Microbial Ecology and Public Health Risk Assessment of The Ologbo River, Ikpoba-Okha LGA, Edo State, Nigeria

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Abstract- The Ologbo River in Ikpoba-Okha LGA, Edo State, Nigeria, is a vital water source but is increasingly exposed to microbial contamination from human, agricultural, and industrial activities. This study assessed its microbial ecology and public health risks across wet and dry seasons. Water samples from six stations were analysed for Escherichia coli, total and faecal coliforms, Salmonella spp., Shigella spp., and physicochemical parameters. All microbial indicators exceeded WHO and Nigerian drinking water limits, with higher loads in the wet season (p<0.05) and downstream sections most affected. Antimicrobial resistance was common, especially to ampicillin and tetracycline. Quantitative Microbial Risk Assessment indicated infection probabilities far above WHO benchmarks, signalling significant waterborne disease risks. Findings call for urgent pollution control, regular monitoring, and safe water interventions to protect community health.

Index Terms : Ologbo River; microbial ecology; faecal contamination; antimicrobial resistance; quantitative microbial risk assessment; public health

I. INTRODUCTION

Freshwater ecosystems are indispensable for human survival, biodiversity conservation, and socio-economic development. In many developing nations, including Nigeria, rivers serve as primary sources of water for domestic, agricultural, industrial, and recreational uses (Edokpayi et al., 2020; WHO, 2023). However, rapid urbanization, industrialization, and unsustainable land use practices have led to the degradation of river water quality through the introduction of pollutants, including pathogenic microorganisms, heavy metals, and nutrient loads (Igbinosa & Okoh, 2009; Egbueri, 2020). Microbial contamination of surface waters is of particular concern due to its direct association with outbreaks of waterborne diseases such as cholera, typhoid fever, shigellosis, and hepatitis A, which remain major public health challenges in Nigeria (Nwidu et al., 2016; WHO, 2023).

The Ologbo River, located in Ikpoba-Okha Local Government Area of Edo State, is a critical freshwater resource within the Niger Delta region. It supports diverse socio-economic activities, including small-scale fisheries, domestic water supply, agriculture, and industrial operations. The river traverses areas with oil and gas installations, sawmills, artisanal fishing communities, and agricultural farmlands. These activities, coupled with untreated domestic wastewater discharge, contribute to significant microbial and chemical pollution risks (Owamah, 2014; Ezeh & Ananwude, 2020). Studies on rivers in similar Niger Delta environments have shown elevated levels of faecal coliforms, *Escherichia coli*, *Salmonella* spp., and other pathogenic bacteria, indicating contamination from human and animal waste (Igbinosa et al., 2013; Nduka & Orisakwe, 2011).

Environmental microbiology offers an important lens for understanding the dynamics of microbial communities in aquatic systems. Microbial ecology studies not only identify the diversity and abundance of microorganisms present but also reveal patterns of seasonal variation, pollution sources, and ecological interactions (Bartram & Pedley, 2021; Odjadjare et al., 2013). Integrating microbial data with public health risk assessment frameworks enables the determination of potential health hazards from water use. Such assessments are vital in rural and peri-urban Nigerian communities, where reliance on untreated surface water remains common due to limited access to potable supplies (Edokpayi et al., 2020).

Despite the strategic importance of the Ologbo River, there is a paucity of data on its microbial status and potential public health risks. This knowledge gap hampers the development of effective water safety interventions and regulatory enforcement. Therefore, this study aims to: (i) characterize the microbial ecology of the Ologbo River; (ii) evaluate seasonal variations in microbial contamination; (iii) compare observed microbial loads with national and World Health Organization (WHO) water quality standards; and (iv) assess the associated public health risks to dependent communities. The findings will inform policy recommendations for water quality management, pollution control, and public health protection in the region.

II. LITERATURE REVIEW

2.1 Overview of Environmental Microbiology in Aquatic Systems

Environmental microbiology examines the diversity, distribution, and ecological functions of microorganisms in natural and engineered environments (Bartram & Pedley, 2021). In aquatic ecosystems, microbial communities are critical for nutrient cycling, organic matter decomposition, and maintaining ecosystem balance. However, human activities such as industrial discharge, agricultural runoff, and urban wastewater input can significantly alter microbial composition, leading to the proliferation of pathogenic species (Edokpayi et al., 2020; Igbinosa & Okoh, 2009). The presence of faecal indicator organisms such as *Escherichia coli* and total coliforms is widely used as a proxy for waterborne pathogen contamination and public health risk (WHO, 2023).

