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Physicochemical and Trace Metals Characterisation: An Impact Assessment of Badagry Creek on Groundwater Quality in Ojo Community, Lagos, Nigeria

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ABSTRACT

Groundwater is a major source of water supply with comparative advantages including convenient availability of water close to where it is required, and near excellent natural quality. However, groundwater quality is often compromised by various threats, both of natural and anthropogenic origins, including intrusion from big water bodies like seas. The aim of this study is to assess the possible impacts of Badagry creek on groundwater quality in Ojo community, Lagos. Fifteen (15) groundwater samples were collected from different hand-dug wells during both dry and wet seasons for physicochemical and some trace metal analyses using standard procedures. The physicochemical parameters analyzed included pH, electrical conductivity (EC), total dissolved solids (TDS), anions (NO_3^-, PO_4^{3-}, Cl^-), and some trace metals (Fe, Zn, Ca, Mg, Cu, Na, Pb, and K). Principal Component Analysis (PCA), Correlation Coefficient, and Cluster Analysis were applied on the data obtained. The concentrations of EC, TDS, and NO_3^-, were observed to be higher above World Health Organization (WHO) permissible limits, with values of 0.94, 0.81, and 2.92% respectively. Very strong correlation coefficient was observed between EC and TDS, Cl^-, and NO_3^-. Four principal components were extracted, and hierarchical dendrogram showed four (4) distinct clusters of wells. Iron and lead had mean concentrations above the WHO allowable limits which portends health risk. The quality of the groundwater investigated was questionable, especially with respect to high concentrations of NO_3^-, pointing at influence from the Badagry creek. Hence, there is need for regular monitoring, to ensure safety of man and sustainable environments.

Keywords: Badagry, Creek, Ojo, Principal Component Analysis (PCA), Trace metals

INTRODUCTION

Groundwater makes up about 30% of the world's freshwater, and is easily accessible to humans for domestic, industrial, and agricultural purposes (Dokka, 2011; Sneed *et al*, 2013; Famiglietti and Ferguson, 2021).Over two (2) billion people rely on groundwater as their primary water source worldwide (Famiglietti, 2014). It is also a more preferred source of water supply, for it is often cheaper, more convenient and less susceptible to pollution compared to surface water. Polluted groundwater is more difficult to clean up than pollution in surface water, and most often, it results from improper disposal of wastes on land. Other major sources include industrial and household chemicals, excessive fertilizers and pesticides used in agriculture. Additionally, groundwater is susceptible to a phenomenon known as saltwater intrusion in coastal areas which can cause land subsidence when extracted unsustainably, leading to sinking cities, and loss in elevation. These issues are made more complicated by sea level rise and other changes caused by climate transformation which affect the water cycle (Erkens *et al.*, 2015).

Groundwater is a highly useful and often abundant resource. However, over-abstraction can cause major problems to humans and the environment. The most evident problem, as far as human use is concerned, is a lowering of the water table beyond the reach of existing wells, leading to change in movement dynamics into the aquifer.

If too much groundwater is pumped near the coast, salt-water may intrude into freshwater aquifers causing contamination of freshwater supplies. Many coastal aquifers, such as those close to the Niger Delta Basin and Benin Basin, have problems with salt water intrusion as a result of over pumping and sea level rise (Oteri and Atolagbe, 2003).

Saltwater intrusion remains a major factor of water quality compromise in coastal aquifers around the world. It is the human-induced flow of seawater into freshwater aquifers primarily caused by groundwater development near the coast. Under normal conditions, fresh water flows from inland aquifers and recharge areas to coastal discharge areas, then to the sea. The groundwater flows from areas with higher groundwater levels (hydraulic head) to areas with lower groundwater levels. This natural movement of fresh water towards the sea prevents salt water from entering freshwater coastal aquifers (Barlow, 2003).

