Journal of Engineering Research and Reports

Volume 25, Issue 1, Page 110-120, 2023; Article no.JERR.99379
ISSN: 2582-2926

Water Quality Assessment of Nigerian Port Authority Waterway in Port-Harcourt, Rivers State, Nigeria

Awosanya Babatunde [a], Ify L. Nwaogazie [b*]
and Chiedozie F. Ikebude [b]

[a] Centre for Occupational Health, Safety and Environment, University of Port Harcourt, Choba, Rivers State, Nigeria.
[b] Department of Civil and Environmental Engineering, University of Port Harcourt, Choba, Rivers State, Nigeria.

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/JERR/2023/v25i1875

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/99379

Original Research Article

Received: 01/03/2023
Accepted: 03/05/2023
Published: 13/05/2023

ABSTRACT

The aim of this study is to assess the water quality of the Nigerian Port Authority Water way. A cross-sectional study was carried out using a composite sampling method, where three water samples were collected randomly from each station to ensure that the samples were representative of the entire station. Water samples were taken from four different locations along the waterway with new unused bottles, chosen based on the level of port activity in the area. The samples were thereafter analysed for physiochemical parameters, and heavy metal, and compared to the World Health Organization's Permissible Limits. Data analyses covered descriptive statistics, Pearson correlation coefficient analysis, Agglomerative hierarchy clustering, parallel coordinate plot and Water Quality Index computation**.** The results showed that most parameters were above the standards, indicating a potential risk of bioaccumulation. The water quality index for the station was

---

**Corresponding author: Email: ifynwaogazie@yahoo.com;*

found to range from 3192.635 to 5061.35 for the four stations, indicating that the waterway is of poor water quality and unsuitable for consumption, and irrigation purposes. The parallel coordinate plot identified Lead and Salinity as the main contaminant in the waterway.

Keywords: Nigeria port authority; seaport; water quality index; physiochemical; heavy metal; agglomerative hierarchy clustering.

1. INTRODUCTION

Water is a known universal solvent because of its capacity to dissolve more substance than any other liquid. This implies that wherever water is present either in the atmosphere or within the ground or on the surface of the ground or even through the human body, there is always the collection and deposition of substances, which could be in the form of chemicals, nutrients, minerals, radiological or even microbes. Therefore, as a global phenomenon that is peculiar to all living thing and has exceptional qualities that makes it indispensable for humans to live without, there is a need to subject all forms of ambient water to appropriate testing, because they definitely have a use. Aside from the daily required usage of water for drinking, cooking, and other domestic uses, it is also of value for recreational, agricultural, industrial, commercial, energy and transportation purposes. However, [1] WHO emphasizes the importance of water quality for health in both developed and developing countries. The quality of water, whether it is used for drinking, irrigation or recreation, is considered to have a major impact on health through the outbreak of waterborne diseases and by contributing to the general incidence of disease [1].

Since human civilization resides in a natural/man-made water metabolic system, it is impacted not only by physical qualities and chemical impurities of water but also by pathogenic microbes that co-exist with humans and animals [2]. These infectious microorganisms are called pathogens due to their ability to cause disruption to normal bodily processes. While chemical toxicants and toxins can be cancer-causing, aquatic pathogens are typically not harmful until they enter an animal or human body, at which point they can cause significant damage.

Therefore, it is critical to guarantee that any type of ambient water utilized by a community is tested for potability. People in developing countries, the majority of which have massive debt burdens, population explosions, and moderate to rapid urbanization, have little or no choice but to accept the water of questionable quality due to a lack of better alternative sources or economic and technological constraints to adequately treat the available water before use [3,4]. However, the justification is, failing to monitor the quality of water in bodies of water can have serious negative consequences for both people and the environment. Ignoring these issues can lead to harm to human health, harm to the economy and the health of ecosystems [5].

As Selvam et al. [6] stated, surface water systems are some of the most productive ecosystems and they can be affected by pollutants due to their proximity to highly populated and industrialized areas. Arimieari and Sangodoyin [7] also highlighted, in the Niger Delta region of Nigeria, surface water is a vital resource for the local population and is used for a variety of purposes such as drinking, farming, and manufacturing, particularly during dry seasons or when the public water supply is unreliable. Surface water is a broad phrase that refers to any body of water that flows or stands on the earth's surface, such as streams, rivers, ponds, lakes, and reservoirs [8]. This means that seaport waters can be considered a type of surface water, as defined by the Glossary of Environment Statistics [9].

Surface water refers to all water bodies that are exposed to the atmosphere, such as rivers, lakes, reservoirs, streams, impoundments, seas, estuaries, and others. Hence, the quality of surface water in a seaport can indicate the physio-chemical and microbiological state of the seaport. Seaports are a key component of the "blue economy", which involves the movement of cargo by ships or vessels at port terminals. These cargos are of different forms such as containers, liquids, dry bulk cargo, break bulk cargo, or roll-on and off cargo. According to Mesut [10], dredging for the removal of sediment from the harbour bottom causes the destruction of habitat, siltation rate change and de-oxygenation.

