Analele Universităţii din Oradea, Seria Geografie **XXX**, no. 1**/2020**, pp.**53-64**
ISSN **1221-1273**, E-ISSN **2065-3409** DOI 10.30892/auog.301107-814

VARIATIONS IN PHYSICO-CHEMICAL PROPERTIES OF SHALLOW GROUNDWATER AQUIFERS ACROSS RURAL-URBAN DIFFERENTIALS

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Citation: Asingbi, T., Durowoju, O., Olusola, A., & Obateru, R. (2020). Variations in Physico-Chemical Properties of Shallow Groundwater Aquifers Across Rural-Urban Differentials. *Analele Universităţii din Oradea, Seria Geografie*, 30(1), 53-64. https://doi.org/10.30892/auog.301107-814

Abstract: The quality of groundwater is controlled mostly by geology, lithology and depth of aquifers. However, anthropogenic activities can also influence the chemical characteristics of groundwater and this relates directly or indirectly to land use/land cover characteristics. To this effect, this study aimed at evaluating the effect of land use/land cover on the quality of shallow groundwater aquifers in Yenagoa City and its Environs, Bayelsa State, Nigeria. Fifteen groundwater samples were collected randomly from each of the urban and rural land use types making a total of 30 water samples from hand-dug wells that tap into shallow aquifers in the study area. The water samples were subjected to laboratory analyses for Temperature (T), pH, Salinity (Sal), Electrical Conductivity (EC), Total Dissolved Solids (TDS), Nitrate (NO_3), Chloride (Cl^-), Sulphate (SO_4^{2-}), Total Alkalinity (TA), Total Hardness (TH), Iron (Fe), Manganese (Mn), Fluoride (F) and Arsenic (As). Factor analysis and Independent samples t-test were employed for analyses in the study. The results revealed that all minimum concentrations of physic-chemical contaminants analyzed were recorded in the rural land use type with exception of pH and Iron (Fe) while all maximum concentrations were recorded in the urban land use type with exception of Fluoride, Sulfate and Total Hardness. Independent samples t-test show that there is a significant difference in the groundwater physico-chemical characteristics between urban and rural land use types.

Key words: Land use/Land Cover, physicochemical contaminants, shallow groundwater aquifers

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INTRODUCTION

The concentration of contaminants in groundwater is largely a function of both natural and anthropogenic activities (Romocea et al., 2018; Beketova et al., 2019). Serious health hazard could be the outcome when such contaminants level exceeds the recommended standards set by water quality regulating bodies like Federal Environmental Protection Agency (FEPA), Environmental Protection Agency (EPA) and World Health Organization (WHO) may result in serious health hazards (USEPA, 2002; Olusola et al., 2017; Herman et al., 2019a, 2019b).

Shallow aquifers are more vulnerable to contamination from various land uses than deep aquifers. The susceptibility of shallow aquifers to contaminants from surface sources depends on the permeability of the overlaying rock/soil units (Narayanan, 2007) and depth to the water table (Ifabiyi, 2008). These factors are variable especially in areas where anthropogenic inputs are remarkable. Yenagoa is underlain by a sedimentary basin characterized by an unconfined aquifer with rainfall being the direct recharge source (Etu-Efeotor and Akpokodje, 1990). The aquifer is sensitive to changes in land use because the water table is close to the surface (about 3-4 m) during the dry season and during the rainy season the water table rises considerably, in some cases to the ground surface. This makes the shallow aquifer in the area vulnerable to contamination from various land use. Rapid urbanization and population growth are the major threat to groundwater contamination (Olusola et al., 2017) especially shallow aquifers as found in the study area. Due to the attendant population increase in the area, unprecedented waste generation and indiscriminate disposal have become major environmental issues. Landfills within Yenagoa and its environs are mostly in the form of uncontrolled residential dumps with refuse piling up with increasing residency time. Solid waste in landfills decomposes and most often than not pollutes underlying groundwater through seepage or percolation (Offodile, 2002). Other threats to shallow aquifers are point sources of pollution such as leaking septic systems, industrial discharge (liquid waste), oil spillage and pipeline vandalisation (Egboka et al., 1989; Majolagbe et al., 2011; Fashae et al., 2019) and saltwater intrusion (Smith, 1988; Postel et al., 1996; Majolagbe et al., 2011; Morris et al., 2003). It has been posited that unpalatable high concentration of salt particularly chloride renders groundwater non-potable (Majolagbe et al., 2011), while saline water intrusion is mostly enhanced by over-extraction of fresh groundwater resources due to attendant population increase and rapid urbanization of coastal cities (Smith, 1988; Postel et al., 1996). In Morris et al, (2003), it was confirmed that seepage from contaminated surface waters (rivers, lakes and creeks) can also impair the quality of shallow aquifers and that the presence of chloride, sulphate and other inorganic chemicals can be indicators of pollution. However, contaminants introduced at the land surface can readily enter the underlying aquifer and affect nearby wells that are screened near the water table (Eckhardt and Stackberg, 1995; Fashae et al., 2019). Although the movement and fate of subsurface contaminants depend on the rainfall pattern, depth of water table, distance from the source of contamination and soil properties like permeability, the composition of recharge components as well as geology and hydrology of the area, the greatest concern bothers on the number of pollutants present on the land surface.

