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CHEMOMETRIC APPROACH TO THE PREDICTION OF POLLUTANTS DISTRIBUTION IN WATER SOURCES AROUND ASHAKA CEMENT INDUSTRY

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ABSTRACT

Cement production can negatively affect nearby water resources. This study used chemometrics to predict the source and distribution of pollution indicators around the Ashaka Cement Industry in Nigeria. Seventy-two water samples were collected from twelve stations between July and October 2023 and analyzed for pH, dissolved oxygen (DO), electrical conductivity (EC), total dissolved solids (TDS), turbidity, salinity, total suspended solids (TSS), chemical oxygen demand (COD), biochemical oxygen demand (BOD), and the BOD/COD ratio using standard methods. Results showed that while most parameters were within WHO limits, elevated TSS and turbidity were observed at all stations, with high salinity at one sampling station. Generally, there were increases in the concentrations of most physicochemical parameters during August and September compared to July and October. Thus, while many individual parameters fell within WHO guidelines, the widespread and persistent issues with TSS and turbidity, along with the localized high salinity, indicate that the water sources were not of consistently good quality. Also, seasonal variations need to be considered in water management. Multivariate data analysis (PCA, HCA, CA, and DA) using IBM SPSS effectively correlated and classified physicochemical indicators of pollution based on their sources and spatial distribution patterns. This study demonstrates the potential of chemometrics for assessing industrial pollution and provides insights into the relationships between water quality indices and their sources around the cement industry. Thus, this information can guide monitoring and mitigation to minimize the industry's environmental impact around its environs.

Keywords: *Chemometric, Distribution, Effluent, Pollutants, Surface runoff, Water quality.*

INTRODUCTION

Industrialization, urbanization, and the escalating use of synthetic chemical compounds have exerted significant and detrimental impacts on freshwater ecosystems. The discharge of industrial effluents into rivers poses a serious threat to water quality. Traditionally, water quality assessment has relied heavily on expensive and time-consuming laboratory and statistical analyses, rendering real-time monitoring impractical. The pressing need to address the adverse consequences of poor water quality necessitates the development of alternative, more rapid, and cost-effective monitoring methods (Ahmed *et al.,* 2019).

Chemometric approaches offer a powerful alternative by leveraging mathematical and statistical techniques to extract meaningful information from complex water quality datasets (Inobeme *et al.,* 2022). The key advantages include enhanced data analysis capabilities, such as dimensionality reduction through techniques like Principal Component Analysis (PCA) and Factor Analysis, which identify key underlying factors influencing water quality, simplifying interpretation and pinpointing significant contributors to variations (Essamlali *et al.,* 2024). Pattern recognition, employing cluster analysis, groups water samples with similar characteristics, revealing potential pollution sources and identifying areas with distinct water quality profiles, invaluable for identifying pollution hotspots and prioritizing remediation efforts (Syeed *et al.,* 2023; Hussain *et al*., 2008). Moreover, chemometric models can predict water quality parameters based on other measured variables, enabling more accurate assessments and forecasting potential future water quality issues. Some chemometric techniques can even be integrated with real-time monitoring systems, enabling rapid assessment of water quality changes and facilitating timely responses to pollution incidents (Duan *et al*., 2024; Platikanov *et al.,* 2019). For these reasons, chemometric approaches can enhance our understanding of water quality dynamics. This is particularly interesting as they reveal complex interrelationships between different water quality indices that may not be apparent through traditional analysis, leading to a deeper understanding of the underlying factors driving water quality variations. By analyzing the relationships between different pollutants, chemometric techniques can help identify the sources of pollution, such as industrial discharges, agricultural runoff, or natural sources (Mas *et al*., 2010). Therefore, chemometric approaches have been successfully applied to various water quality assessment challenges, including source distribution of pollution, monitoring the impact of human activities, developing water quality indices, and predicting future water quality trends (Inobeme *et al*., 2022; Egbueri & Mgbenu, 2020).

Water quality covers the chemical, physical, and biological properties of water, ultimately determining its suitability for diverse applications such as drinking water supply, irrigation, and the support of aquatic ecosystems. It is typically assessed against established standards, with deviations indicating potential pollution or degradation. Key parameters considered in water quality assessment include indicators of ecosystem health, human contact safety, pollution levels, and suitability for drinking purposes. Water quality significantly influences the availability and suitability of water supplies (Cordy *et al.,* 2018).

Industrial discharges or effluents that constitute industrial waste are usually discharged carelessly into the environment and find their way into neighborhood water sources used for drinking, fishing, and other agricultural purposes.

Therefore, environmental monitoring studies require the collection of huge amounts of physical and chemical parameters of affected environmental compartments, especially water. Industrial drainage water frequently contains elevated levels of chemical effluents, in addition to sewage effluents, leading to significant chemical contamination of water bodies and soils (Olukoya *et al.,* 2019). Consequently, chemical pollution has emerged as a significant threat to aquatic ecosystems and their inhabitants.

Industrial emissions and wastewater discharges often contain a range of contaminants, including toxic substances, heavy metals, and other hazardous materials. These chemical constituents can cause kidney and liver damage, skin manifestations, and other health problems. Therefore, comprehensive knowledge of various physicochemical indicators, including color, temperature, acidity, hardness, pH, sulfate, chloride, dissolved oxygen (DO), biochemical oxygen demand (BOD), chemical oxygen demand (COD), and alkalinity, is crucial for water quality assessment. Special attention must be given to heavy metals such as lead (Pb), chromium (Cr), iron (Fe), and arsenic (As), as they can accumulate in aquatic organisms and lead to acute or chronic toxicity (Patil *et al.,* 2012). Therefore, this study aims to investigate the levels of physicochemical parameters in water bodies surrounding the Ashaka Cement Industry, employing a chemometric approach to predict the source and spatial distribution of physicochemical parameters in water sources around the Ashaka Cement Industry.

In many developing nations, including Nigeria, access to safe and reliable water sources remains a significant challenge. In the Gombe State region, particularly the Ashaka area, a substantial portion of the population relies on natural water sources such as rivers and non-public water supply systems such as wells and boreholes system (Okonko *et al.,*2018). The proximity of the Ashaka Cement Industry raises concerns about the potential adverse impacts of industrial operations on the quality and suitability of the nearby water sources. In response, this research work investigated the levels of physicochemical indicators in water sources surrounding the Ashaka Cement Industry by use of a chemometric approach to predict the sources and spatial distribution of pollutants. Hence, the novelty lies in the combination of investigating physicochemical parameters in water sources and the use of a chemometrics approach to predict pollutant sources and their spatial distribution specifically around the Ashaka Cement Industry, which goes beyond simply measuring physicochemical parameters of the water sources.

MATERIALS AND METHODS

Study area and sample collection

The study area, encompassing approximately 25 km² around the Ashaka cement plant in Funakaye Local Government Area of Gombe State, Nigeria, is situated roughly 140 km north of Gombe town. Geographically, it falls between longitudes 11°25'E and 11°32'E and latitudes 10°50'N and 11°00'N. Access to the area is facilitated by the Gombe-Bajoga-Ashaka Cement Factory road and the Gombe-Maiduguri railway line. Within this area, twelve sampling stations were selected. Specifically, in Ashaka Gari, samples were taken at ASR1 (Ashaka river water point 1) (10°53'13.90776"N, 11°31'19.10928"E), ASR2 (Ashaka river water point 2) (10°53'12.86304"N, 11°31'17.82984"E), ASB1 (Ashaka borehole water point 1) (10°55'39.48888"N, 11°28'35.92884"E), and ASB2 (Ashaka borehole water point 2) (10°53'12.9"N, 11°31'17.8"E). In Feshingo, sampling occurred at FSB (Feshingo borehole water)

(10°55'5.23308"N, 11°28'6.55392"E) and FSW (Feshingo well water) (10°55'4.96992"N, 11°28'8.43708"E). Katsinawa was represented by samples KTB1 (Kastsinawa borehole water point 1) (10°57'23.0"N, 11°30'01.3"E), KTB2 (Kastsinawa borehole water point 1) (10.93498°N, 11.50483°E, altitude 281m, accuracy 4m), and KTW (Kastsinawa well water) (10°57'35.5"N, 11°29'54.4"E). Finally, in Juggol, samples were collected at JGT1 (Juggol tap water sourced from river point 1) (10.9499°N, 11.51041°E, altitude 257m, accuracy 4m), JGT2 (Juggol tap water sourced from river point 2) (10°56'59.6"N, 11°30'37.5"E), and JGT3 (Juggol tap water sourced from river point 3) (10°55'39.48708"N, 11°28'35.92776"E).

