Comparative Assessment of Physicochemical Properties of Available Drinking Water Quality from Different Sources in Lagos State, Nigeria

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Abstract
The Physicochemical properties of drinking water from different sources in Lagos state, Nigeria were determined with a view of comparing the effects of level of Industrialization, population density and urbanization on the water quality in the centre of Lagos and off town of Lagos (Ikorodu LGA, a relatively less Industrialized and less Urbanized town of Lagos state) as a case study. The different sources of drinking water considered were wells, boreholes, surface water and tap water. In each of Lagos and Ikorodu; Seven wells, boreholes and tap water for Lagos since no surface water is drinkable; Seven wells, boreholes and the only identifiable drinkable stream for Ikorodu, were collected from different areas randomly and composited together to obtain a total of six (6) representative samples; - three (3) for Lagos centre and three (3) for Ikorodu in all. The physiochemical parameters analysed were pH, Temperature, Turbidity, Conductivity, Total Solids, Total Suspended Solids, Total Dissolved Solids, Dissolved Oxygen, Biochemical Oxygen Demand, Total Hardness, Total alkalinity, Total acidity, Chloride, Sulphate, and Nitrate using standard procedures.The results reveal the heavy impact of Industrialization, Population density and Urbanization on drinking water sources in Lagos state as a whole which could result in adverse health hazards but with more implications on central Lagos. Bar charts were used to present the mean data for Lagos centre and Ikorodu in comparison with the permissible limits for all the Parameters. Regular monitoring of the drinking water sources especially underground water which is the only dependable source is necessary. Adequate treatment of the water before use in order to reduce or avoid water borne diseases is also recommended.

Keyword: Comparative; Quality; Standards; Water; Borehole; Well.

Introduction

Water is one of the most vital natural resources necessary for the existence of life. In most urban cities in various countries such as Nigeria, it is the duty of the government to provide potable water. Most often the responsibility is not adequately discharged, causing the inhabitant of those cities to look elsewhere to meet their water needs. The alternative may be unwholesome (Okoye and Adeleke, 1991).In most developed countries, the water supplied to households, commerce and industry is all of drinking water standard, even though only a very small proportion is actually consumed or used in food preparation.

Water covers about 70% of the earth crust; hence it is the most abundant substance on the earth surface. This is because the source of surface water such as rivers, lakes, streams, oceans, sea, and wetlands are found in abundance on this planet. Surface water is used for recreational purpose, industrial water supply and on the negative side dumping of all sorts of refuse and as a channel for conveying sewage and industrial effluent (Lester, 1967). Water is colourless, odourless and tasteless in its pure form and has a boiling point of 100^0C and freezing point of 0^0C. It has the ability to exist in three different phases - solid, liquid and gases. Liquid water consists of a continuous network of randomly connected hydrogen bonds which form a liquid rather than a true fluid with individual molecules more freely.

Surface water is water in a liquid form which always flows downwards usually, on mountain slopes. The quality of river water depends on the feeding source of the river which includes surface runoff, water of glaciers, underground water, swamp, rain, treated sewage, water of industrial enterprises and polluted area. Surface water is a basic natural resource essential to man for his various and intense agricultural and industrial activities. Surface runoff water held in reservoirs provides water supply for the urban centers, irrigation water for highly productive lowlands in arid region; and are used in hydroelectric power generation where grade of river is stern, or routes of in-land navigation where the grade is gentle (Voznaya, 1981). Groundwater has long served as a source of drinking water and it is still very important today. The development of ground water has provided great socio-economic benefits to humanity. Globally, groundwater is estimated to provide about 50% of current drinking water supplies. As groundwater is isolated from the surface, most people take it for granted that groundwater should be relatively pure and free from pollutants. Although most groundwaters are still of high quality, at some locations, it is becoming increasingly difficult to maintain the purity of groundwater. One of the major sources of pollution of groundwater is by saltwater intrusions. Others include seepages from underground storage tanks, oil wells, septic tanks, landfills and agricultural leaching (Adewuyi *et al.*, 2010). Groundwater is a reliable source of water supply, because it is often unpolluted due to restricted movement of pollutants in the soil profile (Lamb, 1985). However, shallow and permeable water table aquifers are most susceptible to contamination (Moody, 1996). The potential of such water to harbour microbial pathogens and cause illness is well documented for both developed and developing countries (Wright *et al.*, 2004). Introduction of pollutants into the natural water occur directly through point source (septic tanks, disposal sites etc.,) near the ground water or indirectly through non-point source when already polluted water in the area enters into the freshwater body by lateral or side movement (Hammer, 1986).