Groundwater quality has been a concern around the world, and has led to a number of studies on the pollution of groundwater due to seawater intrusion (Vesali *et al.*, 2018; Carrard *et al*., 2019). Akoteyon and Soladoye (2011), carried out a study on the assessment of groundwater quality in Eti-Osa, Lagos State, Nigeria, employing multivariate analysis. Studies were also done to investigate the traces and impacts of seawater intrusion on the quality of groundwater and its evolution in coastal areas of South Gujarat, India (Chandrashekha *et al.*, 2021). Zheli *et al*.(2020) in Eygpt discussed seawater intrusion (SI) as a significant threat to groundwater and soil quality in arid coastal ecosystems. Kyungsun *et al.*, (2020) investigated the impacts of seawater on the groundwater in the Archipelago of South Korea, through hydro geochemical characteristics, revealing positive influence of the seawater on the groundwater. A study in Tripoli city at the Mediterranean coast of Jifarah Plain, indicated salinization and pollution of the aquifer (Nawal and Kristin, 2018). In China, Lou Sand his co environmental researchers in 2017 studied the quality of groundwater with impacts of saltwater intrusion on the Chongming Island, showing influence of pollution from the seawater and nearby landfill (Lou *et al.*, 2017).

The dearth of information on the possible impacts of the Badagry creek on groundwater quality in the Ojo community of Lagos State, Nigeria, geared the purpose of this study towards physicochemical evaluation of groundwater in the Ojo community, so as to ascertain the safety of man and environment.

MATERIALS AND METHODS

Study Area

Ojo community is located in the Ojo Local government area, Badagry division of Lagos State, Nigeria, with latitude of N6°28’0, and longitude of E3°10’59. The community is primarily a residential community and bounds the south of the Badagry creek, which through Victoria Island, empties into the Atlantic ocean. It houses some major markets, such as the Alaba international market, which is West Africa’s largest electronic market. The local government area consists of mangroves, swamps and sandy beaches. The main source of water supply is underground water: The major preoccupations include fishing, trading, and sediment dredging. Ojo is also home to the state-owned Lagos State University (LASU). The sampling locations are captured in the map of the study area (Figure 1).

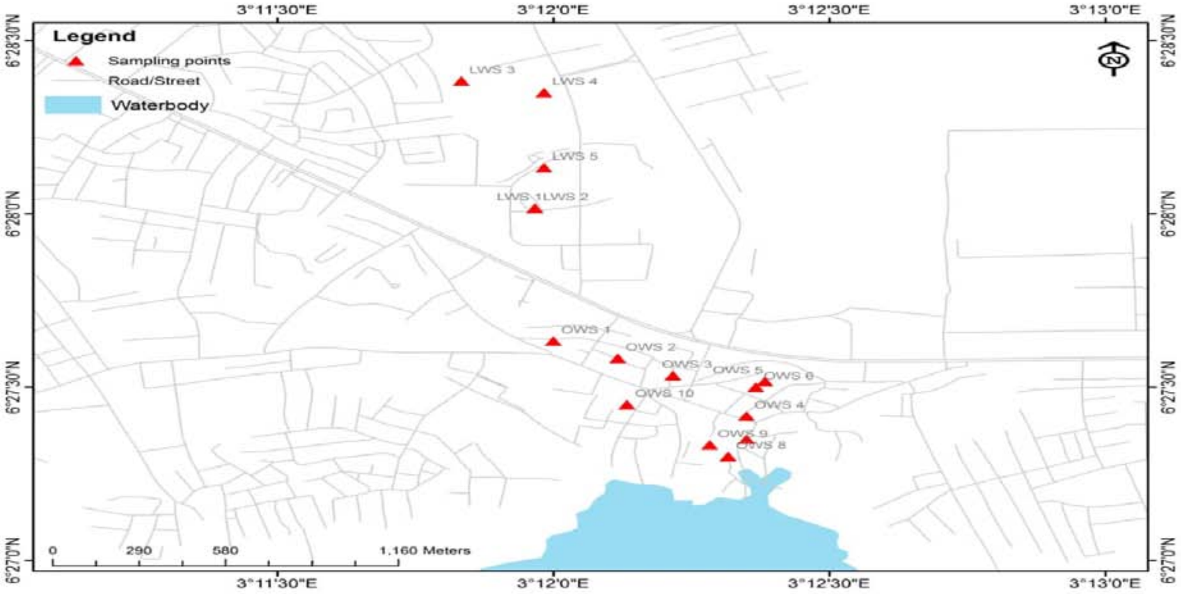

Figure 1: Map showing sample locations

Sampling

Groundwater samples were collected from fifteen (15) locations (hand-dug wells), in the Ojo community, as shown in the map (Figure 1). The plastic bottles used (1.5 L and 0.75 L) were acid-washed using 10% nitric acid for physicochemical and trace metal analyses respectively. The water samples taken for metal analyses (0.75 L) were preserved with about 1.5cm^3 of concentrated HNO_3, while water samples collected for physicochemical analyses were filled to the brim of the 1.5 L plastic bottles, to avoid microbial degradation of water samples. The collected samples were transported to the laboratory, and stored in the refrigerator at 4°C.