Water sampling was conducted during the rainy season between July and October 2023. A random sampling method was employed across the study area. Before sample collection, 1-L polyethylene bottles were soaked in 10% nitric acid and rinsed with distilled water. River water samples were collected downstream at intervals of approximately 2 meters along the river course, following the procedure described by Egbueri & Mgbenu (2020). Additionally, tap water, hand-dug well water, and borehole water samples were collected from locations proximate to the industry. At each sampling point, bottles were rinsed several times with the sample water before final collection. *In situ,* measurements of pH and DO were performed using portable pH and DO meters immediately following collection. To prevent cation precipitation, all samples were preserved by acidification with 1 mL of concentrated nitric acid (HNO_3), as described by Egbueri & Mgbenu (2020).

Physicochemical parameters analyses

Water quality parameters were determined using standard methods recommended by the American Public Health Association (APHA, 2008). pH and DO were determined *in situ* using a pH meter (HANNA: HI-99191) and DO Meter (HANNA: HI-98198), respectively. EC, DO, salinity, and TDS were measured using a multi-parameter analyzer equipped with a pH/ORP/EC/TDS/Salinity/DO/Pressure/Temperature probe (HANNA: HI-98194). Turbidity was measured using a calibrated digital nephelometer (HANNA: HI-98703, range 0-1000 NTU). Calibration was performed using a 400 NTU standard and verified with 0 NTU distilled water. Turbidity values were recorded in nephelometric turbidity units (NTU). Total suspended solids (TSS) were determined gravimetrically using 0.85-µm membrane filters. Filters were weighed before filtration, and water samples were then passed through them. The filters were subsequently dried in an oven until a constant weight was achieved. The TSS concentration (mg/L) was calculated from the difference between the initial and final filter weights, divided by the volume of water filtered. BOD was measured by collecting two samples at each site. One was tested *in situ* immediately for DO, while the other was incubated in the dark at 20-25°C for 5 days before DO was measured again. The BOD_5 value (mg/L) is the difference between the initial and final DO, representing oxygen consumed by microorganisms breaking down organic matter (APHA, 2008). In the COD test, the water sample was oxidized using potassium dichromate in sulfuric acid, with silver and mercury sulfates as catalysts. The remaining dichromate was titrated with ferrous ammonium sulfate, and the difference in titration volumes (compared to a blank) was used to calculate the COD, based on the stoichiometric relationship between dichromate consumed and oxygen required (APHA, 2008).

Data analysis

Chemometric Statistical Analysis which includes PCA, HCA, CA, and DA was performed using IBM SPSS Software (version 29). Correlation analysis examines the relationships between different variables. In this case, a strong positive correlation between two pollutants suggests they might have a common source. Hierarchical cluster analysis groups similar data points together. In this context, it groups sampling stations with similar pollutant profiles where stations clustered together likely share similar pollution sources and spatial distribution patterns.

RESULTS AND DISCUSSION

Physicochemical indicators

Table 1 presents the results of physicochemical indicators measured in water samples collected from various locations. pH values ranged from 6.36 to 7.75, with most samples falling within the acceptable range of 6.5-8.5 as per WHO/NSDWQ standards. However, samples ASB2 and KTW exhibited slightly acidic pH values outside the recommended range. The EC and TDS showed substantial disparities across the samples, with some, particularly ASB2 and FSB, displaying high values, indicative of elevated dissolved salt concentrations. Total suspended solids also varied considerably, with certain samples demonstrating high levels at ASB2, suggesting the presence of suspended particles. Turbidity levels ranged from 5.77 NTU at ASB1 to 7.91 NTU at JGT3, exceeding the WHO/NSDWQ recommended limit of <5 NTU in most cases, indicating reduced water clarity and the potential presence of significant amounts of suspended matter. Salinity levels varied from 0.39% to 3.91%, with the water samples at ABS2 exceeding the WHO/NSDWQ limit of 3.6%, suggesting elevated salt concentrations in the water source, which could pose concerns for both human consumption and aquatic life. Overall, the results revealed spatial variations in water quality within the study area. Specifically, TSS, turbidity (across all sampling stations), and salinity (at station ABS2) exhibited deviations from recommended standards in certain samples.

The results obtained show most of the physicochemical parameters concentration recorded increased in content during the Months of August and September over the Months of July and October, which perhaps attributed to the surface runoff from stormwater because the study was carried out during the rainy season. This result aligns with the findings of Ujoh & Alhassan (2014), who studied the physicochemical properties of stream water around a cement plant in central Nigeria, where physicochemical parameters varied across all water samples with highest mean value nearly double the WHO permissible limit was observed for TDS.

Table 1: Results of physicochemical indicators obtained in water samples.

S/N	Sample	p^H	EC (μScm^{-1})	TDS (mg/L)	TSS (mg/L)	Turbidity (NTU)	Salinity (%)
1	**ASR_2**	7.75±0.04	75.32±6	37.84±3	1135.17±460	6.99±1.85	0.39±0.05
2	**ASB_1**	7.10±0.69	332.63±113	166.70±58	891.33±402	5.77±0.92	1.55±0.90
3	**ASR_1**	7.62±0.510	87.01±16	43.56±8	1541.67±432	7.60±2.51	0.46±0.25
4	**ASB_2**	6.74±0.727	652.67±152	325.67±26	872±474	6.47±1,19	3.91±0.42
5	**FSB**	6.82±0.434	452.83±94	225.83±46	905.83±198	5.99±0.44	2.27±1.27
6	**FSW**	6.867±0.387	438.55±148	252.08±19	988.33±332	6.83±1.45	2.72±2.18
7	**KTB_1**	6.96±0.218	438.17±52	219.17±25	715±188	6.32±0.93	2.3±1.41

8	**JGT_2**	7.53±0.295	91.53±16	47.88±9	1017.17±340	7.64±2.36	0.54±0.37
9	**KTB_2**	7.09±0.323	314.83±172	156.07±28	775±235	7.27±1.77	2.6±1.39
10	**KTW**	6.36±0.573	144.48±85	72.38±42	879.17±275	6.42±0.55	0.92±0.93
11	**JGT_3**	7.12±0.376	241.13±159	71.88±38	1165±386	7.91±2.54	0.95±1.456
12	**JGT_1**	7.13±0.266	165.70±148	92.90±37	1350.83±449	7.89±2.40	0.94±1.17
13	**Min.**	6. 36±0.573	75.32±6	37.84±3	715±388	5.77±0.92	0.39±0.05
14	**Max.**	7. 75±0.041	652.67±245	325.67±26	1541.67±432	7.91±2.54	3.91±0.42
15	**Mean**	7.09	286.24	142.66	1019.71	6.92	1.63
16	**WHO/ NSDWQ**	6.5-8.5	<1000	<500.00	<300.00	<5.00	3.6

The Values are the mean ± SD of twelve (12) samples of water analyzed individually in triplicate and mean value.

Figure 1 presents a comparative analysis of pH, turbidity, and salinity across sampled water locations, benchmarked against WHO/NSDWQ standards. While most locations exhibited acceptable pH levels (6.5-8.5), some (e.g., ASB2, FSB, FSW, KTB1, and KTW) were slightly acidic. Turbidity varied, with all locations, notably JGT1 and JGT3, exceeding recommended limits, indicating elevated suspended particle concentrations. Similarly, salinity levels were within the recommended values except ASB2 surpassed WHO/NSDWQ guidelines. These findings reveal spatial variations in water quality, with TSS, turbidity, and salinity of particular concern in certain areas. Accordingly, the Ashaka Cement Industry's vicinity could likely contribute to elevated turbidity and salinity in surrounding water sources. Potential mechanisms include: (1) aerial deposition of dust and particulate matter (containing salts), (2) wastewater discharge containing suspended solids and dissolved salts, (3) runoff carrying pollutants from the plant and surrounding areas, (4) groundwater contamination *via* infiltration, and (5) leaching from waste disposal sites. However, the specific impact depends on factors such as distance from the plant, wind patterns, rainfall, soil type, and hydrogeology.