From the foregoing, this study is aimed at assessing the physico-chemical characteristics of groundwater from shallow aquifers. To effectively achieve this aim, the study will examine the concentrations of physico-chemical parameters of groundwater in the study area based on recommended standards (World Health Organization, WHO); map the spatial distribution of physic-chemical characteristics of groundwater across rural-urban differentials.

Study Area

The study area lies between latitude 4° 54'N - 5° 08'N of the Equator and between longitude 6° 05'E - 6° 23' East of the Greenwich meridian (figure 1). The study area cuts across three Local Government Areas of Bayelsa State, Nigeria. They are Yenagoa, Kolokuma/Opokuma, and Southern Ijaw Local Government Areas. The total land area is 84 989 km^2. The area under study is bounded by Sagbama Local Government Area in the North, in the South by Ogbia Local Government Area, in the West by Ekeremor Local Government Area and in the East by Rivers State. Part of the study area falls within the state capital, Yenagoa.

The study area has an equatorial hot-humid climate which is characterized mainly with wet and dry seasons. The annual rainfall experience is usually between (2500 mm-3000 mm). The mean temperature is 30±2˚C, relative humidity is 80% and above (Iloeje, 1972). The vegetation of the area is characterized by rainforest, marshes, back swamps, mangroves and wetlands. The vegetation is comprised of a multitude of evergreen trees that yield tropical hardwoods such as Mahogany and Abura (Macrophylaciliata). The study area lies within the freshwater forest swamps and back swamps geomorphic unit of the Niger Delta. The Niger Delta is an alluvial plain formed by the deposition and build-up of fine-grained sediments eroded and transported to the area by River Niger and its distributaries (streams). The Coastal Plain Sands of the Benin Formation are the main regional and most important aquifer in the study area (Short and Stauble, 1967). Groundwater in the coastal plain sands occurs mainly under phreatic (unconfined) conditions. The lithology of this formation is dominated by loose sands (fine-medium-coarse), while gravel and pebbles constituting minor components. Thin clay horizons and lenses create discontinuities in the vertical and lateral continuity of the porous sands and gravel. This condition results in the presence of local perched aquifers. Rainfall is the direct recharge source of the groundwater (Short and Stauble, 1967; Etu-Efeotor and Akpokodje, 1990).

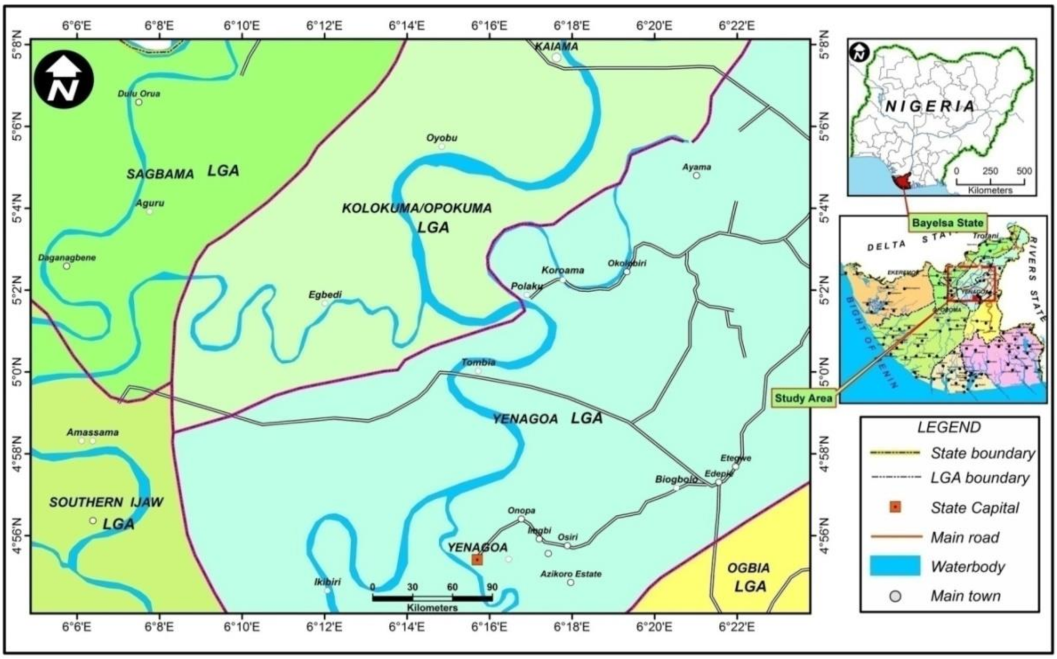

Figure 1. The Study Area Map
Source: Office of The Surveyor General

MATERIALS AND METHODS

Water Sampling

Water samples were collected from wells and kept in 1.5 liter plastic bottles. A total of 15 water samples were collected randomly from each urban and rural land use types in the study area (figure 1) with their respective locations taken with the aid of a GPS (Garmin GPS_{MAPS} 78s). During sampling, precautions were taken to avoid contamination and to achieve a reflection of the collected sample in the laboratory analyses.