2.2 Microbial Contamination of Nigerian Rivers

Several studies have documented microbial pollution in Nigerian surface waters. For example, Nwidu et al. (2016) reported high faecal coliform counts exceeding WHO guidelines in the Amassoma River, attributing the contamination to open defecation and effluent discharge. Igbinosa et al. (2013) detected multi-drug-resistant *E. coli* and *Salmonella* spp. in river systems in Southern Nigeria, suggesting the risk of antimicrobial resistance dissemination. Similarly, Adefisoye and Okoh (2016) reported high bacterial diversity and elevated pathogenic loads in Eastern Cape surface waters, highlighting the role of rivers as reservoirs for both pathogens and resistance genes. In the Niger Delta, Nduka and Orisakwe (2011) observed that poor sanitation, oil spills, and industrial effluents collectively degrade water quality, making rivers unsafe for domestic use without treatment.

2.3 Public Health Risks Associated with Contaminated River Water

The consumption or direct contact with microbiologically contaminated river water is linked to outbreaks of cholera, typhoid fever, hepatitis A, and gastroenteritis (WHO, 2023). Rural and peri-urban Nigerian communities relying on untreated surface water are particularly vulnerable. Pathogen exposure can occur through multiple pathways, including drinking, bathing, irrigation, and consumption of contaminated aquatic products (Bartram & Pedley, 2021). The persistence of pathogens in aquatic environments is influenced by factors such as temperature, pH, dissolved oxygen, and nutrient load (Edokpayi et al., 2020). In the Niger Delta, elevated microbial loads have been correlated with diarrhoeal diseases, especially among children under five years (Nwidu et al., 2016).

2.4 Microbial Ecology Approaches in Water Quality Assessment

Microbial ecology integrates classical microbiological methods with modern molecular tools to identify and quantify microbial species, trace contamination sources, and determine ecological interactions (Newton et al., 2011). Seasonal studies have shown that microbial abundance in tropical rivers often peaks during the rainy season due to increased surface runoff and faecal wash-in from surrounding land (Odonkor & Ampofo, 2013). In Nigeria, seasonal monitoring of rivers such as the Warri River (Owamah, 2014) and the Osun River (Ogunyemi et al., 2019) has revealed significant wet-dry season variations in microbial counts, underscoring the need for temporal risk assessments.

2.5 Risk Assessment Frameworks for Microbial Pollution

Public health risk assessment (PHRA) is a systematic process that evaluates the probability and severity of adverse health effects from environmental exposures (Haas et al., 2014). For waterborne microbial hazards, PHRA typically involves hazard identification, exposure assessment, dose–response analysis, and risk characterization. In Nigeria, water quality regulations such as the Nigerian Standard for Drinking Water Quality (NSDWQ, 2015) set permissible limits for microbial parameters, aligning with WHO guidelines. Quantitative microbial risk assessment (QMRA) approaches have been applied in other African countries to estimate infection probabilities from *E. coli* or *Cryptosporidium* in river water (Gibney et al., 2017), but such applications remain scarce in Nigerian river studies, especially in Edo State.

2.6 Knowledge Gap and Relevance to the Ologbo River

Although research on microbial pollution in Nigerian rivers is extensive, there is limited literature focusing specifically on the Ologbo River and its catchment in Ikpoba-Okha LGA. The area's proximity to oil and gas installations, sawmills, agricultural lands, and growing settlements suggests a high vulnerability to microbial contamination. Furthermore, there is no published study that combines microbial ecology with a structured public health risk assessment for this river. Addressing this gap is critical for informed policy-making, improved water quality management, and safeguarding the health of river-dependent communities.

III. MATERIALS AND METHODS

3.1 Study Area

The study was conducted on the Ologbo River, located in Ikpoba-Okha Local Government Area of Edo State, Nigeria. Geographically, the river lies within the coordinates 6°02′–6°07′ N and 5°40′–5°45′ E, forming part of the Niger Delta freshwater ecosystem. The river originates from upstream tributaries in Edo State, flowing southward through Ologbo community before merging with the Benin River. Surrounding land use is characterized by oil and gas installations, artisanal fisheries, sawmills, agricultural farmlands, and human settlements. The climate is tropical humid, with a distinct rainy season (April–October) and dry season (November–March). Average annual rainfall is approximately 2,200 mm, with mean temperatures ranging between 24°C and 32°C (NIMET, 2023). The river is a major source of domestic water, fishing livelihood, irrigation, and recreational activities for local communities.

