Assessment of the physicochemical qualities and microbiological profile of Idah River, Kogi State, Nigeria

Deborah Ebunoluwa Adedire¹, Adijat Ozohu Jimoh¹, Zainab Kashim-Bello¹, Bilyaminu Adam Wase Shuaibu³, Oluwabukola Atinuke Popoola¹, Kabiru Isa Pate⁴, Onyinyechi Stainless Uzor¹, Eno Etingwa¹, Jumoke Florence Joda¹, Oyetola Olanrewaju Opaleye¹, Kehinde Rukayyat Adeniran², Ene Elizabeth Francis², Gbadebo Barnabas Olukotun⁵ and Oyekanmi Nashiru¹,²*

¹Genetics, Genomics and Bioinformatics Department, National Biotechnology Development Agency, Abuja, Nigeria. ²Center for Genomics Research and Innovation, National Biotechnology Development Agency, Abuja, Nigeria. ³Aquatic Bioresources Training Center, National Biotechnology Development Agency, Idah, Kogi, Nigeria. ⁴Aquatic Bioresources Training Center, National Biotechnology Development Agency, Tunari, Taraba, Nigeria. ⁵Bioentrepreneurship and Extension Services Department, National Biotechnology Development Agency, Abuja, Nigeria.

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Analysis of water bodies, such as rivers and lakes can provide an insight into their intrinsic composition and potential impact on the environment. Water samples collected from four designated sites in Idah River, were assessed for their physicochemical parameters and microbial diversity using standard procedures. The temperature from all sites was 26.00°C and the pH ranged from 6.93 to 7.08. Turbidity values ranged between 32.00 and 38.00 NTU, while dissolved oxygen ranged between 6.28 and 9.28 ppm. Heavy metals, such as Selenium and Arsenic (with peak values of 0.10 and 0.09 ppm, respectively) were detected in the river. However, dissolved oxygen, arsenic and turbidity values across all sites exceeded the maximum limit set by World Health Organisation and the Standard Organisation of Nigeria. The total heterotrophic bacterial counts showed excessive bacterial load from all sample sites, while pathogenic bacteria, including Escherichia coli, Klebsiella and Shigella species, were isolated from regions with intense anthropogenic activities along the river, indicative of microbial pollution. Fungal studies identified the presence of Fusarium, Aspergillus and Trichoderma species as the most abundant in the river. Obtained results showed that Idah River is exposed to heavy metal seepage and subject to microbial contamination. Therefore, continuous monitoring and better management of the river body is recommended to prevent disease outbreak.

Key words: Aquatic ecosystems, Idah River, microbial diversity, physicochemical analysis.

INTRODUCTION

Water can be sourced from water bodies such as rivers, boreholes, lakes, springs and other large water bodies. However, the quality of water bodies can be adversely affected by man-made activities. For example, pollution...
of freshwater bodies such as rivers (e.g. Idah River, Kogi State), streams, lakes and ponds are mostly experienced due to industrial discharge, municipal waste disposal and surface run-off (Akaniwor et al., 2007). Anthropogenic activities, such as discharges of domestic waste, untreated waste from sewage treatment plants, plastic materials, disposal of personal care products and household chemicals, improper disposal of car batteries, construction activities, mining activities, and pilgrim activities constantly deteriorate the water quality of rivers (Environmental Pollution Centers, 2018). Such deterioration in water bodies include an alteration in pH, increased turbidity, higher content of total dissolved solids and metals, as well as a higher risk of such water body hosting water-borne pathogens (Shaji et al., 2009; Ananthakrishnan et al., 2012). Water-borne pathogens pose a great health risk to humans, animals and plants, most especially, infants, young children under the age of five and immunocompromised individuals (EPA, 2016; WHO, 2014).

River Niger, at Idah, is an extension of the two major Nigerian rivers; River Niger- after which the country Nigeria is named, and River Benue, after their confluence in Lokoja. The Idah River is located between latitude 7°6’1"N and longitude 6°42’23"E (Figure 1) and it serves as a boundary between Kogi and Edo states. The temperature of the water ranges between 22 and 31°C (which greatly depends on the season). It is relatively turbid and has a slightly alkaline pH between 7.5 and 7.8 (depending on the sampling location). The highest water levels are usually recorded between August and September, while the lowest water level is usually recorded between March and April (Adeyemi, 2010).