Laboratory Analysis

Groundwater samples collected were analyzed in the Central Research Equipment Laboratory (Niger Delta University, Wilberforce Island, Bayelsa State) for Temperature, pH, Salinity, Electrical Conductivity, Nitrate, Chloride, Sulfate, Total Hardness, Total Alkalinity, Iron, Manganese, Fluoride and Arsenic. Temperature, pH, Electrical Conductivity (EC), Salinity of the water samples were measured with the aid of a Wagtech Digital Thermometer/pH Meter/Conductivity/Salinity Meter respectively. The Total Dissolved Solids (TDS) was measured using a JENWAY 3540 Bench TDS meter (UK). Titration method was also used in the determination of Total Hardness and Total Alkalinity. Wagtech Spectrophotometer was used in the determination of Nitrate (NO_3^-) and Sulphate SO_4^{2-} at wavelengths of 5000 nm and 425 nm respectively. Fluoride and Arsenic concentrations of the water samples were determined using the Atomic Absorption Spectroscopic method. This was done with the aid of the Wagtech UV/VIS Spectrophotometer equipment.

Statistical Analysis

A simple descriptive statistic summary table was generated from the laboratory results using mean, standard deviation and coefficient of variation of the physic-chemical datasets Independent samples T-test is used to assess the difference in groundwater characteristics between the urban and rural land use types. A plot of loadings of the Factors (components) was done in rotated space to categorize as well as to characterize the hydro-chemical characteristics of the analyzed groundwater parameters in the study area. The SPSS 15.0 (Statistical Product and Service Solutions) was used for the statistical analysis.

RESULTS AND DISCUSSION

Landuse/land cover classification

Five major land use types were identified within the study area. These are: minor built-up areas, major built-up areas, open space, vegetation cover and water bodies (figure 2). The minor built-up areas represent the rural/undeveloped areas within the study area (table 1). The rural lands/minor built-up areas accounted for about 1493 km^2 (1.5%) of the study area (table 1). The dominant activities in this area are farming, fishing and boat making. There is also an existence of a periodic market in the area. The major built-up areas represent the capital city (Yenagoa) where major industrial and commercial activities are predominant. Hence, the major built-up areas represent the urban/developed lands (table 1). The industrial, commercial and landfill areas were all classified under this land use category since they are within the Major Built-up areas. The major built-up areas/urban lands accounted for about 2241 km^2 (2.3%) of the study area (table 1, figure 2). This area is closer to the Atlantic Ocean than the minor built-up areas. The Vegetation cover represents the rainforest areas, mangroves, wetlands and swamps within the study area.

Table 1. Land Use/Land Cover Classifications in the Study Area

S/N	Land Use Type	(m^2)	(Km^2)	(%)
1	Minor built-up area	14917243	1493	1.5
2	Open space	2260430	226	0.2
3	Vegetation (mangrove)	810933596	89012	91
4	Water body	49026383	4904	5
5	Major built-up area	22416907	2241	2.3

This area accounted for about 89 012 km^2 (91%) of the study area (table 1, figure 2). This is the largest land use type in the study area. Hunting and lumbering are the predominant activities within this. The open space accounted for the smallest land use type in the study area with an area extent of about 226 km^2 (0.2%) of the study area. Water Bodies accounted for 4904 km^2 (5%) of the study area (table 1, figure 2). The Water bodies also accounted for the second-largest land use category in the study area. The water bodies in the area include; rivers, lakes, creeks and small streams. The major river in the area is the Nun River which is a network of River Niger. The lakes are Lake Efi, an Ox-bow Lake. The Creeks are Epie and Taylor Creeks. The water bodies are constantly being used for transportation, fishing and recreational purposes. Dumping of solid waste into the water bodies is a regular occurrence especially the creeks (Izonfuo and Bariweni, 2001).

