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Assessing the Impact of Petrol Service Stations on Selected Physico-Chemical Water Quality Parameters within Port Harcourt Metropolis, Nigeria

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Abstract

This study assessed the impact of petrol service stations on physico-chemical water quality in Port Harcourt metropolis, Rivers State. This threw light on the extent of damage and alteration of water quality in Port Harcourt metropolis as a result of the proliferation of petrol service stations especially the condition of ground and nearby surface water. This serves as a useful tool to government and regulatory authorities for planning especially due to lack of central water supply system in Port Harcourt metropolis. The parameters studied were sampled, measured and analyzed using *in situ* and other standard methods. Remarkable results above permissible limits of interest for physicochemical parameter analysis revealed pH values from 4.6 to 6.8, electrical conductivity from 0.002 µS/cm to 0.42 µS/cm, salinity from 3 ppm to 4050 ppm, and temperatures from 19.9˚C to 32.6˚C. Total dissolved solids (TDS) varied from 7 ppm to 1000 ppm, biochemical oxygen demand (BOD) from 0.167 mg/L to 2.167 mg/L, chemical oxygen demand (COD) from 0.257 mg/L to 3.253 mg/L, and dissolved oxygen (DO) concentrations from 1.70 mg/L to 4.30 mg/L. Specifically, water samples from NNPC Filling Station (Choba) and Eneka Pond displayed "Poor" water quality with WQI values of 112.003 and 112.076, respectively. Similarly, ALLTEC Filling Station (Eneka) and TOTAL Filling Station (Rumuomasi) had "Poor" water quality with WQI values of 173.707 and 180.946, respectively. In contrast, Excelsis Filling Station (Akpajo) demonstrated "Good" water quality with a WQI of 85.2072, while Total Filling Stations (Slaughter) and Choba River revealed "unsuitable for drinking" water

quality with WQI values of 552.461 and 654.601, respectively. Slaughter River also indicated very poor water quality with a WQI of 442.024. The physico-chemical and nutrient analyses of the water samples showed that activities of the filling stations within the study area may have polluted groundwater in the environment posing poor aesthetics and great health risk to consumers of the water bodies. The findings underscore the need for immediate remediation efforts and stricter regulatory measures to protect water quality. The study concluded that surface and groundwater near petrol service stations in Port Harcourt are unfit for drinking and irrigation purposes without adequate treatment.

Keywords

Water Quality Index, Petrol Service Stations, Contamination, Environmental Impact Assessment, Eneka, Drilling Points

1. Introduction

Water is one of the most vital natural resources. Virtually all plants and animals must have water to survive. Apart from drinking to survive, people have many other uses for water. They include cooking, bathing, washing of clothes, utensils and equipment recreation. Record has it that 2/3 of the earth crust is dominated with water (WHO, 2017). Water is the basic element that powers the geo-chemical processes and supports all forms of life (Rani et al., 2021). Water is also essential for the healthy growth of farm crops and farm livestock, as well as habitat for numerous aquatic lives, and is used in the manufacture of many products (Srivastava, 2020). Water is becoming increasingly a scarce resource in many parts of the world. The major reason for this is anthropogenic activities that have despoiled and contaminated the various sources of water. In addition to water scarcity, the problem of access to safe water supplies and sanitation is also intensifying. The World Health Organization (WHO, 2017) estimates that close to 6 million people die yearly from diseases caused by unsafe drinking water and lack of water for sanitation and hygiene (Srivastava, 2020).

The ground water is the central focus of this research since it is the major source of drinking water. The ground water is largely vulnerable to contamination and when the ground water is polluted, it is almost impossible to clean it up (Moeck et al., 2018). Surface Water Pollution entails the pollution of water bodies displayed on the earth surface which is easily assessed by man in form of rivers, lakes, oceans, *etc.* In some situations, contaminants may flow down and percolate into groundwater hence cause pollution. The various sources of ground water and surface pollution via the establishment of petrol service stations include but not restricted to fuel underground storage tank leaks, storm water run-offs, discharging operations and equipment failure, high level of urbanization, increase in population, and industrialization (Sarker et al., 2021). In another study by Iyama et al.

(2020), conducted a study aimed at assessing the pollution load of Woji Creek River Water in Port Harcourt, Nigeria, using eight key water quality parameters including DO, COD and BOD using three study stations. Anthropogenic factors such as leakages from fuel storage facilities contribute to the release of petroleum hydrocarbons into groundwater (Fei-Baffoe et al., 2024). Petrol service stations built around residential houses can have impact on water quality through oil and petrol spills, stormwater run-off, wastewater generation, soil contamination. Nutrient and physicochemical parameters of interest which could be affected by petrol service stations include nitrogen, phosphorus, ammonia, total organic carbon, pH, conductivity, turbidity, total dissolved solids, total suspended solids, hydrocarbons, biochemical oxygen demand (BOD), chemical oxygen demand (COD), heavy metals, surfactants and detergents due to various service activities in the locality (Andeng, 2013; Ngala et al., 2022; Odipe et al., 2020). A petrol station is not the best for the planet as it contributes to excess greenhouse gas emissions, air and water pollution, and could cause land degradation and destruction in order to build gas stations themselves.

Urbanization is the major cause of the springing up of petrol stations in Port Harcourt. The petrol service stations also deal on other products aside the popular PMS (Premium Motor Spirit) that can also alter the ground water surface water quality in Port Harcourt metropolis. These products include; kerosene brake fluids, diesel, power oils, etc. The proper handling of these products is of environmental importance. If they are not properly handled or disposed, these pollutants will leach into the ground and surface water and despoil them. The setting up of petrol service stations within residential areas was majorly caused by unchecked, uncontrolled, and rapid sprawl of built-up areas. Petrol service stations are supposed to be located in designated areas, but unchecked urbanization in Port Harcourt has resulted in the haphazard setting up of petrol service stations in Port Harcourt metropolis. The setting up of petrol stations should be at least 100 meters away from residential settlements, but this not taken seriously in Port Harcourt metropolis (Ochia, 2022). This study looks at the analysis of parameters such as pH, DO, COD, BOD, and some nutrient parameters. Surface and ground water resources in urban areas are at risk of contamination from many human activities such as oil spills due to improper location of fuel filling stations in developing nations like Nigeria (Ngala et al., 2022).

