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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 services, with water 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 activities, leading to 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 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, 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 (H_0) 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
рН	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

	рН	Turbidity (NTU)	Temperature (°C)	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

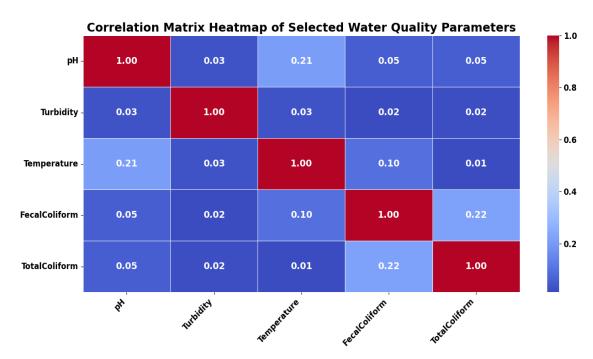


Figure 1: Correlation Matrix Heatmap of Selected Water Quality Parameters

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 they can harbor pathogenic concerning as 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 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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