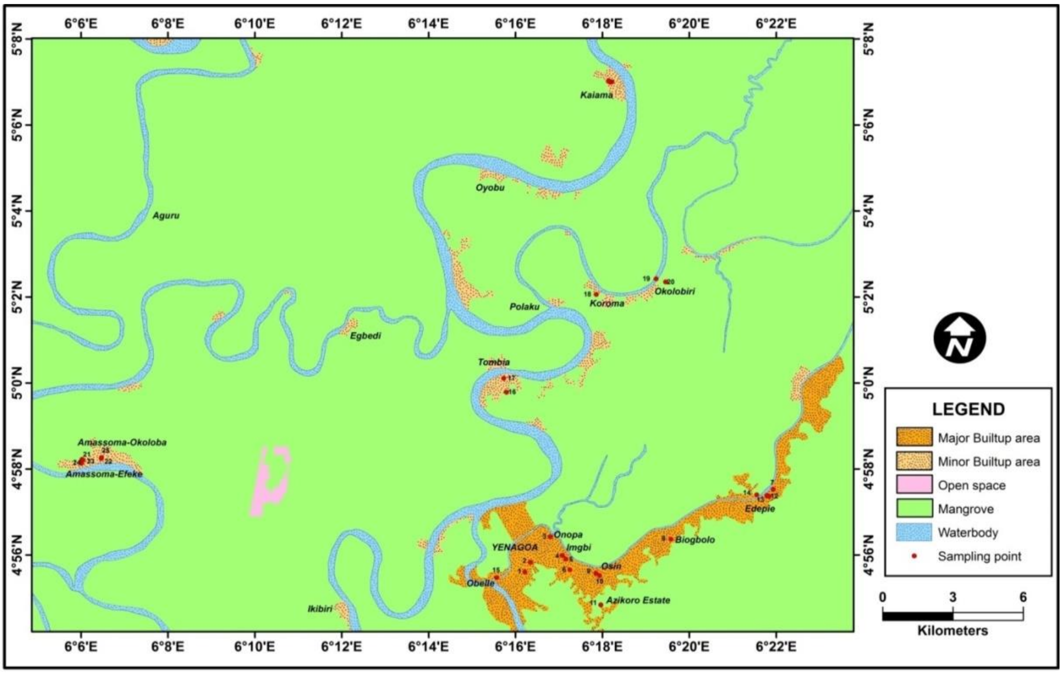

Figure 2. Land use/land cover map of the study area showing sampling points

Physical and Chemical Analysis of Groundwater from the Shallow Aquifers

From the observed values of pH in table 2, the minimum and maximum values were 6.97 and 7.6 respectively. It was also observed that both minimum and maximum values of pH were recorded in the urban land use type. The pH of all water samples from the shallow aquifers in the study area recorded a mean value of 7.38 (table 2) which is within the recommended drinking water guideline (table 3). These pH values obtained in the study (table 2) are similar to previously reported values (Nwala et al., 2007; Manilla and Tamuno-Adoki, 2007; Bolaji and Tse, 2009; Chindah et al., 2011) in the Niger Delta region, Nigeria. Saline water intrusion is inevitable since the study area is close to the Atlantic Ocean. It was observed from all the samples that the minimum and maximum salinity levels in the shallow aquifers were 0.02 mg/l and 0.39 mg/l respectively (table 2) with a mean value of 0.195 mg/l. The minimum salinity level (0.02 mg/l) was reported in the rural land use type while the maximum salinity level was reported in the urban land use type. The minimum and maximum electrical conductivity (EC) were 71 µs/cm and 775 µs/cm respectively (table 2). The mean conductivity for all samples in the study area was 405 µs/cm (table 2). It was observed that the minimum conductivity for all samples was recorded in the rural land use type while the maximum conductivity was recorded in the urban land use type. Though there is no recommended guideline for conductivity by WHO (2008), the Standard Organization of Nigeria (2007) recommended a maximum limit of 1000 µs/cm in drinking water supplies. All samples recorded values below this threshold. Electrical conductivity values tend to be slightly high in the study area. This is an indication of high total dissolved solids (TDS). Places that recorded high conductivity also recorded high TDS values. As expected, an increase in dissolved solids will increase conductivity and corrosivity of the water. Changes in conductivity with time, or high conductivity values can both indicate that the water has become contaminated (e.g. from saline intrusion, fecal pollution or nitrate pollution). Over time, the contamination can become very inimical to both aquatic life and human beings (Olusola et al., 2017; WHO/UNICEF, 2010; Fashae et al., 2019) and also affect water conduits.

It was observed from the groundwater samples that the minimum and maximum TDS concentrations were 36 mg/l and 388 mg/l respectively, with the minimum level (36 mg/l) been recorded in the rural land use while the maximum level (388 mg/l) was recorded in the urban land use (table 2). The mean concentration of TDS was 202.9 mg/l. It was generally observed that the TDS concentrations were relatively high which accounts for the high value in EC. High conductivity values were recorded in locations with high TDS values as expected. The high TDS values obtained (table 2) are similar to those reported by (Ozoemenam, 2012; Okiongbo et al, 2014; Fashola, 2013) in the Niger Delta region. It is a known fact that shallow aquifers within this area and the larger Niger Delta region serve as a domestic water supply source especially in communities where these sources are not polluted by hydrocarbons (oil spills). However, the negative effect of consuming water with high TDS is largely inconclusive (WHO, 2008).

