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Risk Assessment of Water Quality in Public Institutions in Warri, Delta State

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ABSTRACT: This study aimed to evaluate the risks associated with water quality in public institutions in Warri, Delta State. Water samples were collected from five public institutions namely, School, Hospital, Mall, Church and Hotel. Physico-chemical and microbial analyses were conducted using standard methods. The water quality index (WQI) and risk assessment matrix (RAM) were applied the quality and potential risks. Results revealed slightly acidic pH levels (5.1-6.63) in water samples. Dissolved oxygen levels (3.8-4.2 mg/L) were below WHO recommendations. Iron was detected in all samples, with the hospital exceeding WHO guidelines (0.703 mg/L). Remarkably, microbial parameters were not detected in the water samples. The WQI categorized all locations as having "Good water quality' except for the mall which has a medium water quality. However, the RAM identified extreme risks for pH at the mall and iron concentration at the hospital. Dissolved oxygen levels were consistently categorized as medium risk across all locations. Though, overall water quality is good, specific parameters present varying degrees of risk requiring attention.

Keywords: Borehole, Water quality index, Risk assessment matrix, Physicochemical, Microbial parameters

Introduction

Water of good drinking quality is a commodity of basic importance to human physiology, and the further continued existence of man is depended to a great deal on its availability (Oboh and Egun, 2017). Man has, through history, grappled with the challenge of ensuring that there is adequate, appropriate water of quality good enough for use. The availability of water cannot guarantee such water to be safe for potable uses. The presence of objectionable taste, odor, color, and harmful substances in such water, no matter how abundant, renders it unsuitable for domestic and other uses (Ikpesu, *et al*., 2021).

According to the World Health Organization and UNICEF Joint Monitoring Programme 2021 report, 26% of the global population lacked safely managed drinking water services in 2020. Global disparities are more pronounced in certain regions, especially Sub-Saharan Africa, where only 30% of its population had access to safely managed drinking water services as of 2020. While the percentage of the population with access to at least basic drinking water, safely managed or basic, has also increased in comparison with the previous 21 years, Sub-Saharan Africa lags behind compared to other regions (Haruna and Tony, 2023). Whereas in the other six regions, more than 90% of people have access to at least basic drinking water services, this is only 64% of the population living in Sub-Saharan Africa. However, there are considerable gaps \between urban and rural areas.

A study by Emenike *et al.* (2017) showed that in South-West Nigeria, 33% of the population had access to improved sources of water, despite great disparities between urban and rural areas. Delta State, within which Warri is located, has its own different sets of challenges as regards the quality of water. The main sources of water for residents include boreholes, wells, rivers, and packaged water, each with its own quality concerns (Etchie *et al.*, 2013).

While comprehensive and recent data specific to Delta State is limited, studies have pointed to concerns on water quality and accessibility. Akpoborie and Ehwarimo (2012) noted that packaged drinking water produced within Warri Metropolis usually fell below the standards recommended by WHO; as many as 80% of samples were found to contain coliform bacteria. This finding exposes the fact that water quality in this region can be a potential threat to the health status of the people. Further, Ama *et al.* (2018) conducted a study on water quality in selected water bodies in Warri, with the WQI ranging between 52.98 and 66.69. These results indicate generally that the water quality was in the "good water" category but still below the "excellent" range and of particular concern is the situation in public institutions.

Guo *et al.* (2017) in their cross-sectional study indicated that 50% of the rural health-care facilities in a number of African countries did not have access to improved water sources. This study did not involve Nigeria, but it actually reveals the characteristic problems of most public institutions in Africa that might relate to the situation in Warri. Indeed, a critical review of water quality monitoring in Delta State by Eyankware and Ephraim (2021) noted that various studies have reported cases of the exceeding of WHO-permissible limits for parameters such as pH, turbidity, and microbial contamination, hence the need for constant monitoring and analysis of water quality within the region.

Public institutions in Warri (schools, hospitals, hotels, churches, malls), serve large populations daily and require a consistent supply of safe water for various purposes. These institutions often rely on a mix of water sources, including, private boreholes, and packaged water. Contaminated water coupled with poor sanitation, and inadequate hygiene practices may result in the incidence of waterborne and sanitation-related diseases such as cholera, dysentery, and typhoid fever (WHO, 2019). These diseases can have significant impacts on individual and community health, as well as economic and social consequences (Prüss-Ustün *et al.*, 2014).

