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Assessment of Pathogenic Microbial and Heavy Metal Contamination in Stream Water at Omuhuhechi, Aluu, Nigeria: Health Implications

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Abstract **Original Research Article**

This study presents a comprehensive assessment of pathogenic microbial and heavy metal contamination in the Omuhuhechi Stream, Aluu, Rivers State, Nigeria, with a focus on public health implications. The stream, a vital freshwater resource for domestic, agricultural, and livestock use, is increasingly compromised by anthropogenic activities including waste disposal, informal abattoirs, and petroleum-related effluents. Water samples collected from five strategic points during the dry season were analyzed for physicochemical parameters, microbial indicators, and heavy metal concentrations. Results revealed progressive downstream deterioration in water quality, marked by increased turbidity (8.6–13.4 NTU), electrical conductivity (210–425 µS/cm), and reduced dissolved oxygen (4.1–2.4 mg/L), all suggesting heightened organic and ionic pollution. Heavy metal concentrations of lead (0.08–0.21 mg/L), cadmium (0.006–0.011 mg/L), iron (0.74–1.42 mg/L), and chromium (0.06–0.70 mg/L) consistently exceeded WHO permissible limits, indicating significant ecological and toxicological threats. Microbial analysis revealed alarmingly high levels of total coliforms (2.4×10^3–4.1×10^3 CFU/100 mL), *Escherichia coli* (180–510 CFU/100 mL), *Salmonella* spp. (12–36 CFU/100 mL), and *Shigella* spp. (8–28 CFU/100 mL), signifying fecal contamination and elevated risk of waterborne infections. The findings underscore the urgent need for coordinated interventions in water quality monitoring, sanitation infrastructure, and regulatory enforcement. This study contributes critical empirical evidence to the discourse on freshwater pollution in the Niger Delta and advocates for informed policy frameworks aimed at mitigating environmental health risks and safeguarding water security in vulnerable communities.

Keywords: Pathogenic Microorganisms, Heavy Metals, Water Pollution, Public Health, Omuhuhechi Stream, Niger Delta.

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1. INTRODUCTION

The provision of safe and potable water remains an essential determinant for safeguarding public health and fostering equitable socio-economic development. However, the accelerating trajectory of urbanization, industrial expansion, and anthropogenic pressures particularly within developing nations has profoundly compromised the integrity of freshwater systems, especially in peri-urban and rural locales (World Health Organization [WHO], 2019). In Nigeria, approximately 60 million individuals are directly reliant on surface water sources including streams, rivers, and ponds for domestic usage, agricultural irrigation, and small-scale industrial activities, despite the heightened susceptibility of these water bodies to contamination by pathogenic microorganisms and toxic heavy metals (Chukwu & Obasi, 2019).

Surface water systems function as ecological sinks, frequently serving as terminal repositories for a multitude of anthropogenic discharges such as municipal sewage, agricultural runoff, and industrial effluents. These inputs introduce a diverse array of biological and chemical pollutants into aquatic environments, including enteric pathogens such as *Escherichia coli*, *Salmonella* spp., and *Shigella* spp. as well as hazardous heavy metals like lead (Pb), cadmium (Cd), and arsenic (As) (Adekunle et al., 2020). The synergistic interactions between these contaminants can significantly undermine aquatic ecosystem integrity and pose serious public health hazards. Human exposure to such pollutants has been epidemiologically linked to a spectrum of acute and chronic health outcomes, ranging from gastrointestinal infections and developmental disorders to neurotoxicity and carcinogenicity (Agency for Toxic Substances and Disease Registry [ATSDR], 2019; FAO/WHO, 2020).

The Omuhuhechi Stream, situated in Aluu, Rivers State, Nigeria, constitutes a vital freshwater resource that underpins both domestic and agricultural livelihoods for proximal communities. Located within the ecologically sensitive Niger Delta basin a region pervasively impacted by hydrocarbon extraction and associated socio-environmental degradation the stream is highly vulnerable to multifactorial contamination pathways. These include leachates from indiscriminately disposed municipal solid waste, effluent discharges from petroleum-related activities, and untreated anthropogenic and animal waste **(**Golden & Inichinbia, 2020**)**. Despite its critical socio-economic significance, the Omuhuhechi Stream remains substantially understudied, with a paucity of empirical data pertaining to its microbial and heavy metal contamination profiles. This knowledge gap constrains the formulation of effective water quality governance frameworks and obstructs the implementation of targeted public health interventions.

