Open Access

SCHOLARENA

Journal of Environmental Pollution and Management

RESEARCH ARTICLE

ISSN: 2639-7269

Assessing Seasonal Changes in Physical and Chemical Properties of Ground Water Quality around Coastal Slum Settlements in Lagos Metropolis, Nigeria

Okimiji OP[1*], Okafor AT[3], Adedeji OH[1], Oguntoke O[1], Shittu OB[2] and Aborisade MA[1]

[1]Department of Environmental Management and Toxicology, Federal University of Agriculture, Abeokuta, PMB 2240, Ogun State, Nigeria

[2]Department of Microbiology, Federal University of Agriculture, Abeokuta, PMB 2240, Ogun State, Nigeria

[3]Department of Environmental Management and Toxicology, Michael Okpara University of Agriculture, Umudike, PMB 7267, Abia State, Nigeria

[*]**Corresponding author:** Okimiji OP, Department of Environmental Management and Toxicology, Federal University of Agriculture, Abeokuta, PMB 2240, Ogun State, Nigeria, Tel: +2348035665979, E-mail: princessokimiji@yahoo.com

Citation: Okimiji OP, Okafor AT, Adedeji OH, Oguntoke O, Shittu OB, et al. (2021) Assessing Seasonal Changes in Physical and Chemical Properties of Ground Water Quality around Coastal Slum Settlements in Lagos Metropolis, Nigeria. J Environ Pollut Manage 3: 104

Abstract

This study assessed the effect of seasonal changes on the physical and chemical properties of ground water quality used for drinking purpose around coastal slum settlement within Lagos Metropolis. Water samples were collected from different boreholes at different slums around the settlement comprising Slum A (Majidun), Slum B (Oworoshoki), Slum C (Bariga), Slum D (Iwaya) and Slum E (Ijora Badia) for wet and dry seasons. Parameters of temperature, TDS, pH, hardness, EC, nitrate, sulphate and chloride are analyzed using standard methods. The obtained data were analyzed using SPSS for Windows. Result of the analyses showed that all the parameters have higher concentration during the dry season than in the wet season in all the Slums. Pearson correlation was applied in order to determine the relationship between two parameters. Result of PCA revealed that pH and chloride contributed a strong positive loading across the Slums, except for Slum A, B, and C. while TDS, EC, nitrate, sulphate and hardness exhibited a strong positive loading in Slum A, B, C, D and E in the wet season. More so, nitrate revealed a strong positive loading across the Slums. TDS, EC, temperature, chloride and sulphate constituted a strong positive loading across the Slums, except for Slum C, D and E during dry season. pH and hardness participated strong loading in Slum D and E in dry season. The study concludes that seasonal changes consequentially impact the quality of ground water used for drinking in the slum settlements, the water are more polluted during the dry season and recommended that it must be adequately treated if it is to be used for drinking.

Keywords: Assessment; Seasonal Changes; Drinking Water Quality; Slum; Settlements

Introduction

Ground water historically has been recognized as the most elected source of drinking water globally [15], constantly considered more trustable and reachable than surface water which can be directly exploited by users [23]. More so, [35] ascertained that groundwater has frequently been proven as clean and reliable source of water; hence it is threatened and repeatedly taken for granted due to careless disposal of organic and chemical wastes that has resulted to water pollution. [4] Notes that water pollution is a physical process that occurs in various water resources such as lakes, ground water, and rivers due to anthropogenic activities. Although, [10] stipulated that drinking water quality and quantity are very low because of poor treatment of deteriorated water and old sanitation system in urban areas especially the slum settlements. Thus is due to the lack of treatment technology, trained personnel, lack of awareness and quality monitoring [9]. [45] Documented that large proportion of population residing in developing countries is suffering from health-related issues due to unsafe drinking water. And the degree of magnitude is amplifying day by day due to the fast population growth that has eventually resulted to poor management of water quality [16]. Moreover, Urban growth has been betiding substantially in developing countries; from 2010 to 2020 [43].

Hence, numerous new urban residents in developing countries are moving into unplanned slum settlements, heavily populated urban areas represented by wretched housing and squalor [42]. Presently, over 1.2 billion people live in slum settlements worldwide [44]. Slum settlements oftentimes have deficient infrastructure [13, 52, 28, 20]. Moreover, Industrialization and emergence of urban units placed immense stress on water resources and discharge of wastewater into natural water resources that decreases ground water quality [7]. More so, saltwater intrusion into the aquifers can occur most times in coastal areas, and this process decreases access to water supply by lowering supply and increasing contamination [37]. The various concentrations of inorganic and organic contaminants are on the increase in groundwater, thereby causing adverse effect on human health. Although Industries, poor sewage discharge system, unprotected septic tanks and dumping of sewage sludge in urban location can also directly contaminate the ground water [19]. Utilization of ground water for beneficial use causes contrary effects on the environment and public health. The physical and chemical properties of ground water for drinking have great importance because a minor fluctuation in these parameters affects the human health. This study therefore aimed to assess the seasonal changes that affect the quality of ground water used for drinking by urban slum dwellers in order to improve water quality in regards to protecting the health of poor people residing in slum settlements.

Materials and Methods

Study Area

Slum settlements within Lagos Metropolis, south-western Nigeria was were the study was carried out. Thus, having the Longitudes 3˚249 'E and latitudes 6˚279 'N with a coastline of approximately 180 km [12]. The state has a total land area of 3577.28 km^2 out of which 22 % is wetland and population density of approximately 5926 persons per km^2 [27]. Lagos state population is estimated to be 24.5 million in 2015 [41] and 29 million by 2020 [14] with a growth rate of 3.2 and 8 % [46].

