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Research Article

An Analytical Study of Some Water Quality Parameters and Their Implications for Public Health in Port Harcourt, Nigeria

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ABSTRACT

This study presents a comprehensive statistical analysis of water quality parameters in Port Harcourt, Nigeria, with the aim of identifying key trends, correlations, and potential public health implications. The dataset comprises 1000 water samples. All data analysis was performed using the Python programming language with libraries such as Pandas and NumPy for data manipulation, and SciPy and Matplotlib for statistical analysis and visualization. Descriptive statistics revealed significant variability in water quality, with an average pH of 4.88, indicating acidity in many samples. The mean turbidity was 1.31 NTU, with some samples showing extremely high values up to 240 NTU. The presence of microbial contamination was evident, with mean Fecal Coliform and Total Coliform counts of 9.66 and 11.33, respectively. A correlation analysis indicated weak linear relationships between most parameters, highlighting the complex nature of water quality. An ANOVA test showed a statistically significant difference in turbidity levels across various water sources (F-statistic = 2.64, p-value = 0.032), suggesting that the source type is a significant determinant of water clarity. Furthermore, a comparison of Total Coliform levels between the dry and wet seasons showed similar contamination, challenging the assumption that microbial pollution is solely influenced by seasonal precipitation. The findings underscore a need for a multi-parameter approach to water quality assessment and highlight critical public health risks associated with acidic and microbiologically contaminated water.

Keywords: Coliform; Port Harcourt; Public health; Statistical analysis, Turbidity; Water quality

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INTRODUCTION

Access to safe and clean drinking water is a fundamental human right and a critical determinant of public health (United Nations General Assembly, 2010). The World Health Organization estimates that approximately 2 billion people worldwide lack access to safely managed drinking water services, with the burden disproportionately affecting developing nations (Amnesty International, 2009). In sub-Saharan Africa, including Nigeria, water quality challenges are exacerbated by rapid urbanization, inadequate infrastructure, industrial pollution, and limited regulatory oversight (Isukuru *et al.,* 2024). Port Harcourt, the capital of Rivers State and a major industrial hub in the Niger Delta region of Nigeria, faces unique environmental challenges that significantly impact its water resources (Effiong *et al.,* 2021). As the epicenter of Nigeria's oil and gas industry, the city experiences substantial industrial pollution, inadequate waste management systems, and rapid population growth, all of which can severely compromise water quality (Jaja, 2010). The Niger Delta region has been particularly affected by decades of oil exploration and production activities, leading to widespread environmental degradation and contamination of surface and groundwater bodies (Ola *et al.,* 2024). Water quality assessment involves the evaluation of multiple physical, chemical, and biological parameters that collectively determine the safety and potability of water sources. Key indicators such as pH, turbidity, temperature, total dissolved solids (TDS), nitrate, fluoride, and microbial content provide crucial insights into water safety and public health risks (Omer, 2020). The pH level indicates the acidity or alkalinity of water, with values outside the World Health Organization recommended range of 6.5-8.5 potentially causing gastrointestinal issues, affecting taste, and compromising the efficacy of water treatment processes (World Health Organization, 2017). Turbidity, a measure of water clarity caused by suspended particles, not only affects aesthetic quality but can also harbor pathogenic microorganisms and interfere with disinfection processes (World Health Organization, 2017). Microbial contamination, particularly the presence of coliform bacteria, serves as a critical indicator of fecal pollution and the potential presence of pathogenic organisms including bacteria, viruses, and parasites (World Health Organization, 2017). Epidemiological studies have demonstrated that waterborne diseases account for a significant proportion of morbidity and mortality in developing countries, with children under five years being particularly vulnerable to diarrheal diseases, cholera, and typhoid fever (World Health Organization, 2017). In Nigeria, waterborne diseases continue to pose major public health challenges, particularly in densely populated urban areas with inadequate sanitation infrastructure and limited access to treated water (Isukuru *et al.,* 2024). Groundwater studies have documented contamination with heavy metals, elevated levels of total dissolved solids, and hydrocarbon pollution linked to oil industry activities (Fei-Baffoe *et al.,* 2024). Research on seasonal variations in water quality has shown that rainfall patterns significantly influence contaminant transport and microbial contamination levels, though local environmental factors may override general seasonal trends (Ngandwe *et al.,* 2025). Recent studies have emphasized the importance of statistical approaches in water quality assessment to identify patterns, correlations, and significant differences across water sources and temporal variations (Huda *et al.,* 2025). Analysis of variance (ANOVA) has been effectively used to compare water quality parameters across different sources, while correlation analysis helps identify relationships between various physicochemical and biological parameters (Hassan *et al.,* 2024). These statistical methods provide robust frameworks for evidence-based decision-making in water quality management and public health interventions. The study is aimed at understanding water quality and public health risks through the analysis of water sourced from different means in Port Harcourt, Nigeria. The primary objectives are to perform a descriptive statistical analysis to establish baseline water quality profiles, analyze the relationships between different parameters using correlation analysis, statistically compare turbidity levels across different water sources using ANOVA, and compare microbial contamination between dry and wet seasons. The findings from this comprehensive statistical assessment will provide evidence-based insights for water quality monitoring, treatment strategies, and policy interventions to mitigate public health risks in the Port Harcourt region. The results will contribute to the growing body of knowledge on water quality assessment in the Niger Delta and provide valuable information for public health officials, water management authorities, and policymakers working to ensure safe water access for the urban population.