According to Puertos del Estado [11] the complexity and diversity of environmental problems are determined by the specific peculiarities of each port. Aspects such as their location, the type of activities pursued and the interactions arising from the confluence of these with other uses developed determine the type of actions required to halt their environmental deterioration. Pradhan and Youssef [12] pointed out that substantial amounts of generated waste are mostly assimilated by water depending upon its capacity, while the hydrodynamics of the region play a greater role in the further dispersion of waste contaminants.

Therefore, this study's objective is to assess the water quality of the Nigerian Port Authority Waterway using a composite sampling method collected randomly to ensure that the samples were representative of the entire station. The samples will thereafter be analysed for physiochemical parameters and heavy metal for comparison to the World Health Organization's Permissible Limits. The analysis shall be based on descriptive statistics, Pearson correlation coefficient analysis and Agglomerative hierarchy clustering method.

2. MATERIALS AND METHODS

2.1 Study Area

The study area that is, the Port of (Nigerian Port Authority NPA in Port Harcourt) is located between Latitude: 4° 45' 23'' N, Longitude: 7° 00' 25'' E.It is bound by the Ibeto cement factory in the north at a distance of 610m and the Abonnema wharf in the south at a distance of 34m. The study is on the surface water around the Nigeria Port Authority (NPA) in Port Harcourt. The NPA Port in Port Harcourt, Rivers State, is located in the southern region of Nigeria, along the Bonny River. It is one of the major ports in the country and serves as a hub for the export of oil and gas from the Niger Delta region. The port is operated by the Nigerian Ports Authority (NPA) and has facilities for handling a variety of cargo, including containers, liquid bulk, and general cargo. It is also home to several oil and gas terminals such as the Ports and Terminal Operators Nigeria Limited (PTOL), BUA Group of Companies (BUA) and the Bonny Terminal, which is one of the largest export terminals in Africa.

Water in the study area has already been subjected to several impacts because of the Port and industrial activities around it. Four sample stations were identified (as shown in Fig. 1). This sample station was identified based on the level of Port Activities going on around it.

The choice of location for each sampling station was based on specific criteria. Station one was selected because it is close to both the Ibeto cement factory and the under-construction Ibeto port terminal, which could potentially affect the surrounding waters. Station two was chosen as a baseline for comparison since it is near a disbanded recreational centre and has no port activity in the area. Station three is near an oil terminal, bitumen storage tanks, and salt facilities, and is considered to be an area where port-related activities take place. Station four is located near PTOL and BUA oil and gas terminals and has a visible discharge point, with significant port-related activities taking place.

2.2 Data Collection

During the sample collection process, great care was taken to ensure that only surface water was collected and that the samples were well-mixed. To achieve this, the samples were taken at least 10 cm below the water surface and far away from the banks of the Nigeria Port Authority waterway. The study area was divided into four distinct sample stations, named Station One, Station Two, Station Three and Station Four. The composite sampling method was used, where three water samples were collected randomly from each station to ensure that the samples were representative of the entire station. These individual samples were then combined to create a composite sample for each station, resulting in a total of four composite samples that were analyzed. The samples were then transported to the laboratory at the Institute of Pollution Studies, River's State University for analysis. Data from each station are used to evaluate the extent of pollution caused by various industrial and port operations in the area.

2.3 Water Quality Index (WQI)

The water quality index (WQI) is a numerical value that represents the overall water quality of a specific water body. It is a composite index that combines several water quality parameters into a single value, making it easy to understand and compare water quality across different water bodies. There are several different methods for determining the WQI, but the most commonly used method is the Canadian Council of Ministers of the Environment's (CCME) Water Quality Index (CCME-WQI), however, for this study the Weighted Arithmetic Water Quality Index (WAWQI) was used. The Weighted Arithmetic Water Quality Index (WAWQI) is a