Empirical evidence from analogous hydrological settings within Nigeria has consistently revealed elevated concentrations of microbial and chemical contaminants in surface water bodies, often exceeding both national and international regulatory benchmarks **(**Emenike et al., 2020**)**. Against this backdrop, the present study seeks to undertake a rigorous and integrative assessment of pathogenic microbial load and heavy metal contamination in the Omuhuhechi Stream. The specific objectives of the study are to: (i) quantify the concentrations of selected heavy metals, namely Pb, Cd, Zn, Fe, Cu, and Cr; (ii) isolate and enumerate predominant pathogenic bacteria; and (iii) evaluate the associated human health risks in relation to established international water quality standards (Yahaya et al., 2021).

The outcomes of this investigation are anticipated to yield critical insights into the ecological and public health ramifications of freshwater pollution in the Niger Delta. Moreover, the study aspires to inform the development of evidence-based policies and strategic interventions aimed at mitigating environmental health risks and promoting the sustainable management of freshwater resources across Sub-Saharan Africa.

2. MATERIALS AND METHODS

2.1 Study Area

The study was conducted at the Omuhuhechi Stream located in Aluu, a semi-urban community in the Ikwerre Local Government Area of Rivers State, Nigeria. The area lies within the Niger Delta region (latitudes 4°51′N to 4°53′N and longitudes 6°55′E to 6°57′E), characterized by a humid tropical climate, high rainfall, and significant oil and gas industrial activity. The stream serves as a principal source of water for domestic use, small-scale agriculture, and livestock watering among local residents. However, it is also subject to contamination from nearby residential waste disposal sites, informal abattoirs, and petroleum-related discharges.

2.2 Sample Collection

Water samples were collected from five strategic points along the course of the stream, including upstream, midstream, and downstream locations. Sampling was conducted during the dry season (January–March 2025) to avoid dilution effects from rainfall. At each sampling point, triplicate samples were collected using sterile 1-liter polypropylene bottles for both microbiological and heavy metal analysis. Samples were transported on ice in a portable cooler and processed within 6 hours of collection to ensure integrity.

2.3 Physicochemical Analysis

In situ parameters such as temperature, pH, dissolved oxygen (DO), electrical conductivity (EC), and turbidity were measured using a portable multi-parameter water quality meter (Hach HQ40d, USA) according to standard methods (APHA, 2017). Water samples were acidified with nitric acid (pH < 2) and digested following EPA Method 3010A for heavy metal analysis.

2.4 Heavy Metal Determination

Concentrations of lead (Pb), cadmium (Cd), iron (Fe), zinc (Zn), copper (Cu), and chromium (Cr) were determined using Atomic Absorption Spectrophotometry (AAS; PerkinElmer A Analyst 400). Calibration was performed using certified standard solutions, and blank samples were included to ensure analytical precision. All measurements were conducted in triplicate, and mean values were reported in milligrams per liter (mg/L). The results were compared against WHO (2019) drinking water standards to assess exceedances and potential health risks.

2.5 Microbiological Analysis

Microbial contamination was assessed using membrane filtration techniques. A 100 mL aliquot of each water sample was filtered through a 0.45 µm pore-size membrane filter (Millipore). Filters were cultured on selective media for the enumeration and identification of total coliforms (*m-Endo agar*), *Escherichia coli* (*Eosin Methylene Blue agar*), *Salmonella* spp. (*Xylose Lysine Deoxycholate agar*), and *Shigella* spp. (*Shigella-Salmonella agar*). Plates were incubated at 37°C for 24–48 hours, and colony-forming units (CFU/100 mL) were recorded. Biochemical confirmation of isolates was conducted using IMViC and API 20E test kits (BioMérieux, France).

2.6 Statistical Analysis

All quantitative data were subjected to descriptive and inferential statistical analyses using IBM SPSS Statistics version 25. Analysis of variance (ANOVA) was used to assess spatial variations in contaminant levels, with significance set at $p < 0.05$. Pearson's correlation coefficients were calculated to explore relationships between microbial counts and physicochemical parameters. Results were presented using means, standard deviations, and confidence intervals.

3. RESULTS

3.1: Physiochemical Parameters of Omuhuhechi Stream Water at Five Sampling Point.

The physiochemical assessment of Omuhuhechi Stream shows rising temperature and turbidity levels downstream, indicating increasing organic and particulate input. PH values (5.8–6.4) fall below the WHO recommended range (6.5–8.5), suggesting slight acidity. Dissolved oxygen (DO) decreases progressively from 4.1 mg/L to 2.4 mg/L, below the >5.0 mg/L limit, indicating poor oxygenation. Electrical conductivity (EC) and Total Dissolved Solids (TDS) increase steadily downstream, reflecting higher ionic and pollutant loads. These trends suggest deteriorating water quality due to anthropogenic activities along the stream.