MATERIALS AND METHODS

Source of Data

The dataset used in this study is titled "Port Harcourt, Nigeria - Key Water Quality Parameters for Dry and Wet Season," published by The World Bank Water Data in 2020. The dataset consists of 1000 water samples, with a wide range of variables.

Data Analysis

All data analysis and statistical computations were performed using the Python programming language. The following libraries were utilized; Pandas and NumPy was used for efficient data loading, cleaning, manipulation, and numerical operations. SciPy was used for conducting statistical tests, including the Analysis of Variance (ANOVA). Matplotlib and Seaborn was used for data visualization, including scatter plots and bar charts. A variety of statistical methods were employed to analyze the water quality data. The methods are outlined below:

Descriptive Statistics

A preliminary descriptive analysis was conducted to summarize the main features of the dataset. This involved calculating the mean, standard deviation, minimum, and maximum values for all numerical parameters using Pandas functions. The data was also grouped by the primary drinking water source (e.g., borehole, bottled, sachet) to provide a comparative analysis.

Correlation Analysis

A correlation matrix was generated to assess the linear relationships between the different numerical water quality parameters. The Pearson correlation coefficient was calculated using the corr () function in Pandas. Scatter plots were also generated using Matplotlib to visually represent the relationship between selected pairs of variables, such as Temperature and Turbidity.

Analysis of Variance (ANOVA)

A one-way ANOVA test was performed using the f_oneway function from the SciPy library to determine if there was a statistically significant difference in Turbidity levels across the different water sources. The null hypothesis (H_0) was that the mean turbidity levels are the same for all water sources, while the alternative hypothesis (Ha) was that at least one of the means is different. A significance level (α) of 0.05 was used for this test.

Seasonal Comparison

The levels of microbial contamination (Total Coliform) were compared between the dry and wet seasons. This involved grouping the data by season and calculating the average Total Coliform count for each using Pandas, and then comparing the two values to understand the impact of seasonal changes on water quality.

RESULTS

Descriptive Statistics

The descriptive statistics (Table 1 and Table 2) revealed substantial variability in water quality parameters across the study area, indicating significant heterogeneity in water quality throughout Port Harcourt.

The distribution of pH levels across water source types (Table 3) revealed concerning patterns, with borehole water sources exhibiting the highest proportion of acidic samples (616 out of total samples).

Correlation Analysis and Statistical Relationships

The correlation matrix analysis (Figure 1) revealed predominantly weak linear relationships between measured parameters, suggesting that water quality in Port Harcourt is influenced by multiple independent contamination sources and processes.