The minimum and maximum nitrate concentrations as observed in the collected samples within the study area (table 2) are 0.09 mg/l and 0.38 mg/l respectively. The values obtained are similar to those reported by Nwala et al, (2007) and Manilla and Tamuna-Adoki, (2007). A mean concentration of 0.23 mg/l was recorded within the study area. The minimum and maximum chloride concentrations as observed in the shallow aquifers in the study area are 1.40 mg/l and 10.50 mg/l respectively (table 2). The rural land use type in the study area recorded the minimum concentration (1.40 mg/l) while the urban land use type recorded the maximum concentration (10.50 mg/l). Chloride concentration in the study area had a mean concentration of 5.32 mg/l. The chloride values obtained (table 2) are within the range of values reported by Ekpete (2002) and Nwala et al., (2007); but are below the values reported by Manilla and Tamuno-Adoki (2007), Bolaji and Tse (2009) in the Niger Delta region. Nitrate and chloride concentrations are all within the acceptable limits (table 3).

It was observed that the minimum and maximum concentrations of Sulphate (SO_4^{2-}) in the shallow aquifers in the study area are 0.30 mg/l and 3.80 mg/l respectively (table 2). Both minimum and maximum concentrations of Sulphate (SO_4^{2-}) were reported in the rural land use type. A mean concentration of 2.0440 mg/l was recorded.

The mean concentration of total alkalinity (TA) as observed in (table 2) was 2.33 mg/l. The alkalinity values obtained in the study area (table 2) are below reported values by Koinyan et al., (2013) and Okiongbo et al., (2014) in the Niger Delta region. The total hardness mean concentration in the study area was recorded as 12.54 mg/l (table 2). Total hardness (TH) values obtained in the study area (table 2) are quite low and are below reported values by Agbalagba et al., (2011), Koinyan et al., (2013) and Okiongbo et al., (2014) in the Niger Delta region. The World Health Organization (WHO) International Standard for Drinking Water (1998) classified water with a total hardness of $CaCO_3$< 50 mg/l as soft water, 50 to 150 mg/l as moderately hard water and water hardness above 150 mg/l as Hard water. Based on this classification, all water samples in the study area can be regarded are soft water since all values were below 50 mg/l of $CaCO_3$. The groundwater in the study area is therefore not suitable for drinking based on total hardness. Soft waters with a hardness of less than about 100 mg/l have a low buffering capacity and may be more corrosive to water pipes (WHO, 2008) which in most cases leaves residues or particulate matter in the water.

As observed in (table 2), Iron (Fe) recorded a minimum and maximum concentration of 0.02 mg/l and 0.82 mg/l respectively. Both minimum and maximum concentrations were reported in urban land use in the study area. Iron (Fe) in the study area recorded a mean concentration of 0.139 mg/l for all groundwater samples. As observed in table 2, the minimum and maximum Fluoride concentrations were 0.20 mg/l and 1.50 mg/l. Both maximum and minimum concentrations of Fluoride were reported in rural land use. A mean concentration of 0.64 mg/l was recorded which is within the health-based guideline of 1.5 mg/l recommended by WHO (WHO, 2008). It was observed that the fluoride concentration in the study area is relatively low. This may be as a result of the moderate pH values in the study area. Fluoride increases with a significant increase in pH (Amini et al., 2007). The minimum and maximum concentrations of Arsenic in the study area were (-0.001 µg/l) and (0.010 µg/l) respectively (table 2). It was observed that Arsenic concentrations in the shallow aquifers of the study area were very low. Some locations gave a negative sign which indicates that the concentration of Arsenic in those locations was below detectable limits. A mean concentration of 0.001433 µg/l was recorded, with a standard deviation and coefficient of variation of 0.0030 and 0.000 respectively. A health-based guideline of 10 µg/l (0.01 mg/l) is recommended by (WHO, 2008). Elevated concentration of Arsenic in drinking water has some carcinogenic effects.

Table 2. Descriptive statistics of the physical and chemical analysis of groundwater from the Shallow Aquifers in the Study Area
Source: WHO (2008)

Parameters	Minimum	Maximum	Mean	Std Dev.	Coeff. Var
T (T^0C)	25.50	27.50	26.2503	.54974	.302
pH	6.97	7.60	7.3820	.12702	.016
SAL (mg/l)	.02	.39	.1953	.09250	.009
EC (µscm-1)	71.00	775.00	405.333	178.570	31887.264
TDS (mg/l)	36.00	388.00	202.900	89.2130	7958.972
$N0_3^-$ (mg/l)	.09	.38	.2287	.08072	.007
Cl^- (mg/l)	1.40	10.50	5.3233	2.06493	4.264
SO_4^{2-} (mg/l)	.30	3.80	2.0440	1.03095	1.063
TA (mg/l)	1.10	4.70	2.3367	.83397	.696
TH (mg/l)	2.20	27.80	12.5367	5.89614	34.764
Fe (mg/l)	.02	.82	.1387	.15704	.025
Mn (mg/l)	.00	.04	.0182	.00915	.000
F^- (mg/l)	.02	1.50	.6447	.43042	.185
As (µg/l)	-.001	.010	.00143	.003002	.000