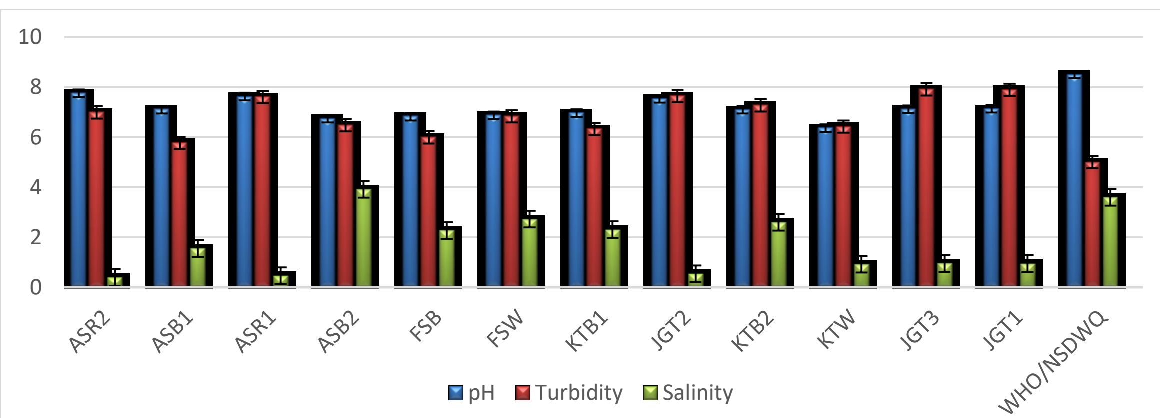

Figure 1: Comparison of the pH, Turbidity, and Salinity determined from various water sample locations.

Similarly, water quality, specifically EC, TDS, and TSS, was assessed at various sampling points (**Fig. 2**). The measurements revealed substantial differences in these parameters across the study area. Notably, sites ASB1, ASB2, FSB, FSW, KTB1, and KTB2 showed increased EC and TDS, suggesting a higher concentration of dissolved salts which could negatively affect the usability of the water sources. Similarly, locations ASR1, ASR2 JGT1, and JGT3 had elevated TSS, pointing to a greater presence of suspended particles that could reduce water clarity. These findings raise concerns about the overall water quality in the concerned locations. Although groundwater contamination may not be directly affected by TSS, it can indirectly influence other water quality measures.

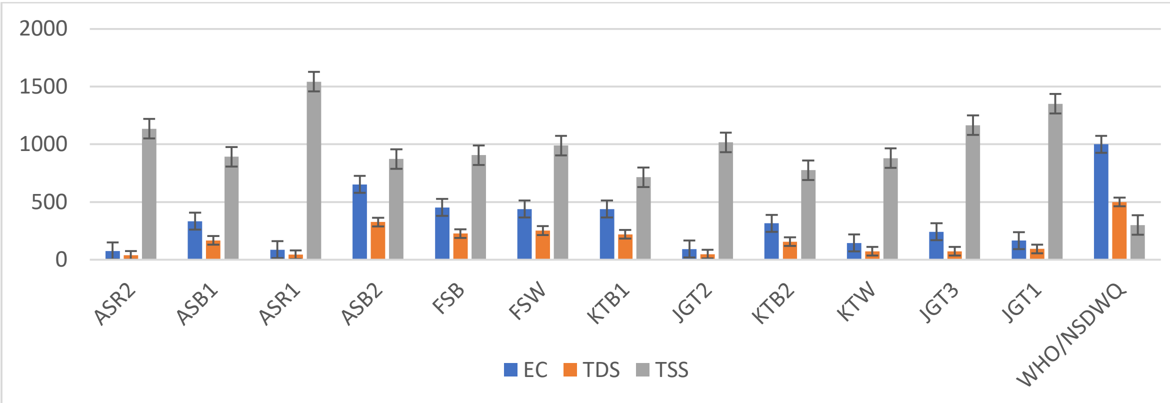

Figure 2. Comparison of the EC, TDS, and TSS determined from various water sample locations.

Table 2 presents the results of DO, BOD, COD, and the BOD/COD ratio in water samples collected from various locations. The DO values ranged from 3.42 mg/L to 4.48 mg/L, with all measured values falling below the WHO/NSDWQ standard of 6.0 mg/L. Low DO levels indicate a potential oxygen deficit in the water, which can negatively impact aquatic life. The BOD values ranged from 1.18 mg/L to 2.28 mg/L, generally lower than the DO values, suggesting that the water bodies can still support some level of aerobic biological activity. The COD values ranged from 3.92 mg/L to 8.71 mg/L, indicating the total oxygen demand for the oxidation of both organic and inorganic matter present in the water sample. The BOD/COD ratio ranged from 0.18 to 0.31, indicating the biodegradability of the organic matter present in the water sample. The results align with those presented by the significant elevation of COD and BOD levels, which suggested a temporal impact on the Onyi River's water quality due to discharges from the cement plant (Ipeaiyeda & Obaje, 2017).

Table 2: Result of DO, BOD, COD and BOD/COD Ratio.

S/N	Sample	DO (mg/L)	BOD (mg/L)	COD (mg/L)	BOD/COD
1	**ASR_2**	3.65±1.457	1.30±0228	4.36±0.985	0.30±0.108
2	**ASB_1**	3.98±2.211	1.73±0.750	7.03±1.932	0.25±0.087
3	**ASR_1**	3.85±1.766	1.42±0.867	4.98±1.778	0.29±0.160
4	**ASB_2**	4.02±1.363	1.57±0.829	8.71±2.053	0.18±0.041
5	**FSB**	4.48±1.160	2.28±0.852	7.37±2.282	0.31±0.055
6	**FSW**	3.52±1.345	1.55±0.459	6.46±1.509	0.24±0.129
7	**KTB_1**	4.10±1.757	1.65±0.524	7.14±1.956	0.23±0.060
8	**JGT_2**	3.77±1.357	1.18±0.412	3.92±1.434	0.30±0.106
9	**KTB_2**	3.68±2.017	1.68±0.685	7.44±1.892	0.23±0.092
10	**KTW**	3.42±1.559	1.23±0.427	4.20±0.414	0.29±0.089
11	**JGT_3**	3.43±1.226	1.38±0.366	4.73±1.845	0.29±0.093
12	**JGT_1**	4.00±1.075	1.57±0.242	5.07±1.926	0.31±0.146
13	Min.	3.42±1.559	1.18±0.412	3.93±1.434	0.18±0.041

14	Max.	4.48±1.160	2.28±0.852	8.71±2.053	0.31±0.055
15	Mean	3.83	1.55	5.95	0.27
16	WHO/NS DWQ	6.00	6.00	10.00-20.00	0.3-0.8

The Values are the mean ± SD of twelve (12) samples of water analyzed individually in triplicate and mean value.

An analysis of DO, BOD, COD, and the BOD/COD ratio across the water sampling sites is presented in Figure 3. DO levels were inconsistent, with the majority of sites falling short of the WHO/NSDWQ recommended minimum of 6.0 mg/L, indicating oxygen depletion in these water sources. BOD, a measure of biodegradable organic material, was elevated at several locations (FSB, ASB1, KTB1, and KTB2). Similarly, COD, which reflects the presence of oxidizable organic and inorganic substances, was notably high at ASB1, ASB2, FSB, KTB1, and KTB2. The BOD/COD ratio, an indicator of biodegradability, was generally below the WHO/NSDWQ target range of 0.3-0.8, suggesting that much of the organic matter present may not be easily broken down by microorganisms at these water sources. These findings reveal substantial spatial variability in key water quality indicators. The combination of low DO, high BOD, and COD, and low BOD/COD ratios at certain sites points to potential problems, including oxygen deficiency, significant organic pollution, and limited biodegradability at the concerned water sources. Therefore, the data suggests that the nearby cement industry could be negatively impacting local water quality.