Analysis of Variance (ANOVA) Results

The ANOVA analysis yielded statistically significant results (F-statistic = 2.64, p-value = 0.032), confirming significant differences in turbidity levels among different water source types. This finding demonstrates that water source type is a critical determinant of water clarity, with important implications for treatment strategies and quality control measures (Tetali *et al.,* 2024).

Seasonal Variation Analysis

The seasonal comparison of total coliform levels revealed substantially higher contamination during the rainy season (mean = 25.12 CFU/100ml) compared to the dry season (mean = 0.96 CFU/100ml).

Table 1. Descriptive Statistics of Some Parameters by Primary Drinking Source

Parameter		borehole	Bottled	piped	Sachet	vendor
pH	count	398	90	4	498	10
	mean	4.32	5.16	6.12	5.25	5.44
	std	1.84	1.7	4.61	1.55	0.89
	min	0	0	0	0	3.88
	max	7.43	9	9.71	7.63	6.57
Turbidity	count	398	90	4	498	10
	mean	1.12	4.28	0.63	0.93	1.34
	std	5.86	27.14	0.55	2.76	1.71
	min	0	0	0	0	0.55
	max	99.5	240	1.24	41.7	6.13
Temperature	count	398	90	4	498	10
	mean	23.01	20.33	18.28	22	22.34
	std	6.25	8.86	12.23	7.25	7.89
	min	0	0	0	0	0
	max	28	27	25.6	33	26.7
Fecal Coliform	count	398	90	4	498	10
	mean	10.48	5.82	0	9.55	20.9
	std	26.64	19.27	0	26.69	35.69
	min	0	0	0	0	0
	max	101	101	0	101	101
Total Coliform	count	398	90	4	498	10
	mean	11.83	10.04	0	11.11	18.1
	std	28.42	26.8	0	30.04	37.59
	min	0	0	0	0	0
	max	101	101	0	101	101

Table 2. Descriptive Statistics for Some Water Quality Parameters

	pH	Turbidity (NTU)	Temperature (℃)	Fecal Coliform	Total Coliform
Count	1000	1000	1000	1000	1000
Mean	4.88	1.31	22.24	9.66	11.33
Std	1.76	9.17	7.09	26.16	29.12
Min	0	0	0	0	0
25%	4.28	0.41	23.2	0	0
50%	5.17	0.57	24.2	0	0
75%	6	0.78	25.1	1	0
Max	9.71	240	33	101	101

Table 3. Water pH Levels across Water Source Types

Source Type	Acidic	Neutral	Basic
Borehole	616	23	0
Bottled	28	11	3
open well	8	0	0
Piped	2	0	2
Sachet	179	71	1
Vendor	50	6	0