The geology of Lagos state comprises of coastal plain sand and a tidal flat with alluvium [26] and the vegetation is tropical rainforest zone consisting of mangrove swamps, freshwater swamps, lagoons and creeks. Relief occupies a low-lying topography of 1– 4 % slope, elevation of 0–2 m above sea level [8] that is characterized by dendritic drainage system of Rivers Ogun, Adiyan and Ossa [17]. The state is ranked 15th in the world in terms of population exposed to coastal flooding because over 70 % of its population are living in slum settlements [1]. This is not surprising as only 45.2 % of its built-up areas are connected with drains [25] and only less than 30 % of the existing drains are maintained [3]. Lagos has two distinct climatic seasons; dry and wet (rainy). It experiences high air temperatures ranging from 30.0˚C to 38.0˚C (40). Figure 1 presents map of the study area indicating the sample locations.

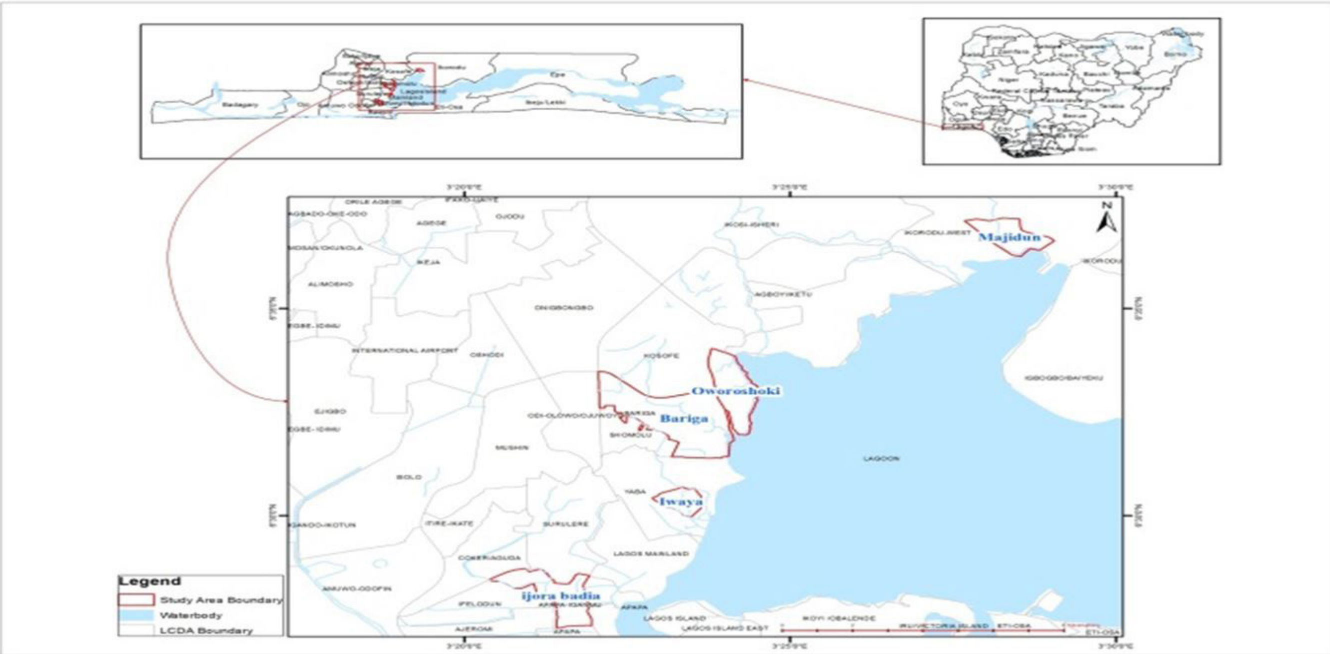

Figure 1: Map of the study area

Sampling Locations

Water samples used for drinking were collected from selected boreholes around five selected slum settlements in Lagos metropolis during wet (rainy) and dry seasons from 2018 to 2019. Fifth water samples were collected in the slum settlements of Majidun, Oworoshoki, Bariga, Iwaya and Ijora Badia in each different season for twelve months (six months in wet season and six months in dry season). The samples were labeled with different codes according to the locations (Slum A Majidun; Slum B Oworoshoki; Slum C Bariga; Slum D Iwaya; Slum E Ijora Badia).

All samples were collected in sterile auto clavable plastics and immediately stored in a cooler containing ice block at 3 - 4˚C for preservation. Samples were transported back to the laboratory for analysis. Temperature, pH, EC and TDS were determined at the point of collection of the samples. Other parameters such as nitrate, chloride, hardness and sulphate were analyzed respectively.

Sample Collection Points

Sample sites geographical coordinates ((latitude and longitude) were determined using a GPS device Garmin (GPSMAP 76CSX model). Lagos metropolis map was obtained and gridded to create cells of 300 m^2 using Arc Map 10.1 (Figure 2) for a proper representative collection of data across the entire slums. Ten cells out of the existing cells were randomly selected from each of the study areas using random number table, according to the method proposed by Kriging [32]. Figure 2 presents grid map of the study area indicating the sample locations.