Physicochemical Analyses

The pH and temperature of the groundwater samples were determined in-situ electronically, using pH meter and thermometer respectively, while electrical conductivity (EC) by conductivity meter, and total dissolved solids

(TDS) by a TDS meter. Acidity, alkalinity, total hardness (TH), and chloride were determined titrimetrically. Phosphate (PO_4^{3-}) was determined using the colorimetric method, while nitrate (NO_3^-) was detected using the ultraviolet spectrophotometric screening method, and sulphate (SO_4^{2-}) was determined by turbidimetry. Salinity was determined from its mathematical relationship with chloride (Cl^-) concentration, (Salinity (ppt) = 0.00180665 x Cl^- (mg/L)). The groundwater samples were analyzed for Na and K using flame photometry and other trace metals by acid digestion method, and quantification by Flame Atomic Absorption Spectrophotometer (FAAS), (APHA, 2022).

Data Analyses

The following statistical tools were used in analyzing the data: Descriptive analysis: Mean, Standard deviation (SD) and Exceedance using Statistical Package for Social Sciences (SPSS), Pearson Correlation Coefficient, Principal Component Analysis (PCA), Cluster Analysis (CA).

$$Exceedance = \frac{Conc. of\ a\ Quality\ Parameter}{WHO\ Acceptable\ Limit} \quad (1)$$

RESULTS AND DISCUSSION

Descriptive statistics of the data generated from physicochemical determination of groundwater quality parameters are shown in Table 1.0.

The pH of this study ranged between 5.0 and 8.0.withaverage value of 6.3. About 46.7% of the Ojo community water samples analyzed had pH values within the WHO allowable range of 6.5 – 8.5. pH values lower than 6.5 (acidic in nature) in water, is dangerous to human health, and could cause acidosis, while water samples with pH values higher than 8.5 is said to be alkaline, and unfit for consumption. The acidic nature of groundwater in Lagos could probably be due to the high level of CO_2 in the atmosphere (Aboyeji and Eigbokhan, 2016; Nganje, Hursthouse, and Edet, 2017).

Therefore, the water will need further treatment processes to be potable. The temperature for the Ojo groundwater samples ranged between 27.1 and 32.6 °C with a mean value of 29.9°C. Although, there is no set allowable limit for the temperature by world regulatory bodies, the results from this study spread around ambient temperature. The mean value of total alkalinity was 48.7 ± 24, while for acidity, was59.9 ± 17 mg/L. These values are within the WHO allowable limits (2005). Alkalinity of water could be caused by the presence of carbonate ions (CO_3^{2-}), bicarbonate ions (HCO_3^-), or hydroxide ions (OH^-), while the presence of carbon dioxide is the most common cause for acidity in groundwater. Electrical conductivity (EC) measures the ability of the water source to allow flow of electric currents, and it is related to the concentration of ionized substances in water. The EC value of the Ojo community groundwater ranged between 0.32 and 2.94 mS/cm, with mean and standard deviation values of 1.31 ± 0.8 mS/cm, and an exceedance value of 0.94.

Table 1: **Descriptive Statistics of Physicochemical and Metal data in the Ojo Groundwater samples**