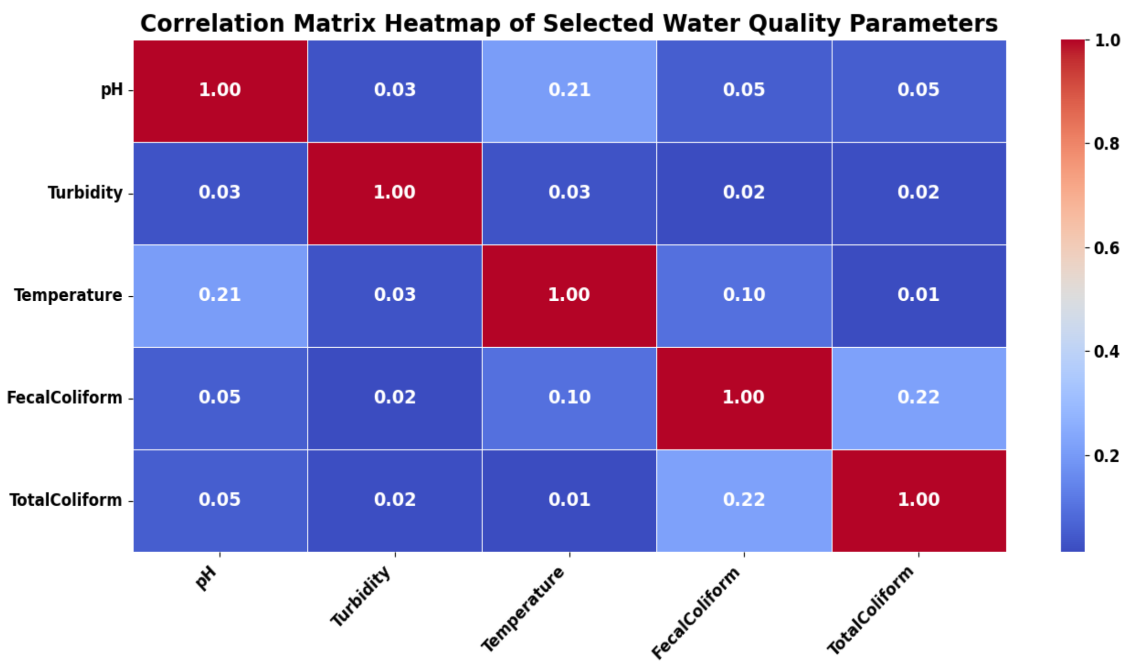

Figure 1: Correlation Matrix Heatmap of Selected Water Quality Parameters

DISCUSSION

The comprehensive statistical analysis reveals multiple water quality challenges that pose significant public health risks to Port Harcourt residents. The combination of acidic pH levels, elevated microbial contamination, and seasonal variability creates conditions conducive to waterborne disease transmission and chronic health effects (Ashbolt, 2004; Clasen *et al.,* 2006). The average pH of 4.88, is substantially below the WHO recommended range of 6.5-8.5 for drinking water, with some samples reaching extremely acidic levels as low as 0 (Arhin *et al.,* 2023). Borehole water sources exhibited the highest proportion of acidic samples (616 out of total samples). This finding is particularly alarming given that boreholes serve as the primary drinking water source for most of Port Harcourt residents (Gbarabe & Ikiriko, 2021). Sachet and vendor water sources demonstrated more balanced pH distributions, suggesting better treatment processes or source water selection. However, the overall acidic trend across all sources indicates systemic contamination that requires immediate intervention (Doria, 2006). This pronounced acidity represents a critical public health concern, as acidic water can cause gastrointestinal irritation, dental erosion, and corrosion of distribution systems, potentially leading to heavy metal leaching (WHO, 2017). These findings align with previous studies in the Niger Delta region that have documented groundwater contamination from petroleum activities (Osokpor & Omo-Irabor, 2020).

Turbidity measurements showed a mean value of 1.31 NTU, which falls within WHO guidelines (<5 NTU), but the extreme variability (ranging up to 240 NTU) indicates significant quality inconsistencies (Allen *et al.,* 2008). The significant source-type variations in turbidity suggest that targeted intervention strategies should be developed based on specific water source characteristics. High turbidity levels are particularly concerning as they can harbor pathogenic microorganisms, reduce disinfection efficacy, and indicate the presence of suspended particles that may carry contaminants (Cinque *et al.,* 2004). Studies in urban environments have demonstrated strong correlations between elevated turbidity and increased waterborne disease incidence (Wang *et al.,* 2018). The weak correlation between temperature and turbidity (r = 0.03) indicates that thermal effects alone do not significantly influence water clarity, contrasting with findings from regions where temperature variations show stronger correlations with turbidity (Birmachu *et al.,* 2024). This pattern of weak inter-parameter correlations is consistent with studies in complex urban environments where pollution sources create heterogeneous contamination patterns (Hatt *et al.,* 2004). The independence of these parameters suggests that comprehensive multi-parameter monitoring approaches are essential for accurate water quality assessment, as single-parameter measurements may not adequately represent overall water safety (Amadi *et al.,* 2012). The statistically significant result for ANOVA analysis (F-statistic = 2.64, p-value = 0.032), gives a confirmation of the significant differences in turbidity levels among different water source types. This finding demonstrates that water source type is a critical determinant of water clarity, with important implications for treatment strategies and quality control measures (Tetali *et al.,* 2024).