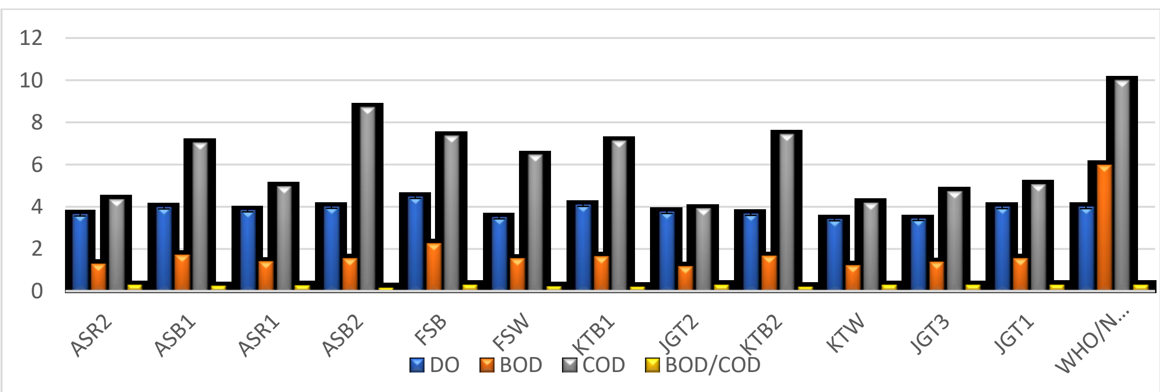

Figure 3: Comparison of the DO, COD, and BOD/COD Ratio in various water sample locations.

Chemometric analytics-Dendrogram analysis (Hierarchical cluster analysis) for water quality parameters

The dendrogram in Figure 4 was generated using the Average Linkage method to cluster water samples based on their EC, Salinity, TDS, TSS, Turbidity, and pH. HCA is a valuable tool in water quality assessment, enabling the classification of samples into groups with similar quality and risk characteristics. The dendrogram reveals distinct clustering patterns. EC and Salinity formed a tight cluster, which then merged with TDS, suggesting a strong correlation between these parameters. This cluster likely represents water samples influenced by a common source of pollution, possibly related to the presence of dissolved salts. In contrast, TSS and Turbidity formed a separate cluster, which subsequently merged with pH. This cluster suggests a relationship between suspended particles and water clarity, likely influenced by factors such as soil erosion and sedimentation. These findings are consistent with previous studies, such as Egbueri & Unigwe (2019), which used dendrograms to classify water samples based on various parameters including pH, trace metal content, and water quality indices. Similarly, Olukoya *et al*. (2019) employed chemometric techniques, including cluster analysis, to evaluate heavy metal pollution patterns in soil samples.

The dendrogram, generated using the Average Linkage method, effectively clustered water samples based on their EC, Salinity, TDS, TSS, Turbidity, and pH. This clustering pattern provides valuable insights into the potential sources of pollution and their impact on water quality in the vicinity of the cement industry. The strong clustering of EC, Salinity, and TDS suggests a strong correlation between these parameters, likely representing water samples influenced by the leaching of soluble salts from the cement industry. Cement production involves the use of various minerals and chemicals, some of which are highly soluble in water. Improper disposal of cement dust and other waste materials can lead to the leaching of salts into the surrounding soil and groundwater. If the cement plant discharges untreated or inadequately treated effluent, it can also contribute to elevated levels of dissolved salts in nearby water bodies. The clustering of TSS, Turbidity, and pH suggests a relationship between suspended particles and water clarity, likely influenced by factors such as the generation of dust and particulate matter during cement production, which can be carried by wind and deposited into nearby water bodies, increasing turbidity and TSS. Massive loading of cement by heavy trucks and other disturbances associated with the cement industry can also lead to soil attrition, which can increase the amount of suspended particles in water sources. The presence of suspended particles can influence the pH of water through various mechanisms, such as the adsorption of ions and the release of dissolved substances. The dendrogram analysis provides valuable information for the cement industry in terms of understanding and mitigating its impact on water quality. The results can guide targeted monitoring efforts by focusing on parameters that are closely correlated (e.g., EC, Salinity, and TDS). Overall, the dendrogram provides valuable insights into the interrelationships among various water quality parameters, facilitating the identification of potential pollution sources and areas of concern.

Case Processing Summary

Cases Valid		Cases Missing		Total	
N	Percent	N	Percent	N	Percent
72	100.0%	0	0.0%	72	100.0%

a. Correlation between Vectors of Values used

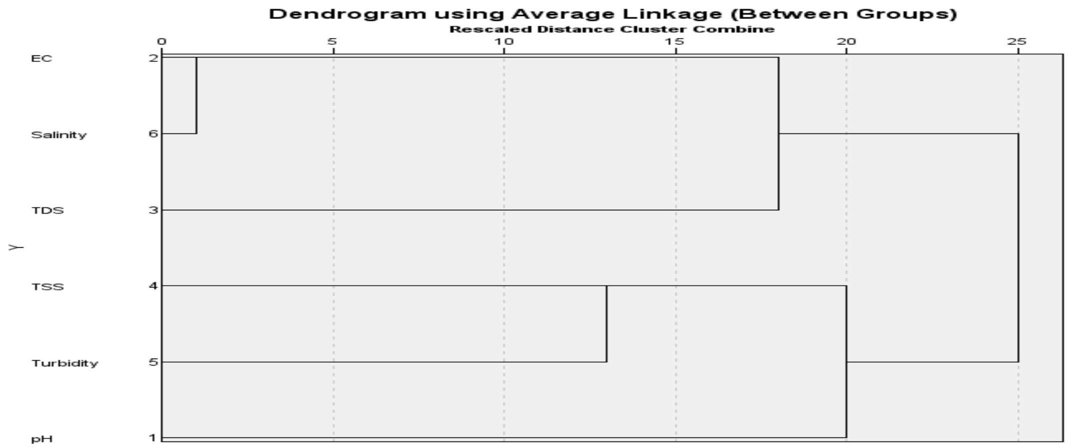

Figure 4: Dendrogram for EC, Salinity, TDS, TSS, Turbidity and pH.

Similarly, Figure 5 presents a dendrogram generated using the Average Linkage method to cluster water samples based on their DO, BOD, COD, and BOD/COD ratio. The dendrogram reveals distinct clustering patterns. DO and the BOD/COD ratio formed a tight cluster, which then merged with BOD, suggesting a strong correlation between these parameters. This cluster likely represents water samples with higher levels of biological activity, as higher DO levels can support increased microbial activity, leading to higher BOD and a corresponding increase in the BOD/COD ratio. In contrast, COD formed a cluster with BOD and subsequently merged with DO. While BOD and COD are both measures of organic matter in water, their inverse relationship within this cluster suggests that as COD increases, the relative contribution of readily biodegradable organic matter (reflected in BOD) may decrease. This could indicate the presence of more refractory organic matter that is less easily broken down by microorganisms, potentially impacting DO levels. These findings are consistent with previous studies which employed dendrograms to classify water samples based on various parameters including BOD and COD (Adejuwon *et al*., 2025; Warsito *et al*., 2021; Ogwueleka & Christopher, 2020).

