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Original Research Article

Comparative Analysis of Groundwater Quality of Island and Mainland Areas of Lagos State, Nigeria

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ABSTRACT

This paper compares the physical, chemical and biological quality of boreholes water from 25 locations in Lagos Island and Mainland. Laboratory analyses were conducted using Standard Methods of Water Analysis. The results of the physical characteristics show that the temperature (21.6 – 28.3 °C) and total dissolved solids (TDS) (86.5 – 150.1 mg/l) values recorded for both Island and Mainland were within the stipulated values. Statistical analysis revealed that a significant difference exists between the dissolved solids (p = 0.002) and no significant difference in the temperature (p = 0.196), total solids (p = 0.151) and turbidity (p = 0.597) of the tested sample. The turbidity values obtained for all water samples (5.80 – 14.20 mg/l) were well above the specified standards (5.00 mg/l). The pH and conductivity values were within the recommended values. The statistical analysis of chemical parameters revealed that a significant difference exists in the chloride concentration (p = 0.001), pH (p = 0.032) and conductivity (p = 0.001) of the water samples. It should be noted that the values obtained in the Island are higher than the values obtained from mainland. The total coliform obtained are within permissible limit. It was observed that the dissolved solid, conductivity and chloride values obtained in island were higher than the values obtained from mainland. This could be attributed to the close proximity of Island to ocean which could be as a result of salt water intrusion. In other to safeguard the health and wellbeing of the users, groundwater from Inland and Mainland of Lagos metropolis need be treated to remove excess chloride and total dissolved solid before use.

1. INTRODUCTION

The most basic natural resource on earth is water. However, freshwater quality and availability is one of the most concerning environmental and sustainability issues of the twenty-first century (UNICEF, 2013). The acute water shortage has forced many people to drink untreated water obtained from surface and underground sources thereby exposing them to hazardous chemicals and infectious agents (Ilori *et al*., 2019). This has made many researchers to focus their attention towards evaluation of physicochemical and microbial characteristics of water supplies (Yerima *et al*., 2008; Kumar *et al*., 2011; Okonkwo *et al.,* 2011).

The problem of water quality in developing countries including Nigeria is also a problem of water crises (Adewumi and Oguntuase, 2016). These crises have been categorized as economic water crises, political water crises, institutional water crises, technological, operational, and water quality crises (Sojobi, 2016). Government's inability at all levels (i.e. federal, state, and local government) to meet the basic water needs of their citizens have resulted in economic, social, environmental, and health costs. The attendant results are poor water access in urban, peri-urban, and rural areas, high rate of premature mortality and morbidity, environmental pollution, consumption of contaminated, over-exploited and polluted groundwater, and surface water resources and decreased household income and productivity (Sojobi *et al*., 2014; Sojobi, 2016).

Among all sources of freshwater on the earth, groundwater constitutes over 90% of the world's readily available freshwater resources with the remaining 10% in lakes, reservoirs, rivers and wetlands (Boswinkel, 2000). Groundwater is the common source of domestic water supply for drinking, cooking, bathing, washing and maintaining basic sanitation in many urban cities of Nigeria. Hence the potential and quantity of groundwater is an economic resource and essential component of human life. Groundwater is a reliable source of water supply, because it is often unpolluted due to restricted movement of pollutants in the soil profile (Lamikanra 1999). However, the deterioration of groundwater quality in major cities and urban centres due to population explosion, urbanization and industrialization results in excessive extraction and large volume of effluent discharge or run-off from solid waste disposal sites generally moves vertically downwards. Today human activities are constantly adding industrial, domestic and agricultural wastes to groundwater reservoirs at an alarming rate (Aremu *et al.*, 2011).