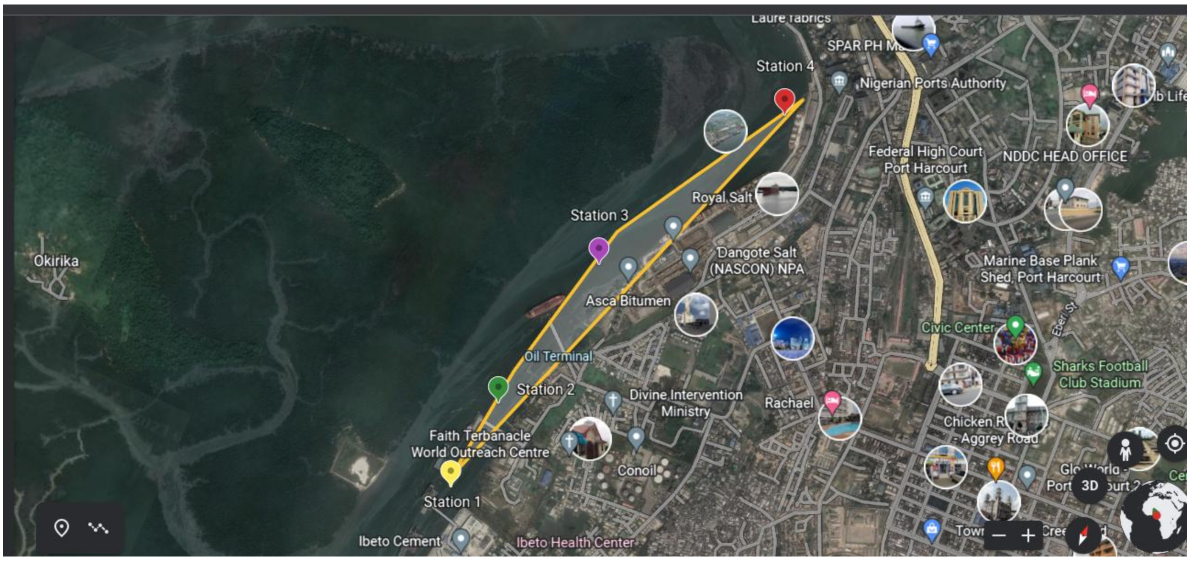

Fig. 1. Satellite view of study area, showing the four stations

📍---*Station 1 (4°45’12”N 7°00’10”E)* 📍--*Station 3 (4°45’54”N 7°00’20”E)*
📍---*Station 2 (4°45’25”N 7°00’14”E)* 📍---*Station 4 (4°46’16”N7°00’33”E)*

method for determining the overall water quality of a specific water body, similar to the Canadian Council of Ministers of the Environment's (CCME) Water Quality Index (CCME-WQI).

The WAWQI method uses the same basic concept as other water quality index methods, but it assigns different weightings to different water quality parameters based on their relative importance and their impact on the environment and human health [13]. The procedure used for calculating WAWQI is as presented in the Result Section in ten distinct steps.

3. RESULTS AND DISCUSION

3.1 Descriptive Statistic of the Physiochemical Parameters for the Four Stations

The physiochemical parameters of water samples from the four stations were analyzed, and their descriptive statistics are presented in Table 1. The pH values ranged from 5.50 to 5.60, with a mean of 5.53 and a standard deviation of 0.05. These values indicate that the water was slightly acidic across the four stations. Temperature values varied between 29.70^{0}C and 29.90^{0}C, with an average of 29.85^{0}C and a standard deviation of 0.10^{0}C. This narrow range suggests that temperature was relatively consistent across the four stations.

Conductivity values ranged from 30,400 µS/cm to 30,600 µS/cm, with an average of 30,500 µS/cm and a standard deviation of 81.65µS/cm. Salinity varied between 13.90‰ and 19.20‰, with a mean of 17.80‰ and a standard deviation of 2.60. The Total Dissolved Solids (TDS) ranged from 21,280 mg/l to 21,420 mg/l, with a mean of 21,350 mg/l and a standard deviation of 57.15mg/l.

Total Suspended Solids (TSS) exhibited a more significant variation, with values ranging from 70 mg/l to 320 mg/l and an average of 140 mg/l with a standard deviation of 120.28mg/l. Turbidity (TURB) ranged from 3.00 NTU to 7.30 NTU, with a mean value of 5.60 NTU and a standard deviation of 1.87NTU. Dissolved Oxygen (DO) values varied between 5.80 mg/l and 6.70 mg/l, with an average of 6.13 mg/l and a standard deviation of 0.40mg/l. Biochemical Oxygen Demand (BOD_5) ranged from 0.40 mg/l to 5.30 mg/l, with a mean of 2.70 mg/l and a standard deviation of 2.33mg/l. Chemical Oxygen Demand (COD) values ranged from 43.13 mg/l to 79.01 mg/l, with an average of 64.66 mg/l and a standard deviation of 16.31mg/l. Alkalinity (as $CaCO_3$) varied between 20.00 mg/l and 26.00 mg/l, with a mean of 21.50 mg/l and a standard deviation of 3.00mg/l. Hardness (as $CaCO_3$) ranged from 3,944.50 mg/l to 4,314.10 mg/l, with a mean of 4,175.13 mg/l and a standard deviation of 161.72mg/l. Concentrations of various ions (NO_3^-, PO_4^{-3}, SO_4^{-2}, and Cl^-) and heavy metals (Mn, Fe, Cd, Cr, Cu, Pb, Zn, Ca, and Mg) were also analysed. The results show higher levels of physiochemical parameters across the four stations, with some exhibiting higher concentrations than others.

3.2 Comparative Analysis of Physiochemical Parameters for the Four Stations

The comparative analysis was done using a radar plot of the physiochemical parameters which is presented in Figs. 2 and 3. Radar plot was used to identify which station had the highest concentration of a particular physiochemical parameters. The result from Fig. 2 showed that the highest salinity concentration was recorded at station 4, while the least salinity was recorded at station 3. The result from the radar plot in Fig. 2 also showed that station 1 and 2 had relatively similar concentration with the salinity recorded at station 4. The turbidity, the result from Fig. 2 showed that station 4 had the highest turbidity followed by station 3. It was observed that station 1 had the lowest turbidity. For alkalinity, station 4 had the highest alkalinity concentration while the other three station had similar alkalinity concentration.