The clustering pattern provides valuable insights into the potential impact of cement industry operations on water quality in the surrounding environment. The close clustering of DO, BOD, and the BOD/COD ratio suggests a strong correlation between these parameters. This cluster likely represents water samples with higher levels of biological activity, as higher DO levels can support increased microbial activity, leading to higher BOD (as microorganisms consume organic matter) and a corresponding increase in the BOD/COD ratio. This cluster may represent water sources impacted by organic pollution from the cement industry, such as the discharge of untreated or inadequately treated wastewater containing organic matter. Even though it is not the primary focus of their operations. However, during raining season, cement plant wastewater can be contaminated with organic matter from several sources, namely, surface runoff (rainwater washing over the plant site, can pick up pollutants such as hydrocarbons from fuel and lubricant spills, organic debris like plant material and animal waste from accumulated dust, and detergents used for cleaning). In addition, though cement production is primarily a dry process, some wet processes, such as cooling and washing water with lubricants and organic matter, and sanitary/laboratory wastewater (containing typical organic waste and chemicals) contribute to organic contamination. While BOD and COD are both measures of organic matter in water, their clustering together with DO, despite an inverse relationship within the cluster, suggests a complex interplay of factors. As COD increases, the relative contribution of readily biodegradable organic matter (reflected in BOD) may decrease, indicating the presence of more refractory organic matter in the water, such as complex organic compounds or recalcitrant pollutants that are not easily broken down by microorganisms. This refractory organic matter could exert a persistent oxygen demand, contributing to low DO levels observed in some samples. The dendrogram analysis provides valuable information for the cement industry in terms of understanding and mitigating its impact on water quality. The results can guide targeted monitoring efforts by focusing on parameters that are closely correlated within each cluster. For instance, monitoring DO, BOD, and the BOD/COD ratio together can provide a more comprehensive assessment of the impact of organic pollution. The clustering patterns can also help identify potential sources of organic pollution within the cement industry operations. For example, the cluster with high COD and low BOD/COD ratio may indicate the presence of more recalcitrant organic pollutants, potentially originating from specific industrial processes or waste disposal practices. Overall, the dendrogram analysis provides valuable insights into the complex relationships between water quality parameters and their potential sources in the vicinity of the cement industry. This information can be used to guide targeted monitoring and mitigation efforts to minimize the environmental impact of the industry.

Case Processing Summary

Cases Valid		Cases Missing		Total	
N	Percent	N	Percent	N	Percent
72	100.0%	0	0.0%	72	100.0%

a. Correlation between Vectors of Values used

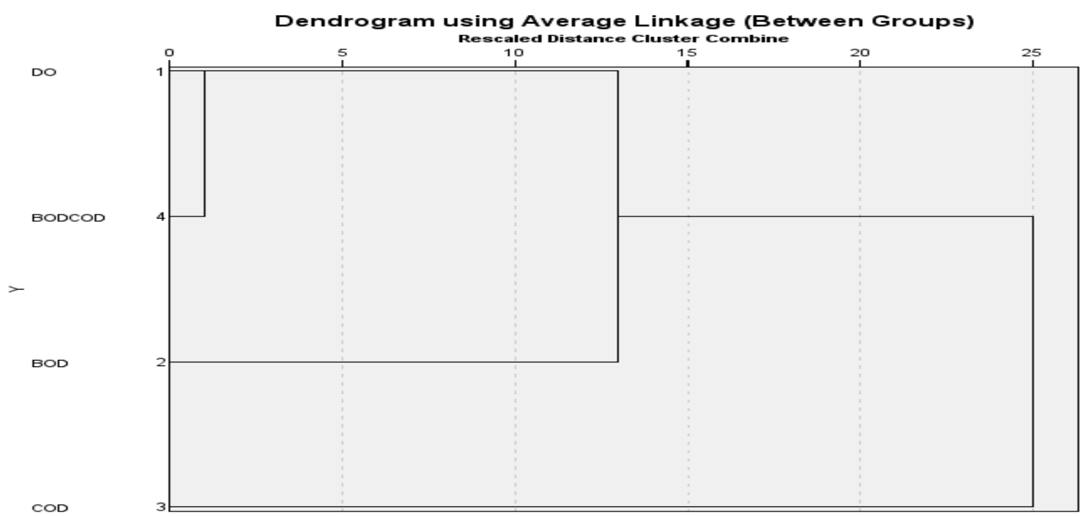

Figure 5: Dendrogram for DO, BOD, COD and BOD/COD.

Correlation analysis

Table 5 presents the Pearson correlation coefficients observed between various physicochemical indicators in the water samples, namely, pH, EC, TDS, TSS, Turbidity, and Salinity. A strong positive correlation (r = 0.830) was observed between EC and Salinity, suggesting a close relationship between these parameters. This indicates that increases in EC are likely accompanied by increases in Salinity, possibly due to the presence of dissolved salts. A strong positive correlation (r = 0.397) was also found between TSS and Turbidity, as expected since increased suspended solids in the water will naturally lead to higher turbidity. A strong negative correlation (r = -0.390) was observed between pH and EC, suggesting that as EC increases, pH tends to decrease, possibly due to the presence of acidic or alkaline salts that affect both conductivity and pH. A strong negative correlation (r = -0.248) was also observed between pH and Salinity, further supporting the influence of dissolved salts on pH. Moderate positive correlations were observed between TDS and other parameters, indicating that increases in TDS are generally associated with increases in other parameters. Weaker correlations were observed between some parameters, suggesting less pronounced relationships. These correlations present valuable insights into the relationships between different water quality indicators. The strong positive correlation between EC and Salinity, and the negative correlations between pH and both EC and Salinity, suggest that these parameters are likely influenced by similar factors, such as the presence of dissolved salts. The strong correlation between TSS and Turbidity highlights the expected relationship between suspended particles and water clarity. Understanding these correlations can aid in identifying potential sources of pollution and assessing the overall water quality. For example, the strong relationship between EC and Salinity suggests that sources of salinity may also be contributing to increased conductivity in the water.

These correlation coefficients provide valuable insights into the interrelationships among various water quality parameters, thereby aiding in the identification of potential pollution sources originating from the cement industry. The strong positive correlation (r = 0.830) between EC and Salinity suggests a close relationship between these parameters. This likely indicates a significant contribution of dissolved salts to both EC and Salinity in the water samples. In the context of a cement industry, the presence of dissolved salts could be attributed to the leaching of salts from cement dust and waste materials, as cement production and handling processes generate significant amounts of dust containing various salts that can leach into the surrounding soil and groundwater, eventually finding their way into nearby water bodies. If the cement plant discharges untreated or inadequately treated wastewater containing dissolved salts, it can directly contribute to elevated levels of EC and Salinity in receiving water bodies. The strong negative correlations between pH and both EC (r = -0.390) and Salinity (r = -0.248) suggest that the presence of dissolved salts is influencing the pH of the water. Some salts, when dissolved in water, can alter the pH of the solution. For example, the presence of alkaline salts can increase the pH, while the presence of acidic salts can decrease it. The strong positive correlation (r = 0.397) between TSS and Turbidity is expected, as increased suspended solids in the water will naturally lead to higher turbidity. This highlights the impact of particulate matter, which can originate from various sources in the vicinity of a cement industry, such as the generation of dust and particulate matter during cement production, which can be carried by wind and deposited into nearby water bodies, increasing turbidity. Construction activities and other disturbances associated with the cement industry can also lead to soil erosion, increasing the amount of suspended particles in water bodies. Moderate positive correlations were observed between TDS and other parameters, indicating that increases in TDS are generally associated with increases in other parameters. Weaker correlations were observed between some parameters, suggesting less pronounced relationships. These correlations provide valuable insights into the interrelationships among various water quality indicators and their potential sources of pollution. The strong positive correlation between EC and Salinity, and the negative correlations between pH and both EC and Salinity, suggest that these parameters are likely influenced by similar factors, such as the presence of dissolved salts. The strong correlation between TSS and Turbidity highlights the expected relationship between suspended particles and water clarity. Understanding these correlations can aid in identifying potential sources of pollution and assessing the overall water quality. For example, the strong relationship between EC and Salinity suggests that sources of salinity may also be contributing to increased conductivity in the water. The dendrogram analysis provides valuable information for the cement industry in terms of understanding and mitigating its impact on water quality. The results can guide targeted monitoring efforts by focusing on parameters that are closely correlated within each cluster. For instance, monitoring DO, BOD, and the BOD/COD ratio together can provide a more comprehensive assessment of the impact of organic pollution. The clustering patterns can also help identify potential sources of organic pollution within the cement industry operations. For example, the cluster with high COD and low BOD/COD ratio may indicate the presence of more recalcitrant organic pollutants, potentially originating from specific industrial processes or waste disposal practices.