Also, anthropogenic activities and natural processes such as agricultural activities, indiscriminate disposal of solid and liquid waste, excessive groundwater pumping, leachate from poorly designed sanitary landfills and septic tank/soak away pits, poorly planned/unplanned rural and urban development, land use changes, soil lithology, hydrogeological condition of the aquifer, tidal fluctuation and saline water intrusion seriously affect the groundwater quality (Oyelami *et al.,* 2013; Porowska, 2014; Wanke *et al*., 2015). In addition, contaminants in groundwater vary from one location to another and include different kinds of microbes, organic and inorganic substances, anions, cations, heavy metals, and minerals (Sojobi, 2016).

Lagos could be classified as one of the most developed cities in Nigeria that is located in the coastal zones. Coaster zones contain some of the most densely populated areas in the world as they generally present the best conditions for productivity. However, these regions are plagued with many hydrological problems like flooding due to cyclones and wave surge, and drinking freshwater scarcity due to problem of salt water intrusion. Lagos residents who rely mostly on groundwater as their main source of freshwater for drinking, continues to grow at an alarming rate and freshwater supplies are constantly being depleted, bringing with it the issue of saltwater intrusion.

Because of the importance of groundwater to sustainable development in Nigeria, several researchers have carried out many works on the quality of groundwater in major urban cities including Lagos (Itah and Akpan, 2005; Adebo and Adetoyinbo, 2009; Adewumi and Babatola, 2009; Akinteyon *et al.,* 2010; Akinteyon and Soladoye, 2011; Idowu *et al.,* 2011; Afolabi *et al.,* 2012; Abdulbaki *et al.,* 2014; Adeyi and Majolagbe, 2014; Soladoye and Ajibade, 2014; Majolagbe *et al.,* 2016). The findings of most of these researchers revealed that most of the measured physicochemical and biological parameters were above the recommended values and routine monitoring and thorough treatment before consumption were recommended for safe consumption. All these researchers considered groundwater samples in the study area without taken cognizance of the differences in geological and hydrological features of the study areas which this research tends to address by separating island area from mainland area of Lagos metropolis.

Groundwater quality assessment has been based extensively on the measurement of the physicochemical and biological parameters of the samples to suggest possible usage of such water. The major advantage of this assessment method is that the water samples are directly analyzed and generates data that show the true quality of water samples. The data resulting from the analysis will reveal any possible trend and pattern in quality variation. This research is therefore aimed at comparatively evaluating the quality of groundwater samples from mainland and island area of Lagos metropolis and determining their suitability for human consumption.

/ Nigerian Research Journal of Engineering and Environmental Sciences
X(X) 2019 pp. xx-xx

2. MATERIALS AND METHODS

2.1. Description of the Study Area

Lagos is a coastal city and the most populous city in Nigeria. Lagos State lies between latitude 8^{o} 151¨ and 8^{o} 451'' and longitude 2^{o} $3^{0}1$¨ and 4^{o} $3^{0}1$¨ (Figure 1). Lagos has a total area of 1380.7 square miles (3577 square kilometers), of which 303.8 square miles (787 square kilometers) is made up of lagoons and creeks. Based on the 2006 population census results, Lagos population was put at 9,113,605 (NPC, 2006). According to New World Encyclopedia (2019), Lagos is the second fastest growing city in Africa and the seventh fastest in the world. Lagos experiences two rainy seasons, with the heaviest raining period experienced from April to July while the weaker rainy period is in October to November. Very brief dry period occurs in August and September and a longer dry period from December to March. Average monthly rainfall during heavy rain period is over 400 mm, while in August and September it is reduced to 200 mm. However, it is as low as 25 mm in December. The temperature ranges between 32 ^{o}C to 37 ^{o}C (New World Encyclopaedia, 2019). There are two major urban islands in Lagos. They are Lagos Island and Victoria Island. These two Island are separated from the mainland by a channel draining the lagoon into the Atlantic Ocean. The islands are connected to Lagos Island by bridges.