Parameters	Min	Max	Mean	SD	CV%	SEM	Exceedance	WHO	NSDWQ
pH	5.0	8.0	6.33	0.72	11.0	0.19	0.84	6.5 – 8.5	6.5 – 8.5
Temp (^{o}C)	27.1	32.6	29.97	1.72	5.67	0.44			
EC (µS/cm)	323	2940	1311.8	782.72	61.1	202.1	0.94	1.4	1.4
Acidity (mg/L)	24.6	96.6	59.93	16.96	28.3	4.38			
Alkalinity (mg/L)	12.6	98.6	48.67	23.93	49.2	6.18			
Total Hardness (mg/L)	22	133.4	83.08	33.66	40.5	8.69	0.17	500	150
Total Dissolved Solids (mg/L)	173.9	1786	808.66	530.19	65.5	136.89	0.81	1000	500
Chloride (mg/L)	1.0	181.24	62.19	55.84	90	14.42	0.25	250	250
Nitrate (mg/L)	6.68	44.01	29.24	16.26	54.8	4.2	2.92	10	10
Phosphate (mg/L)	0.03	0.11	0.04	0.02	50	0.01	0.01	5	5
Sulphate (mg/L)	26.49	274.86	119.66	79.87	66.7	20.62	0.48	250	250
Salinity(mg/L)	0	0.33	0.11	0.1	91.9	0.03			
Zinc(mg/L)	0	0.27	0.12	0.09	70	0.02	0.04	3	3
Iron(mg/L)	0	4.34	0.74	1.42	190.5	0.37	2.48	0.3	0.3
Copper(mg/L)	0	0.06	0.01	0.02	125.6	0	0	1.5	1.
Lead(mg/L)	0	0.18	0.03	0.05	191.5	0.01	27.67	0.001	0.01
Magnesium(mg/L)	0.28	13.02	3.68	3.97	107.6	1.03	7.36	0.5	20
Calcium(mg/L)	4.68	180.31	42.57	52.32	122.9	13.51			150
Sodium(mg/L)	3.16	69.53	29.85	24.03	80.5	6.2	0.15	200	200
Potassium(mg/L)	1.44	48.48	17.96	14.2	78.7	3.67			

Some of the water quality parameters (physicochemical and trace metals) exceeded their respective WHO allowable limits,(WHO, 2005) and these were expressed as exceedance level. It has no unit, and is mathematically expressed as equation 1.

Total Dissolved Solids (TDS) is used to indicate whether a water source is fit for drinking, or requires further treatment. The mean values of total dissolved solids (TDS) for the groundwater samples analyzed were 809 ± 53 mg/L. The range of values of TDS analyzed was between 173.9 – 1786 mg/L. Thirty three percent (33.34%) of the samples investigated had values above the WHO allowable limit of 1000mg/L. This indicates that they are brackish water.

Total Hardness (TH) is an important operational water quality parameter, and is usually caused by the presence of cations such as magnesium and calcium, in water. The TH values of this study classified the water samples into very soft (13.3%,), soft (26.67%) and moderately hard (60%).The total hardness values observed in groundwater samples collected ranged between 22 and 133.4 mg/L with a mean value of 83.1 ± 34 mg/L.

The range of chloride concentration in the groundwater samples was 1 – 181.24 mg/L with a mean value of 62.2 ± 56 mg/L. All the water samples collected were within the 250 mg/L WHO (2005) allowable chloride limits for drinking water. The results show that there could be possible impact of salt water intrusion in the study area, due to the high chloride concentrations in some samples locations. Chloride concentration of 40 mg/L was used to indicate salt-water intrusion, and a chloride concentration greater than 100 mg/L indicated the zone of diffusion. Therefore, the results suggest that about 53.3% of the hand-dug wells sampled are susceptible to salt-water intrusion. Other possible sources of high chloride concentrations in the environment include seepage from septic tanks, and domestic effluent. This is more likely found in wells sampled in residential areas, since NaCl is a common component of diets and is passed out through the digestive system. However, high level of chloride in water gives a salty taste, and may result in hypertension, osteoporosis, renal stones, and even asthma (Wentzel-Viljoen, *et al.*,2013; Ali and Ali, 2018).

The nitrate mean values for the water sample analysed was 29.2 ± 16mg/L, while the range of nitrate values was 6.68 – 44.01mg/L. The results showed that about 66.7% of the water samples analysed exceeded the 10 mg/L acceptable limit by WHO (2005) and Nigerian Standard for Drinking Water Quality (NSDWQ, 2007), and this is very dangerous to human health. Excess nitrate in water causes death of infants, shortness of breath in adults, and methemoglobinemia, also known as "blue baby syndrome"(Majolagbe *et al*., 2014). The known sources of nitrate in groundwater include domestic sewage, run-off from urban and agricultural field and leachate from landfill site. The sample locations with high nitrate values were observed to be in proximity to the Badagry creek, and some are close to septic tanks. Therefore, these could be the possible sources for high nitrate concentrations in the groundwater samples investigated (Olatunde *et al*., 2021).