Therefore, the aim of this study is to assess the impacts of petrol service stations on some selected physico-chemical water quality parameters within Port Harcourt Metropolis.

2. Methodology

2.1. Study Area

Port Harcourt metropolis covers an area of approximately 1960 square kilometers (190,000 hectares of land as shown in **Figure 1** and locations in **Table 1**. The metropolis is chiefly, Port Harcourt and Obio/Akpor local Government Areas

(Naluba & Igwe, 2022). The study was carried on designated petrol filling stations in Port Harcourt metropolis, Rivers State Nigeria. Port Harcourt metropolis is located latitude 4˚51'30"N and longitude 6˚50'00" and 7˚00'00"E Rivers State.

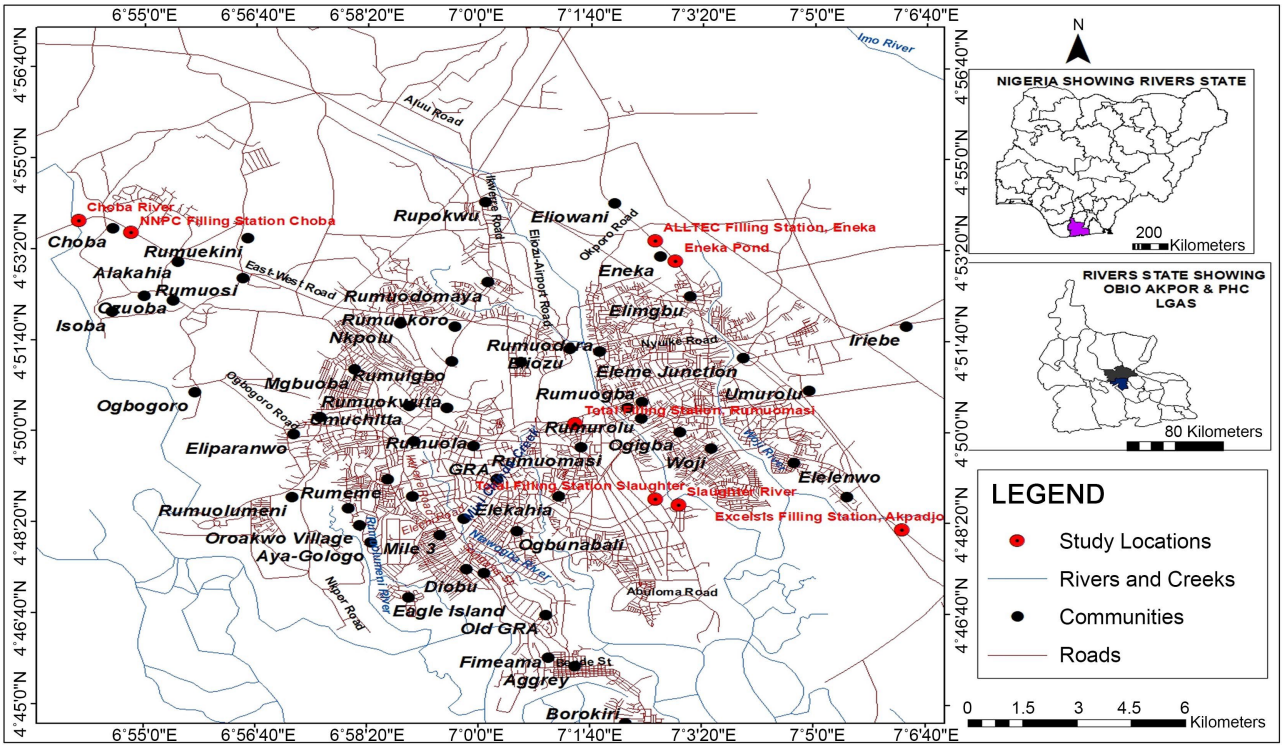

Figure 1. Port harcourt metropolis showing the sampling station. (Source: Researcher's generated, 2024).

Table 1. Sampling stations, their locations and coordinates.

Station	Location	Coordinate
Station 1	NNPC Filling Station, Choba	4.8938922˚N, 6.9134196˚E
Station 2	Total Filling Stations, Slaughter	4.8129948˚N, 7.0439546˚E
Station 3	Eneka Pond	4.8921247˚N, 7.0438534˚E
Station 4	ALLTEC Filling Station, Eneka	4.8917452˚N, 7.0437015˚E
Station 5	Choba River	4.8975330˚N, 6.9003250˚E
Station 6	Excelsis Filling Station, Akpajo	4.823920˚N, 67.085826˚E
Station 7	Slaughter River	4.8118546˚N, 7.0473885˚E
Station 8	TOTAL Filling Station, Rumuomasi	4.8358979˚N, 7.0239474˚E

2.2. Research Design

The research work commenced after interfacing with the owners of the petrol filling stations and residents around the filling stations. The research was conducted using a pure experimental research design with physical observation. The standard methods for water analysis were adopted (APHA, 2012) for field and laboratory investigation. The water samples were collected in boreholes in the filling

station and also from boreholes in residents around the petrol service stations, samples were also collected from drains around the filling station. The samples were also tested for gross organic pollutant, Biochemical oxygen demand (BOD) and Chemical oxygen demand (COD). Chemical parameters such as temperature, salinity, pH, TDS, DO were analyzed *in situ* while the nutrient parameters were taken to the laboratory for analysis using dark bottles following standard methods. The Extech *in situ* equipment for the measurement of variable parameters was used for the pH, DO and salinity.