Figure 1: Map of Lagos State (NigeriaGalleria, 2019)

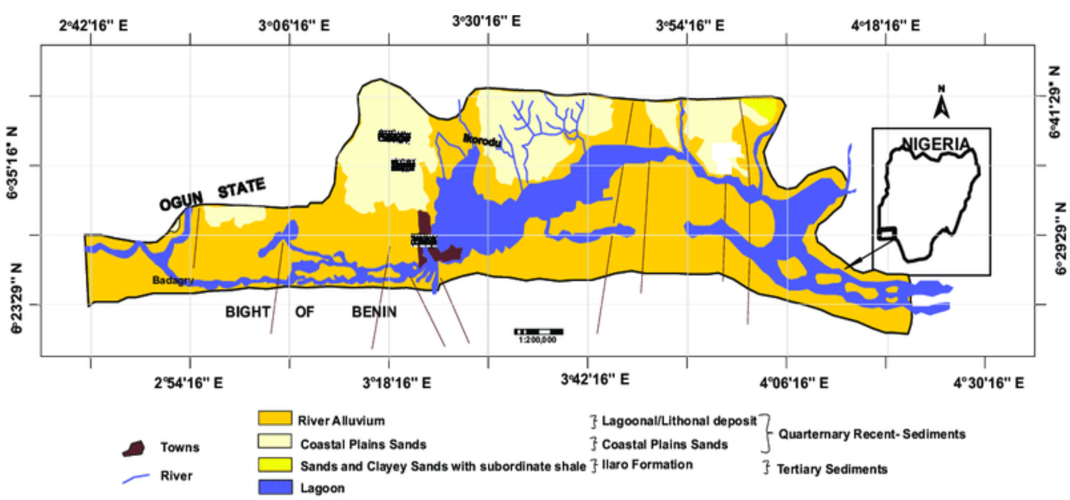

Figure 2: Geological Map of Lagos State, Nigeria, (Orakwe *et al.,* 2018 adopted from Nigeria Geological Survey Agency, 2006)

According to Orakwe *et al.* (2018), the geology of Lagos State is mainly sedimentary of tertiary and quaternary sediments as shown in Figure 2. Tertiary sediments are unconsolidated sandstones, grits with mudstone band and sand with layers of clay. Quaternary sediments are recent deltaic sands, mangrove swamps and alluvium near the coast. The state is located on sedimentary rock mainly of sand and alluvium. The major soil groups are juvenile, organic- hydromorphic and ferrallitic soils Orakwe *et al.* (2018).

2.2. Water Quality Analysis

2.2.1. General

The methods employed for this study are field investigation/sampling and laboratory analysis. Field investigation involves the location of suitable sites in both Island and Mainland area of Lagos state for water samples collection. Water samples from borehole wells were collected in 25 different locations across the Island and Mainland of Lagos State. The analyses of water samples were conducted using standard methods of water analysis (APHA, 2012) to determine the physical, chemical and biological constituents of the boreholes water. The analysis was conducted at the Water Laboratory of the Civil Engineering Department of the Federal University of Technology, Akure.

2.2.2. Sample collection, treatment and preservation

High-density polyethylene (HDPE) screw-capped containers of 1.5 L capacity were used to collect the water samples. The HDPE containers and stoppers were thoroughly washed with distilled water three times and once with the water to be sampled before collecting the actual sample. At the same time, samples for microbial analysis were collected using autoclave-sterilized sample bottles from the same locations. The water samples were transported to the Laboratory of the Chemistry Department of the University of Lagos, Lagos State, Nigeria. The water samples were preserved in a refrigerator at 4 ^{o}C to keep the water content intact until analyses were carried out. Sampling and preservation of samples were carried out as described in APHA (2012). The samples were kept in sterilized/ pre-cleaned 1 litre polythene plastic bottle. The water samples were kept in ice chests and transported from Lagos to Akure for laboratory analysis. Precautions were taken to ensure that all refrigerated samples were analysed within 3 days. In both Island and Mainland, all points of sample collection were not less than 200 m from each other and the borehole were ranging between 10 – 15 m (30 – 45 ft). The sanitation conditions within the close proximity to all sample wells were excellent and the minimum distance to soakaway/septic tanks were between 15 to 25 m.