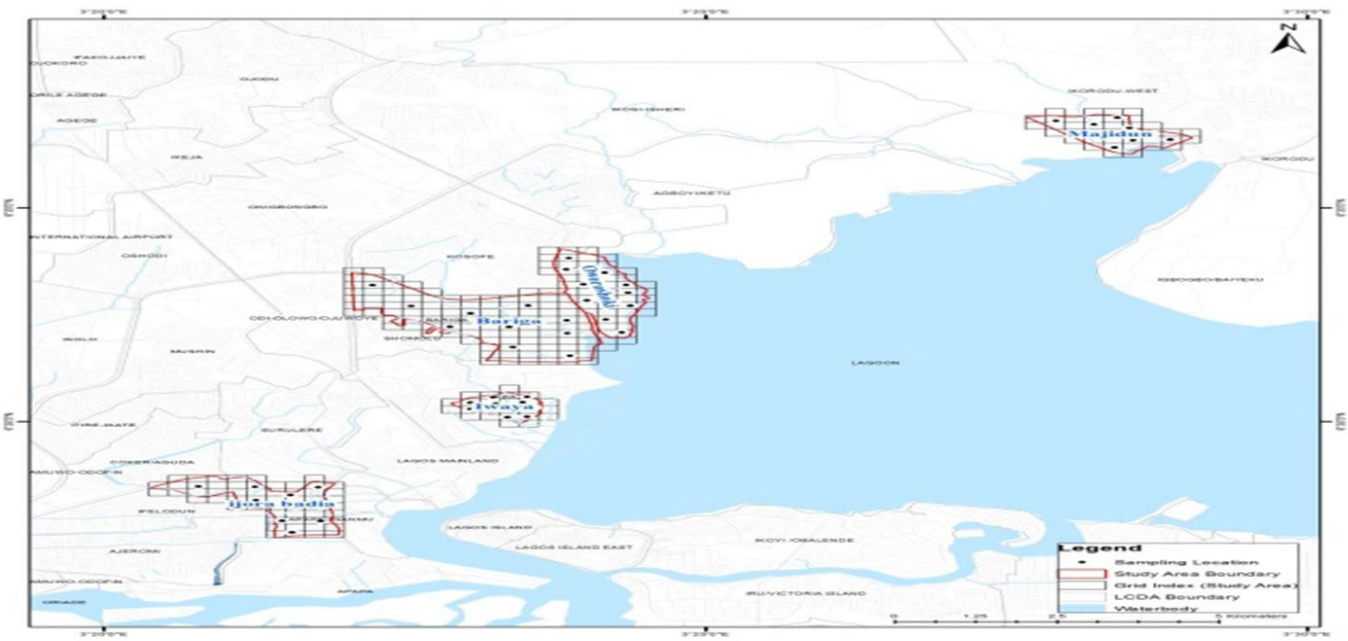

Figure 2: Grid map of the study area

Methods of Analysis

Total dissolved solid, electrical conductivity (EC) and pH was measured in situ using pocket sized pH meter Hanna Combo (H198130 model). Temperature was determined by dipping a mercury-in-glass portable thermometer into the water samples to obtain the reading. Total dissolved solids by Evaporation Method [39]. Hardness and chloride were measured titrimetrically using standard methods of APHA (21st edition, 2005). Nitrate and sulphate was determined by UV-Spectophotometric method (UV-2505 model) [2]. The sampling locations, months and GPS coordinates are depicted in Table 1.

Statistical analysis

Data collected was analyzed for inferential statistics (Pearson coefficient of correlation and principal component analysis) using SPSS for Windows (version 22.0).

Sample Location	Sample Code	Wet Season (Month of Sampling)	Dry Season (Month of Sampling)	GPS Coordinates	
				Latitude	Longitude
Slum A-Majidun	SA1	April - September	October-March	6.53319	3.39734
	SA2	April - September	October-March	6.61784	3.47375
	SA3	April - September	October-March	6.61763	3.47143
	SA4	April - September	October-March	6.61648	3.47422
	SA5	April - September	October-March	6.61564	3.47415
	SB1	April - September	October-March	6.55073	3.39944
Slum B- Oworoshoki					
	SB2	April - September	October-March	6.55094	3.396655
	SB3	April - September	October-March	6.55116	3.40035
	SB4	April - September	October-March	6.55148	3.40157
	SB5	April - September	October-March	6.55105	3.40285
	SC1	April - September	October-March	6.3212	3.2331

Sample Location	Sample Code	Wet Season (Month of Sampling)	Dry Season (Month of Sampling)	GPS Coordinates	
Slum C- Bariga					
	SC2	April - September	October-March	6.53617	3.39236
	SC3	April - September	October-March	6.53796	3.39191
	SC4	April - September	October-March	6.53571	3.39297
	SC5	April - September	October-March	6.53815	3.39191
	SD 1	April - September	October-March	6.50617	3.39132
Slum D- Iwaya					
	SD 2	April - September	October-March	6.50611	3.39288
	SD 3	April - September	October-March	6.50715	3.39306
	SD 4	April - September	October-March	6.50571	3.3912
	SD 5	April - September	October-March	6.506814	3.393192
	SE 1	April - September	October-March	6.60761	3.40853
Slum E- Ijora Badia					
	SE 2	April - September	October-March	6.46592	3.36249
	SE 3	April - September	October-March	6.46673	3.36015
	SE 4	April - September	October-March	6.46672	3.35865
	SE 5	April - September	October-March	6.46822	3.35825

Table 1: Location of drinking water sample

Pearson Correlation Analysis

Table 2-3 disclose the exactness of the statistic examined in drinking water quality from the five locations around coastal slum communities. The degree estimated by Pearson's connection coefficients for the two seasons (wet and dry) at Majidun, Oworoshoki, Bariga, Iwaya and Ijora-Badia is displayed in Tables 2 and 3 respectively. Table 2 shows the significance of the relationship between the parameters in water quality across the coastal slum settlements during wet season. Out of 36 correlations found between two continuous parameters, one was found to have positive significance at 0.05% level. Positive correlation were found to exist between temperature and TDS (0.933*). Hence, TDS in water depends on water temperature and thus total dissolved solid is increased when the water has a higher temperature [31]. More so, high concentrations of TDS may affect persons who are suffering from kidney and heart diseases. Water containing high solid may also cause laxative or constipation effects [38].