Although, microbial communities represent a fundamental part of aquatic ecosystems, and are of great importance for matter and energy flux (Kavka et al., 1996), little is known about the microbial biodiversity of River Niger (Idah Axis), despite its popularity in Nigeria and beyond. Local communities at the different axis of River Niger bank exploit the water for the fishery, aquatic medicinal plants, and domestic purposes, such as cooking, drinking, bathing, washing utensils and clothes, while the water is exposed to both human and animal waste, discharge of untreated industrial and domestic wastewater, runoff and dead organic plants and animals. Studying the unique diversity and functions of microbes in their ecological niche, as well as establishing the factors that affect them would aid in unraveling the role they play in animal, human, plant health, and in their environment (Marchesi, 2017).

This study is therefore aimed at evaluating the total microbial content of water at different points of River Niger at Idah axis, using a conventional approach. In addition, the study seeks to link the community present to...
the physicochemical factors that characterize the river, in a bid to proffer necessary recommendations to avert infectious disease outbreaks.

MATERIALS AND METHODS

Study site

Idah is a town in Kogi State, in the middle belt region of Nigeria and situated on the east bank of Niger River. It has a land mass of 36 km² and located on latitude 7°06'48.42"N and longitude 6°44'19.18" E. Its human population was around 79,815 as at 2006 (National Population Commission, 2006). It has a tropical savannah climate with a wet season between late March and early November, and dry season between early November and late March. Idah River is exposed to water pollutants, such as chemical waste from farming activities, as well as discharge from gullies and streams, including the Inachalo River. The locals consume the water for domestic and dry farming activities. During rainy season, run-off washes domestic and municipal sewage, abattoir effluents and remnants of open defecation of both human and animals into the river.

Sample collection

Towards the end of the dry season in February 2020, a total of 20 water samples were aseptically collected in replicates from 4 selected sites in the river (designated Docking Point A, Docking Point B and the Idah Axis - Midstream and Confluence Area); all characterized by different levels of anthropogenic activities (Figure 1). Samples for bacteriological, mycological and physicochemical analyses were collected, at a depth of 20 cm below the water surface and against the water current into 250 mL sterile clean bottles (Ademorati, 1996). The temperature and water pH were monitored in situ using a mercury glass thermometer and a pH meter (ROHS Model), respectively before sampling (APHA, 2005). Collected samples were preserved in an icebox and transported immediately to the laboratory for microbiological and physicochemical analyses.

Physicochemical examination of water samples

Water samples placed on icepacks were transported to Soil Microbiology Laboratory at the International Institute of Tropical Agriculture, Ibadan, Oyo State, Nigeria within 24 to 48 h, for physicochemical analysis. In addition to pH and temperature (recorded in situ), a total of eighteen physicochemical parameters were evaluated. These included dissolved oxygen, specific ions (calcium, magnesium, potassium, sodium, iron, copper, nickel, arsenic, and selenium), turbidity, nitrates, sulphates, total dissolved solids, total nitrogen and electrical conductivity using titrimetric, colorimetric or spectrophotometric assays (Feng et al., 2009; Ologbosere et al., 2016; Adedire et al., 2021).

Isolation and identification of bacteria

Using aseptic techniques, four-fold serial dilution of each water sample was made, and isolation of bacteria from a serially diluted sample (1 mL) was done in Petri dish through the pour plate method on Nutrient Agar, prepared according to manufacturer’s specification. The plates were incubated at 37°C for 24 h. The mean total viable count of the isolated bacterial colonies was enumerated and recorded. Colonies with distinct morphological differences were randomly picked from the nutrient agar plates and repeatedly streaked on fresh, sterile agar plates (Nutrient Agar (Lifesave Biotech, USA), MacConkey Agar (Lifesave Biotech, USA), Eosin Methylene Blue Agar (Lifesave Biotech, USA), Salmonella-Shigella Agar (Lifesave Biotech, USA), and Centrimide Agar (Oxoid, UK) and subsequently incubated at 37°C for 24 h. Pure cultures were stored in the refrigerator at 4°C for further characterization and analysis. Pure cultures of isolates were characterized and identified using their macroscopic and microscopic characteristics, as well as biochemical tests (Catalase, Oxidase, Centrimide, Citrate Utilization, Methyl Red, Voges Proskauer, Urease, Gelatin Hydrolysis, Motility, Sugar Fermentation: Glucose, Lactose, Maltose, Sorbitol) as described by Cheesebrough (2000) and following the Bergey’s Manual of Determinative Bacteriology (Genhardt et al., 1994).