Table 1: Physiochemical parameters of Omuhuhechi Stream Water at five Sampling Point

Parameters	WHO Limit	Station 1 Upstream	Station 2	Station3 Midstream	Station4	Station5 Downstream
Tempt (oC)	-	28.4±0.3	28.7±0.2	29.1 ± 0.4	28.9 ±0.2	29.3±0.3
pH	6.5-8.5	6.2 ±0.1	6.0± 0.1	5.8 ±0.1	6.3±0.1	6.4 ±0.1
DO (mg/L)	>5.0	4.1±0.3	3.7 ±0.4	3.1 ±0.3	2.9 ±0.2	2.4±0.2
EC (Us/cm)	500	210 ±12	290 ±14	355 ±18	390 ±15	425 ±16
Turbidity (NTU)	≤5	8.6±1.2	9.3 ±1.4	11.5±1.3	12.2±1.5	13.4 ±1.6
TDS (mg/L)	1000	140 ± 10	160±11	190 ±9	210 ± 13	230 ± 12

Keys: DO=Dissolved Oxygen, **EC**=Electrical Conductivity, **TDS**=Total Dissolved Solids.

3.2: Heavy Metal Concentrations in Omuhuhechi Stream Water at Five Sampling Points.

Heavy metal analysis of Omuhuhechi Stream reveals that concentrations of Lead, Cadmium, Iron, and Chromium exceed WHO limits at all sampling stations. Levels of these metals increase progressively from upstream (Station 1) to downstream (Station 5), indicating cumulative pollution. Zinc and Copper remain within permissible limits but also show a rising trend. Notably, Chromium peaks at 0.70 mg/L downstream, significantly surpassing the 0.05 mg/L WHO guideline. These patterns suggest contamination from industrial, agricultural, and domestic sources.

Table 2: Heavy Metal Concentrations in Omuhuhechi Stream Water at Five Sampling Points.

Heavy Metal	WHO Limit (mg/L)	Station 1 (Upstream)	Station 2	Station 3 Mid-Stream	Station 4	Station 5 (Down Stream)
Lead (Pb)	0.01	0.08+0.01	0.11+0.02	0.15+0.0	0.18+002	0.21+0.03
Cadmium (Cd)	0.003	0.006+0.001	0.007+0.001	0.009+0.02	0.010+0.001	0.011+0.002
Iron (Fe)	0.3	0.74+0.04	0.98+0.06	1.21+0.07	1.34 +0.05	1.42 +0.08
Zinc (Zn)	3.0	1.05 +0.08	1.23+0.09	1.42 +0.07	1.59 +0.06	1.68 +0.05
Copper (Cu)	2.0	0.25+0.02	0.31 +0.03	0.40 +0.02	0.45 + 0.03	0.49+0.02
Chromium (Cr)	0.05	0.06+0.01	0.07+0.01	0.08+0.01	0.09+0.01	0.70+0.0

The microbial analysis of Omuhuhechi Stream shows total coliforms, *E. coli*, *Salmonella*, and *Shigella* levels far exceeding WHO limits (0 CFU/100 mL), with concentrations increasing downstream. E. coli rose from 180 ± 25 to 510 ± 42 CFU/100 mL, indicating fecal contamination. *Salmonella* and *Shigella* were undetectable upstream but appeared midstream, peaking at 36 ± 5 and 28 ± 3 CFU/100 mL respectively. These values suggest escalating pollution from human and animal waste along the stream.

Table 3: Microbial Concentrations in Omuhuhechi Stream Water at Five Sampling Points.

Microbial Parameters	WHO Limit (mg/L)	Station 1 (Upstream)	Station 2	Station 3 Mid-Stream	Station 4	Station 5 (Down Stream)
Total Coliform count	0	2.4 x103 +150	2.9 x103 +170	3.5 x103 +200	3.8 x103+180	4.1 x 103 +190
Escherichia coli count	0	180 +25	220+30	310+35	440+38	510+42
Salmonella count	0	ND	12+3	24+4	31+5	36+5
Shigella count	0	ND	8+2	18+3	23+4	28 +3