	Temperature °C	EC µs/cm	TDS mg/L	pH	Nitrate mg/L	Sulphate mg/L	Chloride mg/L	Hardness mg/L	Phosphate mg/L
Temperature °C	1								
EC µs/cm	.673	1							
TDS mg/L	.933*	.472	1						
pH	-.142	-.643	-.135	1					
Nitrate mg/L	.432	.015	.314	.395	1				
Sulphate mg/L	.377	.099	.172	.337	.395	1			
Chloride mg/L	.152	.641	.165	-.995**	-.722	-.414	1		
Hardness mg/L	.331	.716	.288	-.563	-.024	-.579	.624	1	
Phosphate mg/L	.051	-.636	.349	.525	.247	-.166	-.475	-.340	1

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

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

Table 2: Correlation matrix for physical and chemical parameters across the coastal slum communities during the wet season

	Temperature °C	EC µs/cm	TDS mg/L	pH	Nitrate mg/L	Sulphate mg/L	Chloride mg/L	Hardness mg/L	Phosphate mg/L
Temperature °C	1								
EC µs/cm	.560	1							
TDS mg/L	.881*	.480	1						
pH	.284	-.361	.079	1					
Nitrate mg/L	-.001	.589	-.195	.062	1				
Sulphate mg/L	.840	.717	.841	-.277	-.107	1			
Chloride mg/L	.334	.899*	.433	-.700	.360	.693	1		
Hardness mg/L	.481	.805	.136	-.097	.637	.499	.545	1	
Phosphate mg/L	.248	-.626	.227	.835	-.481	-.185	-.777	-.496	1

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

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

Table 3: Correlation matrix for physical and chemical parameters across the coastal slum communities during the dry season

However, during dry season (Table 3), positive correlation was found between temperature and TDS (0.881*) as well as EC and chloride (0.899*) at 0.05% level. Positive correlation exists between temperature and TDS during both seasons. Hence, highly significant correlation between TDS and temperature brace the facts that TDS is increased when the water has a higher temperature [31]. The significant correlation between EC and chloride indicate that chloride ions are the main constituents in waters that directly affect EC. Thus it is primarily acquired from the dissolution of salts hydrochloric acid as table salt (NaCl), $NaCO_2$ and added through industrial waste, sewage, sea water. Hence, high chloride concentration damages metallic pipes and structure as well as harm growing plants [52].

Principal component analysis

Principal component analysis (PCA) of selected physical and chemical parameters in drinking water samples for dry and wet seasons is presented in five Tables (Slum A to E). PCA is a powerful tool that attempts to explain the variance of a large dataset of inter-correlated variables with a smaller set of independent variables [34].

Table 4 result showed Slum A (Majidun) wet season variables on PC 1 which explained 21.96% of the total variance and is mainly carried by pH showing strong positive loading. PC 2 and PC 3 constituted 17.59% and 14.55% of the total variance, having strong positive loading on temperature and nitrate. PC 4 exhibited 11.30 % of the total variance on hardness showing moderate positive loading. Parameters such as pH, temperature, nitrate and hardness contributed significantly during wet season (Slum A). The consequences of these contributing factors on water quality rely on the amount of its specific elements. Substantial hardness, taste, mineral deposition and corrosion are typical attributes of tremendously mineralized water [11].

Slum A (Majidun) dry season variables on PC 1 represents 23.07% of the total variance. It is mostly participated by temperature having strong positive loading (Table 4). PC 2 and PC 3 contributed 15.39% and 14.55% of the total variance. PC 2 showed moderate positive loading on TDS while PC 3 had a strong positive loading on EC. PC 4 and PC 5 constituted 12.34 % and 11.84% of the total variance on nitrate and sulphate having strong positive loading. Slum A most contributing factors are temperature, EC and nitrate. Thus, could be as a result of natural and anthropogenic sources such as run-off and utilization of inorganic fertilizes, landfill leachates, septic tank effluents, animal feeds, industrial effluents, irrigation drainage, and seawater intrusion in coastal areas [33].

The result in Table 5 showed Slum B (Oworoshoki) wet season variables. PC 1 accounted for 22.24 % of the total variance and is characterized by strong positive loadings on EC. PC 2 explained 15.14 % of the total variance with a weak positive loading on nitrate. PC 3 constituted 14.26 % of the total variance and is participated by chloride. Slum B wet season factor contributing significantly to variation in water quality are EC and chloride. EC reflects the nutrient status of water and distribution of macrophytes [24].

Slum A: Majidun wetseason variables on 4 PC	Component				Slum A:Majidun dryseason variables on 5 PC	Component				
	PC1	PC2	PC3	PC4		PC1	PC2	PC3	PC4	PC5
pH	0.732	-0.390	0.223	-0.142	Temperature °C	0.756	-0.159	-0.357	0.162	-0.073
Hardness mg/L	0.621	-0.017	-0.204	0.583	Hardness mg/L	0.755	0.292	0.058	0.180	0.256
Chloride mg/L	0.579	-0.146	-0.476	0.070	Chloride mg/L	0.655	0.078	0.206	-0.416	-0.151
Temperature °C	0.105	0.643	-0.202	-0.043	pH	-0.031	-0.822	0.324	0.003	-0.042
EC µs/cm	-0.305	0.614	-0.050	-0.052	TDS mg/L	-0.530	0.597	-0.189	0.175	-0.183
TDS mg/L	0.297	0.599	0.382	0.466	EC µs/cm	0.169	0.429	0.666	-0.072	0.411
Nitrate mg/L	0.338	0.110	0.845	-0.149	Nitrate mg/L	0.184	-0.053	0.154	0.910	-0.066
Sulphate mg/L	0.490	0.192	-0.069	-0.575	Sulphate mg/L	-0.394	-0.209	0.211	0.110	0.622
Eigenvalue	1.976	1.584	1.310	1.017	Eigenvalue	2.077	1.386	1.310	1.113	1.066
Variance (%)	21.961	17.599	14.552	11.305	Variance (%)	23.079	15.395	14.557	12.364	11.846
Cumulative variance (%)	21.961	39.560	54.112	65.417	Cumulative variance(%)	23.079	38.474	53.031	65.395	77.241