1) Determination of Chloride

The Silver-Nitrate method of APHA (2002) was used. Twenty-four (24) millimeter of the sample was measured into 100 ml conical flask. Two drops of potassium dichromate were added and then titrated with silver nitrate until the appearance of a brick red colour which is the end point. The titre volume was recorded using Equation (1).

$$\text{Amount of chloride}\left(\text{mg/l}\right)=\frac{\text{Titre}\left(\text{ml}\right)\times 100}{\text{Volume of sample}\left(\text{ml}\right)} \tag{1}$$

2) Determination of Total Dissolved Solids (TDS)

The gravimetric method as described by APHA (2012) was used. The evaporating dish was heated first at 200˚C in the oven for 1 hour. It was subsequently cooled to room temperature, weighed and stored in a desiccator. Fifteen millimeters of the sample were filtered using a Whatman No 1 filter paper and transferred to the pre-weighed dish and then evaporated to dryness in the ovens and dried for 1 hour at 105˚C. The dish was subsequently cooled to room temperature in a desiccator and weighed. The level of Total Dissolved Solids (TDS) was calculated as shown in Equation (2).

$$\text{TDS}\left(\text{mg/l}\right)=\frac{\left(A-B\right)\times 100}{\text{Sample Volume}} \tag{2}$$

where:

A = Weight of sample + dish in mg B = Weight

3) Gross Organic Pollutants

a) Chemical Oxygen Demand (COD)

Homogenize the sample, if necessary. Pipette out a 20 ml sample or suitable aliquot of the sample and dilute it to 20 ml with DM water in 250 ml round bottom flasks (Place boiling chips). Carry out blank simultaneously using 20 ml of DM Water in place of Sample. Add about 0.2 gm of powdered HgSO; slowly add 5 ml of cone. H_2SO_4 reagent with cooling of flask. Mix well, to dissolve $HgSO_4$. Add 10 ml 0.25 N standard $K_2Cr_2O_7$ Solution by means of pipette. Slowly add 25 ml of sulphuric acid-silver sulphate solution. Cool during mixing to avoid possible loss of volatile matters. Wipe out the flask from outer side. Attach the flask to the condenser and start circulation of water through condenser. Reflux the solution in flask for 2.0 hours ± 10.0 min. cools the flask to room temperature; wash the condenser with 10 ml of DM water. Make the contents of the flask nearly to 100 ml.

with DM water. Add 8 - 10 drops of Ferroin indicator. Titrate excess of dichromate against 0.10 N Fenous Ammonium Sulphate. Colour change at the end will be sharp changing from blue-green to a reddish brown. Note down the burette reading of test sample in ml. as A and burette reading of blank reagent in mls as *B*.

Calculation:

Calculate the COD in sample in mg/1 as in Equation (3).

$$\text{COD mg/liter} = \frac{(B-A)\times N\times 8000}{\text{Vol. of sample taken in ml}} \tag{3}$$

where;

B = ml of Ferrous Ammonium sulfate solution required for Blank.

A = ml of Ferrous Ammonium sulfate solution required for sample.

N = Normality of Ferrous Ammonium sulphate.

b) Dissolve Oxygen (DO)

Dissolve Oxygen (DOI) was determine using the Winkler's titrimetry, which was also repeated on same sample after being left for five days in the dark as to obtain another Dissolved Oxygen (DOS).

DO was analyzed using the Winkler Methods (APHA, 1998). Fill a 70 ml BOD bottle with 0.5 ml of manganoussulphate solution (Winkler I) and 0.5 ml alkali-iodide-azide reagent (Winkler II). This was stoppered to exclude air bubbles and mixed by several inversions. This is followed by the addition of 0.5 rnl concentrated H_2SO_4 after about 5 - 10 minutes, re-stoppered and mixed for complete dissolution of precipitate.

c) Biological Oxygen Demand (BOD)

Biochemical Oxygen Demand (BOD5) was determined after incubation of the surface water for days at 20˚C. BOD tests are generally carried out by measuring the amount of dissolved oxygen present in the sample before and after incubation in the dark for 5 days at 20˚C. The Azide Modification method as described by APHA (2002) was used.

Phosphate buffer solution, Magnesium sulphate solution, Calcium chloride solution and Ferric chloride solution were prepared as the dilution water. The water sample was diluted by 2%. Into the 125 ml BOD bottles, 100 ml of the 2% diluted samples were placed using a 50 ml long tipped Pipette. Extra 25 m1 of the diluted sample was added to the bottle to bring it to the brim. The stoppers were inserted leaving no air bubble in the boule. An initial determination of the DO was made before dilution from one of the duplicate bottles was done. The samples were then incubated including a blank for 5 days at 20˚C on the 5th day; the DO was measured in the incubated samples and the blank also and BOD calculated using Equation (4).

$$\text{BOD}(\text{mg/I}) = \frac{\text{DO}_0 - \text{DO}_d}{\%\text{ dilution}} \tag{4}$$

where:

DO_0 = DO of the sample immediately after saturation with air (initial DO)

DO_d = DO of the sample after 5 days incubation (final DO).

Turbidity was carried out using clean the sample cell with DM water. Rinse and fill with sample and wipe with tissue paper. Place the sample cell in to sample holder and cover the cell. After few seconds note down the reading from the display. Total Dissolved Solids (TDS) was determined by setting up method 7 on the instrument and filling the bottle with 25 ml of DM water while press zero. Fill the bottle with 25 ml of sample & press read. The result will be displayed.

Phosphate was determined by the Stannous Chloride Method (APHA, 1992). To 50 ml sample, 2.0 ml ammonium molybdate reagent and 0.2 ml stannous chloride reagent and mixed properly. After adding the stannous chloride (after about 10 - 12 minutes), the absorption of the treated sample is read off on spectronic 21 D at 690 nm. Finally, phosphate level is obtained by reading off the absorption level from standard curve using 0.05 mg/l detection limit.

Sulphate was determined using the turbidimetric method (APHA, 1995). To a 50 ml sample or portion diluted to 50 ml contained in a conical flask, 2.5 ml of conditioning reagent (a mixture of 50 ml glycerol with a solution of 30 ml concentrated HCI, 300 ml distilled water, 100 ml 95% ethanol and 75 g sodium chloride) and a quarter spatula full barium chloride ($BaCl_2$). The mixture was swirled for a minute and the barium sulphate ($BaSO_4$) turbidity read off at the 5th minute on the Spectronic 21D at 420 nm against water. Sulphate level was read from a calibration curve prepared for sulphate standards_ treated the same way as the samples using 1.0 mg/l detection limit.