3.3 Relationship between the Physiochemical Parameters

The result of the Pearson correlation between the physiochemical parameters is presented in Table 2. Pearson correlation coefficients was used to establish the degree of the relationship between any two physiochemical parameters. The result from Table 2 revealed that there was a strong negative correlation between the pH and the salinity of the water and it was statistically significant. Increase in the pH of the water will lead to a corresponding decrease in the salinity of water. The result indicate that the salt that are dissolved in the water for most of the station are acid based salt which brought about the increase in the pH. When acid base salt dissolve in water it result to an increase in the acidity of the water due to the release of acidic ion. The result from Table 2 also revealed that there was a strong positive correlation between the pH and the dissolved oxygen. The Pearson correlation between the dissolved oxygen and pH was 0.95 and it was statistically significant. Increase in the pH of the water will result to an increase in the dissolved oxygen of the water and vice versa. The result from the Pearson also showed that there was a strong positive association between the alkalinity of the water and the Total Suspended Solid. The result indicate that increase in the TSS will result to a corresponding increase in the alkalinity of the water. There was a negative relation between nitrate and the biochemical oxygen demand, with a Pearson correlation of -0.95. The relationship between the nitrate and BOD_5 was statistically significant. Increase in the BOD will result to decrease in the nitrate concentration and vice versa.

3.4 Agglomerative Hierarchy Clustering

Agglomerative Hierarchy clustering was done to cluster station with similar physiochemical parameter and the dendrogram showing the clustering of the stations is shown in Fig. 4. The result shown in Fig. 4, revealed that two distinct clusters were found. The first cluster comprised of station 1, 2, and 4 which is indicated by the orange legs in the dendrogram tree. The second cluster was just made up of station 3 indicated by blue leg. The result of the parallel coordinate plot is presented in Fig. 5. The result from Fig. 5 showed that cluster 1 (line with circular marker) had relatively high salinity, COD, Ca, NO_3, PO_4, Cd, Cu and Zn than the cluster 2. However cluster 2 (station 3) had relatively high pH, DO, Mg, Cr, Pb, and Hardness than cluster 1. The result from the parallel coordinate plot indicate that cluster 2 tend to have relatively lower concentration of physiochemical parameters than cluster 1. Therefore, station 3 (cluster 2) tends to have a better water quality than station 1, 2 and 4.

3.5 Water Quality Index

The Water Quality Index is obtained by using the simple arithmetic mean given in Equation (1):

$$WQI = \sum_{i=1}^{n} \frac{W_i Q_i}{\sum_{i=1}^{n} W_i} \tag{1}$$

Where:

Q_i = Sub-Index of the i*th* parameter,
W_i = the unit weightage of the i*th* parameters
n = number of parameters

The ideal value for pH = 7, dissolved oxygen = 14.6 mg/l, and for other parameters, it is equal to zero [14,15].

Table 1. Descriptive statistic of physiochemical parameters for the four stations

Parameters	Mean	Std	Median	Min	Max	Skew
pH	5.53	0.05	5.50	5.50	5.60	2.00
Temperature (^{0}C)	29.85	0.10	29.90	29.70	29.90	-2.00
Conductivity (µS/cm)	30500.00	81.65	30500.00	30400.00	30600.00	0.00
Salinity (‰)	17.80	2.60	19.05	13.90	19.20	-1.99
TDS (mg/l)	21350.00	57.15	21350.00	21280.00	21420.00	0.00
TSS (mg/l)	140.00	120.28	85.00	70.00	320.00	1.97
TURB (NTU)	5.60	1.87	6.05	3.00	7.30	-1.22
DO (mg/l)	6.13	0.40	6.00	5.80	6.70	1.47
BOD5 (mg/l)	2.70	2.33	2.55	0.40	5.30	0.18
COD (mg/l)	64.66	16.31	68.25	43.13	79.01	-0.89
Alkalinity (mg/l as CaCO3)	21.50	3.00	20.00	20.00	26.00	2.00
Hardness (mg/l as CaCO3)	4175.13	161.72	4220.95	3944.50	4314.10	-1.44
NO3- (mg/l)	0.14	0.03	0.15	0.10	0.17	-0.63
PO4-3 (mg/l)	0.11	0.02	0.11	0.09	0.12	-0.37
SO4-2 (mg/l)	1410.70	406.02	1319.10	1036.30	1968.30	1.12
Cl- (mg/l)	4013.75	547.69	3952.00	3458.00	4693.00	0.48
Mn (mg/l)	0.01	0.01	0.00	0.00	0.03	2.00
Fe (mg/l)	0.70	0.25	0.61	0.53	1.07	1.71
Cd (mg/l)	0.07	0.02	0.07	0.05	0.10	0.92
Cr (mg/l)	0.30	0.13	0.27	0.18	0.48	1.07
Cu (mg/l)	0.10	0.02	0.11	0.07	0.12	-1.46
Pb (mg/l)	1.19	0.36	1.24	0.71	1.58	-0.74
Zn (mg/l)	0.06	0.07	0.05	0.00	0.14	0.17
Ca (mg/l)	419.45	53.68	417.30	356.80	486.40	0.23
Mg (mg/l)	760.25	51.55	748.50	712.00	832.00	1.20