Isolation and identification of fungi

Fungi were isolated through serial dilution (10⁻² and 10⁻¹) method using sterile distilled water. One milliliter of each dilution was aseptically transferred into Potato Dextrose Agar (Lifesave Biotech, USA) media plates supplemented with Streptomycin (0.03 g/L) to inhibit bacterial growth (Hageskal et al., 2006). The plates were incubated at room temperature (25 ± 3.00°C) for 5 to 7 days. Using a flame aseptic inoculating needle, the edge of each growing colony was picked and slides of the different colonies were made. A drop of Lactophenol cotton blue stain was added to the prepared slides, covered with a coverslip before microscopic examination using 10x and 40x magnifications to observe the microscopic features (hyphal characteristics, shape of sporangia, conidia and spores) of each isolate. Fungal colonies were also identified using cultural (macroscopic) characteristics (colony texture, elevation, chromogenesis/pigmentation, opacity and size) (Watanabe, 2002).

Statistical analysis

Data from physicochemical determinations and bacteriological plate counts were analyzed using Duncan’s Multiple Range Test using SPSS (version 25.0). Mean occurrences of bacterial and fungal isolates were tested using Tukey Pairwise comparison of grouping at a 5% level of probability using SPSS (version 25.0).

RESULTS

Physicochemical characteristics of water samples from different sites of Idah River

The results of the physicochemical analyses of water samples collected from four different sites in Idah River are shown in Table 1. The observed water quality of the river was compared to acceptable standards reported by the World Health Organization (WHO, 2011) and Standard Organization of Nigeria (SON, 2007). The pH of water samples taken from different sampling points within Idah River was significantly different. However, the pH of Docking point A (DPA) and Idah Axis Confluence (IAC) water samples, as well as Docking point B (DPB) and Idah Axis Midstream (IAM) water samples, respectively were not significantly different. The pH ranges obtained also showed that IAM had the highest mean pH value of 7.08, which was quite similar to that obtained at Docking Point B (7.07). The lowest pH recorded was at the IAC...
The recorded temperature was uniform across all sampled sites at 26.00°C. The mean values of calcium (7.01 ppm), magnesium (2.30 ppm), copper (0.36 ppm), arsenic (0.09 ppm) and selenium (0.10 ppm) were all found to be the highest in IAM. DPA had the lowest mean values for calcium (5.98 ppm), magnesium (1.83 ppm), sodium (3.98 ppm) and iron (0.49 ppm). The mean values of nickel, at 0.01 ppm, were uniform across all sampled sites. The highest potassium (3.08 ppm) and sodium (4.24 ppm) were recorded at DPB, and they were significantly higher than values recorded from other locations. Copper had a uniform value (0.34 ppm) at three sites: DPA, DPB and IAM areas. Turbidity mean values ranged from 33.10 NTU (at DPA and DPB) to 37.67 NTU (at IAM) and the values were not significantly different from one another. Nitrates, dissolved oxygen and sulphates were all found to be the highest in DPA with mean values of 3.73, 9.28 and 1.89 ppm, respectively.