Table 4: Factor loading of physical and chemical drinking water parameters for wet and dry season Majidun (Slum A)

Slum B: Oworoshoki wet season variables on 3 PC	Component			Slum B: Oworoshoki dry season variables on 4 PC	Component			
	PC1	PC2	PC3		PC1	PC2	PC3	PC4
EC µs/cm	0.713	0.054	-0.329	Temperature °C	0.712	-0.175	-0.165	0.058
Sulphate mg/L	-0.658	0.267	-0.045	Chloride mg/L	0.639	0.223	0.343	-0.448
TDS mg/L	0.553	-0.411	0.043	pH	-0.576	0.321	-0.122	0.244
Nitrate mg/L	0.314	0.487	-0.201	TDS mg/L	-0.297	0.520	0.515	0.017
Hardness mg/L	0.178	-0.391	0.379	Hardness mg/L	-0.488	-0.515	0.193	-0.097
Chloride mg/L	0.469	0.112	0.595	Sulphate mg/L	0.196	-0.316	0.699	-0.122
Temperature °C	-0.501	0.079	0.574	Nitrate mg/L	-0.007	0.421	0.537	0.328
pH	-0.351	-0.388	-0.550	EC µs/cm	0.559	0.239	-0.104	0.661
Eigenvalue	2.002	1.363	1.284	Eigenvalue	1.923	1.487	1.357	1.134
Variance (%)	22.241	15.145	14.264	Variance (%)	21.370	16.522	15.083	12.601
Cumulative variance (%)	22.241	37.386	51.650	Cumulative variance (%)	21.370	37.893	52.975	65.576

Table 5: Factor loading of physical and chemical drinking water parameters for wet and dry season Oworoshoki (Slum B)

Slum C: Bariga wet season variables on 4 PC	Component				Slum C: Bariga dry season variables on 4 PC	Component			
	PC1	PC2	PC3	PC4		PC1	PC2	PC3	PC4
TDS mg/L	0.887	0.092	-0.083	-0.106	Sulphate mg/L	0.738	-0.337	0.022	-0.058
EC µs/cm	0.773	-0.054	-0.121	-0.082	Hardness mg/L	0.686	-0.321	0.186	0.174
Sulphate mg/L	-0.161	0.668	-0.005	-0.442	pH	0.501	0.383	-0.384	0.260
Hardness mg/L	0.517	0.596	-0.348	0.094	Temperature °C	0.317	0.686	0.087	0.239
Chloride mg/L	-0.037	0.540	0.454	-0.192	Nitrate mg/L	-0.395	0.222	0.538	0.362
Temperature °C	0.194	0.050	0.736	0.409	Chloride mg/L	-0.411	-0.395	-0.515	0.248
pH	-0.400	0.291	-0.453	0.609	TDS mg/L	0.062	-0.328	0.450	-0.445
Nitrate mg/L	0.443	0.205	0.136	-0.505	EC µs/cm	-0.014	-0.248	0.472	0.580
Eigenvalue	2.203	1.551	1.117	1.060	Eigenvalue	1.695	1.428	1.211	
Variance (%)	24.481	17.230	12.417	11.776	Variance (%)	18.835	15.870	13.459	12.121
Cumulative variance (%)	24.481	41.710	54.127	65.903	Cumulative variance (%)	18.835	34.705	48.164	60.285

Table 6: Factor loading of physical and chemical drinking water parameters for wet and dry season Bariga (Slum C)

Slum D: Iwaya Wet Season Variables on 4 PC	Component				Slum D: Iwaya Dry Season Variables on 4 PC	Component			
	PC1	PC2	PC3	PC4		PC1	PC2	PC3	PC4
Nitrate mg/L	-0.645	0.017	0.210	-0.061	TDS mg/L	0.644	0.234	0.096	0.128
Chloride mg/L	0.598	0.387	0.250	0.182	Sulphate mg/L	0.630	-0.417	0.319	0.030
pH	-0.269	0.817	-0.083	-0.029	Temperature °C	0.557	0.240	-0.413	-0.324
EC µs/cm	0.467	-0.659	0.297	-0.036	Hardness mg/L	-0.533	-0.062	-0.062	-0.482
Temperature °C	0.294	-0.162	-0.649	0.169	pH	-0.227	0.755	0.225	-0.072
Hardness mg/L	0.458	0.368	0.622	0.035	EC µs/cm	-0.304	0.497	-0.137	0.168
TDS mg/L	0.168	0.223	-0.235	-0.775	Chloride mg/L	0.053	0.302	0.722	0.233
Sulphate mg/L	0.412	0.299	-0.376	0.454	Nitrate mg/L	-0.049	0.035	-0.461	0.781
Eigenvalue	1.931	1.556	1.222	1.057	Eigenvalue	1.858	1.411	1.134	1.098
Variance (%)	21.461	17.289	13.572	11.746	Variance (%)	20.646	15.676	12.605	12.200
Cumulative variance (%)	21.461	38.750	52.322	64.068	Cumulative variance (%)	20.646	36.322	48.927	61.126

Table 7: Factor loading of physical and chemical drinking water parameters for wet and dry season Iwaya (Slum D)