3.2 Sampling Design

A stratified sampling approach was adopted to capture spatial and seasonal variability in microbial contamination. Six sampling stations (S1–S6) were established along the river, representing upstream (reference), midstream (settlement influence), and downstream (industrial/agricultural influence) segments. Sampling was conducted in both the wet season (July–August 2024) and dry season (January–February 2025) to account for seasonal hydrological changes. At each station, triplicate surface water samples were collected at a depth of 30 cm using sterile 1-L polypropylene bottles. All samples were labelled, stored in iceboxes at 4°C, and transported to the microbiology laboratory within 6 hours for analysis.

3.3 Physicochemical Parameters

In-situ measurements of water temperature, pH, electrical conductivity (EC), and dissolved oxygen (DO) were taken using a portable multi-parameter meter (Hanna Instruments HI98194). Turbidity was measured using a Hach 2100Q turbidity meter. These parameters were recorded at each station to assess environmental conditions influencing microbial survival and distribution.

3.4 Microbial Analysis

Microbiological assessment followed the standard methods outlined in APHA (2017) and WHO (2023).

- Total Heterotrophic Bacteria (THB): Determined using the pour plate technique on Nutrient Agar, incubated at 35±2°C for 48 hours.

- Total Coliforms (TC) and Faecal Coliforms (FC): Enumerated using the membrane filtration method on m-Endo agar and m-FC agar respectively, with incubation at 37°C for 24 hours (TC) and 44.5°C for 24 hours (FC).
- Escherichia coli (E. coli): Confirmed using Eosin Methylene Blue (EMB) agar, with characteristic colonies subjected to IMViC biochemical tests.
- Salmonella spp. and Shigella spp.: Isolated using Xylose Lysine Deoxycholate (XLD) agar and confirmed via Gram staining and biochemical profiling.Microbial counts were expressed as colony-forming units per 100 mL (CFU/100 mL) of water.

3.5 Antimicrobial Susceptibility Testing

Representative isolates of *E. coli*, *Salmonella*, and *Shigella* were subjected to antimicrobial susceptibility testing using the Kirby–Bauer disc diffusion method on Mueller-Hinton agar, following CLSI (2023) guidelines. Antibiotics tested included ampicillin (10 µg), ciprofloxacin (5 µg), tetracycline (30 µg), chloramphenicol (30 µg), and gentamicin (10 µg).

3.6 Public Health Risk Assessment

Public health risk assessment followed the Quantitative Microbial Risk Assessment (QMRA) framework (Haas et al., 2014), comprising four steps:

1. Hazard Identification – Pathogens of concern identified from microbial analysis results.
2. Exposure Assessment – Estimation of daily ingestion rates for different exposure scenarios (domestic use, recreation, irrigation) based on WHO default values and local survey data.
3. Dose–Response Assessment – Application of published dose–response models for *E. coli* and *Salmonella* (Teunis et al., 2008).
4. Risk Characterization – Calculation of annual infection probabilities and comparison with the WHO tolerable risk benchmark of $\leq 10^{-4}$ infections/person/year.

3.7 Data Analysis

Microbial counts were $\log_{10}$-transformed prior to statistical analysis. Descriptive statistics (mean, standard deviation) were calculated for each parameter. Seasonal and spatial differences in microbial loads were tested using one-way ANOVA, with significance set at $p<0.05$. Pearson correlation analysis was used to examine relationships between microbial counts and physicochemical parameters. All analyses were performed using IBM SPSS Statistics version 26.

IV. RESULTS AND DISCUSSION

4.1 Physicochemical Characteristics of the Ologbo River

The physicochemical parameters recorded during wet and dry seasons are presented in Table 1. Mean pH values ranged from 6.42 to 7.13, remaining within the WHO (2023) guideline range for drinking water (6.5–8.5), except for slightly acidic conditions observed upstream during the wet season. Water temperature varied between 26.4°C and 29.8°C, consistent with tropical river systems. Dissolved oxygen (DO) concentrations ranged from 4.1 to 6.5 mg/L, with higher values in the wet season due to enhanced aeration from increased flow. Turbidity levels were markedly higher in the wet season (22.6–41.3 NTU) compared to the dry season (10.5–18.2 NTU), exceeding the WHO limit of 5 NTU for potable water, suggesting elevated sediment and particulate matter from surface runoff (Edokpayi et al., 2020).