Despite the importance of water quality in public institutions, there is a lack of comprehensive studies assessing the risks associated with water quality in Warri's public institutions. Many of these institutions rely on different water sources, including, boreholes, and packaged water, which vary in quality and safety (Etchie *et al.*, 2013). The absence of regular monitoring and risk assessment of water quality in these institutions poses potential health risks to the public. Furthermore, the relationship between water quality, sanitation facilities, and hygiene practices in these institutions and their impact on human health has not been thoroughly investigated. This gap in knowledge hinders the development of effective strategies to improve water safety and public health in Warri's public institutions.

There have been a number of studies carried out in Delta State to assess the water quality in the area however without a focus on Warri and her public institutions. Some of whch include the assessment of water quality of boreholes in Agbor Metropolis ((Oboh and Egun, 2017), shallow and deep boreholes in Ekpan (Ozoemenam, *et al.*, 2018), bottled water potability in Effurun (Ikpesu, *et al.*, 2021), combination of river, rain, well, borehole, and sachet water in Sapele (Edeki, *et al.*, 2023), different water sources in Okorenkoko, Delta State (Asionye *et al.*, 2023) among others.

Meanwhile, researchers like Akpoborie and Ehwarimo (2012) have earlier established some reservations on packaged drinking water quality in Warri Metropolis, hence a possible implication for public health. In fact, studies to date, such as that by Iloba *et al.*, (2021) on the water quality assessment in the Delta State using the weighted arithmetic WQI have continued to show that water sources in these areas are mostly below acceptable limits of quality. Thus, this study investigated the risks associated with water quality in public institutions in Warri, Delta State.

Materials and methods

Description of study area: The study was conducted in Warri South Local Government Area, one of the three local government areas that make up Warri, Delta State, Nigeria. Warri South is a bustling urban center known for its oil and gas industry. The region experiences a dry season from November to April, characterized by a dusty haze from the northeast winds, but even during the dry season, which runs from May to October with a brief dry spell in August, it still rains frequently. The climate is tropical monsoon with a mean annual temperature of 32.8 °C (91.0 °F) and 2,770 millimeters of rainfall (109 inches). High temperatures range from 28 °C (82 °F) to 32 °C (90 °F). The area is mostly rainforest with occasional swamplands, and is rich in fruit trees, palm trees, and lumber trees. The study locations encompassed five key public institutions: a school, hospital, hotel, church, and shopping mall. These diverse settings represent typical gathering points for the local population, offering a comprehensive view of public water and sanitation facilities.

Sampling: A total of five (5) bore hole water samples were sampled from a mall (BH1), School (BH2), Hotel (BH3), Church (BH4) and Hospital (BH5) within Warri metropolis in Delta State. The water collection process involved using a 2 L plastic containers and BOD bottles that had been treated beforehand by washing with and rinsed with distilled water. Prior to sample collection, the plastic containers were rinsed with the relevant water sample to be collected. Water samples were taken in replicates by direct filling of the container from the tap and allowing it to overflow.