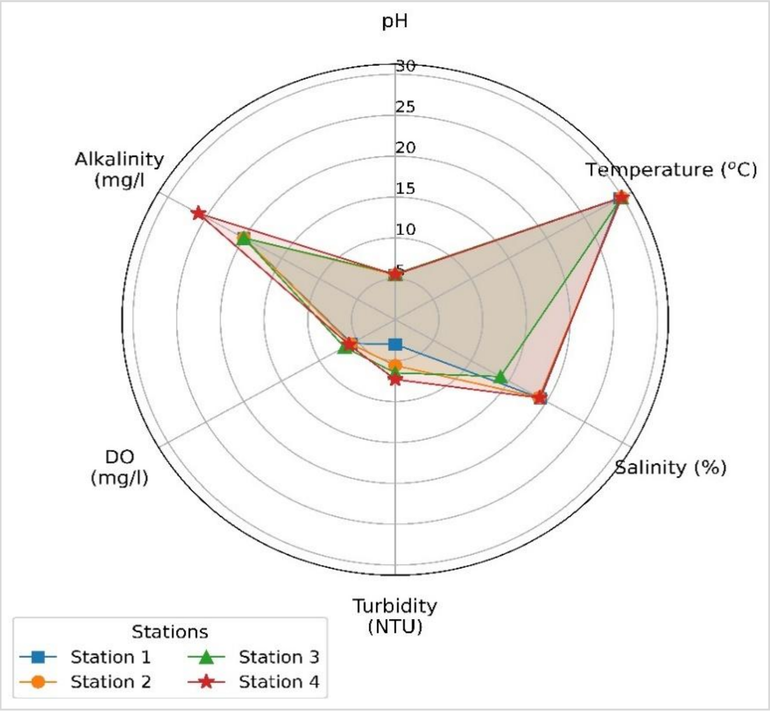

Fig. 2. Radar plot showing the physiochemical parameters in the four stations

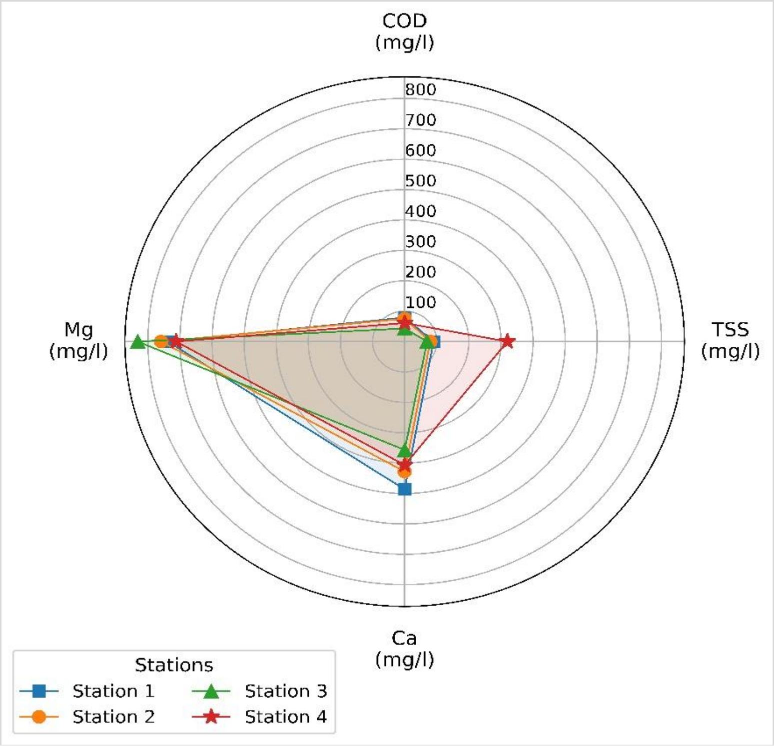

Fig. 3. Radar plot showing the physiochemical parameters in the four stations

Table 2. Pearson correlation for the relationship between physiochemical parameters

Variables	pH	Temp.	Salinity	Turbidity	DO	Alkalinity	COD	TSS	Ca	Mg	Mn	BOD5
pH	1.00											
Temperature	0.33	1.00										
Salinity	-1.00	-0.36	1.00									
Turbidity	0.32	0.93	-0.34	1.00								
DO	0.95	0.54	-0.95	0.58	1.00							
Alkalinity	-0.33	0.33	0.33	0.61	-0.04	1.00						
COD	-0.88	-0.59	0.88	-0.69	-0.98	-0.15	1.00					
TSS	-0.39	0.28	0.39	0.55	-0.10	1.00	-0.09	1.00				
Ca	-0.78	-0.83	0.79	-0.84	-0.91	-0.16	0.93	-0.09	1.00			
Mg	0.93	0.29	-0.93	0.14	0.80	-0.62	-0.68	-0.67	-0.65	1.00		
Mn	-0.33	0.33	0.31	0.00	-0.37	-0.33	0.44	-0.33	0.11	-0.02	1.00	
BOD5	0.37	0.66	-0.38	0.89	0.63	0.74	-0.77	0.70	-0.75	0.06	-0.46	1.00