2.2.3. Physicochemical analysis

Water samples collected were analysed using automated instrument named HACH DR/890 Colorimeter, pre-programmed which can test for at least 90 parameters. DR/890 series Colorimeter offer simple, push button program selection and step by step prompts that guide users through testing procedure.

2.2.4. Bacteriological analysis

Standard methods were used to count the total coliform bacteria as maximum probability number (MPN) in water samples (APHA, 2012).

2.3. Statistical Analysis

Statistical Package for the Social Sciences (SPSS) version 16.0 was used to statistically analyze data with a significance level of $P < 0.005$ using paired t-test for the hypothesis of this study. The hypothesis states that "there is no significant difference in the physicochemical properties of groundwater in Lagos Island and Lagos mainland".

3. RESULTS AND DISCUSSION

The results of the physicochemical and biological analysis are as presented in Table 1. Appropriate temperature value primarily indicates good water quality, as it influences pH, alkalinity, acidity and dissolved oxygen (DO). The temperature values recorded in both Island (21.6 – 27.7 ^{o}C) and Mainland (23.3 – 28.3 ^{o}C) are within the stipulated values for National Standards for Drinking Water Quality, NSDWQ (20 – 33 ^{o}C) (SON, 2017). Thus, this value is favourable to the dissolved oxygen and therefore has the potential to reduce or eliminate completely any possible odour due to anaerobic reaction (less oxygen), which can render the water unwholesome for drinking.

A fair indication of the amount of minerals and other inorganic substances present in the groundwater is determined by the dissolved solid. The value of the dissolved solids obtained ranged from (113.5 – 150.0 mg/l) for Island and (92.0 - 150.1 mg/l) for Mainland which is far less than the recommended maximum value of 500 mg/l. All dissolved solids value obtained from Island were well above 100 mg/l while most of the values obtained from mainland were below 100 mg/l.

The turbidity of water depends on the quantity of solid matter present in the suspended state. It is a measure of light transmitting properties of water and the test is used to indicate the quality of waste discharge with respect to colloidal matter. All the turbidity values obtained ranged from (7.9 – 13.1 NTU) for Island and (5.8.0 – 14.20 NTU) for Mainland were above the specified values for NSDWQ (5.00 NTU) and the WHO standards (5.00 NTU). This is as a result of the high total dissolved solids obtained from the water samples as indicated in the Table 1. This could be attributed to the conduct of the research during raining season where many underground waters do have seepage problems.