Temperature (T), pH, Salinity (Sal), Electrical conductivity (EC), Total Dissolved Solids (TDS), Nitrate ($N0_3^-$), Chloride (Cl^-), Sulphate (SO_4^{2-}), Total Alkalinity (TA), Total Hardness (TH), Iron (Fe), Manganese (Mn), Fluoride (F^-) and Arsenic (As)

Table 3. World Health Organization (WHO) Guidelines
Source: WHO (2008)

S/N	Parameters	Mean	WHO Guidelines
1	Temperature (T°C)	26.2503	Not defined
2	pH	7.3820	6.5-8.5
3	Salinity (SAL) mg/l	0.1953	Not defined
4	Electrical Conductivity (EC) µscm-1	405.3333	Not defined
5	Total Dissolved Solids (TDS) mg/l	202.9000	1000 (taste concerns)
6	Nitrate (NO_3) mg/l	0.2287	50
7	Chloride (Cl^-) mg/l	5.3233	250 (taste concerns)
8	Sulphate (SO_4^{2-})	2.0440	200
9	Total Alkalinity (TA) mg/l	2.3367	Not defined
10	Total Hardness (TH) mg/l	12.5367	200 (scale deposition)
11	Iron (Fe) mg/l	0.1387	0.3
12	Manganese (Mn) mg/l	0.0182	0.4
13	Fluoride (F^-) mg/l	0.6447	1.5
14	Arsenic (As) µg/l	0.00143	10 µg/l (0.01 mg/l)

Factor analysis of groundwater samples

Factor analysis (FA) of the studied groundwater samples was performed in other to get an overall impression about assembling the samples in a multi-dimensional space defined by the analyzed parameters. The results were (0.609) for Kaiser-Meyer-Olkin Measure of Sampling Adequacy (KMO) and (566.505) for Bartlett's Test of Sphericity ($p<0.0001$). This indicates that the results are significant and that Factor Analysis may be useful in providing significant reductions in dimensionality. From the analysis performed five factors (components) explaining 80.179% of the total variance were estimated based on Kaiser criterion (Kaiser, 1960) of the eigenvalues greater or equal to one (1) (table 6) and from a Cattel Scree plot. The Scree plot (figure 3) shows the eigenvalues sorted from large to small as a function of the factor number.

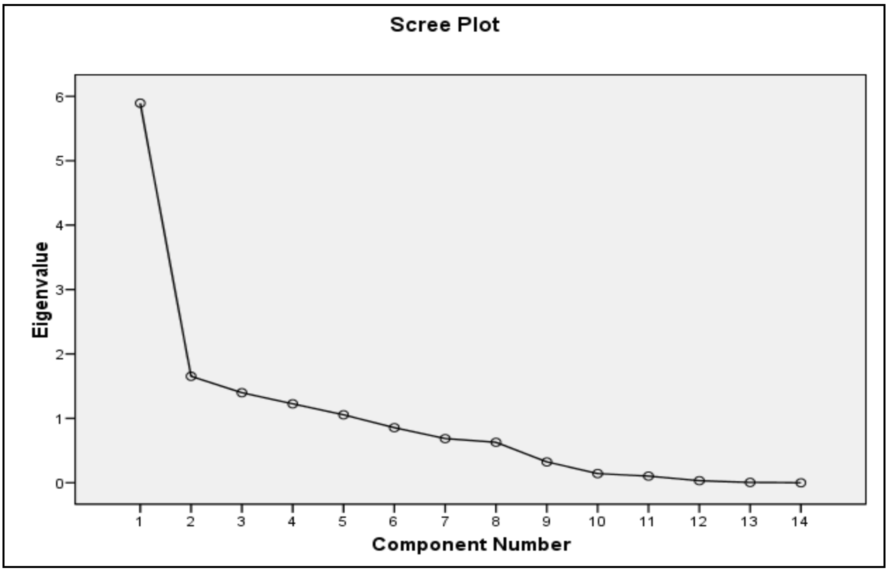

Figure 3. Scree Plot Test

Table 4. Factor loading matrix of physico-chemical parameters

PARAMETERS	FACTORS				
	1	2	3	4	5
T	.106	-.140	.149	.843	.064
Ph	.089	.602	.669	.009	.256
SAL	.948	.015	.215	.091	.108
EC	.953	.043	.210	.115	.082
TDS	.953	.044	.210	.114	.082
$N0_3$	.639	-.077	.058	.182	.304
Cl^-	.888	.192	.003	.087	-.209
SO_4^{2-}	.819	.215	-.144	.028	-.200
TA	.717	-.120	.313	-.177	.414
TH	.469	.304	-.353	-.007	.118
Fe	-.083	-.932	-.008	-.048	-.010
Mn	.299	-.038	.819	.051	-.120
F^-	.125	.408	-.152	.698	.084
As	.040	.103	-.066	.121	.890
Eigen value	5.894	1.653	1.398	1.225	1.055
% Variance	42.099	11.810	9.983	8.752	7.535
Cumulative %	42.099	53.910	63.893	72.644	80.179