2.3. Data Analysis

The sampling points were designated SP1-SP7 representing the seven water sources including the ground water and surface water. Data obtained from the study was compared with that of National Standard of Drinking Water Quality (NSDWQ, 2015), Standard Organization of Nigeria (SON, 2007) and World Health Organization (WHO, 2017) to ascertain the water quality for consumption and the results correlated with the soil profile vulnerability. The data obtained from the sampling would be used to determine the water quality of the boreholes and compared to the water quality index (WQI) that is the overall quality of water for drinking purposes. Statistical tools such as mean, standard deviations and variance were used to analyze the data obtained to ascertain how representative and close the data obtained were. Bar charts and multiple bar charts were used for illustration while correlation coefficient used to highlight relationship between parameters.

The quality and suitability of the water sources for drinking and domestic purposes was determined by comparing laboratory results with the World Health Organization (WHO, 2017) maximum permissible limits. Furthermore, the Water Quality Index (WQI) for all the samples was then calculated. This was done to get a comprehensive summary of the quality status of the water samples (Mgbenu & Egbueri, 2019). The water classification and hydrogeochemical properties was

analyzed according to Durov diagram and Piper (1944) trilinear diagram. The sample cuttings were also physically examined and weighed, and sieve analysis was conducted to ascertain the material characteristics of the formation.

2.4. Water Quality Index

A Water Quality Index is a means to summarize large amounts of water quantity data into simple terms (e.g. good) for reporting to management and the public in a consistent manner. It is similar to the Ultraviolet (UV) index or an Air Quality Index. It gives an idea of the overall quality of a water source, it is potential threat to various uses - habitat for aquatic life, irrigation for agriculture and livestock, recreation and aesthetics, and drinking water supplies (Fernández del Castillo et al., 2022; Tyagi et al., 2013). The WQI is computed in four steps, calculated using the following Equations (5)-(8) adopted from Sener (2017) in previous research study.

Assign a weight (W_1) to each parameter according to its importance in drinking water purposes:

Step 1: Compute the Relative Weight (W_i) for each parameter using Equation (5).

$$W_1 = \frac{w_i}{\sum_{i=1}^{n} w_i} \tag{5}$$

Step 2: Assign a quality rating scale (q_i) for each parameter by dividing its determined concentration (C_i) in each sample by its respective guideline value (S_i); multiplied by 100 (Equation (6))

$$Q_i = \left(\frac{C_i}{S_i}\right) \times 100 \tag{6}$$

Step 3: Determine the index (SI_i) for each parameter using Equation (7)

$$SI_i = W_i \times q_i \tag{7}$$

Step 4: Sum all sub-indices to get the WQI

$$\mathrm{WQI} = \sum_{i=1}^{n} SI_i \tag{8}$$

"where SI_i represents the sub-index of the ith indicator, W_i is the relative weight, q_i represents the quality rating for each chemical indicator, W_i is the weight of each element". The WQI classifies the water quality as Excellent (WQI < 50), Good (WQI = 50 - 100). Poor (WQI = 100 - 200), Very Poor (WQI = 200 - 300) and Unsuitable for Drinking (WQI > 300)" (Zohud et al., 2023).

3. Results and Discussion

3.1. Results

The results obtained from the analysis of water sampled collected from 8 sampling stations are presented below in **Table 2** and the correlational analysis is displayed in **Table 3**. The spatial distributions of parameters pH, EC, salinity, temperature, TDS, BOD, COD and DO are also shown in **Figures 2-9** respectively.

Table 2. Physicochemical parameter of water samples.

Parameters	NNPC Filling Station, Choba	Total Filling Stations, Slaughter	Eneka Pond	ALLTEC Filling Station, Eneka	Choba River	Excelsis Filling Station, Akpajo	Slaughter River	TOTAL Filling Station, Rumuomasi	WHO/ NSDWQ Limits mean
pH	5	4.7	6.8	4.6	5.7	4.7	6.2	6.1	6.5 - 8.5 5.5
Electrical Conductivity (uS/c)	0.01	0.07	0.08	0.05	0.42	0.01	0.002	0.01	1000 0.08
Salinity (ppm)	3	45	26	6	160	3	4050	6.5	100 537
Temperature (˚C)	19.9	21.8	22.3	21	32.6	20.6	28.9	20.7	30 23.5
TDS (ppm)	7	56	70	40	301	8	1000	11	500 187
BOD (mg/L)	0.334	0.583	1.543	0.417	1.583	0.754	2.167	0.167	5 0.944
COD (mg/L)	0.570	0.875	2.313	0.625	2.375	1.125	3.253	0.257	5 1.424
DO (mg/L)	1.96	2.50	3.89	2.10	4.10	1.70	4.30	2.01	5 2.89

Table 3. Correlation analysis of physicochemical parameters.

	pH	*Electrical Conductivity (uS/c)*	*Salinity (ppm)*	*Temperature (˚C)*	*TDS (ppm)*	*BOD (mg/L)*	*COD (mg/L)*	*DO (mg/L)*
pH	1.000							
EC (uS/cm)	0.119	1.000						
Salinity (ppm)	0.356	−0.193	1.000					
Temperature (˚C)	0.369	0.748	0.503	1.000				
TDS (ppm)	0.400	0.055	0.969	0.700	1.000			
BOD (mg/L)	0.591	0.354	0.700	0.785	0.806	1.000		
COD (mg/L)	0.592	0.352	0.703	0.784	0.808	1.000	1.000	
DO (mg/L)	0.695	0.507	0.574	0.829	0.718	0.931	0.932	1.000

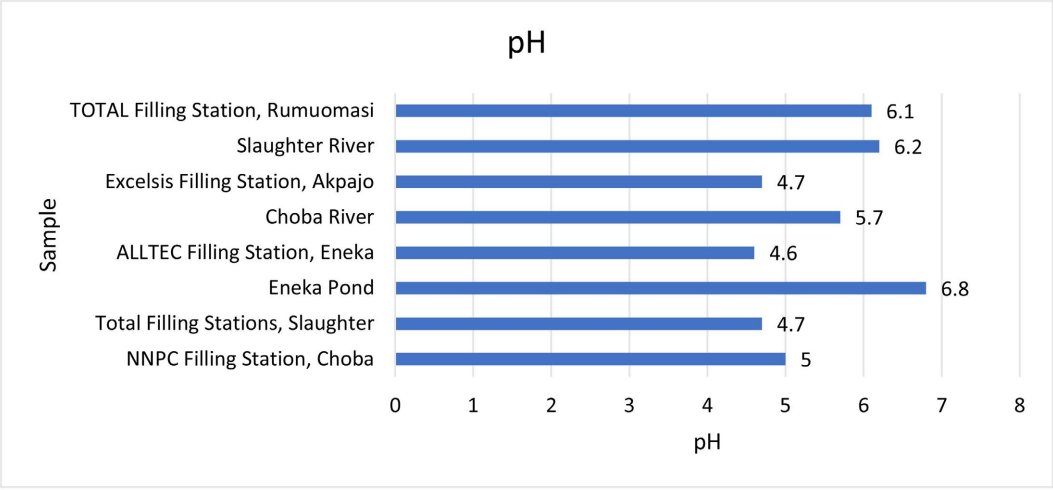

Figure 2. Spatial distribution of pH in water samples.