Water pollution results in transmission of infectious diseases. The implications of waterborne bacteria and virus infection include polio, hepatitis, cholera, diarrhoea, typhoid etc. (Kukkula *et al.*, 1997) but nitrate contamination is very severe. Thus, contamination of drinking water from any source is of primary importance due to the danger and risk of water diseases. In 1997, the World Health Organization (WHO) reported that 40% of deaths in developing nations occur due to infections from water related diseases and an estimated 500 million cases of diarrhea, occurs every year in children below 5 years in parts of Asia, Africa and Latin America.

Water that has good drinking quality is of basic importance to human physiology and human's continued existence relies very much on its availability (Larnikanra, 1999). According to Davis and De-Wiest (1966), the standard for drinking water can be attributed to two main criteria, namely: The presence of objectionable taste, odour and colour and the presence of substances with adverse physiological effects. However, most of the groundwater from most sources is therefore unfit for immediate consumption without some sort of treatment. The extent of treatment needed therefore is determined by the quality of the raw water source (Adejuwon and Mbuk, 2011; Macrea *et aI.*, 1993). Therefore, water has to meet up with certain physical, chemical and microbiological standards, that is, it must be free from diseases producing micro-organisms and chemical substances, perilous to health before it can be termed potable (Ihekoronye and Ngoddy, 1985).

Though, much of the land mass of Lagos state is covered by water, getting a clean drinking water poses a major challenge. It is almost impossible to get drinking water from the large volume of surface water found in Lagos. This is largely due to salinity of the water bodies and also pollution by anthropogenic activities. As a result of immense industrialization and high population growth, groundwater is heavily relied on in Lagos metropolis to serve as an alternative source of water where surface water is seriously polluted. The continued reliance on ground water has resulted in its decline in quantity and quality. Contamination of drinking water supplies from industrial waste is as a result of various types of industrial processes and disposal practices. Industries which use large amount of water in their processes (like steam production as solvent for washing purposes, as a coolant for rinsing, for waste disposal practices and for finishing operations etc.) including chemical manufacture, steel plants, battery industries, metal processes, textile manufacturers, tanneries etc. (David and Brad, 1998).

The presence of detergent phosphate pollution has also been noticed in the source of water supply in Lagos Metropolis. This has played a significant role in stimulating the explosive growth of algae in the water in the area. There are reports that most oil terminals and gasoline stations in Lagos lack effluent treatment plants and as a consequence, the oil gains access to groundwater in the area (Egereonu and Odumegwu, 2006). Oil spills in groundwater irrespective of their volume are potentially dangerous (Schnider, 1988).

The aim of this work is to investigate in totality the quality of water consumed in Lagos and its surroundings bearing in mind the population and high pollution in this area. The work will embrace the three possible sources of drinking water at Lagos metropolis like boreholes, well-waters and river/stream. A comparative study of these sources will be carried out in respect of central Lagos and Ikorodu LGA which is somehow outskirt to the main metropolis in Lagos state. The result obtained in this work would throw light to the nature of water being consumed in one of the most populated cities in Nigeria. The Off Lagos metropolitan result would also indicate the possible degree of pollution or of the contaminated water. Such result could also give an insight to the possible steps to take in order to improve water quality where there is deficiency.

Materials and Methods

Site Description

Lagos State is one of the states in the south-western Nigeria, boarded in the south by the Atlantic Ocean, in the north and east by Ogun state and in the west by Republic of Benin. It occupies an area of about 3,577 sq. km with a population of about 14 million. About 80-85% of the industries in Nigeria are located in Lagos state and 80% of the population resides in the metropolitan (central) Lagos, making the state the most urbanized in Nigeria (Longe and Williams, 2006).

Ikorodu is one of the largest Local Government Areas, but outskirt from the main Lagos city in Lagos state. Ikorodu town is one of the twenty (20) local governments in Lagos State. The local government is located between longitude 4˚ 12' and 4˚ 47' E and latitude 7 ˚ 15' and 7 ˚ 36'N. It shares part of its boundary with Ogun State. The area falls within the high forest region whereas the drier Northwestern part is attributed to the vegetation growth of the Guinea Savannah (Adejuwon and Mbuk, 2011). Ikorodu here is less developed and less industrialized.

Sampling and Sample Collection

For Lagos Centre

Sample A; POOLED WELL WATER –collected from 7 areas i.e Baruwa Ayobo, Abulegba dumpsite surroundings, Olusosun-ojota, Ilupeju industrial area, Solus dumpsite Lagos state university-Igando road, Surulere LG swampy areas, Ijegun pipeline environs.