Bacteria distribution and frequency

The total heterotrophic bacteria counts (THBC) of bacteria are seen in the four sites shown in Table 1. The highest microbial load was recorded at both DPA and DPB with mean values of $1.55 \times 10^4$ and $2.52 \times 10^4$ CFU/mL, respectively. The lowest microbial load was recorded at IAM with a mean population of $1.27 \times 10^2$ CFU/mL. Ten genera of bacteria were identified from a total of 97 isolates. These genera included _Acinetobacter_, _Staphylococcus_, _Bacillus_ species, _Pseudomonas_ species, _Escherichia coli_, _Klebsiella_ species, _Bacillus subtilis_, _Aeromonas hydrophila_, _Shigella_ species and _Streptococcus_ species. Out of these ten species, _Acinetobacter_ spp. had the highest percentage frequency of occurrence (50.52%), followed by _Staphylococcus_ (18.56%) and _Bacillus_ spp. (10.31%) (Figure 2). Across all sampled sites, _Acinetobacter_, _Staphylococcus_ and _Bacillus_ spp. were the most predominant. The least dominant microbes from each sample site were _B. subtilis_ (in DPA and IAM), _A. hydrophila_ (in DPB and IAM), _Shigella_ spp. (DPB and IAM) and lastly, _Streptococcus_ spp. (in IAM only). Cumulatively, _Acinetobacter_ spp. had a mean microbial prevalence of 12.25 and was the most predominant bacteria (P<0.05), while _Streptococcus_ spp. was the least with a cumulative mean value of 0.25. Also, the two docking points A and B had the highest number of bacterial isolates with 30.00 and 39.00, respectively, while the least number of bacterial isolate (10) was observed at the Idaho midstream area (Table 2). Concerning the total viable THBC observed in water
samples collected from the four sample sites, bacteria colonies ranged from $1.27 \times 10^2$ CFU/mL (IAM) to $2.52 \times 10^4$ CFU/mL (DPB).

**Fungi distribution and frequency**

Seven fungal genera were identified from a total of 23 fungal isolates. These included *Aspergillus flavus*, *Aspergillus niger*, *Penicillium* species, *Fusarium* species, *Cladosporium* species, *Trichoderma* species and *Curvularia* species. Table 3 shows their distinct morphological differences and microscopic characteristics with 2 of the fungi species belonging to *Aspergillus* genus. *Fusarium* spp. had the highest percentage occurrence (39.13%), followed by *Trichoderma* spp., *A. flavus* and *Penicillium* spp. (all at 13.04%) (Figure 3). *Fusarium* spp. had the highest microbial incidence across all sites with a mean value of 2.25 (P<0.05), and the least occurring isolate being *Curvularia* spp. with a cumulative
### Table 3. Fungi isolates and their probable identification.

| Isolate | Form     | Elevation | Surface | Opacity | Morphological observations                                      | Microscopic characteristics                                      | Probable fungal identity       |
|---------|----------|-----------|---------|---------|---------------------------------------------------------------|-------------------------------------------------------------------|-------------------------------|
| 1       | Irregular| Flat      | Glistening | Opaque  | White edge, yellowish green in the center                   | Septate hyphae with long and erect conidiophores                    | Aspergillus flavus            |
| 2       | Irregular| Raised    | Rough    | Opaque  | Initially white, then changes to dark brown/black            | Covers entire surface                                              | Aspergillus niger             |
| 3       | Irregular| Flat      | Rough    | Opaque  | Green and black edge with a velvety look                    | Broom-like conidiophores with septate hyphae                        | Penicillium spp.              |
| 4       | Circular | Flat      | Smooth   | Opaque  | White cottony look                                           | Hyaline and abundant microconidia with one or two septa, short conidiophores | Fusarium spp.                |
| 5       | Irregular| Umbonate  | Smooth   | Opaque  | Suede-like and black                                         | Erect conidiophores, conidia in branched chains                     | Cladosporium spp.            |
| 6       | Circular | Raised    | Rough    | Translucent | Yellowish green and white in the center                   | Repeatedly branched conidiophores with clusters of bent phialides  | Trichoderma spp.             |
| 7       | Irregular| Flat      | Rough    | Opaque  | Black, spiky and fluffy                                    | Curved conidia                                                      | Curvularia spp.              |

**Figure 3.** Percentage frequency of total fungi isolates found in sites of study at Idah River.

Mean of 0.25. Also, DPA had the highest number of fungi isolates (9.00), followed by DPB (7.00) while the IAM area had the lowest number of fungi isolates 2 (Table 4).