Slum E: Ijora Badia Wet Season Variables on 4 PC	Component				Slum E: Ijora Badia Dry Season Variables on 4 PC	Component			
	PC1	PC2	PC3	PC4		PC1	PC2	PC3	PC4
TDS mg/L	0.679	0.314	-0.030	0.266	pH	0.849	0.243	0.006	0.045
Temperature °C	0.478	-0.324	0.109	0.073	Temperature °C	0.828	0.069	-0.247	0.231
pH	-0.317	0.689	-0.190	-0.213	Sulphate mg/L	-0.111	-0.650	-0.013	0.491
Hardness mg/L	0.556	0.608	-0.129	0.118	EC µs/cm	0.169	-0.604	0.469	0.178
Chloride mg/L	0.185	0.421	0.629	0.058	Chloride mg/L	-0.198	0.437	0.339	-0.339
Sulphate mg/L	0.510	0.016	0.257	-0.664	Nitrate mg/L	-0.001	0.123	0.779	0.181
EC µs/cm	0.168	-0.331	0.406	0.565	Hardness mg/L	-0.303	0.389	-0.027	0.666
Nitrate mg/L	-0.446	0.436	0.196	0.461	TDS mg/L	0.283	-0.328	0.401	-0.407
Eigenvalue	1.728	1.527	1.313	1.187	Eigenvalue	1.681	1.504	1.356	1.180
Variance (%)	19.200	16.967	14.589	13.184	Variance (%)	18.676	16.706	15.066	13.116
Cumulative variance (%)	19.200	36.167	50.756	63.940	Cumulative variance (%)	18.676	35.382	50.448	63.564

Table 8: Factor loading of physical and chemical drinking water parameters for wet and dry season Ijora Badia (Slum E)

Slum B (Oworoshoki) dry season variables (Table 5) showed that PC 1 represent 21.37 % of the total variance. Thus it is carried by temperature having strong positive loading. PC 2 accounted for 16.52 % of the total variance having moderate positive loading on TDS. PC 3 and PC 4 explained 15.08 % and 12.60 % of the total variance on sulphate and EC showing strong positive loading. Group B dry season contributing factors are temperature, sulphate and EC. [6] Revealed that the causes of high electrical conductivity may be due to differences in geochemical conditions and soluble ions in the slum settlements.

Principal component analyses (Table 6) for Slum C (Bariga) wet season result revealed 24.48 % of the total variance represented under PC 1, participated by TDS having a strong positive loading. PC 2 and PC 3 explained 17.23 % and 12.41 % of the total variance on sulphate and temperature having strong positive loading. PC 4 revealed 11.77 % of the total variance that is exhibited by pH showing strong positive loading. The significant factors in these groups are TDS, sulphate, temperature and pH. pH is one of the most important chemical factor of water that is considered as important ecological factor of aquatic ecosystem [24]. pH values are commonly changed by the existence of organic and inorganic solutes collectively with the reaction of Carbon dioxide [47].

Slum C (Bariga) dry season variables revealed 18.83 % of the total variance and is participated by sulphate showing strong positive loading (Table 6). PC 2 contributed 15.87 % of the total variance on temperature having strong positive loading. PC 3 and PC 4 explained 13.45 % and 12.12 % of the total variance on nitrate and EC having moderate positive loading. The significant factors in these groups are sulphate, temperature, nitrate and EC. Hence, thus implies that the quality of groundwater is normally characterized by different physical and chemical parameters level. These parameters change widely due to various types of pollution, seasonal variation and groundwater extraction [30].

The result in Table 7 showed Slum D (Iwaya) wet season variables. PC 1 accounted for 21.46 % of the total variance. Thus, it showed moderate positive loading on chloride. PC 2 contributed 17.28 % of the total variance on pH having strong positive loading while PC 3 explained 13.57 % of the total variance and is characterized by hardness showing a strong positive loading. PC 4 constituted 11.74 % of the total variance on sulphate having a weak positive loading. The significant factors in these groups are chloride, pH, hardness and sulphate. [49] Reported that hardness and sulphate content in drinking water exceeding permissible limits imparts bitter, medicinal taste and may cause gasto-intestine irritation and catharsis.

Slum D (Iwaya) dry season variables revealed 20.64 % and 15.67 % of the total variance. PC 1 showed strong positive loading on TDS whereas pH had a strong positive loading on PC 2 (Table 7). PC 3 and PC 4 constituted 12.60 % and 12.20 % of the total variance on chloride and nitrate showing strong positive loading. The significant factors in these groups are TDS, pH, chloride and nitrate. TDS, chloride and nitrate indicates the pollution in ground water due to sewage percolation beneath the surface. Nitrate in natural water come from organic sources or from industrial and agricultural chemicals [21].

The result of the principal component analyses for Slum E (Ijora Badia) wet season revealed 19.20 % of the total variance under PC 1 having strong positive loading on TDS. PC 2 contributed 16.96 % of the total variance showing strong positive loading on pH (Table 8). PC 3 constituted 14.58 % of the total variance having strong positive loading on chloride. Additionally, 13.18 % of the total variance is exhibited by EC having a moderate positive loading under PC 4. The contributing factors in these groups are TDS, pH, chloride and EC. [29] Reported that low pH, EC and chloride are known to favour the solubility of ions associated with total dissolved solid.

Slum E (Ijora Badia) dry season variables (Table 8) revealed 18.67 % of the total variance under PC 1 having strong positive loading on pH. PC 2 represented 16.70 % of the total variance and is participated by chloride showing a weak positive loading. PC 3 constituted 15.06 % of the total variance with strong positive loading on nitrate. PC 4 contributed 13.11 % of the total variance on hardness having a strong positive loading (Table 8). The most contributing factors in these groups are pH, nitrate and hardness.

The pH is crucial factor that greatly affects water quality and quantity of pollution in water bodies [18]. More so, pH of drinking water has no direct effect on human. Indirectly it changes meat solubility and provides suitable environment for pathogens. [50] Noted that the principal constituents in water are usually calcium, magnesium, sodium and potassium cation, carbonate, hydrogen carbonate, chloride, sulphate and nitrate anion.