Table 5: Correlation Table for (pH, EC, TDS, TSS, Turbidity, Salinity)

		pH	EC	TDS	TSS	Turbidity	Salinity
pH	Pearson Correlation	1	$-.390^{**}$	-.055	.034	$.266^{*}$	$-.248^{*}$
	Sig. (2-tailed)		<.001	.644	.775	.024	.036
	N	72	72	72	72	72	72
EC	Pearson Correlation	$-.390^{**}$	1	.220	-.102	-.117	$.830^{**}$
	Sig. (2-tailed)	<.001		.063	.393	.328	<.001
	N	72	72	72	72	72	72
TDS	Pearson Correlation	-.055	.220	1	.161	$.261^{*}$	.220
	Sig. (2-tailed)	.644	.063		.176	.027	.063
	N	72	72	72	72	72	72
TSS	Pearson Correlation	.034	-.102	.161	1	$.397^{**}$	-.155
	Sig. (2-tailed)	.775	.393	.176		<.001	.192
	N	72	72	72	72	72	72
Turbidity	Pearson Correlation	$.266^{*}$	-.117	$.261^{*}$	$.397^{**}$	1	.132
	Sig. (2-tailed)	.024	.328	.027	<.001		.270
	N	72	72	72	72	72	72
Salinity	Pearson Correlation	$-.248^{*}$	$.830^{**}$	.220	-.155	.132	1
	Sig. (2-tailed)	.036	<.001	.063	.192	.270	
	N	72	72	72	72	72	72

**Correlation is significant at the 0.01 level (2-tailed).
*Correlation is significant at the 0.05 level (2-tailed).

Table 6 presents the Pearson correlation coefficients between DO, BOD, COD, and the BOD/COD ratio in water samples. A strong positive correlation (r = 0.488) was observed between DO and the BOD/COD ratio, suggesting that higher DO levels may be associated with a greater proportion of biodegradable organic matter. A strong positive correlation (r = 0.370) was also observed between BOD and the BOD/COD ratio, as expected since an increase in BOD would naturally lead to an increase in the BOD/COD ratio. A negative correlation (r = -0.244) was observed between COD and the BOD/COD ratio, suggesting that as COD increases, the relative contribution of readily biodegradable organic matter (reflected in BOD) may decrease. Weak positive correlations were observed between

DO and BOD (r = 0.047) and between DO and COD (r = 0.104). A weak negative correlation was observed between BOD and COD (r = -0.014). These correlations provide valuable insights into the interrelationships among various water quality indicators. The strong positive correlation between DO and the BOD/COD ratio suggests that higher DO levels may support increased microbial activity, leading to higher BOD and a corresponding increase in the BOD/COD ratio. The negative correlation between COD and the BOD/COD ratio indicates that as COD increases, the relative contribution of readily biodegradable organic matter (reflected in BOD) may decrease, potentially due to the presence of more refractory organic matter that is less easily broken down by microorganisms. Understanding these correlations can aid in identifying potential sources of pollution and assessing the overall water quality. For example, the relationship between DO, BOD, and the BOD/COD ratio can provide valuable information about the state of the aquatic ecosystem and the presence of biodegradable organic matter.

These correlations provide valuable insights into the interrelationships among various water quality indicators and their potential implications for water quality degradation in the vicinity of the cement plant. A strong positive correlation (r = 0.488) was observed between DO and the BOD/COD ratio, suggesting that higher DO levels are associated with a greater proportion of readily biodegradable organic matter. This is logical as higher DO levels support increased microbial activity, enabling more efficient breakdown of biodegradable organic matter. A strong positive correlation (r = 0.370) was also observed between BOD and the BOD/COD ratio, as expected, since an increase in BOD (biodegradable organic matter) directly increases the BOD/COD ratio. However, a negative correlation (r = -0.244) was observed between COD and the BOD/COD ratio, suggesting that as COD increases, the relative contribution of readily biodegradable organic matter (reflected in BOD) may decrease. This could indicate the presence of more refractory organic matter in the water, such as complex organic compounds or recalcitrant pollutants that are not easily broken down by microorganisms. These correlations provide valuable insights into the relationships between different water quality parameters and their potential impacts on the environment in the vicinity of the cement industry. The observed relationships suggest that the water bodies in the vicinity of the cement industry may be impacted by organic pollution. The presence of refractory organic matter could be attributed to the discharge of untreated or inadequately treated effluent from the cement plant, which may contain complex organic compounds that are difficult to degrade. Improper disposal of industrial waste can also lead to the leaching of organic matter into the surrounding soil and groundwater. Additionally, organic compounds present in dust and particulate matter emitted from the cement plant can be deposited into water bodies, contributing to the organic load. The presence of refractory organic matter can exert a persistent oxygen demand, potentially leading to low DO levels, as observed in the study, which can have significant negative impacts on aquatic life. These findings underscore the importance of implementing effective effluent treatment systems to remove or reduce the concentration of organic pollutants in wastewater discharged from the cement plant. Proper waste management practices are crucial to prevent the leaching of organic matter from waste disposal sites. Dust control measures are also necessary to minimize the emission of dust and particulate matter from the cement plant. By understanding the interrelationships between different water quality indicators and their implications, targeted monitoring and mitigation strategies can be implemented to minimize the environmental impacts of the cement industry and protect aquatic ecosystems.

Table 6: Correlation Table for (DO, BOD, COD and BOD/COD)

		DO	BOD	COD	BODCOD
DO	Pearson Correlation	1	.047	.104	.488**
	Sig. (2-tailed)		.694	.385	<.001
	N	72	72	72	72
BOD	Pearson Correlation	.047	1	-.014	.370**
	Sig. (2-tailed)	.694		.907	.001
	N	72	72	72	72
COD	Pearson Correlation	.104	-.014	1	-.244*
	Sig. (2-tailed)	.385	.907		.039
	N	72	72	72	72
BODCOD	Pearson Correlation	.488**	.370**	-.244*	1
	Sig. (2-tailed)	<.001	.001	.039	
	N	72	72	72	72

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).

Factor/principal component analysis result of (pH, EC, TDS, TSS, Turbidity, Salinity)

Figure 6 displays a component plot in rotated space derived from Principal Component Analysis (PCA). PCA is a statistical technique employed to reduce the dimensionality of a dataset by identifying principal components, which are linear combinations of the original variables that account for the majority of the variance within the data. In this study, PCA was applied to the following water quality indicators, namely, EC, Salinity, TDSs, TSSs, Turbidity, and pH. Two principal components were extracted from the analysis. Component 1 primarily explains the variation associated with EC, Salinity, and TDS. The proximity of these parameters on the plot suggests a strong correlation and is likely a common source of influence, possibly related to the presence of dissolved salts. Component 2 primarily explains the variation associated with Turbidity, TSS, and pH. The clustering of these parameters suggests an interrelationship between suspended particles and water clarity, potentially influenced by factors such as soil erosion and sedimentation. The PCA results provide valuable insights into the interrelationships between different water quality indicators and their potential sources of variation. By identifying groups of parameters with similar patterns of variation, PCA can aid in understanding the underlying processes driving water quality changes. These findings are consistent with previous studies, such as Egbueri *et al.* (2018), which have utilized PCA to explore interrelationships between various water quality indicators and identify potential sources of pollution.