Table 1. Physicochemical parameters of Ologbo River water during wet and dry seasons

Parameter	Wet Season (Mean ± SD)	Dry Season (Mean ± SD)	WHO Limit*
pH	6.42 ± 0.15	7.13 ± 0.12	6.5–8.5
Temp (°C)	27.6 ± 0.4	28.9 ± 0.5	–
EC (µS/cm)	365 ± 14	298 ± 10	1000
DO (mg/L)	6.5 ± 0.3	4.1 ± 0.2	≥5
Turbidity (NTU)	41.3 ± 5.1	18.2 ± 3.2	5

Source: Aurthur's Survey, 2025 & WHO (2023) Guidelines for Drinking Water QualityThese results indicate that while most physicochemical parameters are within permissible limits, turbidity and occasional DO depletion could promote microbial persistence, especially in downstream sections influenced by domestic and industrial discharges.

4.2 Microbial Load and Spatial-Seasonal Variations

The microbial counts for total heterotrophic bacteria (THB), total coliforms (TC), faecal coliforms (FC), *E. coli*, *Salmonella* spp., and *Shigella* spp. are presented in Table 2.

Table 2. Mean microbial counts ($\log_{10}$ CFU/100 mL) in Ologbo River water

Parameter	Wet Season Range	Dry Season Range	WHO Limit*
THB	3.8–4.7	3.1–3.9	No guideline
Total Coliforms	3.4–4.1	2.9–3.5	0
Faecal Coliforms	3.1–3.8	2.5–3.1	0
E. coli	2.9–3.4	2.1–2.8	0
Salmonella spp.	2.2–2.6	1.7–2.2	0
Shigella spp.	1.9–2.4	1.5–2.0	0

Source: Aurthur's Survey, 2025 & WHO (2023) Guidelines for Drinking Water Quality

All microbial indicators exceeded WHO permissible limits for drinking water (0 CFU/100 mL), confirming faecal contamination throughout the river. Wet season counts were significantly higher ($p<0.05$) than dry season counts across all parameters, consistent with the enhanced transport of contaminants during rainfall and runoff events (Odonkor & Ampofo, 2013). Downstream stations recorded the highest microbial loads, likely due to cumulative inputs from settlements, agriculture, and industrial activities.

4.3 Antimicrobial Resistance Profiles of Isolates

Antibiotic susceptibility testing revealed high resistance rates among *E. coli* isolates to ampicillin (78%) and tetracycline (64%), with moderate resistance to chloramphenicol (42%). *Salmonella* spp. showed resistance to tetracycline (58%) and ampicillin (71%), while *Shigella* spp. demonstrated multi-drug resistance patterns. These findings align with Igbinosa et al. (2013), who reported similar resistance profiles in riverine bacteria in Southern Nigeria, underscoring the role of contaminated surface water as a reservoir for antimicrobial resistance genes.

4.4 Public Health Risk Assessment (QMRA)

Using the QMRA framework, the estimated annual infection probabilities for primary exposure scenarios (domestic use, recreation, irrigation contact) exceeded the WHO benchmark of 10^{-4} infections/person/year. For *E. coli*, the infection probability for domestic use during the wet season was calculated at 3.4×10^{-2}, representing a 34-fold exceedance of the tolerable risk. *Salmonella* spp. risk estimates were even higher for recreational contact during the wet season (5.1×10^{-2}), indicating high likelihood of gastrointestinal infections.

These results demonstrate that untreated use of Ologbo River water presents a substantial public health risk, especially during the wet season when contamination peaks. Similar trends have been reported in Amassoma River (Nwidu et al., 2016) and Warri River (Owamah, 2014), where seasonal flooding amplifies pathogen transport.

4.5 Comparative Analysis with Other Nigerian Rivers
The microbial loads recorded in the Ologbo River are comparable to those reported for the Warri River (Owamah, 2014) and the Osun River (Ogunyemi et al., 2019), both of which are impacted by mixed domestic, agricultural, and industrial activities. However, the detection of multi-drug-resistant isolates in Ologbo River samples may indicate stronger anthropogenic pressures, possibly linked to pharmaceutical residues and livestock antibiotic use in the catchment.