The mean concentration of sulphate was 120 ± 80 mg/L, with a minimum concentration of 26.5 mg/L and maximum concentration of 274.9 mg/L. The results show that sulphate concentrations in 13.3% of the sample locations exceeded the WHO allowable limit of 250 mg/L. Phosphate values ranged from 0.03 to 0.11 mg/L, while the mean values were 0.04 ± 0.02 mg/L in the groundwater samples, and these values were within the WHO (2005) allowable limit. The low concentration of phosphate could indicate a low level of detergent pollutant, or phosphate rich sewage material in the study area, which characterized the impact of landfill leachate (Ojoawo *et al.,* 2012; Khanzada, 2020).

Salt content is an essential component for testing drinking water quality. Salinity can also be measured in freshwater. Generally, freshwater has lesser concentration levels of “salt ions” such as Na^+ and Cl^-, as compared to seawater or brackish water. Salinity analysis is also essential in water bodies where seawater mixes with freshwater, especially for aquatic organisms which have varying abilities to survive and thrive with changes in the levels of salinity. The salinity results gave a range between 0.00 and 0.32 part per n thousand (ppt) with mean concentration of 0.11 ± 0.1 ppt. These values were below 0.5 ppt, hence the groundwater samples collected in the Ojo community are classified as fresh water, and can be used for drinking or irrigation purposes. Classification of groundwater based on salinity content is shown in Table 2.

Trace metals

Zinc is an essential trace element found in most foods and potable water. It is necessary in minimal quantities for plant and animal metabolism. A high level of zinc often results in zinc toxicity, which may lead to cancer in the human system (Plum *et al*., 2010). The mean concentrations of zinc in the groundwater samples were 0.13 ± 0.09 mg/L, while the minimum and maximum concentrations were ND and 0.27 respectively.

Table 2: Salinity Classification for Groundwater

Salinity Status	Salinity (%)	Salinity (ppt)	Use
Fresh	<0.05	<0.5	Drinking and all irrigation.
Marginal	0.05 - 0.1	0.5 – 1	Most irrigation, adverse effects on ecosystems become apparent.
Brackish	0.1 - 0.2	1 – 2	Irrigation certain crops only; useful for most stock.
Saline	0.2 – 1.0	2 – 10	Useful for most livestock.
Highly Saline	1.0 – 3.5	10 – 35	Very saline groundwater, limited use for certain livestock.
Brine	>3.5	>35	Seawater; some mining and industrial uses exist.

Iron, as an element, is very abundant in the Earth’s crust. The concentration of iron in the water analyzed ranged between 0.00 – 4.34 mg/L with 0.04 ± 1.42 mg/L as mean values in the Ojo groundwater samples. About 46.67% of the Ojo groundwater samples had iron concentration levels above the WHO (2005) allowable limit of 0.30 mg/L of Iron in drinking water. The high coefficient of variation value also indicates the significant deviation from the standard limits.

Rusting of water pipes often results in excessively high levels of iron, known as “red water”. Some other major sources of iron are nature of rock and soil which usually consists of igneous rock, leachate from waste dumps, industrial waste, and seepage from septic tanks in residential areas. Iron is an essential element for the human system; and it helps in the formation of haemoglobin, necessary for pregnancy and lactation. Excess iron in drinking water could cause diseases such as idiopathic hemochromatosis in humans (Milman, 2021).

The mean concentration of copper in the Ojo groundwater samples was 0.01 ± 0.02, while the values ranged from ND to 0.06 mg/L. None of the samples analyzed exceeded the WHO (2005) allowable limit of 1.5 mg/L of copper in drinking water. Copper is an essential metal and a toxic element, depending on its concentration in a substance. A high concentration of copper in drinking water can cause gastrointestinal imbalance in man. The sources of copper in groundwater include leaks from landfills, agricultural run-offs and geochemical composition of the soil/rock beneath the Earth’s surface"(Majolagbe *et al.*, 2014).

The lead values for the Ojo groundwater samples ranged between ND – 0.18 mg/L with mean value of 0.03 ± 0.05 mg/L. The results showed that about 33.3% of the groundwater samples analyzed had values exceeding the WHO (2005) allowable limit of 0.001 mg/L of lead in drinking water. Lead is primarily used in the manufacture of lead acid battery and alloys. It can however, enter the environment by untreated wastewater or solid waste dumps. Drinking water is known to be a major form of intake of Lead into the human system, thus indoor plumbing systems, consisting of pipes made of lead or alloy could be a probable source. Lead is extremely toxic; and it accumulates in the kidney and skeletons of humans and animals alike. Pregnant women and young children are more susceptible to its adverse effects"(Majolagbe *et al.*, 2014).