**DISCUSSION**

From the analysis of the physicochemical features of water samples, recorded pH values were within a narrow range of 6.93 to 7.08. This fell within the acceptable range according to the standards set by WHO (2011) and SON (2007), thus making it suitable for aquatic life. This observation was in
agreement with the findings of Adesakin et al. (2020) who reported a similar pH range for domestic water sources in Zaria, Nigeria. The pH values observed in this study could be attributed to the major soil type in the area or the buildup of organic materials from runoff, as described by Taiwo et al. (2020).

The pH in water bodies is among the major physiological factors that play a critical role in shaping microbial structures and other biological activities in water (Adesakin et al., 2020). There appears to be a correlation between the microbial population observed across all sample sites and the pH of Idah River. All isolated microbes were neutrophilic in nature and this may be related to the near-neutral pH of the river body, encouraging the proliferation and prevalence of neutrophils.

The temperature of any water body determines the proliferation and survival rate of microorganisms (Bouzid, 2016). In this study, the temperature value of 26.00°C in water samples could be regarded as optimal for the growth of heterotrophic mesophilic bacteria and fungi. However, this was within the standard permissible temperature limit of SON (2007) set for aquatic water life. Igbinosa et al. (2012) also observed a similar temperature range of 26 to 27.2°C in Shanomi creek, in the Niger Delta region. In addition, Nwoko et al. (2015) in their report on the assessment of seasonal physicochemical parameters of Oguta Lake in Nigeria, observed a similar temperature range.

The calcium (Ca) levels in water samples collected from different points along the river, was significantly different from each other and ranged from 5.98 ppm (DPA) to 7.01 ppm (IAM); however, these levels were below the permissible limit (200.00 mg/L) recommended by WHO (2011). As such, there might be no detrimental effect on aquatic life and on humans who ingest foods harvested from the river. Magnesium is generally associated with calcium in water bodies and with a concentration usually lower than that of calcium (Venkatasubramani and Meenambal, 2007). Magnesium values observed in this study support this statement as they ranged from 1.83 ppm (DPA) to 2.30 ppm (IAM).

The potassium and sodium values ranged from 2.89 ppm (IAC) to 3.08 ppm (DPB) and 3.96 ppm (DPA) to 4.23 ppm (IAC), respectively. Many water bodies have sodium concentrations well below 50.00 mg/L (Ikuhoriah et al., 2016). Copper levels ranged narrowly from 0.34 to 0.36 ppm and they were notably lower than what Kuz’mina and Ushakova (2007) reported in their metal assessment of fishponds (10.6 ppm). The heavy metal, Nickel is known to be associated with gastrointestinal irritation without inherent toxicity (Hammer and Hammer, 2003). In this study, Nickel value was recorded as 0.01 ppm across the four different samples, which was within the acceptable limit in WHO (2011) recommendations, hence, the river appeared devoid of the heavy metal. These values were contrary to the much higher values reported by Okereke (2014), who assessed the physicochemical properties of the Ihuku River (0.07 - 0.082 mg/L).

Arsenic is a metalloid widely distributed in the earth and usually found in natural groundwater (Thi et al., 2009) but its concentrations vary based on the geological formations, weathering processes of rocks, microbial activities, leaching or other anthropogenic activities such as mining and application of pesticides (Katsoyiannis et al., 2004; Oremland and Stolz, 2003). The metal has no known biological function and is extremely toxic in high concentrations. The arsenic mean values in this study were slightly above the WHO permissible limit, with the highest being 0.09 ppm in the IAM area. This can pose certain risks to consumers of water from the river, as this metal has been characterized as a carcinogen. Regular consumers of contaminated water and contaminated aquatic foods may be at risk of arsenic buildup in the body. Selenium is an essential micronutrient found in groundwater as well but toxic at elevated levels. Its concentration levels usually rise when there is an occurrence of industrial emissions or mining activities (Fernandez-Martinez and Charlet, 2009). Selenium recorded for the different water samples were relatively close to recommended WHO limit (0.05 mg/L) except for