Sample B; POOLED BOREHOLE WATER-collected from Baruwa- Ayobo, Abulegba dumpsite surroundings, Olusosun-Ojota dumpsite, Ilupeju industrial area, solus dumpsite Lagos state university –Igando road, Surulere swampy areas, Ijegun pipeline environs.

Sample C; TAP WATER- Obtained from Ketu area, Baruwa- Ayobo, Abulegba surroundings, Ojota, Surulere LGA, Ijegun- Ikotun area, Ikeja.

For Lagos Offtown (Ikorodu)

Sample A; POOLED WELL WATER-collected from 7 different areas i.e Owode, Ogolonto, Fasheun estate, Orile Idera, Etunrenren road, CAC/Lagos road, Majidun.

Sample B; POOLED BOREHOLE WATER –Obtained from Owode, Ogolonto, Fasheun estate, Orile Idera, Etunrenren road, CAC/Lagos road, Majidun.

Sample C; SURFACE WATER – obtained from 'etunrenren' streams.

Samples were preserved and digested. The following physicochemical parametres were analysed, temperature, pH, turbidity, total solids dried at 105^{o}C, total suspended solids dried at 105^{o}C, total dissolved solids, alkalinity, total acidity, electric conductivity, dissolved oxygen, biochemical oxygen demand, chloride, total hardness by EDTA titrimetric method, nitrates, sulphates and heavy metals using standards methods.

Stringent precautions were taken for quality assurance, and all the reagents used were of analytical grade. All the containers used for the sampling were thoroughly washed. Plastic bottles were used for the collection of samples for determination of metals. All materials that came in contact with the samples and sample containers were thoroughly washed and rinsed with 1:1 nitric acid and then with distilled water. 5mL concentrated nitric acid was added per litre of samples at the time of collection, to minimize adsorption of metals onto the container walls (ALPHA, 1995). The samples were all stored in the refrigerator throughout the period prior to analysis.

Results

The results of the physicochemical parameters obtained from the Assessment of drinking water quality from the centre and off town (Ikorodu) of Lagos state are presented in table 1. Table 2 show the World Health Organization, European Union and Nigerian Industrial Standards for Potable water while table 3 presented the Mean values of the entire Lagos centre samples as well as the mean values for the entire Ikorodu drinking water samples from the various sources for physicochemical properties. **Figures 1-4** present the Bar charts showing the mean physicochemical properties of the samples from the various sources in Lagos centre and Ikorodu in the samples studied i.e. Lagos centre and Ikorodu, all in comparison with the permissible limits.
Measure of location like mean and bar charts were employed in the data analysis.

pH

pH is a measure of hydrogen ion concentrations in the water sample. pH has profound effects on water quality, affecting the metal solubility, alkalinity and hardness of water.
The pH of the six samples ranged from 6.29 ± 0.05 for 1C (Lagos tap waters) to 6.90 ± 0.10 for 1A (Lagos wells) showing some degree of acidity generally (Table 1).
However, the mean value of the pH for 1 i.e. the Lagos centre water samples was found to be 6.62 ± 0.31 which is within the range of WHO, EU and NIS standards (6.5-8.5) while the mean value of the pH for 2 (Ikorodu water samples) was found to be 6.49 ± 0.18 which is slightly below the permissible limits (Table 2, 3 and Figure 1). This indicates the acidic nature of the groundwater and drinking water in the whole of the two areas studied.

Temperature (°C)

The result for the temperature showed a range of 26.8 to 27.0°C with a mean value of 26.9±0.1°C for the Lagos water samples, and a range of 26.6 to 28.1°C, with a mean value of 27.4±0.76°C for the Ikorodu water samples of which sample 2C (Ikorodu stream) is exceptionally too high with 28.1°C (Table 1, Figure 2). This could be due to the nature of the surrounding, shallowness of the stream and atmospheric variability in temperature.

Turbidity (NTU)

The turbidity values obtained for all the samples were within the desirable limit set by World Health Organization and NIS which is **5** NTU (table 2). However, the mean value obtained for Lagos drinking water samples analyzed was 0.13±0.06 NTU while the mean turbidity value obtained for Ikorodu drinking water samples was estimated to be 0.73±0.55 NTU as shown in Table 1and Figure 1. These values are far below 5 indicating that the water is suitable for domestic purposes.