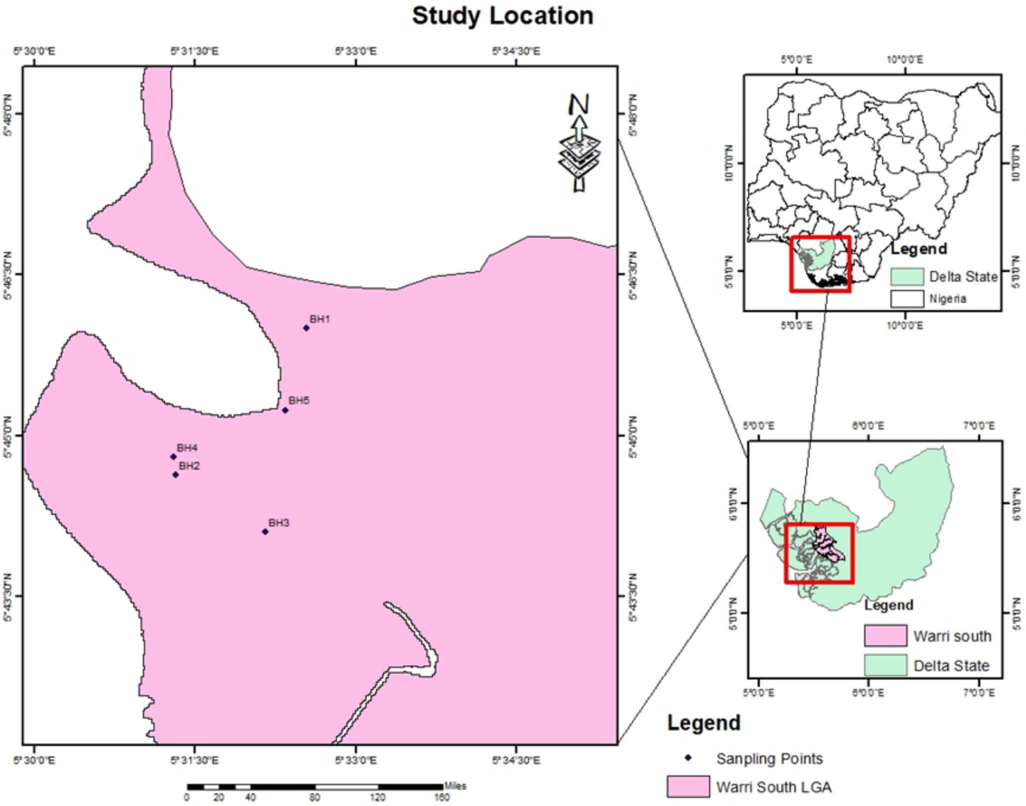

Figure 1: Map of study area

Analysis: On-site (in-situ) analysis was conducted for various water quality parameters, including pH, electrical conductivity (EC), dissolved oxygen, total dissolved solids (TDS), and temperature. All the samples were preserved by cooling at approximately 4°C. For metal analysis, the samples were preserved using 1 mL of nitric acid (HNO_3) to lower the pH to ≤2. The physicochemical properties (pH, electrical conductivity, turbidity, total suspended solids (TSS), chloride, nitrate, sulphate, alkalinity, salinity, total hardness, dissolved oxygen (DO), biochemical oxygen demand (BOD) and chemical oxygen demand (COD)) and metal levels (calcium, magnesium, sodium, potassium, cadmium, lead, chromium, copper, nickel, manganese, zinc and iron) of the water samples were determined in accordance with standard methods by APHA (2017).

Water Quality Assessment: The Water Quality Index (WQI) was calculated using the Weighted Arithmetic Index method, which is widely recognized for its effectiveness in assessing overall water quality (Tyagi et al., 2013). This method considers the relative importance of various water quality parameters by assigning them specific weights. Eight key water quality parameters were chosen based on their significance in determining water portability and their relevance to public health. In this study, the eight important parameters chosen include, Temperature, pH, TSS, BOD, DO, Sulphate, Fecal coliform, Total coliform. Each parameter was assigned a weight (Wi) based on its relative importance to overall water quality. Thereafter, for each parameter, qi was calculated using the formula:

$$qi = 100 * [(Va - Vi) / (Si - Vi)]$$

where: Va is the actual value found in the water sample, Vi is the ideal value (0 for all parameters except pH = 7.0 and DO = 14.6 mg/L), and Si is the standard permissible value for each parameter.
The Water Quality Index was then calculated using the formula:

$$WQI = \sum(Wi * qi) / \sum Wi$$

The resulting WQI values were interpreted using the following scale in Table 1.

Table 1: Water quality classification based on water quality index (WQI) values (Bora and Goswami, 2017)

Water quality Index value	Water quality Status
0-25	Excellent water quality
25-50	Good water quality
51-75	Moderate
76-100	Poor
>100	Very poor

Risk assessment: The risk assessment method used in this study is based on a risk matrix approach, adapted from the World Health Organization's Water Safety Plan Manual (WHO, 2023). The risk was obtained using the equation;
Risk level = Hazard severity x Likelihood of occurrence
Likelihood and severity are scored on a scale of 1-5, with risk levels categorized as: Low risk (1-4), Medium risk (5-9), High risk (10-14), Extreme risk (15-25).