Mean concentration value for magnesium was 3.68 ± 3.97 mg/L, and the range of values in the water analyzed were between 0.28 – 13.02 mg/L. The results showed that some of the groundwater samples far exceeded the WHO (2005) allowable limit of0.5mg/L. A major source of magnesium in groundwater is the ion exchange of minerals in rocks and soils.

Calcium mean concentration was 42.57 ± 52.3mg/L, and the range of values for calcium concentration in the water analyzed were between 4.68 – 180.31 mg/L. Some of the groundwater samples under investigation exceeded the allowable limit of 150 mg/L set by NSDWQ (2007) Major sources of calcium are carbonate minerals such as calcite and dolomite.

The concentration of sodium in the groundwater samples were 29.88 ± 24.06 mg/L, while the minimum and maximum concentrations for sodium in the water samples analyzed were 3.16 and 69.53 mg/L respectively. These values were within the WHO allowable limit of 200 mg/L. Potassium mean values was 18.00 ± 14.17 mg/L, and the range of values for potassium concentration in the water samples analyzed was between 1.0 – 48.0 mg/L.

Correlation coefficient was performed in a pair-wise fashion using Pearson correlation coefficient as shown in Table 3.0.

Principal component analysis (PCA), factor analysis (FA), and cluster analysis (CA) which is represented with a dendogram, were also performed using the SPSS software. The Pearson correlation coefficient shows correlations between variables, as ‘strong’, ‘medium’, or ‘weak’, as well as positive or negative correlations.

PCA indicates the association between variables and it reduces the dimensionality of data structure. It involves transforming variables into new ones called principal components (PCs).

Cluster analysis (CA) was also performed using SSPS, and it was used to identify the dissimilarities in locations using physicochemical and metal parameters analyzed in the groundwater samples.

Table 3: Pearson Correlation Co-efficient for Physicochemical and Metal data in the Ojo Groundwater Sample

	pH	Tem	EC	Acid	Alk	TH	TDS	Cl	NO3	PO4	SO4	SAL	Zn	Fe	Cu	Pb	Mg	Ca	Na	K
pH	1																			
Temp (oC)	.410	1																		
EC (µS/cm)	-.432	-.374	1																	
Acidity (mg/L)	-.111	-.315	.515*	1																
Alkalinity (mg/L)	.794**	.031	.046	.162	1															
TH (mg/L)	.047	-.288	.787**	.615*	.509	1														
TDS (mg/L)	-.402	-.291	.957**	.481	.061	.767**	1													
Chloride (mg/L)	-.467	-.420	.979**	.531*	.034	.749**	.959**	1												
Nitrate (mg/L)	-.603*	-.427	.786**	.235	-.228	.517*	.775**	.734**	1											
Phosphate (mg/L)	-.250	.392	.222	-.120	-.205	-.043	.412	.264	.173	1										
Sulphate (mg/L)	-.484	-.594*	.909**	.491	.081	.677**	.856**	.924**	.762**	.171	1									
Salinity (mg/L)	-.467	-.420	.979**	.531*	.034	.749**	.959**	1.000**	.734**	.265	.924**	1								
Zinc (mg/L)	.206	-.201	-.322	-.092	.267	-.007	-.289	-.319	-.192	-.414	-.284	-.319	1							
Iron (mg/L)	-.128	-.257	-.249	.012	-.238	-.218	-.255	-.234	-.134	-.276	-.266	-.234	.522*	1						
Copper (mg/L)	.062	-.279	.117	.451	.167	.081	.075	.118	-.062	-.129	.186	.118	.113	.079	1					
Lead (mg/L)	-.127	-.106	-.258	-.028	-.196	-.147	-.251	-.259	-.094	-.259	-.294	-.259	.679**	.861**	.006	1				
Mg (mg/L)	-.109	-.325	-.027	.163	.027	.108	-.040	-.020	.119	-.376	.014	-.020	.623*	.764**	-.008	.853**	1			
Calcium (mg/L)	-.228	-.393	-.035	.091	-.127	.032	-.056	-.025	.100	-.378	-.033	-.025	.685**	.881**	.008	.887**	.935**	1		
Sodium (mg/L)	-.448	-.289	.612*	.451	-.161	.390	.654**	.612*	.742**	.282	.669**	.612*	-.435	-.254	.135	-.186	.081	-.101	1	
Potassium (mg/L)	-.454	-.459	.944**	.624*	.034	.727**	.889**	.936**	.798**	.116	.929**	.936**	-.280	-.202	.253	-.172	.110	.034	.756**	1