| Genus or Species | Docking point A | Docking point B | Idah Axis Midstream | Idah Axis Confluence | Mean values (Tukey’s test) |
|------------------|----------------|----------------|---------------------|---------------------|---------------------------|
| Aspergillus flavus | 2.00          | 0.00          | 1.00                | 0.00                | 0.75<sup>a</sup>           |
| Aspergillus niger  | 1.00          | 0.00          | 0.00                | 1.00                | 0.50<sup>a</sup>           |
| Penicillium spp.   | 1.00          | 2.00          | 0.00                | 0.00                | 0.75<sup>a</sup>           |
| Fusarium spp.      | 2.00          | 2.00          | 1.00                | 4.00                | 2.25<sup>a</sup>           |
| Cladosporium spp.  | 1.00          | 1.00          | 0.00                | 0.00                | 0.50<sup>b</sup>           |
| Trichoderma spp.   | 2.00          | 1.00          | 0.00                | 0.00                | 0.75<sup>b</sup>           |
| Curvularia spp.    | 0.00          | 1.00          | 0.00                | 0.00                | 0.25<sup>b</sup>           |
| Total             | 9.00          | 7.00          | 2.00                | 5.00                | -                         |

Mean values (across the row) with same letters are not significantly different (P < 0.05) using Tukey’s test at 95% confidence interval.
the IAM sample, which showed a high value of 0.10 ppm.

Turbidity is the degree of clarity or cloudiness of water and it is evaluated by the presence of suspended solids in the water (Health Canada, 2012). The mean turbidity values obtained from all water samples ranged from 32.43 to 37.67 NTU. This raises another concern, as the values obtained exceeded recommended limits by WHO and SON, thereby rendering it unfit for drinking. Suspended solids in water promote the growth of microorganisms and as such, high turbidity is often correlated with a high presence of disease-causing microorganisms (Shittu et al., 2008). The high turbidity values obtained are clear indicators of Idah River pollution. The concentrations of the nutrients (nitrates and sulphates) were within the acceptable limits for both WHO and SON standards. Therefore, they did not pose a serious water quality issue.

Dissolved oxygen (DO) is a measure of oxygen levels dissolved in an aqueous solution, which plays a major role in the biological activities of cultured organisms (Murphy, 2005). It is an important criterion for assessing quality, as it provides details on pollution levels, metabolic activities of microorganisms and nutrient availability (Premlata, 2009). The DO concentration range for the four sites: DPA (9.28 ppm), DPB (9.28 ppm), IAM (6.67 ppm) and IAC (6.27 ppm) were all higher than the statutory permissible limit (5 mg/L) necessary for aquatic life. Although, slightly above the permitted threshold, there have been higher concentrations of DO reportedly used for agricultural purposes in brackish aquaculture (Ayyedun et al., 2011). Also, microorganisms use DO for the decomposition of organic materials at the bottom of water bodies. Low DO may lead to an anaerobic environment, resulting in a bad odour of water (Adekunle et al., 2007).

Electrical conductivity is defined as a measure of the degree of ions in an aqueous solution or the capacity of water to pass electrical flow. The source of these conductive ions could be from dissolved salts and inorganic materials such as chlorides, carbonate compounds or sulfides (Miller et al., 1988). The range of electrical conductivity values recorded from all sample sites was within the acceptable limit reported by WHO (2011). This may imply that the river receives low amounts of dissolved salts and inorganic substances (Kido et al., 2015).

Results also showed that lesser concentrations of calcium, magnesium, potassium, nitrates and sulphates were recorded in IAM and IAC sample sites. This might be connected to the continuous movement of water, thereby diluting the concentrations of organic and inorganic wastes that might have been introduced at the docking sites of the river.

The total heterotrophic bacteria counts of bacteria exceeded the WHO’s stipulated standards for water bodies. Notably, the high population of bacteria seen at the two docking points could be due to the fishing and other observed anthropogenic activities occurring around the Idah riverbank. The high abundance of bacteria isolated from these two areas could also be linked to the bathing activities, washing and sewage run-offs, which was noticed at the riverbank, and is most likely to transmit an array of infectious diseases (Anyawu and Okoli, 2012).

In the IAM area, the highest arsenic and selenium values were recorded, which were above the WHO limit. This might be indicative of toxicity, and could be the reason for the low heterotrophic bacterial plate count and the low number of bacteria and fungi isolated (Leon et al., 2018).