The presence of fecal coliform bacteria (mean = 9.66 CFU/100ml) and total coliform bacteria (mean = 11.33 CFU/100ml) in water samples represents a severe public health risk. According to WHO guidelines, drinking water should contain zero coliform bacteria per 100ml sample (Some *et al.,* 2021). The detected levels exceed safe limits and indicate widespread fecal contamination, likely originating from inadequate sanitation infrastructure, sewage overflow, and surface runoff contamination (Caleb, 2024). Research conducted in similar urban settings in sub-Saharan Africa has linked coliform contamination levels of this magnitude to increased incidence of diarrheal diseases, particularly among children under five years of age (Demissie *et al.,* 2021). There was pronounced seasonal variations of total coliform levels with higher contamination during the rainy season (mean = 25.12 CFU/100ml) compared to the dry season (mean = 0.96 CFU/100ml). This pronounced seasonal variation aligns with established patterns in tropical regions where increased precipitation enhances surface runoff, leading to greater transport of fecal matter and organic pollutants into water sources (Ngandwe *et al.,* 2025). The magnitude of seasonal difference observed in this study (>25-fold increase) exceeds variations reported in similar studies from other West African cities, suggesting that Port Harcourt's water sources are particularly vulnerable to rainfall-induced contamination (Kumpel *et al.,* 2017). This vulnerability likely stems from inadequate drainage systems, proximity of water sources to sanitation facilities, and extensive urban surface sealing that increases runoff velocity and contaminant transport. These seasonal patterns have critical implications for public health planning, as the rainy season coincides with peak transmission periods for waterborne diseases in tropical regions (BioPerfectus, 2025). The findings support the need for enhanced water treatment and monitoring protocols during wet seasons, as well as improved urban drainage and sanitation infrastructure to reduce contamination sources.

The widespread acidic conditions across water sources require immediate attention through pH adjustment treatments and source protection measures. The presence of coliform bacteria at levels exceeding WHO guidelines necessitates enhanced disinfection protocols and regular monitoring programs (Stevens *et al.,* 2003). The significant seasonal variations in contamination levels support the implementation of adaptive management strategies that intensify treatment and monitoring during high-risk periods (Alver *et al.,* 2025). These findings provide evidence-based support for policy interventions including improved water treatment infrastructure, enhanced regulatory oversight of water suppliers, and integrated urban planning approaches that protect water sources from contamination.

CONCLUSION

The statistical analysis of water quality parameters in Port Harcourt, performed using Python, revealed several critical findings with significant implications for public health. The data indicates that a substantial portion of the water sources in the region, particularly boreholes, are acidic and do not meet the recommended pH standards for safe consumption. Furthermore, the presence of Fecal and Total Coliform in many samples' points to widespread microbial contamination, posing a direct threat of waterborne diseases. The study also established a significant difference in water clarity (turbidity) across different water sources, underscoring the varying quality of water available to the public. The findings that microbial contamination is much higher during the rainy season further highlight the need for seasonal monitoring and preventative measures.

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Conflicts of Interest: The authors declare no conflict of interest.

REFERENCES

Allen, M. J., Brecher, R. W., Copes, R., Hrudey, S. E., & Payment, P. (2008). *Turbidity and microbial risk in drinking water* (Report). British Columbia Ministry of Health Services.

Alver, A., Baştürk, E., & Kılıç, A. (2025). Impact of seasonal variations and water quality parameters on the formation of trihalomethanes and haloacetic acids in drinking water treatment processes. *Journal of Environmental Management*, *384*, 125567. https://doi.org/10.1016/j.jenvman.2025.125567

Amadi, A. N., Olasehinde, P. I., Yisa, J., Okosun, E. A., Nwankwoala, H. O., & Alkali, Y. B. (2012). Geostatistical assessment of groundwater quality from coastal aquifers of Eastern Niger Delta, Nigeria. *Geosciences*, *2*(3), 51–59.