This PCA analysis provides valuable insights into the relationships between these parameters and their potential sources of variation, offering a deeper understanding of the impact of cement industry operations on water quality. The proximity of EC, Salinity, and TDS on Component 1 suggests a strong correlation between these parameters. This cluster likely represents water samples influenced by the presence of dissolved salts, which can originate from various sources associated with cement industry operations, such as the leaching of salts from cement dust and waste materials. Cement production and handling processes generate significant amounts of dust containing various salts, which can leach into the surrounding soil and groundwater, eventually finding their way into nearby water bodies, contributing to elevated EC, Salinity, and TDS. If the cement plant discharges untreated or inadequately treated wastewater containing dissolved salts, it can directly contribute to elevated levels of EC, Salinity, and TDS in receiving water bodies. The clustering of Turbidity, TSS, and pH on Component 2 suggests a relationship between suspended particles and water clarity. This cluster likely represents water samples impacted by factors such as the generation of dust and particulate matter during cement production, which can be carried by wind and deposited into nearby water bodies, increasing turbidity and TSS. Construction activities and other disturbances associated with the cement industry can also lead to soil erosion, increasing the level of suspended particles in water bodies. The presence of suspended particles can influence the pH of water through various mechanisms, such as the adsorption of ions and the release of dissolved substances. The PCA results highlight the importance of monitoring not only individual parameters but also groups of parameters that exhibit strong correlations. For example, focusing on EC, Salinity, and TDS together can provide valuable insights into the impact of dissolved salts on the cement industry. The clustering patterns can also aid in identifying potential sources of pollution within the cement industry operations. Targeted mitigation measures, such as improved effluent treatment to minimize the discharge of dissolved salts and other pollutants into water bodies, dust control measures to reduce the emission of dust and particulate matter into the environment, proper waste management practices to prevent the leaching of salts and other pollutants from waste disposal areas, and erosion control measures to minimize soil erosion and sedimentation in nearby water bodies, can be implemented to minimize the environmental impact of the industry. Overall, the PCA analysis offers valuable insights into the interdependencies among water quality indicators, thereby facilitating the identification of potential sources of variability in water quality within the vicinity of the cement industry. By understanding these relationships and identifying key clusters, targeted monitoring and mitigation strategies can be implemented to minimize the environmental impact of the industry.

For the results of DO, BOD, COD, AND BOD/COD, only a single PC was extracted. Therefore, the solution cannot be rotated, as PC analysis is mainly for matrix data and consequently, the rotation of the solution was not feasible.

Component Matrix[a]

a. 2 components extracted.

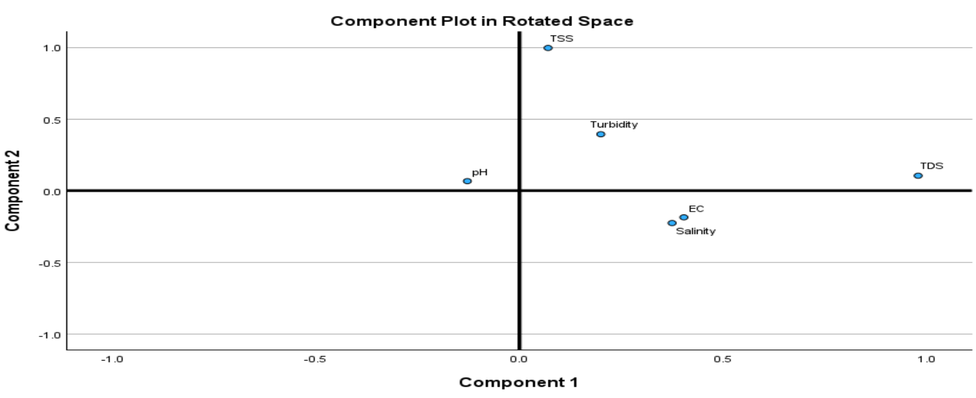

Figure 6: The plot of Principal Components for (pH, EC, TDS, TSS, Turbidity, and Salinity).

Discriminant analysis result of physicochemical parameters for water samples (pH, EC, TDS, TSS, Turbidity, Salinity)

A higher value of Wilks' Lambda, which ranges from 0 to 1, signifies low statistical significance and implies reduced discriminating power of the model. In this analysis, as presented in Table 7, a Wilks' Lambda value of 0.223 indicates satisfactory model performance, as a lower value approaching 0 demonstrates enhanced discriminating capability. Accordingly, as presented in Table 8, Output 1 indicates that Turbidity serves as the most significant predictor, exhibiting a coefficient of 0.436. This coefficient suggests that Turbidity reflects distinct sources and distributions of contaminants. Following turbidity are salinity, pH, TSS, and TDS, with coefficients of 0.249, 0.168, 0.097, and 0.067, respectively, while electrical conductivity (EC) has the lowest coefficient at 0.010.

A higher Wilks' Lambda value (closer to 1) generally indicates lower statistical significance and a poorer model fit. However, in this analysis, the Wilks' Lambda value of 0.223 suggests a satisfactory model performance. A lower value closer to 0 would indicate a stronger discriminating power of the model. This suggests that the model developed based on the analyzed parameters (Turbidity, Salinity, pH, TSS, TDS, and EC) is relatively effective in differentiating between different water quality conditions or potential sources of pollution. The output indicates that Turbidity has the highest coefficient (0.436), suggesting it is the most significant predictor of water quality variations in the study area. This aligns with the expected impact of cement industry operations, as discussed earlier. Cement production and handling processes can generate significant amounts of dust and particulate matter, which can be carried by wind and deposited into nearby water bodies, increasing turbidity. Salinity (0.249), pH (0.168), TSS (0.097), and TDS (0.067) also exhibit significant coefficients, indicating their importance in differentiating water quality conditions. These parameters, as discussed previously, are closely linked to various aspects of cement industry operations, such as the leaching of salts, soil erosion, and the generation of particulate matter. EC has the lowest coefficient (0.010), suggesting a relatively weaker influence on the overall discrimination between water quality conditions compared to the other parameters. The high significance of Turbidity as a predictor highlights the importance of considering particulate matter pollution in the vicinity of the cement industry. Monitoring turbidity levels can provide valuable insights into the impact of dust emissions and soil erosion on water quality. The analysis emphasizes the importance of considering multiple parameters (Turbidity, Salinity, pH, TSS, TDS, and EC) together to gain a comprehensive understanding of water quality variations and their potential sources.

Table 7: Wilks' Lambda for (pH, EC, TDS, TSS, Turbidity, Salinity)

Test of Function(s)	Wilks' Lambda	Chi-square	Df	Sig.
1	.223	100.593	6	<.001

Table 8: Structure Matrix for (pH, EC, TDS, TSS, Turbidity, Salinity)

	Function 1
Turbidity	.436
Salinity	.249
Ph	.168
TSS	-.097
TDS	.067
EC	.010

Pooled within-groups correlations between discriminating variables and standardized canonical discriminant functions
Variables ordered by the absolute size of correlation within the function.

In this model (Table 9), a coefficient of 0.707 suggests that the model exhibits poor performance, as a value approaching 1 indicates inadequate discriminating power. Conversely, Table 10, Output 1 reveals that COD is the most significant predictor, with a coefficient of 0.788. This finding suggests a distinct source and distribution of contaminants associated with COD. Following COD, DO and BOD demonstrate coefficients of 0.518 and 0.198, respectively. In contrast, the BOD/COD ratio exhibits the lowest coefficient at 0.084.

Table 9 shows a Wilks' Lambda value of 0.707. Unlike the previous analysis, a higher Wilks' Lambda value (closer to 1) in this context indicates poorer model performance. This suggests that the model developed based on the analyzed parameters (DO, BOD, COD, and BOD/COD ratio) may not be as effective in differentiating between water quality conditions or identifying distinct sources of pollution compared to the previous model. Table 10, Output 1 reveals that COD has the highest coefficient (0.788), indicating that it is the most significant predictor of water quality variations in this analysis. This finding suggests that COD plays a crucial role in differentiating water quality conditions in the study area. This is consistent with the potential impact of the cement industry, as cement production processes can generate significant amounts of organic and inorganic matter that increase the COD of receiving water bodies. DO (0.518) and BOD (0.198) also exhibit significant coefficients, indicating their importance in differentiating water quality conditions. These parameters are closely linked to the presence and activity of microorganisms in the water, which can be impacted by the discharge of organic pollutants from the cement industry. The BOD/COD ratio has the lowest coefficient (0.084), suggesting a relatively weaker influence on the overall discrimination between water quality conditions compared to other parameters in this analysis. The high significance of COD as a predictor emphasizes the importance of monitoring and controlling COD levels in water bodies impacted by cement industry operations. The findings suggest that organic pollution may be a significant concern in the study area. This could be attributed to the discharge of untreated or inadequately treated effluent from the cement plant, the leaching of organic matter from waste disposal sites, and the deposition of organic compounds from dust and particulate matter emitted by the cement plant.

Table 9: Wilks Lambda for (DO, BOD, COD and BOD/COD)

Test of Function(s)	Wilks' Lambda	Chi-square	df	Sig.
1	.707	23.598	4	<.001

Table 10: Structure Matrix for (DO, BOD, COD and BOD/COD)

	Function 1
COD	.788
DO	.518
BOD	.198
BODCOD	.084

Pooled within-groups correlations between discriminating variables and standardized canonical discriminant functions. Variables ordered by absolute size of correlation within function.