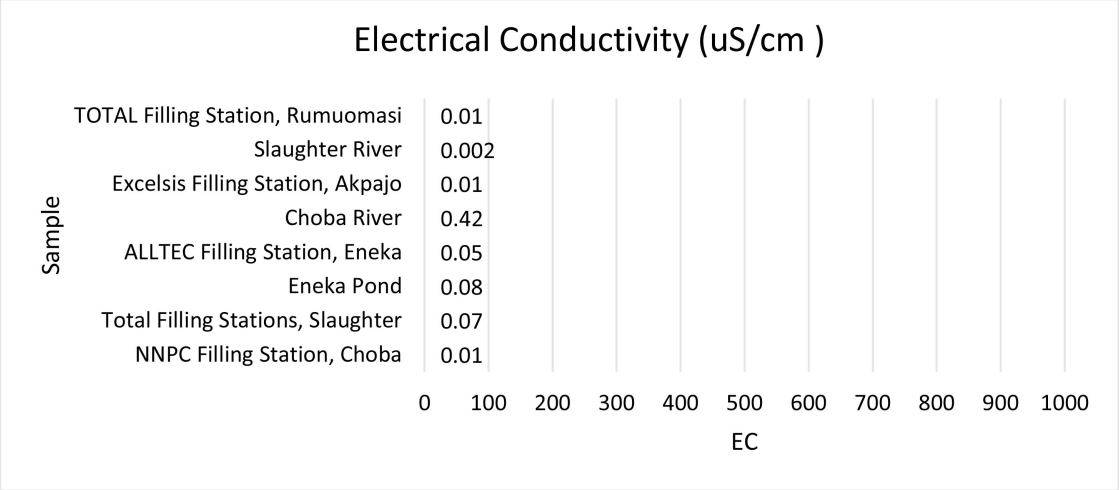

Figure 3. Spatial distribution of electrical conductivity in water samples.

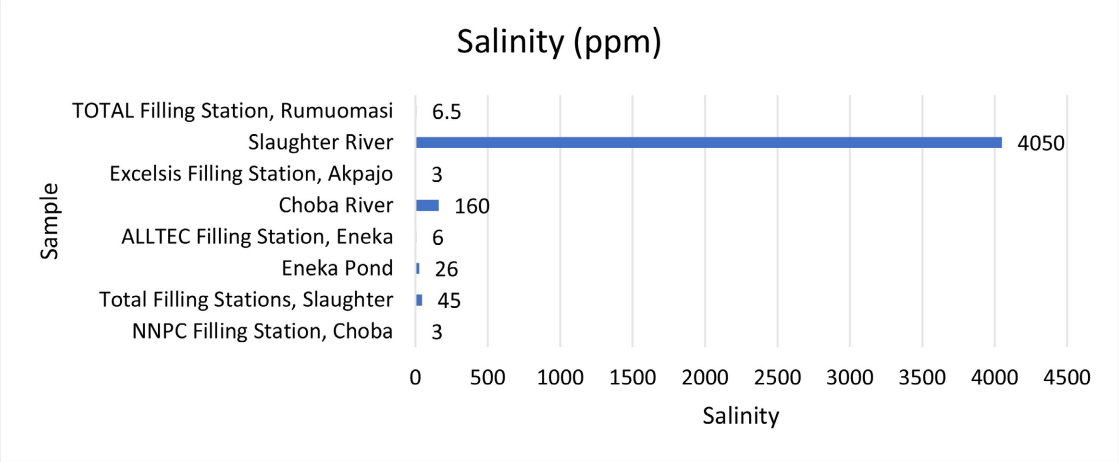

Figure 4. Spatial distribution of salinity in water samples.

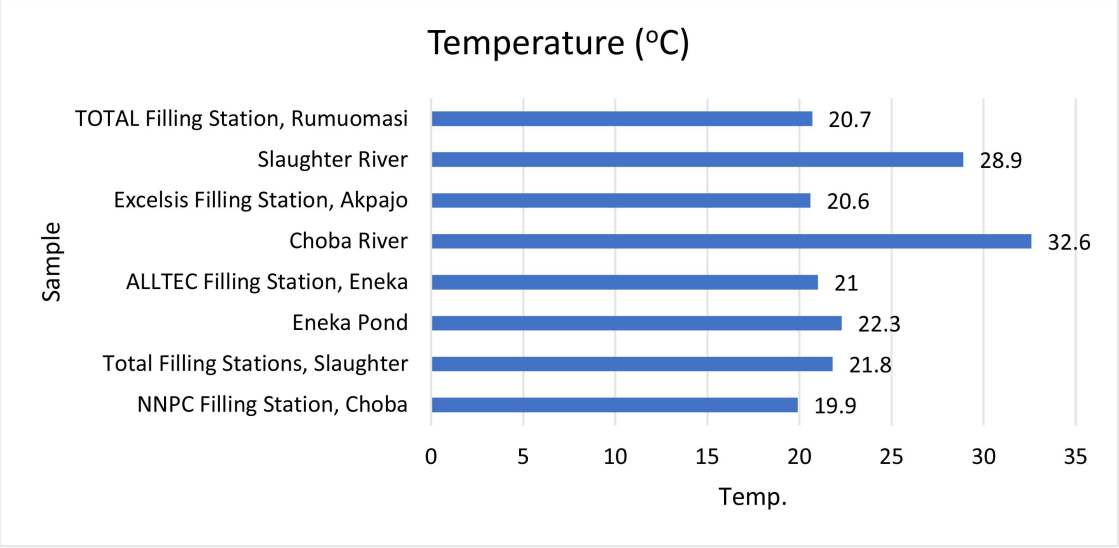

Figure 5. Spatial distribution of temperature in water samples.