Conclusion

This study assessed the seasonal changes that affect the physical and chemical properties of ground water used for drinking by the slum dwellers of Lagos metropolis, Nigeria in order to appraise its suitability for consumption. Correlation coefficient was performed by Pearson correlation matrix in order to examine possible relationship between the analyzed physical and chemical parameters. A positive correlation was found between temperature and TDS as well as EC and chloride in the study area. This study reveals that human activities such as improper waste disposal, has negative effects on the physical and chemical drinking water samples under consideration. PCA analyzes revealed that pH and chloride were contributing more to the drinking water quality across the slums communities in wet season while temperature, sulphate, TDS, and EC are the major contributors in dry season across the groups. Thus, could be as a result of anthropogenic sources around the coastal communities. The study concludes that seasonal changes consequentially impact the quality of ground water used for drinking in the slum communities which makes the residents prone to diseases. This study therefore recommends that water obtained from ground water both during wet and dry season should be treated to ensure their suitability for human consumption.

Acknowledgements

The authors express their gratitude to one another for financial contributions to procure the equipment used for this research and logistics to achieve objectives of the work. The residents of the selected slums appreciated and accommodate the research team in the course of visitation during the project exercises.

Conflict of Interest

The authors declare no conflict of interest.

References

1. Adelekan IO (2010) Vulnerability of poor urban coastal communities to flooding in Lagos, Nigeria. Environ and Urbanization 22: 433–50.

2. Ademoroti CA (1996) Standard methods for water and effluents analyses. Environmental Chemistry and Toxicology. Ibadan, Nigeria: Foludex Press Ltd.

3. Aderogba KA (2012) Qualitative studies of recent floods and sustainable growth and development of cities and towns in Nigeria. Int. J. of Acad. Res. in Econ. and Manage. Sci 3: 187–3.

4. Agarwal SK (2002) Assessment of Water Quality for the Groundwater Resources of Urbanized Part of the Nagpur District, Maharashtra (India) Am. J. of Water Resour. 6: 89-11.

5. American Public Health Association (2005) Standard Methods For The Examination Of Water and Wastewater,21st Ed.USA. Corington,A.K. Bates, R.G, Ducst,R.A (2001) Definition Of Ph Scale, Standard Reference Values.

6. Aremu, MO laofe, O Ikokoh, PP and Yakubu, M M (2011) Physicochemical Characteristics of Strem, Well and Borehole Water Soures in Eggon, Nasarawa State, Nigeria. J. of Chem. Soc. Nigeria 36: 131-36.

7. Awan A.M, Siddiqui M T, Khan R A and Shah A H (2002) "Combined effect of salinity and industrial effluents on the growth of Eucalyptus camaldulensis dehnh," Pakistan J. of Agric. Sci.39: 80-2.

8. Awosika L F., Folorunsho R, Dublin-Green, C O and Imevbore, V O (2000) Review of the coastal erosion at Awoye and Molume areas of Ondo State. A Consultancy Report for Chevron Nigeria Limited.

9. Aziz, J A (2002) National water quality strategy, Report Submitted to The Asian Development Bank as Part of Water Resources Strategy Study, ADB, TA 3130 PAK, Islamabad, Ministry of Water and Power.

10. Bangash, F K and Khan S U (2001) Aesthetic Quality Evaluation of Drinking Water of Peshawar Valley.

11. Basavarajappa H and Manjunatha M (2015) Groundwater Quality Analysis In Precambrian Rocks Of Chitrsdurga District, Karnataka, India Using Geo-Informatics Technique. Int. Conf. on Water Resour. 4: 1354-65.

12. BRNCC (2012) Towards Lagos State climate change adaptation strategy. Building Nigeria's Response to Climate Change.Butuala, N M., Van Rooyen, M.J., and Patel, R.B. (2010). Improved Health Outcomes in Urban Slums through Infrastructure Upgrading. Soc. Sci. and Medicine 7: 935-40.

13. De Snyder V N, Friel S, Fotso J C, Khadr Z, Meresman S, et al. (2011) Social Conditions and Urban Health Inequities: Realities, Challenges and Opportunities to Transform the Urban Landscape through Research and Action. J. Urban Health 88: 1183–93.

15. Guppy L, Uyttendaele P, Villholth K G and S makhtin V (2018) Groundwater and Sustainable Development Goals: Analysis of Interlinkages; UNU-INWEH Report Series, United Nations University Institute for Water; Environ and Health Hamilton ,ON,-Canada.

16. Huang G H and Xia J (2001) Barriers to Sustainable Water-Quality Management, J. of Environ. Manage. 61: 1–23.

17. Idowu O A, and Martins O (2007) Hydrograph analysis for groundwater recharge in the phreatic basement aquifer of the Opeki River basin, Southwestern Nigeria. *Asset Series B*. 6: 132–41.

18. Jonnalagadda S B and Mhere G (2001) Water Quality Of The Odzi River In The Eastern Highlands Of Zimbabwe, Water Res. 35: 2371–76.

19. Kadi A S, Halingali B I and Ravishankar P (2012) Problems of Urbanization in Developing Countries: A Case Study In India. Int. J. of Sci. and Nat. 3: 93-4.

20. Katukiza A Y, Ronteltap M, Niwagaba C B, Foppen J W, Kansiime F and Lens P N (2012) Sustainable Sanitation Technology Options for Urban Slums. Biotechnol. *Adv*. 1: 964–78.

21. Kugali N M, Ankalagi R F and Yadawe M S (2013) Estimation of nitrate, nitirite, arsenic and other physicochemical properties of water. Int. J. of Plant Anim. and Environ. Sci. 3: 132 – 36.