Variables	BOD_5	NO3-	PO4-3	Fe	Cd	Cr	Cu	Pb	Zn	SO4-2	Cl-	Hardness	Cond.	TDS
BOD5	1.00													
NO3-	-0.95	1.00												
PO4-3	-0.07	-0.21	1.00											
Fe	-0.43	0.65	-0.54	1.00										
Cd	-0.68	0.43	0.76	-0.24	1.00									
Cr	0.68	-0.59	-0.50	-0.44	-0.69	1.00								
Cu	-0.54	0.45	0.56	0.39	0.63	-0.99	1.00							
Pb	0.57	-0.62	-0.13	-0.77	-0.31	0.90	-0.89	1.00						
Zn	-0.08	-0.22	0.95	-0.73	0.79	-0.30	0.33	0.13	1.00					
SO4-2	-0.90	0.75	0.31	0.00	0.85	-0.53	0.40	-0.26	0.43	1.00				
Cl-	-0.88	0.71	0.53	0.11	0.94	-0.81	0.72	-0.54	0.52	0.92	1.00			
Hardness	-0.55	0.64	-0.62	0.24	-0.01	0.23	-0.39	0.17	-0.40	0.51	0.18	1.00		
Conductivity	0.23	-0.39	0.82	-0.22	0.35	-0.52	0.65	-0.35	0.60	-0.17	0.18	-0.93	1.00	
TDS	0.23	-0.39	0.82	-0.22	0.35	-0.52	0.65	-0.35	0.60	-0.17	0.18	-0.93	1.00	1.00

Values in bold are different from 0 with a significance level alpha=0.05

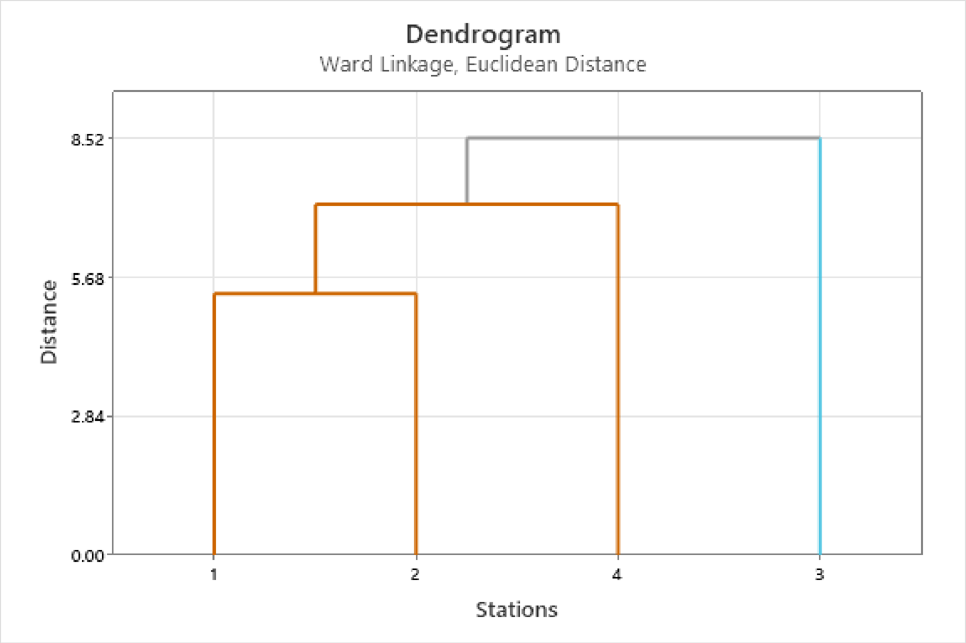

Fig. 4. Dendrogram for the clustering of the physiochemical parameters for the four stations