Temperature (T), pH, Salinity (Sal), Electrical conductivity (EC), Total Dissolved Solids (TDS), Nitrate (NO_3), Chloride (Cl), Sulfate (SO_4^{2-}), Total Alkalinity (TA), Total Hardness (TH), Iron (Fe), Manganese (Mn), Fluoride (F) and Arsenic (As)

As observed from (table 4), SAL, EC, TDS, NO_3, $C^{l-,}$ SO_4^{2-} and TA are marked factor one (1), which explained 42.099% of the total variance. Factor 1 showed a high positive loading in SAL, EC, TDS, NO_3, Cl^-, SO_4^{2-} and TA. High positive loadings indicate a strong linear correlation between the factor and parameters. Most highly correlated with Factor 1 were SAL, TDS and EC, with TDS and EC recording strong positive loadings. Thus factor 1 can be termed conductivity index. This is an indication that the groundwater in the shallow aquifers in the study area is contained with high levels of dissolved inorganic salts which must have originated from high saline water, possibly saline water intrusion since the study area is close to the Atlantic Ocean. Increased saline intrusion can increase densities of shallow aquifers in the study area and this may in the long run affect ocean circulation. Also, Cl^-, Nitrate and SO_4^{2-} are pollutants that help in increasing conductivity and consequently affecting salinity, hence, their correlation is as expected. Dissolved inorganic constituents can also come from leaking septic systems (soak away pits), sewage, urban runoff, leachates from landfills and industrial wastewater (WHO, 2008). Conductivity, especially specific conductance is a first-order measure as regards water quality parameters especially in zones with shallow water aquifers. It is an early indicator of change in a water system. Salinity, as expected, is associated with conductivity and hence, marine organisms' tolerance depends largely on their osmotic processes. Based on their tolerance range, marine organisms (saltwater, euryhaline, anadromous, catadromous and freshwater) respond differently to varying levels of salinity. The varying levels affect the metabolic activities of these organisms. This implies that an increase in SAL, EC and TDS will increase NO_3, Cl^-, SO_4^{2-} and TA in the shallow aquifers in the study area (Liu et al., 2003).

Factor two (2) with a high loading of pH and Fe explained 11.810% of the total variance with loadings of 0.602 and -0.932 respectively (table 4). This indicates that factor 2 is positively correlated with pH but negatively correlated with Fe. This also means that both (pH and Fe) have an inverse relationship. This again confirms the moderately acidic nature of the groundwater in the study area being neutralized by salt contamination to a large extent (Chindah et al., 2011), therefore resulting in (Fe) having a negative correlation with pH in factor 2. This factor can be termed an oxidizing index.

The third factor is strongly correlated with Mn and pH, which accounted for 9.983% of the total variance with factor loadings of 0.819 and 0.669 respectively (table 4). It also implies that Mn and pH exhibit relationship and as expected this is particularly true of low-relief areas abutting the coast. This can be termed manganese-toxicity index.

Factor four (4) was responsible for 8.752% of the total variance and strongly correlated with Temperature (T^oC) and Fluoride (F), with factor loadings of 0.843 and 0.698 respectively. In factor 4, T^oC showed a strong correlation ahead of Fluoride, implying that T^oC has a strong positive relationship with factor 4. This can be termed a physical attribute index.

Finally, factor five (5) was correlated with only As, which accounted for just 7.535% of the total variance with a factor loading of 0.890 (table 4). This indicates that As has a strong positive relationship with factor 5. The results also reveal that As has no linear relationship with any other parameter in the study area. This indicates that the traces of As concentration in the shallow aquifers in the study area may have originated from other factors. WHO (2008) noted that As may originate from anthropogenic sources, such as sewage, mining and other industrial activities. This factor can be termed an anthropogenic-pollutant index.

In essence, across shallow aquifers in sedimentary basins around coastal regions especially in tropical environments, determination of water quality should focus mostly on conductivity parameters (salinity, electrical conductivity, chloride, sulphate, etc), followed by oxidizing agents such as pH, iron, then manganese-toxicity tests. These three indices account for over 60% of the total variance in the factor analysis tests (table 8). The other two indices, physical attributes and anthropogenic-pollutants, accounts for about 15%. Therefore, water quality studies around this region should focus more on the first three indices in determining the level of water quality (Liu et al., 2003).