The bacteriological analysis showed that Gram-negative bacteria were predominant amongst the bacterial isolates from Idah River. The microorganisms isolated in order of prevalence were *Acinetobacter* spp., *Staphylococcus aureus*, *Bacillus* spp., *Pseudomonas aeruginosa*, *E. coli*, *Klebsiella* spp., *B. subtilis*, *Aeromonas hydrophilia*, *Shigella* spp. and *Streptococcus* spp. The bacterial diversity reported in this study had some similarities to previous reports by Anyawu and Okoli (2012) who reported the presence of *Enterobacter* species, *Alcaligenes* species, *E. coli*, *Proteus* species, *Klebsiella* spp., *P. aeruginosa*, *Acinetobacter* spp., *S. aureus* and *Bacillus* spp. in different water supplies atNsukka, Nigeria. Also, Umeh et al. (2020) reported the prevalence of *Klebsiella pneumoniae*, *Acinetobacter calcoaceticus*, *E. coli*, *S. aureus*, *Vibrio* species, *Pseudomonas* spp., *B. subtilis*, *Shigella flexneri*, *Salmonella* Typhi in selected fish ponds in Anambra State, Nigeria.

Based on the frequency rate of isolated bacteria, *Acinetobacter* spp. was found to be the most predominant across the four sites, constituting 50.52% of the total bacterial community. The high prevalence of this species is most likely linked to the observed discharge of abattoir effluents into the Idah River, which was also reported in the study of Tsai et al. (2018). This is also in agreement with the report of Okechi et al. (2020) who found that *Acinetobacter* was the most predominant bacteria in the sediment area of Otamiri River, constituted about 42.10%. In Northeastern China, Zhao et al. (2014) found that the genus *Acinetobacter* was also the most prominent group of isolates in zinc and arsenic polluted rivers. Species of the genera *Acinetobacter* are ubiquitous in a wide range of ecological areas like water, soil, sludge, and wastewater (Hamouda et al., 2011). However, some scientific reports argued that the *Acinetobacter* genus is a nosocomial pathogen and the possibility of it thriving in natural environments is low (Peleg et al., 2008). It would also seem that they are resilient, as documented by few reports, which showed that they can survive in various environments containing low amounts of nutritious components, as well as their resistance to adverse environmental conditions (Gospodarek and Ziółkowski, 2000). Strains of this organism are commonly known to harbor antibiotic resistance genes and they are regarded as emerging opportunistic pathogens of fish farmed in Poland.
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However, they can also be opportunistic pathogens
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premised on the possibility of its resistance to beta-
lactamase antibiotics, including penicillin and thus, its
presence in water calls for public health concern.
Streptococcus spp. was found only in the midstream area
of the river. This organism has been associated with
illnesses such as pneumonia and upper respiratory tract
infections. Bacillus spp. were identified across all sample
sites. Bacillus spp. can occupy a wide range of ecological
niches and its spores are quite ubiquitous (Nicholson,
2004). In particular, B. subtilis found in the docking and
midstream area could have the potential to be used as
probiotic additives in aquaculture, as reported by Guo
et al. (2016).
The main indicator of faecal pollution, E. coli, was
found in all sites, except for the midstream area of the
water. These bacterial isolates were discovered from
both docking areas, which is suggestive of sewage
pollution and abattoir effluents observed at the Idah
riverbank. Contamination of the river by other members
of the Enterobacteriaceae family seen in this study –
Shigella spp., A. hydrophilia, P. aeruginosa and Klebsiella
spp. could be related to a combination of direct faecal
contamination and agricultural run-off at the docking
sites. These Gram-negative bacteria are typically
responsible for some waterborne diseases, including
Shigellosis, typhoid, dysentery, diarrhea, as well as
urinary tract infections, and they have been implicated in
high mortality rate across the world (WHO, 2011).
Pseudomonas spp. has been isolated from fishes in
contaminated rivers. When consumed raw or insufficiently
processed, such fishes could serve as a vector for the
transmission of pathogens to humans (Jeyasekaran
et al., 2006). Generally, the prevalence of Gram-negative
bacteria in this river could be as a result of faecal
contamination and other human interference, which could
result in the proliferation of pathogenic organisms in fish,
affecting human consumers (Kay et al., 2008).
Their presence is most likely linked to the washing activities in
the area, as well as the agricultural/seepage runoffs
entering the river (Abulreeesh, 2012). This implies a
significant health risk for humans consuming this water
(Franciska et al., 2005).
The mycological analysis in this study showed the
presence of A. niger, A. flavus, Penicillium spp., Fusarium
spp., Cladosporium spp., Trichoderma spp. and
Curvularia spp. in Idah River. This agrees with the
observations of Ifi et al. (2019), who reported Candida
species, Fusarium spp., A. flavus, Penicillium spp., A.
nger and Mucor species in Okokpon River, Edo State.
Furthermore, Agbabiaka and Oyeyiola (2012)
documented the presence of Curvularia, Aspergillus,
Penicillium, Saccharomyces, Cladosporium, Geotrichum,
Trichoderma, Mucor, Rhizopus, Fusarium and Mortierella
(fungi) as sediment contaminants of Foma River, Ita-
Nmo, Ilorin.
The abundance of fungi, in the docking areas of Idah
River, is likely linked to its high sulphate concentration,
thus constituting an indicator of water pollution from
anthropogenic and agricultural origins. Pietryczuk et al.
(2018) reported a similar observation in their study of
fungi diversity in selected rivers. Fungal population
increases with pollution and this might be connected to
the high number of fungal contaminants observed at the
docking areas of the river.