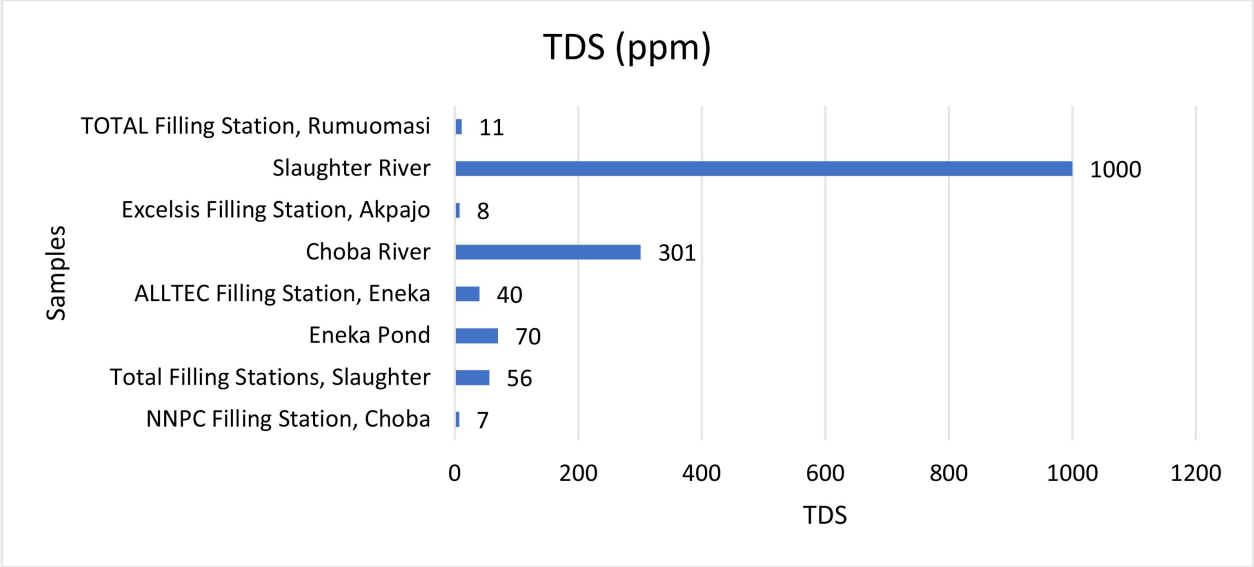

Figure 6. Spatial distribution of TDS in water samples.

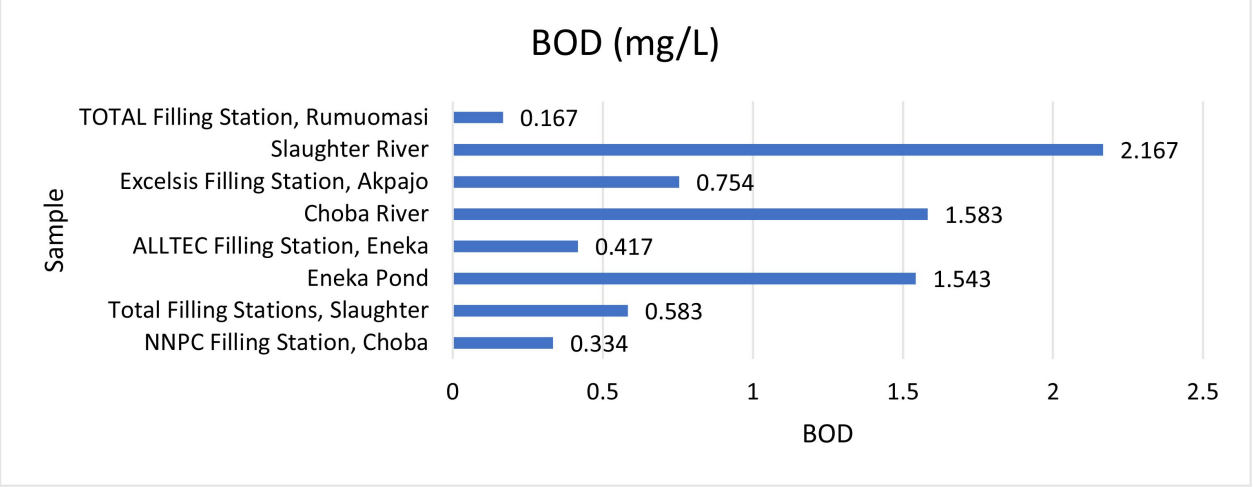

Figure 7. Spatial distribution of Biochemical Oxygen Demand (BOD) in water samples.

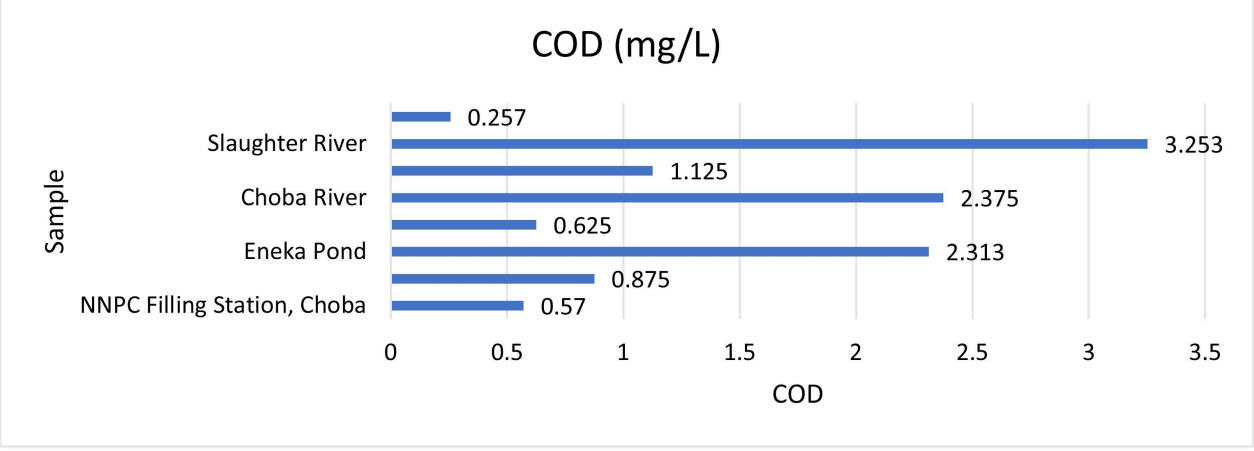

Figure 8. Spatial distribution of Chemical Oxygen Demand (COD) in water samples.