Results

The results from this study are shown in Tables 2 to 4. The physicochemical properties of the water samples are presented in Table 2. The water quality index values are shown in Table 3 while the risk levels are presented in Table 4.
As shown in Table 2, the pH values of borehole water samples ranged from 5.1 to 6.63. The mall shows the most acidic water (pH 5.1). Most locations fall below the ideal pH range of 6.5-8.5 for drinking water, indicating a tendency towards acidity. This could potentially lead to corrosion issues in plumbing systems and may affect the water's taste and safety. Turbidity values ranged from 0.1 to 2.06 NTU. All samples were within the WHO guideline of <5 NTU, with the Church sample having the lowest turbidity (0.1 NTU) and the Mall sample the highest (2.06 NTU). These results indicate generally clear water across all locations. The TDS values ranged from 15 to 295 mg/L. Salinity ranged from 15 to 300 mg/L, and electrical conductivity from 30 to 599 µS/cm. The Mall sample consistently showed the highest values for these parameters, while the Hotel and School samples had the lowest. All samples were within acceptable limits for drinking water, indicating low mineral content.

Table 2: Physicochemical properties of water from the public institutions in Delta State

Parameters	**Study Location**								
	Mall	**Hotel**	**School**	**Hospital**	**Church**	**WHO (2011)**	**CCME (1999)**	**USEPA (1999)**	**SON (2007)**
pH	5.10	6.34	6.35	6.63	5.99	6.5-9.5	6.5-9.0	6.5-8.0	6.5-8.5
Temperature (°C)	27.5	27.3	29.9	27.0	27.9	35-40	-	-	-
Electric Conductivity, µS/cm	599	30.0	33.0	360	131	250	-	-	250
Total Dissolved Solids mg/L	295	15.0	17.0	80.0	150	500	500	500	500
Redox Potential, mV	303	146	176	63.0	191	-	-	-	-
Dissolved Oxygen (DO), mg/L	4.10	3.80	4.20	3.90	4.00	6.0	5.5-9.5	-	-
Salinity mg/L	300	15.0	16.0	188	65.0	-	-	-	-
Biological Oxygen Demand (BOD) mg/L	0.80	1.10	1.20	1.00	0.60	3.0	-	-	-
Turbidity, NTU	2.06	0.25	0.45	1.61	0.10	5.0	-	-	-
Total Suspended Solids (mg/L	0.20	0.60	0.10	0.10	0.30	5.0	-	-	-
Odour	Odourless	Odourless	Odourless	Odourless	Odourless	-	-	-	-
Total Hardness, mg/L	14.4	33.5	40.2	44.9	26.1	100	-	-	150
Alkalinity, mg/L	78.3	28.4	29.4	56.3	33.6	-	-	-	-
Inorganics (Anions & Cations)									
Nitrate (NO_3), mg/L	0.23	0.08	0.11	0.17	0.19	200	-	10	50
Sulphate (SO_4^{2-}), mg/L	0.16	0.10	0.10	0.12	0.13	200	500	-	100
Calcium (Ca^{2+}), mg/L	13.7	0.74	0.73	26.7	3.53	-	-	-	-
Magnesium (Mg^{2+}), mg/L	3.71	0.42	3.66	2.71	0.39	-	-	-	-
Potassium (K^+), mg/L	14.5	4.69	5.62	11.2	5.77	-	-	-	-
Sodium (Na^+), mg/L	7.72	1.58	1.56	7.19	6.47	-	-	-	-
Inorganics (Heavy metals)									
Zinc (Zn), mg/L	ND	ND	ND	ND	ND	5.0	0.03	0.12	3.0
Lead (Pb), mg/L	ND	ND	ND	ND	ND	0.01	0.017	0.003	0.01
Iron (Fe), mg/L	0.45	0.14	0.10	0.70	0.20	0.03	0.30	0.30	0.30
Cadmium (Cd), mg/L	ND	ND	ND	ND	ND	-	-	-	-
Chromium (Cr), mg/L	ND	ND	ND	ND	ND	0.05	0.05	0.10	0.05
Microbial Parameters									
Total Heterotrophic Fungi (THF), cfu/100mL	NIL	NIL	NIL	NIL	NIL				
Faecal Coliform, cfu/100mL	NIL	NIL	NIL	NIL	NIL				
Total Coliform Count	NIL	NIL	NIL	NIL	NIL				
E.Coli	NIL	NIL	NIL	NIL	NIL				