22. Kumar X, Rosario A, Giridharan L, Shyamala J, Velmurugan P M and Jayaprakash M (2013) Urbanisation Impact of Ground Water Quality In Cuddalore District, East Coast Of India. J.. of Environ. Chemistry and Ecotoxicol 5: 63-73.

23. Margat J and Van der Gun J (2013) Groundwater Around The World. A Geographic Synopsis; Crc Press Taylor And Francis Group; Boca Raton,FL,USA.

24. Mohammad M J (2015) Analysis of water Quality using Limn logical Studies Wyra Reservoir, Khammam District, Telangana, India, Int. J. of Current Microbiol. and Applied Sci 4: 880-895.

25. Nwigwe C and Emberga T T (2014) An assessment of causes and effects of flood in Nigeria. Standard Scientific Research and Essays 2: 307–15.

26. Odunuga S, Oyebande L and Omojola A S (2012) Socioeconomic indicators and public perception on urban flooding in Lagos, Nigeria. Hydrology for Disaster Management. Niger. Assoc. of Hydrol. Sci 82–96.

27. Oshodi L (2013) Flood management and governance structure in Lagos, Nigeria, Accessed 10 January 2016.

28. Patel R B and Burkle F M (2012) Rapid Urbanization and the Growing Threat of Violence and Conflict: A 21st Century Crisis. Prehosp. Disaster Med. 27: 194–7.

29. Patrick L and William A (2011) Water Chemistry: an Introduction to the Chemistry of natural and Engineered Aquatic Systems. 1st edn. Oxford University Press, USA.

30. Ramakrishnaiah C R, Sadashivaiah C and Ranganna G (2009) Assessment of water quality Index for groundwater in Tumkur Taluk, Karnataka State, India. E-J Chem, 6: 523–530.

31. Rietmanm M, Kaplan L and Cava R J (1985) Lithium Ion-poly (Ethylene Oxide) Complexes. Effects of Anion on Conductivity Solid State Ionics. 17: 67-73.

32. Sajil Kumar P J, Jegathambal P, James E J (2011). Multivariate and Geostatistical Analysis of Groundwater Quality in Palar River Basin .Int J Geol 5: 108-119.

33. Saleh M A, Ewane E, Jones J and Wilson B L (2001) chemical evaluation of commercial bottled drinking water from Egypt. J. of Food Composition and Analysis. 14: 127-152.

34. Simeonov V, J A Stratis, C Samara, G Zachariadis, D Voutsa and Anthemidis A (2003) Assessment of the surface water quality in Northern Greece", Water Research. 3: 4119–24.

35. Somlyody L, Yates D, and Varis O (2001) Challenges To Freshwater Management. In Catchment Processes Land/Water Ecotones And Fish Communities (Guest Eds: M. Zalewski, F. Schiemer And J Thorpe). Int J. Ecohydrol.Hydrobiol. 1: 65-96.

36. Soomro Z A, Khokhar M I A, Hussain W and Hussain M (2011) Drinking Water Quality Challenges In Pakistan," World Water Day.

37. Starke M and Breaugh J A (2000) Research On Employee Recruitment. So Many Remaining Questions. Journal of Management, 1: 405-34.

38. Sasikaran S, Sirtharan K, Balahumar S and Arasaratnam A (2012) Physical, Chemical and Microbial Analysis of Bottled Drinking Water.J Ceylon Medical 57: 111-16.

39. Trivedy R K and Goel P K (1986) Chemical and Biological Methods for Water Pollution Studies. Environ. Publ. Karad India.

40. Uluocha N O and Ekop G (2002) Nigeria: Geography in History and Cultures of Nigeria up to AD 2000, Edited by Osuntokun, A.; Aworawo and F. Masajuwa, Lagos, Frankad Publishers.

41. UN-Habitat (United Nations Human Settlements Programme). (2008) State of the world's cities 2010/2011-Cities for all: Bridging the urban divide. Nairobi, Kenya. Accessed 10 March 2016.

42. United Nations 2003 Global Report on Human Settlements (2011): Cities and Climate Change. Report of United Nations. Earthscan, London, UK and Washington, DC, USA.

43. United Nations 2011 Global Report on Human Settlements (2003): The Challenge of Slums. Report of United Nations. Earthscan, London, VA, USA, UK; Sterling, VA, USA.

44. UNSD (2012) Millenium Development Goals Database: Slum population in urban areas. Report of United Nations Statistics Division. United Nations, New York.

45. Van, L and F.X.R (2000) Safe drinking water: The toxicologist's approach," Food and Chemical Toxicol. 38: S51– S58.

46. World Bank (2013) Cost of pollution in China: Economic estimates of physical damages. Rural Development, Natural Resources and Environment Management Unit. Washington D.C.

47. WHO (2004) Health risks from drinking demineralized water, USA.

48. WHO; UNICEF 2012. Progress on Sanitation and Drinking Water: (2012) Update; World Health Organization/UNICEF: Geneva, Switzerland, 2012.

49. WHO (2006) Guideline for Drinking Water Quality (Electronic Resource). Incorporating First Addendum Recommendations.

50. WHO (2005) Burden of disease from environmental noise: Quantification of healthy life years lost in Europe. Copenhagen: WHO Regional Office for Europe.

51. WHO (2010). Hidden Cities: Unmasking and overcoming health inequities in urban settings. Geneva: World Health Organization.

52. Yirdaw M and Bamlaku A (2016) Drinking Water Quality Assessment and its effects on Residents Health in Wondo Genet Campus, Ethiopia. J.of Environ. Systems Research Springer. 5: 2-3

53. Zulu E M, Beguy D, Ezeh A C, Bocquier P, Madise N J, Cleland J and Falkingham J (2011) Overview of migration, poverty and health dynamics in Nairobi City's slum settlements. J. Urban Health 1: 185–99.