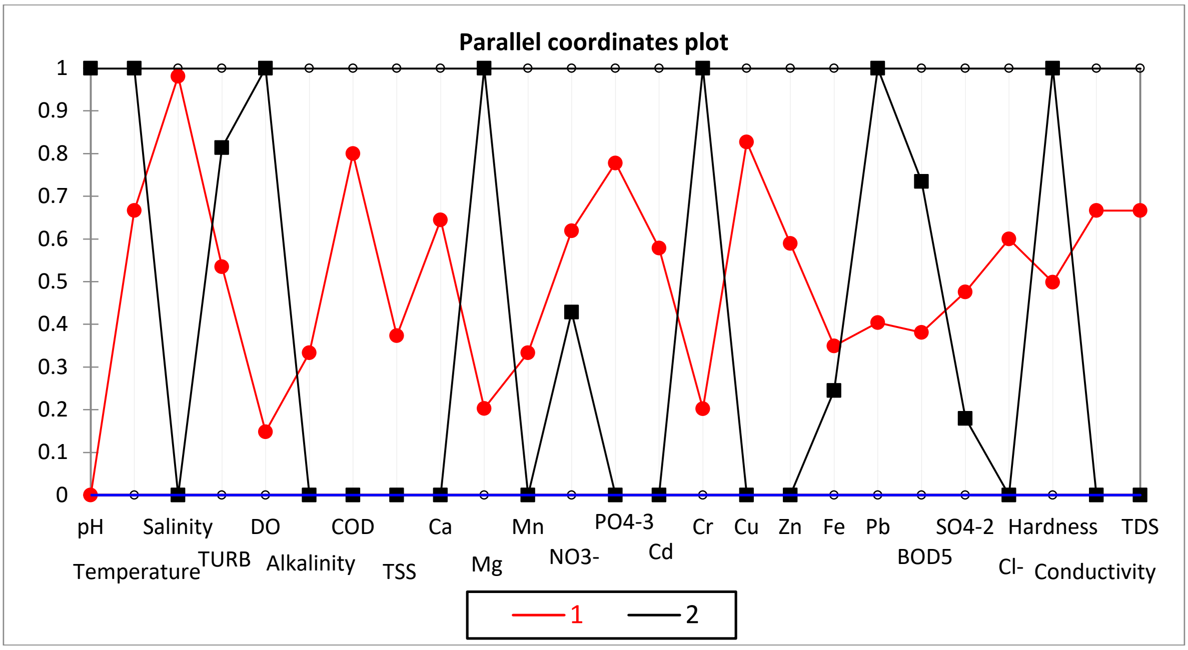

Fig. 5. Parallel coordinate plot

The weightage unit (Wi) of each parameter was calculated as a value inversely proportional to the standard of the World Health Organization (Si) [1], Equation (2):

$$W_i = \frac{K}{S_i} \qquad (2)$$

While quality rating for nth parameter (Q_i) is computed using Equation (3):

$$Q_i = \frac{(M_i - L_i)}{(S_i - L_i)} \times 100 \qquad (3)$$

Where:

M_i = Observed value for physiochemical parameters,
Li = ideal value
S_i = standard value of the *ith* parameter.

3.5.1 Computation for station 1 as a case study

Step 1: Input the physiochemical parameters for station 1 in column 1 (Table 3).
Step 2: Input the value for the physiochemical parameters for station 1 in column 2.
Step 3: Input the WHO permissible limit for each of the physiochemical parameter for drinking water in column 3.
Step 4: Input the Ideal Value for each of the physiochemical parameters in column 4. The ideal value for pH = 7, dissolved oxygen = 14.6 mg/l, and for other parameters, it is equal to zero [14][16].
Step 5: To obtain column 5, divide column 1 by column 3.
Step 6: To obtain K (Column 6), use Equation (4):

$$K = \frac{1}{\frac{1}{S_1}+\frac{1}{S_2}+\frac{1}{S_3}+\cdots+\frac{1}{S_n}} \tag{4}$$

$$i.e, \quad K = \frac{1}{0.133 + 0.003 + 0.001 + \cdots + 100}$$

K = 0.002

The K value is a constant for all physiochemical parameter.

Step 7: To obtain column 7, use Equation (3) to compute for Q

$$Q = \frac{col\ 2 - col\ 4}{col\ 3 - col\ 4} \times 100$$

$$Q = \frac{5.5-7.0}{7.5-7.0} \times 100 = -300$$

Step 8: To obtain W, use Equation (2):

$$W = \frac{col\ 6}{col\ 3} = \frac{0.002}{7.50} = 0.000267$$

Step 9: To obtain WQ, multiply col 7 and col 8, that is:

WQ = -300 x 0.000267 = -0.087

Step 10: To obtain the WQI use Equation (1), (see Table 3, column 9), that is:

$$\text{WQI} = \frac{5061.35}{1} = 5061.35 \text{ (unitless)}$$

The process of WQI computation for Stations 2, 3 and 4 follow similar method presented in Table 3, but summarised in Table 4.

Table 3. WQI for station 1

Physiochemical parameters Col 1	Observed value Col 2	Standard value (S_n) Col 3	Ideal value Col 4	$1/S_n$ Col 5	K Col 6	Q Col 7	W Col 8	WQ Col 9
pH	5.50	7.50	7.00	0.133	0.002	-300.000	0.000	-0.087
E.C (µS/cm)	30500.00	400.00	0.00	0.003	0.002	7625.000	0.000	0.041
TDS (mg/l)	21350.00	1000.00	0.00	0.001	0.002	2135.000	0.000	0.005
COD (mg/l)	79.01	250.00	0.00	0.004	0.002	31.604	0.000	0.000
Sulphate (mg/l)	1968.30	250.00	0.00	0.004	0.002	787.320	0.000	0.007
Temp (^{0}C)	29.70	26.00	0.00	0.038	0.002	114.231	0.000	0.010
T.Hardness (mg/l)	4250.60	500.00	0.00	0.002	0.002	850.120	0.000	0.004
Chloride (mg/l)	4693.00	250.00	0.00	0.004	0.002	1877.200	0.000	0.016
Phosphate (mg/l)	0.12	2.00	0.00	0.500	0.002	6.000	0.001	0.007
Turbidity (NTU)	3.00	5.00	0.00	0.200	0.002	60.000	0.000	0.026
Nitrate (mg/l)	0.16	50.00	0.00	0.020	0.002	0.320	0.000	0.000
DO (mg/l)	5.80	5.00	14.60	0.200	0.002	91.667	0.000	0.040
BOD_5 (mg/l)	0.40	5.00	0.00	0.200	0.002	8.000	0.000	0.003
Alkalinity	20.00	200.00	0.00	0.005	0.002	10.000	0.000	0.000
Mn	0.00	0.40	0.00	2.500	0.002	0.475	0.005	0.003
Cd	0.10	0.003	0.00	333.333	0.002	3366.667	0.723	2432.663
Cr	0.23	0.05	0.00	20.000	0.002	450.000	0.043	19.509
Cu	0.11	2.00	0.00	0.500	0.002	5.400	0.001	0.006
Zn	0.14	3.00	0.00	0.333	0.002	4.633	0.001	0.003
Fe	0.55	0.30	0.00	3.333	0.002	184.000	0.007	1.330
Pb	1.20	0.01	0.00	100.000	0.002	12030.000	0.217	2607.767
				461.31			1.00	5061.35