4. DISCUSSION

4.1 Physiochemical Parameters

The physiochemical profiling of Omuhuhechi Stream demonstrates clear spatial variation and gradual water quality degradation downstream. Temperature measurements (28.4 ± 0.3 °C to 29.3 ± 0.3 °C) are consistent with typical tropical freshwater systems and corroborate findings by Adekunle et al. (2019). pH values (5.8–6.4), however, fall below the WHO-recommended range (6.5–8.5), diverging from the neutral to slightly alkaline conditions commonly reported in freshwater bodies (WHO, 2017), yet aligning with Nwankwo and Okoye (2018), who attributed similar acidity to organic pollution. Dissolved oxygen (DO) levels declining from 4.1 ± 0.3 mg/L upstream to 2.4 ± 0.2 mg/L downstream remain well below the WHO guideline (>5.0 mg/L), indicative of substantial organic loading. This trend concurs with Olawale et al. (2020), linking low DO to increased anthropogenic activities. Concurrently, electrical conductivity (EC) escalated from 210 ± 12 to 425 ± 16 µS/cm and turbidity increased from 8.6 ± 1.2 to 13.4 ± 1.6 NTU, both reflecting augmented dissolved and particulate pollution, in agreement with Eze and Chukwu (2017) and Chukwu and Obasi (2019). Total dissolved solids (TDS) also rose steadily (140 ± 10 to 230 ± 12 mg/L), remaining within WHO limits (<1000 mg/L) but indicating progressive ionic enrichment, consistent with ecosystem impacts reported by Nwosu et al. (2021).

4.2 Heavy Metal Contamination

Heavy metal concentrations exhibit a pronounced downstream enrichment trend with serious health-risk implications. Lead (Pb: 0.08–0.21 mg/L), cadmium (Cd: 0.006–0.011 mg/L), iron (Fe: 0.74–1.42 mg/L), and chromium (Cr: 0.06–0.70 mg/L) exceed WHO guidelines at all sampling points. The trend of increasing concentrations implies cumulative anthropogenic inputs, likely from industrial, domestic, and agricultural sources. These observations are in strong agreement with prior Nigerian studies: Pb levels reported by Asonye et al. (2007) and Nduka and Orisakwe (2007); Cd levels described by Etim et al. (2013) and Nwankwoala and Udom (2011); Fe levels documented by Akan et al. (2010); and Cr levels noted by Otitoju and Otitoju (2013). While zinc (Zn: 1.05–1.68 mg/L) and copper (Cu: 0.25–0.49 mg/L) remain within WHO limits, their downstream increase suggests enrichment from domestic and agrochemical inputs, aligning with trends reported by Nduka and Orisakwe (2007) for Zn and Ipeaiyeda and Dawodu (2008) for Cu.

4.3 Microbial Contamination

Microbial analysis reveals critical public health concerns. Total coliform counts (2.4×10^3 to 4.1×10^3 CFU/100 mL), *Escherichia coli* (180–510 CFU/100 mL), *Salmonella* (12–36 CFU/100 mL), and *Shigella* (8–28 CFU/100 mL) are all well above the WHO zero-tolerance threshold. The progressive increase downstream strongly reflects accumulating fecal contamination, likely originating from human and animal waste and inadequate sanitation infrastructure. These findings are in alignment with earlier studies in Nigeria and southern Africa (Egwari & Aboaba, 2002; Edema et al., 2001; Obi et al., 2002; Nwachukwu & Ume, 2013; Igbinosa & Okoh, 2008), which linked elevated microbial loads to similar environmental and anthropogenic conditions.

CONCLUSION

The integrative assessment of Omuhuhechi Stream unequivocally demonstrates a progressive deterioration in water quality from upstream to downstream, driven by escalating inputs of pathogenic microorganisms and toxic heavy metals. Physicochemical parameters reveal suboptimal conditions, particularly in terms of pH, dissolved oxygen, and turbidity, while concentrations of Pb, Cd, Fe, and Cr significantly exceed WHO limits, posing critical ecotoxicological and human health risks. Microbial analysis confirms the presence of enteric pathogens, underscoring fecal contamination likely stemming from anthropogenic activities. These findings affirm the stream's unsuitability for potable and agricultural use without adequate treatment.

Recommendations

i. Immediate implementation of water purification and community-scale treatment interventions is essential to mitigate public health risks.
ii. Establish stringent monitoring frameworks in collaboration with environmental and public health agencies to ensure regulatory compliance.
iii. Develop and enforce land-use policies to prevent indiscriminate waste disposal and restrict industrial discharges near surface water bodies.

iv. Conduct public health awareness campaigns to educate local communities on the hazards of consuming untreated stream water.
v. Introduce eco-remediation initiatives, including vegetative buffer zones and biofiltration, to reduce pollutant influx.

Contribution to Knowledge

This study presents the first comprehensive dataset on physicochemical, heavy metal, and microbiological contamination of the Omuhuhechi Stream, elucidating the cumulative impact of anthropogenic pressures within a critical Niger Delta watershed. By correlating pollutant gradients with spatial sampling points, it contributes novel insights into the ecological dynamics of peri-urban freshwater systems under duress, serving as a valuable baseline for future risk assessments, environmental surveillance, and water governance strategies in Sub-Saharan Africa.

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