Electrical Conductivity (μS/cm)

The conductivity measurement data obtained for this study ranged from 199.5 $\mu S/cm$ for 2B (Ikorodu boreholes) to 495 μS/cm for 1A (Lagos wells) (table 1) with an average value of 348.67+143.1$\mu S/cm$ for the entire Lagos samples and an average value of 332.5+115.18$\mu S/cm$ for the entire Ikorodu samples (Table 3, Figure 3).Permissible standards for conductivity of drinking water is 250μS/cm by WHO (1993), 250 μS/cm by EU (1998) and 1000μS/cm by Nigerian standards (Table 2). Values exceeding 1000μS/cm limit is indicative of saline intrusions into the groundwater (Adewuyi *et al.*, 2010). All the samples have high value above the 250$\mu S/cm$ standard limits except sample 1C and 2B which are representative, tap water from Lagos centre and Borehole water in Ikorodu respectively. Only the two samples have their values below the WHO and EU standards. The high values recorded in the other samples are indicative of the presence of ionic contaminants. The reason behind this may be due to continuous discharge of chemicals and salts used from the industries, and leachates from the dumpsites which might have find their way into the groundwater.

The 2C (Ikorodu stream) also recorded high conductivity value presumably due to an enriching effect from inland run-off which might contain some dissolved ions. Also, because the sampling was done in dry season, evaporation and concentration of soluble salts causes higher conductivities (Egereonu and Odumegwu, 2006).

Table 1 Physicochemical parameters of the six samples. Values are mean of three replicate values

PARAMETERS	1A	1B	1C	2A	2B	2C
pH	6.90±0.1	6.67±0.02	6.29±0.02	6.35±0.05	6.43±0.0	6.70±0.01
TEMP (°C)	26.8±0.1	26.9±0.1	27.0±0.1	26.6±0.3	27.6±0.3	28.1±0.21
TURBIDITY	0.08±0.005	0.10±0.01	0.2±0.03	1.0±0.12	1.10±0.14	0.10±0.01
TS (mg/L)	250±2.0	257±2.2	263±4.0	180±2.0	205±3.0	217±5.2
TDS (mg/L)	169±9.0	190±5.0	164±7.1	140±11.0	164±10.1	180±11.8
TSS (mg/L)	81±3.0	67±2.0	99±5.7	40±2.1	41±3.5	37±3.9
DO (mgO_2/L)	4.01±0.06	3.1±0.3	3.4 ±0.11	2.2 ±0.20	4.24±0.18	3.8±0.25
BOD (mg O_2/L)	2.06±0.09	1.01±0.05	1.3±0.12	1.91±0.16	2.01±0.11	1.40±0.09
EC (µS/cm)	495±11.0	342±9.0	209±7.0	399±4.0	199.5±5.5	399±10.0
T.H (mg/L)	44±4.0	34±3.0	22±4.0	22±1.0	18±2.0	22±3.0
ALK(mg $CaCO_3$/L)	40±5.0	60±7.0	30 ±3.0	20±2.0	10±2.0	30±4.1
CLRD (mg/L)	177.25±39	191.43±4.07	163.07±2.95	233.97±7.86	191.43±0.03	297.78±8.4
SULPHATES (mg/L)	10.89±1.59	10.6±1.10	20.10±1.3	3.96±0.13	7.84±0.7	15.40±0.99
NITRATE(mg/L)	30.60±1.22	26.1±0.78	35.60±2.51	11.60±0.52	29.30±3.10	26.70±1.95
ACIDITY (mg/L)	100±10.0	40±3.0	40±2.0	70±4.0	100±8.5	80±6.0

Table 2 WHO, EU and NIS (Nigerian Industrial Standards) for drinking water (physicochemical properties)

PARAMETERS (mg/L)	WHO LIMITS	EUROPEAN UNION LIMITS	NIGERIAN IND. STANDARDS
pH	6.5-8.5	6.5-8.5	6.5-8.5
TEMP (°C)	Ambient		
TURBIDITY (NTU)	5	NA	5
TOTAL SOLIDS (mg/L)	1000		
TOTAL DISSOLVED SOLIDS (mg/L)	20-1000	NA	500
TOTAL SUSPENDED SOLIDS (mg/L)	NA	NA	NA
DISSOLVED OXYGEN (mg O_2/L)	5	5	5
BOD (mg O_2/L)	NA	NA	NA
CONDUCTIVITY (µS/cm)	250	250	1000
T. HARDNESS (mg/L)	100-500	100-500	150
ALKALINITY (mg $CaCO_3$/L)	5-500	NA	100
CHLORIDE (mg/L)	250	250	250
SULPHATES (mg/L)	500	250	100
NITRATES (mg/L)	50	50	50
ACIDITY (mg/L)	6.5	NA	NA

NA = Not Available

Table 3Mean values for the entire Lagos centre and the entire Ikorodu samples (Physicochemical Properties).