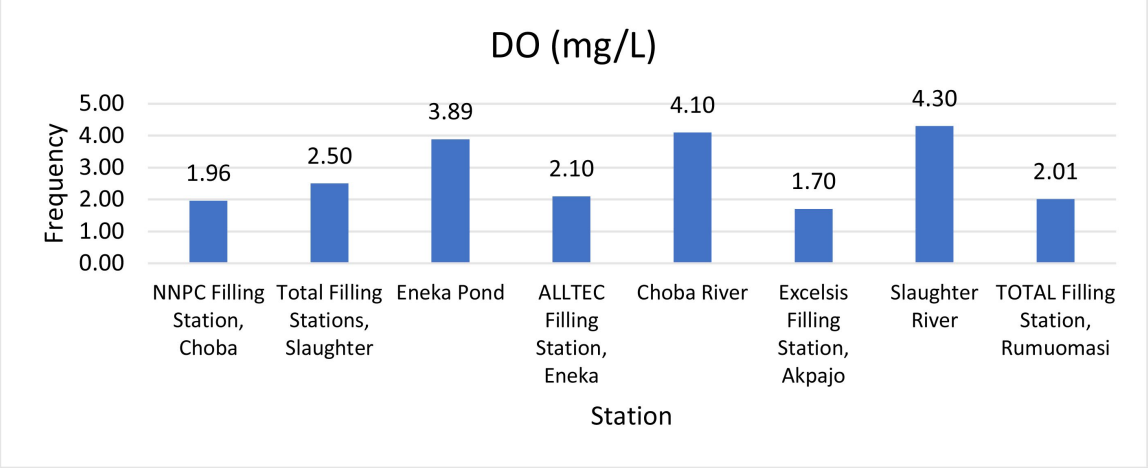

Figure 9. Spatial distribution of Dissolved Oxygen (DO) in water samples.

Figures 2-9 show the spatial distributions of pH, EC, salinity, temperature, TDS, BOD, COD, DO while Figure 10 is the Spatial Distribution of Water Quality Indices of Sampled Stations. The nutrient analysis of samples is shown in Table 4 while Figure 10 depicts the water quality analysis for the samples.

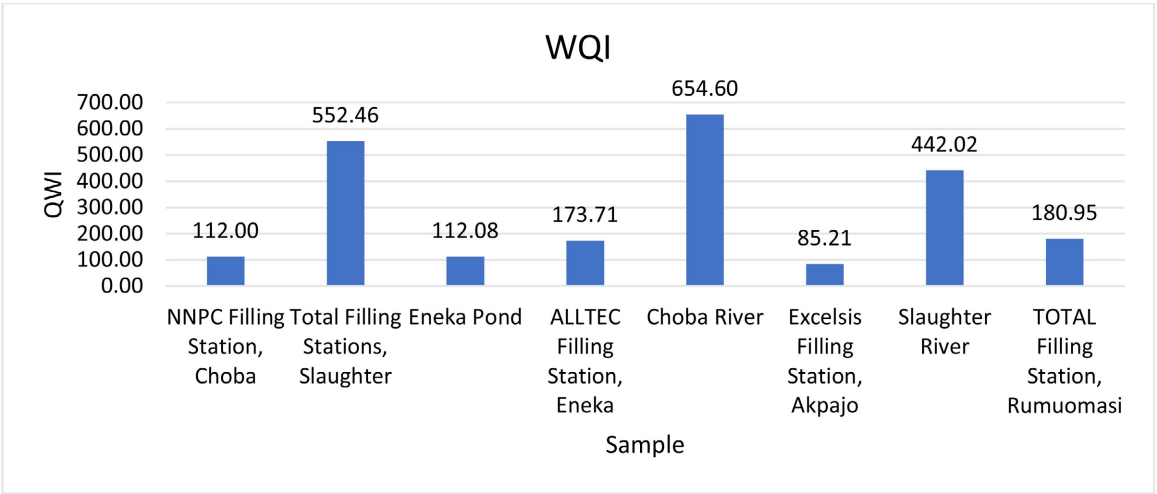

Figure 10. Spatial distribution of water quality indices of sampled stations.

Table 4. Nutrient concentration in water samples.

Parameters	NNPC Filling Station, Choba	Total Filling Stations, Slaughter	Eneka Pond	ALLTEC Filling Station, Eneka	Choba River	Excelsis Filling Station, Akpajo	Slaughter River	TOTAL Filling Station, Rumuomasi
Phosphate	0.12	0.08	6	0.05	0.16	0.01	0.8	0.02
Nitrate	2.9	23.4	23	32.1	2.4	5.2	8.8	7.9
Nitrite	0	0.1	0	0.018	0	0	0	0

3.2. Discussion

The physicochemical results of the water samples are represented in Table 2.

These included the distribution of pH, Electrical Conductivity, Salinity, Temperature, Total Dissolved Solids (TDS), Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), and Dissolved Oxygen (DO). The mean concentrations for tempt (23.48˚), pH (5.5), EC (0.08 µS/cm) were lower than those found earlier in similar areas in Ghana while TDS (187 ppm) and salinity (537 ppm) were higher in this study (Fei-Baffoe et al., 2024). This may be attributed to soil differentials and petrol content and type. Same was also graphically represented from **Figures 2-9** respectively. The maximum concentration of DO, BOD and COD were far lesser than those recorded for the Woji River showing that petrol has infiltrated into the surrounding water leading to reduction in DO (Iyama et al., 2020). The higher concentration of BOD and COD found in the Woji River is an indication of higher pollution probably not due to petroleum fractions but other substances with high organic content for eutrophication such as the nutrient parameters of sulphate, nitrate and phosphate (Iyama et al. 2020).