4.6 Implications for Water Resource Management

The findings highlight the urgent need for integrated catchment management in Ikpoba-Okha LGA, including:

- Enforcement of effluent treatment regulations for industries.
- Provision of community-based water treatment facilities.
- Public awareness campaigns on the risks of using untreated river water.
- Routine microbial monitoring to track contamination trends and antimicrobial resistance profiles.

The data also provide an evidence base for aligning local interventions with the Sustainable Development Goals (SDG 3: Good Health and Well-being; SDG 6: Clean Water and Sanitation).

RECOMMENDATIONS

1. Implementation of Regular Water Quality Monitoring
- Establish routine microbial and physicochemical monitoring of the Ologbo River to detect contamination trends, seasonal peaks, and AMR patterns.
- Develop a local water quality database accessible to environmental agencies, public health authorities, and the community.

2. Strengthening Effluent Regulation and Enforcement
- Enforce compliance with the National Environmental (Sanitation and Waste Control) Regulations by industries and processing facilities along the river.
- Mandate pre-discharge treatment of industrial and domestic wastewater to reduce pollutant loads.

3. Community-Based Water Treatment and Hygiene Education
- Introduce low-cost household water treatment methods such as chlorination, solar disinfection (SODIS), and filtration.
- Conduct targeted public health campaigns on the dangers of using untreated river water for drinking and cooking.

4. Catchment Management and Pollution Prevention
- Promote riparian buffer zones to filter runoff before it enters the river.
- Implement proper waste management in riverside settlements to prevent direct dumping of solid and liquid wastes.

5. Antimicrobial Resistance Surveillance
- Establish coordinated AMR surveillance in riverine environments to track the spread of resistant bacteria.
- Integrate environmental AMR monitoring into the national One Health framework, linking human, animal, and environmental health sectors.

6. Policy Alignment with Sustainable Development Goals (SDGs)
- Align interventions with SDG 3 (Good Health and Well-being) and SDG 6 (Clean Water and Sanitation) to promote sustainable water resource use and protect community health.

CONCLUSION

This study provides the first integrated microbial ecology and public health risk assessment of the Ologbo River in Ikpoba-Okha Local Government Area, Edo State, Nigeria. The findings reveal that the river is significantly contaminated with faecal indicator organisms (*E. coli*, total and faecal coliforms) and pathogenic bacteria (*Salmonella* spp., *Shigella* spp.), with microbial loads far exceeding WHO (2023) and NSDWQ (2015) permissible limits for potable water. Seasonal analysis demonstrated that contamination peaks during the wet season due to increased runoff and pollutant wash-in, while downstream locations recorded the highest microbial loads due to cumulative anthropogenic pressures.

Physicochemical conditions such as high turbidity, moderate dissolved oxygen depletion, and elevated electrical conductivity in certain locations further promote microbial persistence and pathogen survival. The detection of multi-drug-resistant bacterial strains underscore the growing concern of antimicrobial resistance (AMR) dissemination through contaminated surface waters, a finding consistent with earlier studies in the Niger Delta region (Igbinosa et al., 2013; Owamah, 2014).

Quantitative Microbial Risk Assessment (QMRA) indicated that the probability of infection from domestic, recreational, and irrigation contact with the river water exceeds the WHO benchmark (10^{-4} infections/person/year) by more than an order of magnitude, especially during the wet season. This poses significant health risks to river-dependent communities, with potential for waterborne disease outbreaks and the spread of resistant pathogens.

REFERENCES

[1] Adefisoye, M. A., & Okoh, A. I. (2016). Identification and antimicrobial resistance prevalence of pathogenic *Escherichia coli* strains from treated wastewater effluent in Eastern Cape, South Africa. *MicrobiologyOpen*, 5(1),143–151. https://doi.org/10.1002/mbo3.317

[2] American Public Health Association (APHA). (2017). *Standard methods for the examination of water and wastewater* (23rd ed.). APHA/AWWA/WEF.

[3] Bartram, J., & Pedley, S. (2021). Water quality and health: Review of microbiological aspects. *International Journal of Environmental Research and Public Health*, 18(2), 421–437. https://doi.org/10.3390/ijerph18020421

[4] Clinical and Laboratory Standards Institute (CLSI). (2023). *Performance standards for antimicrobial susceptibility testing* (33rd ed.). CLSI Supplement M100.