Table 4. Water quality index summary for the four stations

Water Brands	WQI	Quality
Station 1	5061.35	Unfit for Consumption
Station 2	3192.635	Unfit for Consumption
Station 3	4617.951	Unfit for Consumption
Station 4	4388.548	Unfit for Consumption

WQI rating: 0-25=Excellent water quality, 26-50=Good water quality, 51-75=Poor water quality, 76-100=Very poor water quality, >100 unfit for consumption. Source: Brown et al. 1972

4. CONCLUSION

The results of the study show that the waterway in the Nigerian Port Authority (NPA) port of Port Harcourt is heavily polluted with physiochemical parameters and heavy metals. The increase in the concentration levels of pollutants can be attributed to the activities of the port terminals, as well as other industrial activities within the port. The sample points closest to locations with more port activities have higher levels of pollutants. The result from the parallel coordinate plot indicate that cluster 2 (i.e Station 3) tend to have relatively lower concentration of physiochemical parameters than cluster 1 (i.e, Stations 1, 2 & 4); in effect, station 3 tends to have a better water quality than station 1, 2, and 4.

The presence of heavy metals in the water indicates that there is a possibility of bioaccumulation, as these metals do not degrade and can build up in living organisms. Heavy metals are toxic and there is a risk that they have entered the food chain. The water quality index (3192.635-5061.35) also shows that the water is of very poor quality and is not suitable for consumption, agriculture or any other purpose. The aquatic organisms from NPA port waterway if consumed might be of public health concern. The water in the NPA port is not safe for any use except if it is treated.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. World Health Organisation. WHO. Guideline for Drinking-water Quality in Water, Sanitation and Health Electronic Library. 4th ed., Microsoft Internet Explorer; 2005.
2. Yamamoto S, Izumi K, Okishio, Y, Nagao N, Niwa C, Toda T. Effects of particle size on anaerobic digestion of food waste. International Biodeterioration and Biodegradation. 2010;64(7):601-608. Available:https://doi.org/10.1016/j.ibiod.2010.06.013
3. Calamari D, Naeve H. Review of pollution in the African aquatic environment. CIFA Technical Paper No. 25, FAO, Rome. 1994;118.
4. Aina EOA, Adedipe NO. Water quality monitoring and environmental status in Nigeria. FEPA Monograph 6, FEPA, Abuja, Nigeria. 1996;239.
5. Damania R, Desbureaux S, Rodella AS, Russ J, Zaveri E. Quality unknown: The invisible water crisis, world bank; 2019. Available:https://openknowledge.worldbank.org/handle/10986/32245
6. Selvam AP, et al. Heavy metal assessment using geochemical and statistical tools in the surface sediments of Vembanad Lake, south west coast of India. Environ Monit Assess; 2011. DOI: 10.1007/s10661-011-2389-8.
7. Arimieari L, Sangodoyin A. Assessment of surface water quality in some selected locations in Port Harcourt, Nigeria. International Journal of Engineering Research & Technology. 2014;3:1146-1151.
8. Winter TC, Harvey JW, et al. Ground water and surface water: A single resource. U.S. Geological Survey Circular. 1998;1139. ISBN 0-607-89339-7. Available:https://doi.org/10.3133/cir 1139
9. Glossary of Environment Statistics. Hydrology In: Glossary of Environment Statistics. Geneva: United Nations; 1997.
10. Mesut S. The effects of the ports and water transportation on the aquatic ecosystem. Open access, Journal of Biogeneric Science and Research; 2021. DOI: 10.46718/JBGSR.2021.10.000239
11. Puertos del Estado. State-owned Spanish port system; 2005. Available:http://www.puertos.es/es-es/oceanografia/Paginas/portus.aspx/ Access on December, 2022

12. Pradhan B, Youssef A. Manifestation of remote sensing data and GIS on landslide hazard analysis using spatial-based statistical models. Arabian Journal of Geosciences. 2010;3:319-326.
    Available:https://doi.org/10.1007/s12517-009-0089-2
13. Dendukuri DS, Asadi SS, Raju MVS. Estimation of water quality index by weighted arithmetic water quality index method: A model study. International Journal of Civil Engineering and Technology. 2017;8(4):1215-1222.
    DOI: 10.5958/0976-6308.2017.00136.4
14. Tripathy JK, Sahu KC. Seasonal hydrochemistry of ground water in the barrier spit system of the Chilika lagoon, India. Journal of Environmental Hydrology. 2005;3.
15. Chowdhury A, Hasan K, Hossain N, Mostazir NJ, Fakruddin, Billah M, Ahmed MM. Screening of lactobacillus spp. From Buffalo Yoghurt for probiotic and antibacterial activity, Bacteriology & Parasitology. 2012;3:8.
    Available:http://dx.doi.org/10.4172/2155-9597.1000156

Peer-review history:
The peer review history for this paper can be accessed here:
https://www.sdiarticle5.com/review-history/99379