CONCLUSION

This study successfully utilized a chemometric approach to assess the physicochemical quality of water resources in the vicinity of the Ashaka Cement Industry in Nigeria. Despite adherence to WHO standards for many individual measures, the water quality assessment revealed concerning trends. Across all sampling locations, both TSS and turbidity were consistently elevated. Furthermore, high salinity was detected at station ASB2. A temporal pattern also emerged, with most physicochemical parameters showing increased concentrations during August and September, likely linked to rainy seasonal factors. Therefore, the pervasive nature of elevated TSS and turbidity, coupled with the localized salinity issue, suggests that the water sources, while seemingly acceptable in some respects, do not consistently meet quality standards. On the other hand, chemometric analysis effectively correlated and classified pollutants, revealing potential sources and spatial distribution patterns. This study features the significance of chemometrics as a valuable tool for assessing and predicting environmental pollution from industrial sources. The findings emphasize the need for stringent effluent treatment measures at the cement plant to minimize environmental impact. Furthermore, exploring alternative drinking water sources for communities residing in areas potentially impacted by industrial pollution is crucial to ensure public health and environmental sustainability.

REFERENCES

Adejuwon, E. O., Ogwueleka, T. C., Ogungbemi, E. O., Prabhu, R., Rendon-Nava, A., & Yates, K. (2025). Assessment of surface water quality using chemometric tools: A case study of Jabi Lake, Abuja, Nigeria. *Iranian Journal of Science and Technology, Transactions of Civil Engineering*, 1-24. https://doi.org/10.1007/s40996-024-01712-2

Amadi, A. N., Akande, W. G., Okunlola, I. A., Jimoh, M. O., & Francis, D. G. (2015). Assessment of the geotechnical properties of lateritic soils in Minna, North Central Nigeria for road design and construction. *American Journal of Mining and Metallurgy*, **3**(1): 15-20. https://doi.org/10.12691/ajmm-3-1-3

APHA (American Public Health Association) (2008). *Standard Methods for the*

*Examination of Water and Wastewater***,** 20th edn. Washington DC, USA: American Public Health Association.

Badamasi, H., Hassan, U. F., Adamu, H. M., & Baba, N. M. (2021). Evaluation of heavy metals pollution status of the groundwater around Riruwai mining area, Kano State, Nigeria. *European Journal of Environment and Earth Sciences*, **2**(3): 23-28.

Duan, Q., Zhang, Q., Quan, X., Zhang, H., & Huang, L. (2024). Innovations of water pollution traceability technology with artificial intelligence. *Earth Critical Zone*, **1**(1): 100009.

Egbueri, J. C., & Mgbenu, C. N. (2020). Chemometric analysis for pollution source identification and human health risk assessment of water resources in Ojoto Province, southeast Nigeria. *Applied Water Science*, **10**(4), 98. https://doi.org/10.1007/s13201-020-01180-9

Egbueri, J. C. (2018). Assessment of the quality of groundwaters proximal to dumpsites in Awka and Nnewi metropolises: a comparative approach. *International Journal of Energy and Water Resources*, **2**(1): 33-48. https ://doi.org/10. 1007/ s4210 8-018-0004-1

Egbueri, J. C. (2019). Evaluation and characterization of the groundwater quality and hydrogeochemistry of Ogbaru farming district in southeastern Nigeria. *SN Applied Sciences*, **1**(8): 851. https ://doi.org/10.1007/ s4245 2-019-0853-1

Egbueri, J. C. (2020) Heavy metals pollution source identification and probabilistic health risk assessment of shallow groundwater in Onitsha, Nigeria. *Analytical Letters*, **53**(10): 1620-1638. https://doi.org/10.1080/00032719.2020.1712606

Essamlali, I., Nhaila, H., & El Khaili, M. (2024). Advances in machine learning and IoT for water quality monitoring: A comprehensive review. *Heliyon*, 10(6): e27920. https://doi.org/10.1016/j.heliyon.2024.e27920

Hussain, M., Ahmed, S. M., & Abderrahman, W. (2008). Cluster analysis and quality assessment of logged water at an irrigation project, eastern Saudi Arabia. *Journal of environmental management*, **86**(1): 297-307. https://doi.org/10.1016/j.jenvman.2006.12.007

Inobeme, A., Nayak, V., Mathew, T. J., Okonkwo, S., Ekwoba, L., Ajai, A. I., ... & Singh, K. R. (2022). Chemometric approach in environmental pollution analysis: A critical review. *Journal of Environmental Management*, **309**: 114653. https://doi.org/10.1016/j.jenvman.2022.114653

Ipeaiyeda, A. R., & Obaje, G. M. (2017). Impact of cement effluent on water quality of rivers: A case study of Onyi river at Obajana, Nigeria. *Cogent Environmental Science*, **3**(1): 1319102. https://doi.org/10.1080/23311843.2017.1319102

Liu, C. W., Lin, K. H., & Kuo, Y. M. (2003). Application of factor analysis in the assessment of groundwater quality in a blackfoot disease area in Taiwan. *Science of the Total Environment*, **313**(1-3): 77-89. https://doi.org/10.1016/S0048-9697(02)00683-6

Mas, S., de Juan, A., Tauler, R., Olivieri, A. C., & Escandar, G. M. (2010). Application of chemometric methods to environmental analysis of organic pollutants: a review. *Talanta*, **80**(3): 1052-1067. https://doi.org/10.1016/j.talanta.2009.09.044

Ogwueleka, T. C., & Christopher, I. E. (2020). Hydrochemical interfaces and spatial assessment of Usuma River water quality in North-Central Nigeria. *Scientific African*, *8*, e00371. https://doi.org/10.1016/j.sciaf.2020.e00371

Olukoya, A. B., Yisa, J., & Jacob, J. O. (2019) Chemometric evaluation of heavy metals pollution patterns of soil in the vicinity of some dumpsites in Lokoja, Nigeria. *FUW Trends in Science & Technology Journal*, **4**: 118-121.

Platikanov, S., Baquero, D., González, S., Martín-Alonso, J., Paraira, M., Cortina, J. L., & Tauler, R. (2019). Chemometric analysis for river water quality assessment at the intake of drinking water treatment plants. *Science of the Total Environment*, **667**: 552-562. https:// doi.org/10.1016/j.scitotenv.2019.02.423

Patil, P. N., Sawant, D. V., & Deshmukh, R. N. (2012). Physicochemical parameters foresting of water–A review. *International Journal of Environmental Sciences*, **3**(3): 1194-1207.

Ahmed, U., Mumtaz, R., Anwar, H., Shah, A. A., Irfan, R., & García-Nieto, J. (2019). Efficient water quality prediction using supervised machine learning. *Water*, *11*(11), 2210. https://doi.org/10.3390/w11112210

Singh, K. P., Malik, A., Mohan, D., &Sinha, S. (2004). Multivariate statistical techniques for the evaluation of spatial and temporal variations in water quality of Gomti River (India)—a case study. *Water Research*, **38**(18), 3980-3992. https://doi.org/10.1016/j.watres.2004.06.011

Syeed, M. M., Hossain, M. S., Karim, M. R., Uddin, M. F., Hasan, M., & Khan, R. H. (2023). Surface water quality profiling using the water quality index, pollution index and statistical methods: A critical review. *Environmental and Sustainability Indicators*, **18**, 100247. https://doi.org/10.1016/j.indic.2023.100247

Ujoh, F., & Alhassan, M. M. (2014). Assessment of pollutants in streams around a cement plant in Central Nigeria. *International Journal of Science and Technology*, **4**(3): 59-65. https://doi.org/10.1016/j.indic.2023.100247

Warsito, B., Sumiyati, S., Yasin, H., & Faridah, H. (2021). Evaluation of river water quality by using hierarchical clustering analysis. In *IOP Conference Series: Earth and Environmental Science,* **896**(1): 012072. https://doi.org/10.1088/1755-1315/896/1/01