Amnesty International. (2009). *Nigeria: Petroleum, pollution and poverty in the Niger Delta*. Amnesty International Publications.

Arhin, E., Osei, J. D., Anima, P., Damoah-Afari, P., & Yevugah, L. (2023). The pH of Drinking Water and Its Human Health Implications: A Case of Surrounding Communities in the Dormaa Central Municipality of Ghana. *Journal Healthcare Treatment Development*, *4*(1), 15–26. https://doi.org/10.55529/jhtd.41.15.26

Ashbolt, N. J. (2004). Microbial contamination of drinking water and disease outcomes in developing regions. *Toxicology*, *198*(1-3), 229–238. https://doi.org/10.1016/j.tox.2004.01.030

BioPerfectus. (2025). *Rainy season surge in vector-borne diseases: BioPerfectus solutions for accurate diagnosis*. BioPerfectus. https://www.bioperfectus.com/blog/detail/rainy-season-surge-in-vector-borne-diseases-bioperfectus-solutions-for-accurate-diagnosis

Birmachu, A., Feyissa, T., & Gebi, N. (2024). Assessment of effects of turbidity variation on water temperature and evaporation of Gilgel Gibe I Reservoir, Omo-Gibe River Basin, Ethiopia. *Journal of Engineering*, *2024*, Article 8891990. https://doi.org/10.1155/2024/8891990

Caleb, A. (2024). *Impact of fecal contamination on groundwater quality in urban areas*. ResearchGate. https://www.researchgate.net/publication/385132788

Cinque, K., Stevens, M., Roser, D., Ashbolt, N., & Leeming, R. (2004). Assessing the health implications of turbidity and suspended particles in protected catchments. *Water Science and Technology*, *50*(1), 205–210. https://doi.org/10.2166/wst.2004.0055

Clasen, T., Roberts, I., Rabie, T., Schmidt, W., & Cairncross, S. (2006). Interventions to improve water quality for preventing diarrhoea. *Cochrane Database of Systematic Reviews*, *(3)*, Article CD004794.

Demissie, G. D., Yeshaw, Y., Aleminew, W., & Akalu, Y. (2021). Diarrhea and associated factors among under five children in sub-Saharan Africa: Evidence from demographic and health surveys of 34 sub-Saharan countries. *PLoS One*, *16*(9), e0257522. https://doi.org/10.1371/journal.pone.0257522

Doria, M. F. (2006). Bottled water versus tap water: Understanding consumer preferences. *Journal of Water and Health*, *4*(2), 271–276.

Effiong, E. E., Abam, T. K. S., & Ngah, S. A. (2021). The major challenges of quality water supply in Portharcourt metropolis Rivers State. *International Journal of Environmental Studies and Safety Research*, *6*(3), 27–36.

Fei-Baffoe, B., Badu, E., Miezah, K., Sackey, L. N. A., Sulemana, A., Amuah, E. E. Y., & Alhassan, A. (2024). Contamination of groundwater by petroleum hydrocarbons: Impact of fuel stations in residential areas. *Heliyon*, *10*(4), e25924. https://doi.org/10.1016/j.heliyon.2024.e25924

Gbarabe, F., & Ikiriko, T. (2021). Residents' assessment of dominant reliable sources of water supplies for domestic purposes in Port Harcourt Municipality. *International Journal of Research in Engineering, Science and Management*, *3*(11), 41–46. https://doi.org/10.35629/5252-03114146

Hassan, A., Samy, G., Hegazy, M., Balah, A., & Fathy, S. (2024). Statistical analysis for water quality data using ANOVA (Case study – Lake Burullus influent drains). *Ain Shams Engineering Journal*, *15*(4), 102652. https://doi.org/10.1016/j.asej.2024.102652

Hatt, B., Fletcher, T., Walsh, C. J., & Taylor, S. (2004). The influence of urban density and drainage infrastructure on the concentrations and loads of pollutants in small streams. *Environmental Management, 34*(1), 112–124. https://doi.org/10.1007/s00267-004-0221-8