Table 1: Results of physiochemical and biological properties of the groundwater

Location	Physical				Chemical				Biological
	Temperature (°C)	Dissolved Solid (mg/l)	Total Solid (mg/l)	Turbidity (NTU)	Chloride (mg/l)	pH	Conductivity (µs/cm)	Dissolved Oxygen (mg/l)	Total coliform cfu/mL
Victoria Island	23.50	130.60	280.40	8.26	170.50	8.20	680.20	7.20	0.03
Victoria Island	24.30	120.90	320.20	7.90	158.20	8.10	750.50	5.50	ND*
Victoria Island	25.00	113.50	410.30	12.35	195.10	8.00	950.00	6.10	0.01
Victoria Island	22.00	130.20	360.50	10.45	130.70	8.40	840.60	7.50	ND
Victoria Island	21.60	133.50	420.00	11.69	182.50	8.30	870.00	6.90	ND
Lagos Island	24.00	138.00	385.00	7.80	210.50	8.20	650.00	7.50	ND
Lagos Island	24.20	120.50	380.20	8.50	200.10	8.50	550.30	5.20	ND
Lagos Island	24.30	150.10	480.30	12.20	160.50	8.30	630.20	8.00	0.06
Lagos Island	26.70	110.30	350.70	9.25	120.30	7.90	740.60	6.50	1.00
Lagos Island	27.70	120.60	385.60	10.40	110.80	8.20	480.20	7.20	0.03
Eti – Osa	25.00	150.10	420.30	11.20	180.60	8.10	730.10	5.80	ND
Eti – Osa	26.40	120.40	400.00	9.35	210.20	8.30	880.30	7.20	ND
Eti – Osa	24.00	130.00	710.10	8.90	170.40	8.50	710.20	6.80	0.08
Eti – Osa	25.60	110.50	595.20	13.10	150.50	8.20	650.20	8.10	0.05
Eti – Osa	24.00	130.60	400.50	10.80	195.00	7.80	680.00	7.90	0.01
Ikeja	26.00	92.00	270.50	9.50	100.00	7.30	490.00	6.90	ND
Ikeja	25.40	98.30	285.30	10.30	95.20	7.80	350.80	7.10	ND
Ikeja	28.30	100.40	390.40	11.30	88. 40	7.50	480.30	7.50	ND
Ikeja	26.00	95.20	250.10	9.40	100.30	8.10	500.60	6.10	0.03
Ikeja	26.10	86.90	320.00	11.00	90.50	8.40	520.10	6.40	0.01
Yaba	27.00	120.20	350.20	8.50	85.80	8.10	550.10	5.80	ND
Yaba	25.10	92.20	270.30	6.40	90.10	8.50	490.80	7.10	1.00
Yaba	24.00	100.40	420.20	5.80	100.40	7.90	400.20	7.90	0.03
Yaba	23.30	120.70	480.30	11.20	95.20	8.10	540.70	8.10	0.01
Yaba	24.50	110.00	384.00	11.00	98.00	7.80	450.00	6.60	ND

* ND= not detected

Chlorides in groundwater within coastal region result from the saline water intrusion from sea water. Chlorides are the most stable components in water and their concentration is largely unaffected by most natural physio-chemical and biochemical processes (Akinteyon *et al.,* 2010*)*. Hence the value of chloride concentration in water is a useful measure of electrical conductivity in water sample. The values of chloride obtained from the groundwater in the study area ranged from (110.8 – 210.5 mg/l) for Island and (85.8 - 110.4 mg/l) for Mainland are lower than the NSDWQ recommended values (250 mg/l) but could still be considered to be high. This could be attributed to the close proximity of Island to ocean which could be as a result of salt water intrusion. Of interest is the fact that the values obtained in the Island are higher than the values obtained from mainland but when compared with the results of other researchers on groundwater in Lagos, the values are similar to the results of Afolabi *et al.* (2012); Akinteyon and Soladoye (2011) but at variance with that of Soladoye and Ajibade (2014).

The test for pH of water was carried out to determine whether water from the study area is acidic or alkaline in nature. Although, the values obtained (6.5 – 8.5) were within the acceptable range for fresh waters (Cambers *et al.,* 2002) and as specified by WHO, however, most of the boreholes were slightly basic. According to Boone and Xun (1987), a pH value greater than 7.0 is vital for growth and reproduction for the majority of mesophilic pathogenic bacteria involved in the biodegradation of organic matter dissolved in water.

J.R. Adewumi / Nigerian Research Journal of Engineering and Environmental Sciences
4(2) 2019 pp. 952-960

Increase in dissolved oxygen is important in drinking water to prevent odour resulting from aerobic decomposition of organic matters. The value of the dissolved oxygen (DO) obtained ranged from (5.2 – 8.1 mg/l) for Island and (5.2 – 8.1 mg/l) for Mainland can be judged to be adequate. According to WHO (2003), water meant for domestic and recreational purposes (e.g. recreational activities like bathing, swimming, boating and fishing) should not have DO concentration below 3.0 mg/ L.