Amongst the various fungi species isolated in this river
samples, Fusarium spp. was the most predominant,
constituting about 39.13%. Fusarium spp. are plant
pathogens or rhizosphere fungi, and their presence in
Idah River could be attributed to agricultural activities
occurring around this river. This is quite similar to the
observation of Sharma and Tiwari (2015) who reported
Fusarium spp. as one of the most abundant soil fungi
isolated from the Shivnath River and it is known to cause
several superficial infections. A. niger and A. flavus found
in this river are known to be among the main agents of
food spoilage but it is co-related to a range of infections
such as Aspergillosis, leading to respiratory infections.
Refai et al. (2010) also confirmed Aspergillus as
pathogenic fungi of freshwater fishes. Trichoderma spp.
was found only in DPA and DPB, which had the most
observed anthropogenic activities. It is one of the
beneficial fungi in the environment that can serve as a
bio-fungicide against various fungal pathogens (Schuster
and Schmoll, 2010). It was suggested that it might have
the potential to also control infectious diseases in
aquaculture (Citarasu et al., 2012). Penicillium spp.
was prevalent only in the two docking points, and the genus
was reported to produce mycotoxins (Pohland and Wood,
1997). Contamination of fish with these mycotoxins could
accumulate in their tissues, which could invariably affect
humans when consumed. The processing of fish does
not necessarily eliminate the presence of mycotoxins in
their tissues. Cladosporium and Curvularia spp. isolated
from the docking points in the river are predominantly
saprophytic in nature, and they are known to colonize
and parasitize aquatic plants.

Conclusion
In this study, physicochemical and microbial
(bacteriological and mycological) profiling of Idah River were assessed from four designated sampling points. Although, thirteen physicochemical parameters were within the safe limits as indicated by the WHO (2011) and SON (2007) standards, parameters indicative of pollution were obtained. They included high total heterotrophic bacterial counts, presence of pathogenic microbes and toxic levels of certain physicochemical factors, such as arsenic, selenium, turbidity and nickel, when compared with standards. Such extreme values derived from physicochemical analysis might be connected to anthropogenic activities of locals of the community, resulting in inorganic pollution. In addition, the various fungi and bacterial species found in the river raises health concerns, with regards to direct consumption of water and ingestion of food (such as fishes and aquatic plants) sourced from the water body. It is therefore recommended that programs and policies, such as continuous monitoring and public health awareness programs are set in place to enlighten locals of the community, about the dangers of unsuitable discharge of animal, human and inorganic wastes into the river. This could in turn, prevent the river from being an environmental reservoir of antibiotic-resistant pathogens, hence preventing public disease outbreaks.

This study provides the first report about physicochemical properties and microbial diversity (using culture-based techniques) inherent in the Idah River. However, additional microbial analysis, such as metagenomic studies, could be used to reveal a deeper microbial structure inherent in the river, which culture-dependent methodology might not have captured.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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