Huda, N., Ahmed, T., Masum, M. H., Faruque, N., & Islam, M. S. (2025). Assessment of surface water quality using advanced statistical techniques around an urban landfill: A multi-parameter analysis. *City and Environment Interactions*, *28*, 100237. https://doi.org/10.1016/j.cacint.2025.100237

Isukuru, E. J., Opha, J. O., Isaiah, O. W., Orovwighose, B., & Emmanuel, S. S. (2024). Nigeria's water crisis: Abundant water, polluted reality. *Cleaner Water*, *2*, 100026. https://doi.org/10.1016/j.clwat.2024.100026

Jaja, J. M. (2010). Ecological problems in the Niger Delta: The Port Harcourt experience 1913–1998. *Approaches in International Journal of Research and Development*, *2*(2), 27–36.

Kumpel, E., Cock-Esteb, A., Duret, M., Waal, D., & Khush, R. (2016). Seasonal variation in drinking and domestic water sources and quality in Port Harcourt, Nigeria. *American Journal of Tropical Medicine and Hygiene*, *96*(3), 737–746. https://doi.org/10.4269/ajtmh.16-0175

Ngandwe, S., Ogendi, G. M., Muoria, E., & Ngoma, J. (2025). Seasonal variations of microbial water quality from shallow wells and prevalence of water-related diseases. *Journal of Geoscience and Environment Protection*, *13*(5), 1–19. https://doi.org/10.4236/gep.2025.135001

Ola, I., Drebenstedt, C., Burgess, R. M., Mensah, M., Hoth, N., & Külls, C. (2024). Remediating oil contamination in the Niger Delta Region of Nigeria: Technical options and monitoring strategies. *The Extractive Industries and Society*, *17*, Article 101405. https://doi.org/10.1016/j.exis.2024.101405

Omer, N. H. (2020). Water quality parameters. In K. Summers (Ed.), *Water quality—Science, assessments and policy* (pp. 8). IntechOpen. https://doi.org/10.5772/intechopen.89657

Osokpor, J., & Omo-Irabor, O. O. (2020). Groundwater contamination assessment in a petroleum impacted sites in parts of the Niger Delta, Nigeria. *FUPRE Journal of Scientific and Industrial Research*, *4*(1), 15–26.

Some, S., Mondal, R., Mitra, D., Jain, D., Verma, D., & Das, S. (2021). Microbial pollution of water with special reference to coliform bacteria and their nexus with environment. *Energy Nexus*, *1*, 100008. https://doi.org/10.1016/j.nexus.2021.100008

Stevens, M., Ashbolt, N., & Cunliffe, D. (2003). Review of coliforms: As microbial indicators of drinking water quality. *Australian Government National Health and Medical Research Council.*

Tetali, R., Salomi, K., G, B. N. V., Sharon, P., & Gope, E. R. (2024). Analysis of water quality parameters across diverse sources: Research article. *Journal of Pharma Insights and Research*, *2*(3), 210–216. https://doi.org/10.69613/3jxm7e23

United Nations General Assembly. (2010). *Resolution 64/292: The human right to water and sanitation*. UN.

Wang, Y., McBean, E., & Gharabaghi, B. (2018). Increased risks of waterborne disease outbreaks in Northern Ontario due to climate change. *Journal of Water Management Modeling*, *26*(1), Article C436. https://doi.org/10.14796/JWMM.C436

World Health Organization. (2008). *Safer water, better health: Costs, benefits and sustainability of interventions to protect and promote health*.

World Health Organization. (2017). *Guidelines for drinking-water quality: Fourth edition incorporating the first addendum*. WHO Press.

World Health Organization. (2017). Microbial aspects. In *Guidelines for drinking-water quality* (4th ed., pp. 117–143).

World Health Organization. (2017). Turbidity measurement. In *Guidelines for drinking-water quality* (4th ed., pp. 203–205).

World Health Organization (WHO). (2017). Water quality and health - *Review of turbidity: Information for regulators and water suppliers* (Technical Brief No. WHO/FWC/WSH/17.01). World Health Organization.