Rural-urban differentials in groundwater quality

Independent samples T-Test was carried out to examine the difference in shallow groundwater quality between urban and rural land-use types (table 5). The result shows that there is a significant difference in the level of the following parameters: temperature (t=2.719, df=28, p<0.05); salinity (t=2.182, df=28, p<0.05); Total Dissolved Solids (t=2.371, df=28, p<0.05); and manganese (t=3.894, df=28, p<0.05). Possible explanations to these observed differences can be tied to rapid urbanization, population density especially in the urban areas (Olusola et al., 2017; Fashae et al., 2019), saltwater intrusion causing significant differences in SAL, TDS, EC and Mn, water recharge source(s) to the shallow aquifers mixed with anthropogenic activities (Liu et al., 2003). Mixing is an important process that influences the chemical composition of groundwater. Mixing occurs when groundwater moving along a specific flow path encounters other water that has evolved independently. If the mixing waters have chemical compositions different from each other, the constituent concentrations and proportions in the resulting mixture will be intermediate to the constituent concentrations and proportions of the original waters. Water that may mix with groundwater includes water from another aquifer e.g., saline groundwater especially in areas very close to the sea; groundwater that has travelled along a different flow path within the same aquifer; and surface water or water-related to human activity that infiltrates into the aquifer. Sources of surface water can include rivers, streams, lakes, reservoirs, canals, and ponds which can have different chemical compositions. Water-related to human activity includes animal, human and food processing wastewater, irrigation water, and other water that have significantly different chemical compositions.

Table 5. Independent Samples T-test for physico-chemical properties across rural-urban areas

	Location	N	Mean	Std. Deviation	T	df	Sig. (2-tailed)
T	Urban	15	26.497333	.6245852	2.719	28	.011
	Rural	15	26.003333	.3242941			
PH	Urban	15	7.405333	.1516512	1.006	28	.323
	Rural	15	7.358667	.0962041			
SAL	Urban	15	.230000	.0935796	2.182	28	.038
	Rural	15	.160667	.0799524			
EC	Urban	15	477.200000	177.5343830	2.374	28	.025
	Rural	15	333.466667	153.1870317			
TDS	Urban	15	238.766667	88.8483593	2.371	28	.025
	Rural	15	167.033333	76.3924236			
$N0_3$	Urban	15	.245333	.0838252	1.137	28	.265
	Rural	15	.212000	.0766439			
CL	Urban	15	5.886667	2.1179055	1.528	28	.138
	Rural	15	4.760000	1.9149040			
SO_4	Urban	15	2.242667	.8575086	1.058	28	.299
	Rural	15	1.845333	1.1754687			
TA	Urban	15	2.480000	.6950848	.939	28	.356
	Rural	15	2.193333	.9557844			
TH	Urban	15	12.466667	6.1781489	-.064	28	.950
	Rural	15	12.606667	5.8165364			
Fe	Urban	15	.176667	.2053105	1.344	28	.190
	Rural	15	.100667	.0763887			
Mn	Urban	15	.023533	.0075675	3.894	28	.001
	Rural	15	.012867	.0074342			
F	Urban	15	.710000	.4009809	.827	28	.415
	Rural	15	.579333	.4624078			
As	Urban	15	.002000	.0041404	1.035	28	.309
	Rural	15	.000867	.0009155			

Significant at p<0.05 significance level(2-tailed)

Temperature (T), pH, Salinity (Sal), Electrical conductivity (EC), Total Dissolved Solids (TDS), Nitrate (NO_3), Chloride (Cl), Sulphate (SO_4^{2-}), Total Alkalinity (TA), Total Hardness (TH), Iron (Fe), Manganese (Mn), Fluoride (F) and Arsenic (As).

CONCLUSION

From the study, it was observed that the concentration of groundwater parameters from shallow aquifers is significantly influenced by seawater intrusion within the study area. The groundwater in the study area is moderately acidic in nature but a possibility of saline water intrusion, is making it alkaline and in turn influencing the chemical characteristics of other groundwater parameters in the study area. An increase in salinity has resulted in an increase in pH from an acidic state to an alkaline state. The chemical make-up of groundwater within the study area across rural-urban differentials revealed that the determination of water (ground) quality rests on five major indices. There are: conductivity, oxidising, manganese-toxicity, physical attributes and anthropogenic-pollutants. There first three indices (conductivity, oxidizing and manganese-toxicity) account for over 60% of the variance based on factor analysis. Therefore, this study confirms that within shallow aquifers in sedimentary basins abutting the coast, conductivity, oxidizing and manganese-toxicity indices are the main parameters that should be examined for determining groundwater quality.

There is equally a need for constant monitoring of the underground water quality to ensure that water quality parameters do not build up to levels that will be of environmental concern especially in areas with a growing population and infrastructural developments. There should be a coordinated sampling and monitoring program to check the quality of underground water regularly.

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Submitted:	Revised:	Accepted and published online
May 25, 2019	February 15, 2020	April 23, 2020