The BOD values ranged from 0.6 to 1.2 mg/L. DO values ranged from 3.8 to 4.2 mg/L, with a mean of 4 ± 0.16 mg/L. These values suggest relatively good water quality in terms of organic pollution and oxygen availability. Calcium concentrations varied widely, from 0.725 to 26.699 mg/L, with the Hospital sample having the highest concentration. Magnesium ranged from 0.388 to 3.707 mg/L, potassium from 4.687 to 14.538 mg/L, and sodium from 1.5568 to 7.723 mg/L. These variations indicate differences in mineral content across locations, possibly due to varying geological conditions. Sulphate concentrations ranged from 0.1 to 0.16 mg/L, while nitrate concentrations ranged from 0.08 to 0.23 mg/L. All values were well below the WHO guidelines, suggesting minimal risk of sulphate and nitrate contamination. The concentration of iron ranged from 0.099 to 0.703 mg/L. The sample from the hospital showed the highest concentration of iron, which was above the WHO guideline value of 0.3 mg/L. Other heavy metals such as zinc, lead, cadmium, and chromium were not detected in any of the samples.

The microbial parameters such as total heterotrophic fungi, fecal coliform, total coliform count, and E. coli were not detected in the water samples. This suggests effective water treatment or natural filtration processes, ensuring microbiological safety of the water.

Table 3: Result of water quality index of all sampling locations

Sampling Points	Water Quality Index Level	Water Quality Status
Mall	63.18	Medium water quality
Hotel	37.02	Good water quality
School	37.33	Good water quality
Hospital	30.11	Good water quality
Church	43.51	Good water quality

From Table 3, the water quality index values ranged from 30.11 for hospital to 63.18 for Mall. The WQI of all locations fall within the "Good water quality" range except for the mall which fall into the medium water quality. The hospital has the best water quality and the mall having the lowest water quality among the five locations.

Table 4: Risk assessment result for all the sampling locations

Location	Parameter	Value	Standard	Risk Score	Risk level
Mall	pH	5.1	6.5-8.5	15	Extreme
	Fe	0.447	<0.3	8	Medium
	DO	4.1	>5	6	Medium
	FC	0	0 cfu/100mL	1	Low
	TC	0	0 cfu/100mL	1	Low
Hotel	pH	6.34	6.5-8.5	4	Low
	Fe	0.140	<0.3	1	Low
	DO	3.8	>5	8	Medium
	FC	0	0 cfu/100mL	1	Low
	TC	0	0 cfu/100mL	1	Low
School	pH	6.35	6.5-8.5	4	Low
	Fe	0.099	<0.3	1	Low
	DO	4.2	>5	6	Medium
	FC	0	0 cfu/100mL	1	Low
	TC	0	0 cfu/100mL	1	Low
Hospital	pH	6.63	6.5-8.5	1	Low
	Fe	0.703	<0.3	15	Extreme
	DO	3.9	>5	8	Medium
	FC	0	0 cfu/100mL	1	Low
	TC	0	0 cfu/100mL	1	Low
Church	pH	5.99	6.5-8.5	6	Medium
	Fe	0.197	<0.3	2	Low
	DO	4.0	>5	6	Medium
	FC	0	0 cfu/100mL	1	Low
	TC	0	0 cfu/100mL	1	Low

where DO = Dissolved oxygen, FC= fecal coliform, TC= Total coliform

From Table 4, the mall's water supply shows significant concerns. The pH (5.1) is alarmingly low, posing an extreme risk to health and infrastructure. Iron levels (0.447 mg/L) exceed WHO standards, presenting a medium risk. Dissolved oxygen (4.1 mg/L) is below the recommended level, indicating a medium risk. The combination of these factors suggests potential corrosion issues, metallic taste, and possible microbial growth. Immediate pH correction and iron removal are critical, along with measures to improve dissolved oxygen levels. The water also showed that it is free from total and fecal coliform.

The hotel's water quality is generally good, with most parameters within acceptable ranges. The pH (6.34) is slightly below the ideal range but poses a low risk. Iron content (0.140 mg/L) is within safe limits. The main concern is the low dissolved oxygen (3.8 mg/L), presenting a medium risk that could affect water taste and potentially support microbial growth. While not critical, measures to improve aeration and slightly adjust pH would enhance overall water quality. The water also showed that it is free from total and fecal coliform.

Water quality at the school is relatively good, with most parameters within safe limits. The pH (6.35) is slightly low but poses only a low risk. Iron levels (0.099 mg/L) are well within standards. The primary concern is the dissolved oxygen level (4.2 mg/L), which presents a medium risk. Given the vulnerable population (children), implementing simple aeration methods to improve dissolved oxygen and minor pH adjustment would be beneficial to ensure optimal water quality. The water also showed that it is free from total and fecal coliform.