The Pearson Correlation Coefficient analysis for physicochemical and metal data in the Ojo groundwater samples showed strong inter elemental associations between alkalinity and pH (r = 0.79), as well as Electrical Conductivity (EC) with TDS (r =0.79), Chloride (r = 0.98), and Potassium (r = 0.94). Total Dissolved Solids (TDS) also showed strong correlations with Chloride (r = 0.96), as well as Nitrate (r = 0.76), and Salinity (r = 0.96). The high levels of Chloride, as well as its strong correlations with TDS and EC observed could indicate impact of salt water intrusion in the study area. Zinc (Zn) showed strong inter elemental associations with Pb (r = 0.68), as well as Iron (Fe) with Pb (r = 0.86) and Ca (r = 0.88). Lead (Pb) also showed strong correlations with Mg (r = 0.85), and Ca (r = 0.89), while Lead (Pb) showed strong correlations with Mg (r = 0.85), and Ca (r = 0.88). High levels of Iron in the groundwater samples could be as a result of the abundance of the element in the rocks and soils of Lagos State.

Factor analysis (FA) was employed for the physicochemical and trace metals data for the Ojo groundwater samples, and four major PCs (eigenvalues greater than 1) were extracted, which accounted for a total of 83.51% variability of the original data complex structure as presented in Table 4. PC 1 accounted for 42.650 % of the total variance, in which Electrical conductivity (EC), Total Hardness (TH), Total Dissolved Solids (TDS), Chloride, Nitrate (NO_3^{-2}, Sulphate (SO_4^{2-}), Salinity, Sodium (Na), and Potassium (K) contributed positively. The high concentration of EC value is probably as a result of the involvement of ions in the groundwater quality.

The significant contribution of Chloride indicates pollution from domestic source (human diet). PC 2 accounted for 22.083% of the total variance, with positive contributions from variables such as Zinc (Zn), Iron (Fe), Lead (Pb), Magnesium (Mg) and Calcium (Ca). 12.295% of the total variance was explained by PC 3, with contributors such as pH and alkalinity.

Table 4: Principal Component Analysis for Physicochemical and Metal data in the Ojo Groundwater Samples

Component Matrix

	Components			
	PC 1	**PC 2**	**PC 3**	**PC 4**
pH	-.486	-.245	**.768**	.185
Temp (oC)	-.440	-.523	-.052	.419
EC (µS/cm)	**.969**	.038	.045	.117
Acidity (mg/L)	.571	.224	.368	-.326
Alkalinity (mg/L)	.008	-.088	**.928**	.246
Total Hardness (mg/L)	**.740**	.122	.530	.283
Total Dissolved Solids (mg/L)	**.949**	-.002	.009	.228
Chloride (mg/L)	**.970**	.046	.022	.091
Nitrate (mg/L)	**.814**	.165	-.284	.129
Phosphate (mg/L)	.259	-.452	-.416	.329
Sulphate (mg/L)	**.949**	.072	.042	-.063
Salinity(mg/L)	**.970**	.046	.022	.091
Zinc(mg/L)	-.380	**.688**	.308	.160
Iron(mg/L)	-.308	**.839**	-.170	-.007
Copper(mg/L)	.159	.143	.359	-.710
Lead(mg/L)	-.317	**.863**	-.150	.165
Magnesium(mg/L)	-.051	**.926**	.028	.188
Calcium(mg/L)	-.097	**.974**	-.080	.136
Sodium(mg/L)	**.752**	-.006	-.209	-.119
Potassium(mg/L)	**.966**	.146	.058	-.054
Total variance	8.530	4.417	2.459	1.295
% of variance	42.650	22.083	12.295	6.477
CV%	42.650	64.733	77.027	83.505

According to Cieszynska *et al.*,(2010), the significant contribution of alkalinity (HCO_3^-) is an indication that the variable is related to the minerals present in groundwater. PC 4 had 6.477% of the total variance accounted for, having none of the parameters as strong contributors.