Table 2 presents the results of correlation analysis conducted on various physicochemical parameters of water samples. The parameters investigated include pH, Electrical Conductivity (uS/cm), Salinity (ppm), Temperature (˚C), Total Dissolved Solids (TDS) in ppm, Biological Oxygen Demand (BOD) in mg/L, Chemical Oxygen Demand (COD) in mg/L, and Dissolved oxygen (DO) in mg/L. According to Tang et al. (2019), COD, turbidity and ammonium (nitrogenous compound) are part of the emerging micro- and macro-pollutants. These were similar results by Andeng (2013) on the to determination of the effect of gasoline station spillage on the ground water of the 3rd District Municipalities of Cagayan, Bahrain. According to research study in Ghana by Fei-Baffoe et al. (2024), anthropogenic factors such as leakages from fuel storage facilities contribute to the release of petroleum hydrocarbons into groundwater which could impact on certain water quality parameters. The table illustrates the correlation coefficients between these parameters, highlighting the relationships between them. Correlation coefficients range from −1 to 1, where 1 indicates a perfect positive correlation, −1 indicates a perfect negative correlation, and 0 indicates no correlation. The result indicated that positive correlations existed between interacting physicochemical parameters tested. This analysis offers insights into the interrelationships among different water quality indicators, which is crucial for understanding the overall dynamics of aquatic ecosystems and assessing environmental health.

Table 4 presents the concentrations of key nutrients—Phosphate, Nitrate, and Nitrite—in water samples from various locations, including NNPC Filling Station in Choba, Total Filling Stations in Slaughter, Eneka Pond, ALLTEC Filling Station in Eneka, Choba River, Excelsis Filling Station in Akpajo, Slaughter River, and TOTAL Filling Station in Rumuomasi. Phosphate levels ranged from as low as 0.01 mg/L at Excelsis Filling Station to as high as 6 mg/L at Eneka Pond. Nitrate concentrations varied between 2.4 mg/L at Choba River and 32.1 mg/L at ALLTEC Filling Station. This is also in consonance with those obtained by Ogbozige and Toko (2022) and Ojukwu and Nwankwoala (2022) in their assessment of

groundwater quality in Parts of Port Harcourt Metropolis in earlier studies. The concentration of nitrate was greater than that of phosphate similar to that between nitrate and sulphate shown by Mgbenu and Egbueri (2019) during the study on the hydrogeochemical signatures, quality indices and health risk assessment of water resources in Umunya district, southeast Nigeria. Nitrite was absent in several locations, including NNPC Filling Station, Eneka Pond, Choba River, Excelsis Filling Station, Slaughter River, and TOTAL Filling Station, with the highest recorded concentration of 0.1 mg/L at Total Filling Stations in Slaughter. These results were similar to Makanjuola (2019) on the assessment of air, water quality and health impact on the environment of petrol stations in Ado Local Government Area of Ekiti State, Nigeria.

Figure 10 presents the Water Quality Index (WQI) for water samples from various locations of the study, including NNPC Filling Station in Choba, Total Filling Stations in Slaughter, Eneka Pond, ALLTEC Filling Station in Eneka, Choba River, Excelsis Filling Station in Akpajo, Slaughter River, and TOTAL Filling Station in Rumuomasi. The WQI values classify the water quality as follows: NNPC Filling Station (112.003) and Eneka Pond (112.076) indicated "Poor" water quality; ALLTEC Filling Station (173.707) and TOTAL Filling Station (180.946) also fall into the "Poor" category. The Total Filling Stations in Slaughter (552.461), Choba River (654.601), and Slaughter River (442.024) are categorized as "Unsuitable for Drinking," indicating very poor water quality. In contrast, Excelsis Filling Station (85.2072) is the only location with "Good" water quality. The water quality index was found to be higher than those obtained by Effiong et al. (2022) and Sener et al. (2017) for water quality assessment for drinking and sanitation purposes in secondary schools in Port Harcourt Metropolis, Rivers State, Nigeria but lower than those obtained by Fernández del Castillo et al. (2022) for specific water quality index and the water quality classification of a highly polluted river through supervised machine learning.

4. Conclusion

The study was based on impact assessment of petrol service stations on water quality in Port Harcourt metropolis, Rivers State, Nigeria. The study used various methods, such as water quality analysis and nutrients analysis to assess the impact of petrol service stations on the water quality and the suitability of the water for drinking and industrial purposes.

The study found that the water quality at the drilling point and sampling locations including: NNPC Filling Station, Choba, Total Filling Stations Slaughter, Eneka Pond, ALLTEC Filling Station Eneka, Choba River, Excelsis Filling Station Akpajo, Slaughter River, and TOTAL Filling Station, Rumuomasi, exceeded the permissible limits for some parameters. Samples taken from NNPC Filling Station in Choba (ST1) and Eneka Pond (ST3) displayed "Poor" water quality, as evidenced by their WQI values of 112.003 and 112.076, respectively suggesting potential contamination issues. Similarly, ALLTEC Filling Station in Eneka (ST4)

and TOTAL Filling Station in Rumuomasi (ST8) exhibited similar trends, falling within the "Poor" category with WQI values of 173.707 and 180.946 respectively. In contrast, Excelsis Filling Station in Akpajo (ST6) showed "Good" water quality, with a WQI of 85.2072. However, samples from Total Filling Stations in Slaughter (ST2) and Choba River (ST5) revealed levels of pollution, categorized as "Unsuitable for Drinking" with WQI values of 552.461 and 654.601, respectively. Moreover, Slaughter River (ST7) also indicated very poor water quality with a WQI of 442.024. These findings emphasized the immediate need for remediation efforts and stricter regulatory measures to protect water quality in these areas.

The study concluded that the surface and ground water situated close to petrol service stations within Port Harcourt metropolis in Rivers State, Nigeria, was unfit for drinking and irrigation purposes without adequate treatment. This study therefore, recommends implementation of stricter regulatory measures, enhanced water treatment facilities, public awareness and education campaigns.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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