained can be attributed to similar factors.

Coliform bacteria count obtained from all sampling points were very high. These counts are above WHO and EU standards for drinking water and further support the possibility of sewage discharge into the river. High heterotrophic bacterial counts can also be linked to the use of the Ekpan River for defecation, improper waste disposal and fish farming. These are in line with the report of Edum and Efiuvwevwere (2012) who stated that high heterotrophic bacterial counts are usually associated with waste discharge, high density farming and other human activities.

Results showed that *Escherichia* sp. were among the bacterial isolates obtained from Ekpan River water. These organisms are indicators of recent fecal contamination. Although *Escherichia* sp may be regarded as a member of the normal flora of the human gastrointestinal tract, its presence alongside other Enterobacteriaceae in water indicates a risk because certain strains of pathogenic organisms are likely to be present in the river (Dias-Gonçalves *et al.*, 2019). Furthermore, the isolation of *Bacillus* sp. and *Staphylococcus* sp. from the river water samples also means that the use of the Ekpan River water for domestic purposes could predispose individuals to health risks as some species of these microorganisms are well known to be disease causing microbes (pathogenic). In addition, the isolation of fungal species belonging to the genera *Mucor, Penicillium, Rhizopus* and *Aspergillus,* from Ekpan River water, was similar to the findings of Bakhiet *et al.* (2016) who stated that fungi are prevalent in water distribution systems especially if the water has been exposed to contamination from external sources. The results of this study also corroborate the reports of Gashgari *et al.* (2013) who isolated *Aspergilluss Niger* and *Mucor* sp. among other mycobiota from different drinking water sources. The isolation of fungi from water samples is usually indicative of low water quality (Bakhiet *et al.*, 2016). This further disqualifies the suitability of Ekpan River water for domestic and/or recreational activities.

The Pearson moment correlation analysis signify a strong correlation between BOD and DO, THBC and CBC (r= 0.792 -0.989) while TDS correlated with turbidity, Ca, K, Mn, $SO_4$ and $TN_2$ (r= 0.866 to 0.995). Strong correlations were also observed for Ca, K, Mn, $SO_4$ and $TN_2$ (r= 0.951 to 0.996). These positive correlations among chemical parameters tested suggest a common source of introduction into the river. This is supported by the findings of Ishaku (2011). Also, the strong correlation in BOD, THBC and CBC indicated that the microbial activity in the river invariably depicted a low water quality with respect to use for domestic purposes.

Presence of antibiotic resistant strains in water samples (Table 6) is a token of an inherent public health problem. El-Zanfaly (2015) stated that bacterial resistance may arise in man and animals due to selective pressure of antibiotics used in treatment and prevention of infections or growth promotion in livestock. Also, the misuse of antibiotics by humans may bring about the likelihood of harboring microorganisms that will be more resistant to antibiotics than those found in wildlife. Therefore, the prevalence of multidrug resistant strains of *Escherichia* sp and *Bacillus* sp in Ekpan River can be traced to human sources such as fecal contamination and livestock farming. The MARI values obtained at Locations 1, 3 and 4 presents these regions as high-risk point sources which also correlate with points at the river site where pollution is elevated (Akpan *et al,* 2020). Furthermore, the findings of El-Zanfaly (2015) that antibiotic resistant bacteria persist in drinking water after treatment makes it more alarming. The results of this analysis are similar to those of Ilangovan *et al.* (2016) who isolated MDR strains of *Bacillus subtilis and Staphylococcus pasteuri* as well as other antibiotic resistant species from the Bhavani River in India. The high level of resistance to antibiotics among isolates from Ekpan River is of public health concern since the water is used by individuals for several activities such as bathing, washing and recreation (Odonkor and Addo, 2018). Frequent contact with the water source may expose the inhabitants, to infections by multidrug-resistant pathogens. Multidrug-resistant pathogenic bacteria pose huge medical problems when infections by these organisms set in. This is because, the choice of antibiotics for treatment becomes a very tedious task, combination therapies become less effective and persistent infections become widespread.

## Conclusion

The WQI and high microbial loads as well as BOD obtained at some locations along the river course point to the non-suitability of Ekpan River water for domestic use. Also, the turbidity and coloration may further discourage its use for recreational activities. The high prevalence of MDR- bacteria, which pose great health risks among individuals who depend on this river as source of water, creates a more worrisome situation. As a flowing river, Ekpan River possesses the tendency of self-purification. However, frequent pollution via the activities of man may frustrate/hinder the effect of natural purification process and encourage concentration of pollutants at some point in the river course, especially regions with high particulate and suspended matter. Therefore, bearing in mind that good-quality water is vital for life processes, indiscriminate waste disposal and other anthropogenic activities that tend to debase water quality should be discouraged from occurring in the river. Also, rapid measures and laws should be put in place by regulatory bodies to check the pollution of rivers and other surface waters.

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