[5] Edokpayi, J. N., Odiyo, J. O., & Durowoju, O. S. (2020). Impact of wastewater on surface water quality in developing countries: A case study of South Africa. In *Water Quality* (pp. 401–416). IntechOpen. https://doi.org/10.5772/intechopen.89657

[6] Egbueri, J. C. (2020). Groundwater quality assessment using pollution index of groundwater (PIG), ecological risk index (ERI), and hierarchical cluster analysis (HCA): A case study from Southwestern Nigeria. *Environmental Systems Research*, 9(1), 33. https://doi.org/10.1186/s40068-020-00207-6

[7] Ezeh, C. I., & Ananwude, A. C. (2020). Environmental implications of crude oil exploration and production in Nigeria's Niger Delta. *Energy and Environment Research*, 10(1), 1–14. https://doi.org/10.5539/eer.v10n1p1

[8] Gibney, K. B., O'Toole, J., Sinclair, M., & Leder, K. (2017). Quantitative microbial risk assessment and infectious diseases. In *Encyclopedia of Environmental Health* (2nd ed., pp. 657–666). Elsevier. https://doi.org/10.1016/B978-0-12-409548-9.10857-0

[9] Haas, C. N., Rose, J. B., & Gerba, C. P. (2014). *Quantitative microbial risk assessment* (2nd ed.). John Wiley & Sons.

[10] Igbinosa, E. O., & Okoh, A. I. (2009). Impact of discharge wastewater effluents on the physico-chemical qualities of a receiving watershed in a typical rural community. *International Journal of Environmental Science & Technology*, 6(2), 175–182. https://doi.org/10.1007/BF03327619

[11] Igbinosa, E. O., Uyi, O. O., Odjadjare, E. E., Ajuzie, C. U., Orhue, P. O., & Adewole, E. M. (2013). Assessment of physicochemical qualities, heavy metals and antibiotic resistance properties of bacteria isolated from river water in Southern Nigeria. *African Journal of Environmental Science and Technology*, 7(5), 144–153. https://doi.org/10.5897/AJEST12.177

[12] Nduka, J. K., & Orisakwe, O. E. (2011). Water-quality issues in the Niger Delta of Nigeria: A look at heavy metal levels and some physicochemical properties. *Environmental Science and Pollution Research*, 18(2), 237–246. https://doi.org/10.1007/s11356-010-0376-2

[13] Newton, R. J., Jones, S. E., Eiler, A., McMahon, K. D., & Bertilsson, S. (2011). A guide to the natural history of freshwater lake bacteria. *Microbiology and Molecular Biology Reviews*, 75(1), 14–49. https://doi.org/10.1128/MMBR.00028-10

[14] Nigerian Meteorological Agency (NIMET). (2023). *Nigerian Meteorological Agency Climate Report 2023*. Abuja: NIMET.

[15] Nigerian Standard for Drinking Water Quality (NSDWQ). (2015). *Nigerian Standard for Drinking Water Quality*. Nigerian Industrial

Standard (NIS 554:2015). Standards Organisation of Nigeria (SON).

[16] Nwidu, L. L., Oveh, B., Okoriye, T., & Vaikosen, N. A. (2016). Assessment of the water quality and prevalence of water borne diseases in Amassoma, Niger Delta, Nigeria. *African Journal of Environmental Science and Technology*, 10(9), 293–303. https://doi.org/10.5897/AJEST2016.2120

[17] Odonkor, S. T., & Ampofo, J. K. (2013). Escherichia coli as an indicator of bacteriological quality of water: An overview. *Microbiology Research*, 4(1), e2. https://doi.org/10.4081/mr.2013.e2

[18] Ogunyemi, A. L., Fagbohun, O. F., & Akinloye, O. A. (2019). Bacteriological and physicochemical assessment of Osun River, Southwestern Nigeria. *Applied Water Science*, 9(6), 1–9. https://doi.org/10.1007/s13201-019-1037-4

[19] Owamah, H. I. (2014). Water quality assessment of the Warri River, Nigeria: A study of the impact of industrial discharges. *Journal of Environmental Health Science & Engineering*, 12(1), 1–12. https://doi.org/10.1186/2052-336X-12-56

[20] Teunis, P. F. M., Moe, C. L., Liu, P., Miller, S. E., Lindesmith, L., Baric, R. S., Le Pendu, J., & Calderon, R. L. (2008). Norwalk virus: How infectious is it? *Journal of Medical Virology*, 80(8),14681476.https://doi.org/10.1002/jmv.21237

[21] World Health Organization (WHO). (2023). *Guidelines for drinking-water quality* (4th ed.). WHOPress.https://www.who.int/publications/i/item/9789241549950