The hospital's water supply presents a mixed profile. While the pH (6.63) is within the ideal range, the iron content (0.703 mg/L) significantly exceeds WHO standards, posing an extreme risk. This is particularly concerning in a healthcare setting. Dissolved oxygen (3.9 mg/L) is also low, presenting a medium risk. Given the critical nature of water quality in hospitals, immediate implementation of an effective iron removal system is crucial, along with measures to improve dissolved oxygen levels. The water also showed that it is free from total and fecal coliform.

The church's water quality shows moderate concerns. The pH (5.99) is below the recommended range, posing a medium risk. Iron levels (0.197 mg/L) are within acceptable limits. As with other locations, dissolved oxygen (4.0 mg/L) is below recommended levels, presenting a medium risk. While not as critical as the mall or hospital, measures should be taken to adjust pH and improve dissolved oxygen levels to ensure safe and palatable water for the congregation. The water also showed that it is free from total and fecal coliform.

Discussion

Physicochemical and microbiological parameters of water samples: pH is defined as the acidity or alkalinity of water is considered one of the most imperative water quality variables. In all the studied locations, pH for the borehole water samples ranged between 5.1 and 6.63 indicating that most samples were slightly below the WHO-recommended pH range of 6.5-8.5 for drinking water. The lowest pH recorded was 5.1 from the mall; this is very alarming. This agrees with the findings of Asadu (2013) in Agbarho, Delta State whose pH values were below the WHO optimum limits of between 6.5 and 8.5. It also corroborates with the findings of Edeki *et al.* (2023) whose pH values showed that the different sources, both surface and groundwater, were acidic. The same result agrees with the findings of Ikpesu *et al.* (2021) for bottled water from Effurun. Though pH has no direct effect on human, all the biochemical reactions are pH dependent (Agbaire *et al.,* 2014). However, according to Skalsky *et al.* (2018), acidic water can have several negative impacts on both human health and infrastructure. Long-term consumption of such acidic water may cause gastrointestinal disorders and, in the future, may act to enhance dental erosion risks. It can also lead to corrosion in plumbing systems that sometimes leaches out metals like lead and copper into the water supply. Even though these bore holes were not made for drinking water, students in some schools possibly drink it. This poses a great public health risk, especially in institutions serving vulnerable populations, such as schools and hospitals. Indeed, the incidence of acidic water in such randomly selected public institutions could suggest that the problem may be widespread in the area surrounding Warri, where a large portion of the population could therefore be exposed to the health risks associated with acidic water, should residential water sources have similar characteristics. More importantly, structural damages to infrastructure may increase maintenance costs, both in public and privately-owned buildings-a factor that will contribute indirectly to negative cascading effects on the local economy.

The dissolved oxygen levels in all the water samples analyzed ranged between 3.8 and 4.2 mg/L. These values are below the minimum recommendation of 5 mg/L for drinking water as recommended by the WHO (2017). Low levels of DO can impair water quality in several ways. It promotes the growth of anaerobic bacteria that can give objectionable tastes and odors to water. More importantly, low DO increases the solubility of certain metals, possibly elevating their concentration in water. This consistency of low DO levels in all stations analyzed would show a problem likely to be more pervasive than in these specific institutions and extending into the Warri community as a whole. This could be the general trend of water quality issues, including drinking water, and even in the aquatic systems if surface waters are equally affected.

Results of the study revealed detectable levels of iron in all samples of water analyzed, which were within the range of 0.099 to 0.703 mg/L. The sample from the hospital showed the highest concentration of iron, which was above the WHO guideline value of 0.3 mg/L. This is contrary to the finding of Asadu (2016), whose concentration content of the water samples are <0.001 mg/L and fall within the WHO standard. Notably, other heavy metals such as zinc, lead, cadmium, and chromium were not detected in any of the samples. Though iron is an essential constituent in human health, it is undesirable in large amounts because of the aesthetic issues such as metallic taste, discoloration of water, and staining of laundry and plumbing fixtures. The high content of iron has been reported to encourage the growth of some bacteria (Chaturvedi and Dave, 2012) at the expense of water quality in some instances. High level of iron is not satisfactory, especially in the hospital water supply. It reflects the tendency that iron contamination could be more widespread in local groundwater, and it may spill over to residential areas. Probably this may reflect increased water treatment costs for both public institutions and individual homes.