Table 2: Results of the paired t- test of the hypothesis

Physical properties		Paired samples test – Paired differences: Mean differences	Std. deviation	Std. error mean	95% Confidence interval of the difference: Lower	Upper	t	df	P-value
Pair 1	Temperature (°C) (Lagos island) - Temperature (°C) (Lagos mainland)	-1.24000	2.80721	.88772	-3.24816	.76816	-1.397	9	0.196
Pair 2	Dissolved solid (mg/l) (Lagos island) - Dissolved Solid (mg/l) (Lagos mainland)	25.19000	18.35414	5.80409	12.06024	38.31976	4.340	9	0.002
Pair 3	Total solid (mg/l) (Lagos island) - Total solid (mg/l) (Lagos mainland)	35.19000	70.88066	22.41443	-15.51497	85.89497	1.570	9	0.151
Pair 4	Turbidity (NTU) (Lagos island) - Turbidity (NTU) (Lagos mainland)	.44000	2.54002	.80322	-1.37702	2.25702	.548	9	0.597
Chemical properties		**Paired differences: Mean differences**	**Std. deviation**	**Std. error mean**	**95% Confidence interval of the difference: Lower**	**Upper**	**t**	**df**	**p-value**
Pair 1	Chloride (mg/l) (Lagos island) - Chloride (mg/l) (Lagos mainland)	78.37000	54.80146	17.32974	39.16740	117.57260	4.522	9	0.001
Pair 2	pH (Lagos Island) - pH (Lagos mainland)	.26000	.32387	.10242	.02832	.49168	2.539	9	0.032
Pair 3	Conductivity (µs/cm) (Lagos island) - Conductivity (µs/cm) (Lagos mainland)	236.90000	149.31713	47.21822	130.08496	343.71504	5.017	9	0.001
Pair 4	Dissolved Oxygen (mg/l) (Lagos Island) - Dissolved oxygen (mg/l) (Lagos mainland)	-.19000	1.32870	.42017	-1.14049	.76049	-.452	9	0.662

Note: α = 0.05; The detected total coliforms are within the acceptable limits.

The conductivity of the tested samples was within the NSDWQ maximum permissible limits (1000 µs/cm) for drinking water. However, the values obtained were higher than values reported for wells and bore-hole water in the Northern part of the country (Aremu *et al*., 2011).

The total coliform counts of the sampled wells ranged between 0.01 to 1.0 cfu/ml in 13 out of 25 wells sampled while there was no coliform detected in the remaining 12 wells in both Island and Mainland. Ordinarily, water used for domestic purposes should be free from coliform but it was observed that poor hygiene situation of these wells was responsible for the traces of coliform.

The results of the statistical analysis of paired t-test for the hypothesis of this study on the physical parameters is shown in Table 2. The Table revealed that a significant difference exists between the dissolved solids ($p = 0.002$) of the water sample from Lagos Island and Lagos Mainland. This might be attributed to the variation in the soil texture in these two locations as reported by Akinteyon and Soladoye (2011). It was however revealed that there was no significant difference in the temperature ($p = 0.196$), total solids ($p = 0.151$) and turbidity ($p = 0.597$) of the water sample from Lagos Island and Lagos Mainland.

For the chemical properties of the water samples, it was revealed that a significant difference exists in the chloride concentration ($p = 0.001$), pH ($p = 0.032$) and conductivity ($p = 0.001$) of the water samples from Lagos Island and Lagos Mainland. However, there was no significant difference in the dissolved oxygen ($p = 0.662$) of the water samples gotten from Lagos Island and Lagos Mainland.

4. CONCLUSION

The physical, chemical and biological quality of boreholes from Island and Mainland area of Lagos state has been investigated. The result shows that there is no major difference between results of the analysis obtained from both areas. In general, all biological parameters measure temperature, pH, conductivity, turbidity, chloride, dissolved oxygen and total Coliform are within the acceptable limits set by the NSDWQ and World Health Organization (WHO). Although, the values of chloride obtained in this study are lower than the recommended values (250 mg/l) but could still be considered to be high. This could be attributed to the close proximity of Island to ocean which could be as a result of salt water intrusion. Of interest is the fact that the values obtained in the Island are higher than the values obtained from mainland. The result is a clear indication of the Lagos groundwater approaching states of saline if not properly monitored.

5. ACKNOWLEDGMENT

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6. CONFLICT OF INTEREST

There is no conflict of interest associated with this work.

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