Cluster Analysis

Cluster analysis was performed employing the Statistical Package for Social Sciences (SPSS) to identify groundwater that had similar water chemical quality characteristics. It helps to reveal some inherent common trends in pictorial forms. The dendrogram of hierarchical cluster analysis for physicochemical and metal data as presented in Figure 2 showed four clusters for the Ojo groundwater samples.

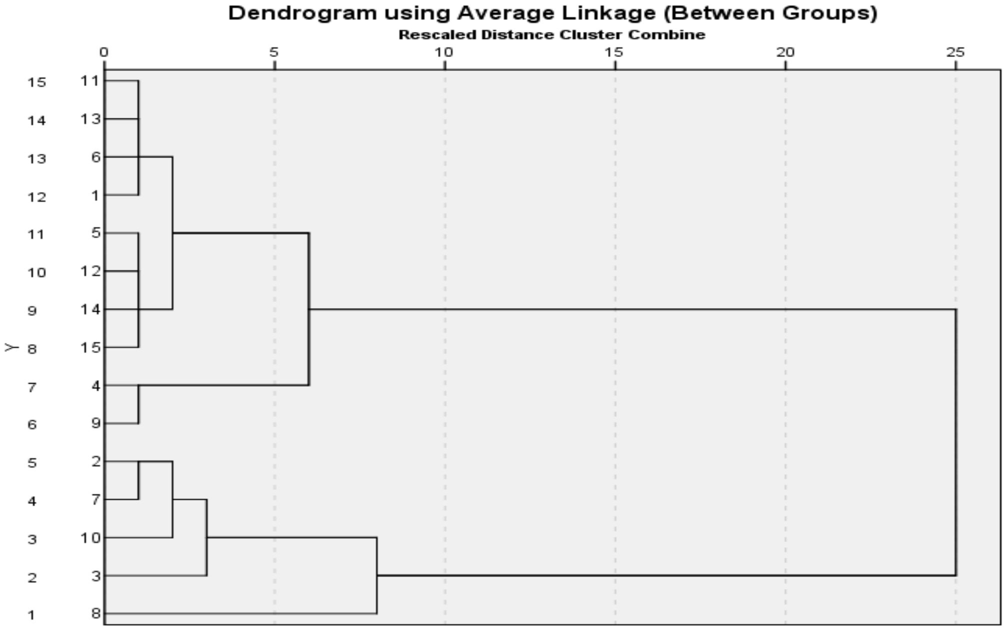

Figure 2: Dendrogram for Physicochemical and metal data in Ojo groundwater samples

The principle by which the hand-dug wells are clustered are geographical distance (sample locations), and content (Physicochemical properties or metal load), and the cluster analysis suggests that the water quality of groundwater could be influenced by both natural (geochemical formation of the environment), and anthropogenic sources which include the pollutants from refuse dumps.

In the dendogram, based on locations (Figure 1.0), the dendogram showed four clusters clearly at the 2.6 index of dissimilarities. Cluster I involves eight sampling locations (wells) 1, 5, 6, 11, 12, 13, 14, 15 which had similarities in the levels of concentration of EC, PO_4^{3-}, Salinity, Cu, Na, Zn, Pb and K. Cluster II is made up of two locations - 4 and 9, which had similarities in EC, NO_3^-, PO_4^{3-}, Zn, Cu, and K. Cluster III consists of locations 2, 3, 7 and 10 with similarities in mean concentrations of SO_4^{2-}, EC, TDS, Ca, Fe, Pb, Mg, Na, and K, while cluster IV comprises only of location 8 due to its extremely high values of TDS, Cl^-, and SO_4^{2-}, and K. This indicates that the different locations in clusters have similarities in their concentrations of physicochemical and metal parameters, as seen in the map (Figure 3).

CONCLUSION

The physicochemical evaluation of groundwater quality parameters was carried out to possibly assess the impact of Badagry creek on groundwater quality in Ojo community, Lagos state. The high concentrations of quality parameters such as nitrate, electrical conductivity, and lead point at effect of the water body (Badagry creek) on the sampling locations, especially those close to the surface water boundary. Four principal components and also, four distinct hierarchical clusters were depicted in both factor and cluster analyses showing various trends and variations in quality parameters investigated. This study aligns with Goal 6 of the Sustainable Development Goals (SDGs), which aims at providing clean, safe water for all.

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