The water samples turned out nil surprisingly for total heterotrophic fungi, fecal coliform, total coliform count, and E. coli. These results therefore suggest that the methods of water treatment or natural filtration processes involved are effective in eliminating microbial contaminants. This is in disagreement with Asadu (2016), who insisted that the presence of coliform bacteria in water suggests the water has been contaminated with the fecal material of man or other animals. It also does not agree with the findings of Oloruntoba and Olannye (2019), whose microbiology result showed positive for their drinking water but the findings of Ikpesu *et al.* (2021) agrees with the findings of this studies in that the coliform bacteriological count of the samples complied with WHO standard 0cfu/100ml. These findings, however, stand as positive findings, which show that the water is safe enough microbiologically for drinking. That microbial contaminations were not present in these public institutions was encouraging; it suggested that in general, water treatment practices within the area were effective. This is positive for public health in that it minimizes the hazard for waterborne diseases.

Water quality index (WQI) characterization: The Water Quality Index results ranged within the "Good and moderate water quality" category for all sampled locations, with the best water quality found at the hospital, WQI: 30.11, and the worst among the five sampled locations being the Mall with a WQI: 63.18. This consistent "Good water quality" rating across most of the locations is indeed encouraging and postulates that the water is generally safe for consumption and domestic use. This is comparable with borehole water as observed by Etim *et al.* (2013) whose index result gave 38.52 to 48.67. The results indicate that the different water samples analyzed from pipe borne and borehole water are safe for human consumption and other domestic purposes. The good water quality in these public institutions could be representative of the general outlook of water management in the Warri environment. This contributes to the public health through a reduction in the levels of waterborne diseases, thereby improving general well-being (Shayo *et al.*, 2023).

Risk assessment matrix for water: The Risk Assessment Matrix used here has been an important tool to assess any health risks associated with the water quality in the locations sampled in Warri, Delta State. It also presented a range of different parameters at different locations, drawing into focus both areas of immediate concern and those needing continued monitoring.

Significantly enough, two parameters were classified as "Extreme" risk, namely pH at the Mall location that is 5.1 and iron concentration at the hospital, which is 0.703 mg/L. Low pH has the tendency to leach metals from plumbing systems, especially toxic materials, into the water supply (Nguyen *et al.,* 2011). High levels of iron concentration, while normally not harmful, may promote bacterial growth and interfere with medical procedures (Sharma *et al.*, 2005). This is also attributed to the fact that the levels of dissolved oxygen had consistently been categorized as medium risk across all locations, hence a systemic problem that calls for attention at the water source or treatment level (Patel and Vashi, 2015). Moreover, absence of fecal and total coliform bacteria across all locations serves as an indication of good news, which depicts upon effective treatment or protection of water sources from fecal contamination. On the other hand, this parameter needs much vigilance with frequent testing, since microbial contamination may happen at any time and at a high rate, with serious consequences for human health (WHO, 2017). Variations in risk from one location to another and among the parameters mentioned stress that the situation regarding water quality management is not so easy within an urban setting and that proper interventions and follow-up monitoring will be needed for public health protection (WHO, 2023). Moreover, this approach to risk assessment provides the most useful information for prioritizing resources and targeting interventions that are better directed to improve the most critical water quality issues, hence contributing to more efficient management of waters and to improving the public health profile in the community.

Conclusion

The present study has evaluated the risks associated with water quality in public institutions in Warri, Delta State. While the overall water quality index indicates good to medium water quality across the locations assessed, the specific parameter levels of pH, iron content, and dissolved oxygen levels set out different levels of risks that demand attention. The risk assessment matrix is used to show targeted interventions, especially for mitigating extreme risks like low pH at the mall and high iron content at the hospital. Such scenarios could potentially have wide ramifications on public health and structural integrity if not mitigated properly. The outcome of this work has wider ramifications on the Warri community. These could be symptomatic of wider problems in the local water supply chain, thus underlining comprehensive strategies in water quality monitoring and management at the community level. This journey of optimum water quality is, of course, continuous and requires sustained effort, investment, and collaboration across different cadres of stakeholders. Taking a cue from the needs around water quality status, Warri should act as an example for other fast-growing urban centers facing similar challenges and support reduced disease burdens, continued sustainable development in the region.

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