PARAMETERS (mg/L)	1(MEAN LAGOS VALUES)	2(MEAN IKORODU VALUES)	PERMISSIBLE LIMITS
pH	6.62±0.31	6.49±0.18	6.5-8.5
TEMP (°C)	26.9±0.1	27.4±0.76	25
TURBIDITY (NTU)	0.13±0.06	0.73±0.55	5.0
TOTAL SOLIDS (mg/L)	256.7±6.5	200.7±18.9	1000
TOTAL DISSOLVED SOLIDS (mg/L)	174.3±13.8	161.3±20.13	500
TOTAL SUSPENDED SOLIDS (mg/L)	82.33±16.04	39.33±2.08	NA
DISSOLVED OXYGEN (mg/L)	3.50±0.46	3.41±1.07	5.0
BOD (mg/L)	1.46±0.54	1.40±0.07	NA
CONDUCTIVITY (µS/cm)	348.7±143.1	332.5±115.2	250
HARDNESS (mg/L)	33.33±11.0	20.67±2.31	150
ALKALINITY (mg/L)	43.33±15.28	20.0±10.0	100
CHLORIDE (mg/L)	177.25±14.18	241.06±53.53	250
SULPHATES (mg/L)	13.86±5.40	9.07±5.82	100
NITRATES (mg/L)	30.77±4.75	22.53±9.56	50
ACIDITY (mg/L)	60.0±34.64	83.33±15.28	6.5

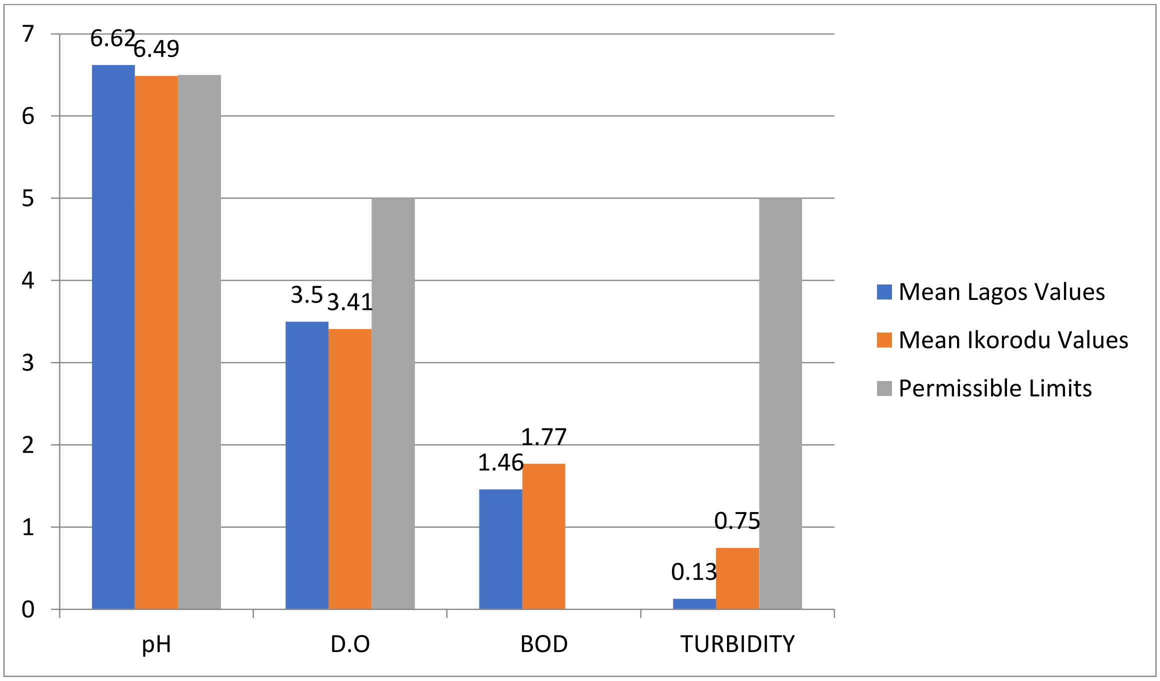

Fig. 1 Bar charts showing mean physicochemical characteristics of Water from different sources in comparison with the permissible Limits for pH, D.O, BOD and Turbidity

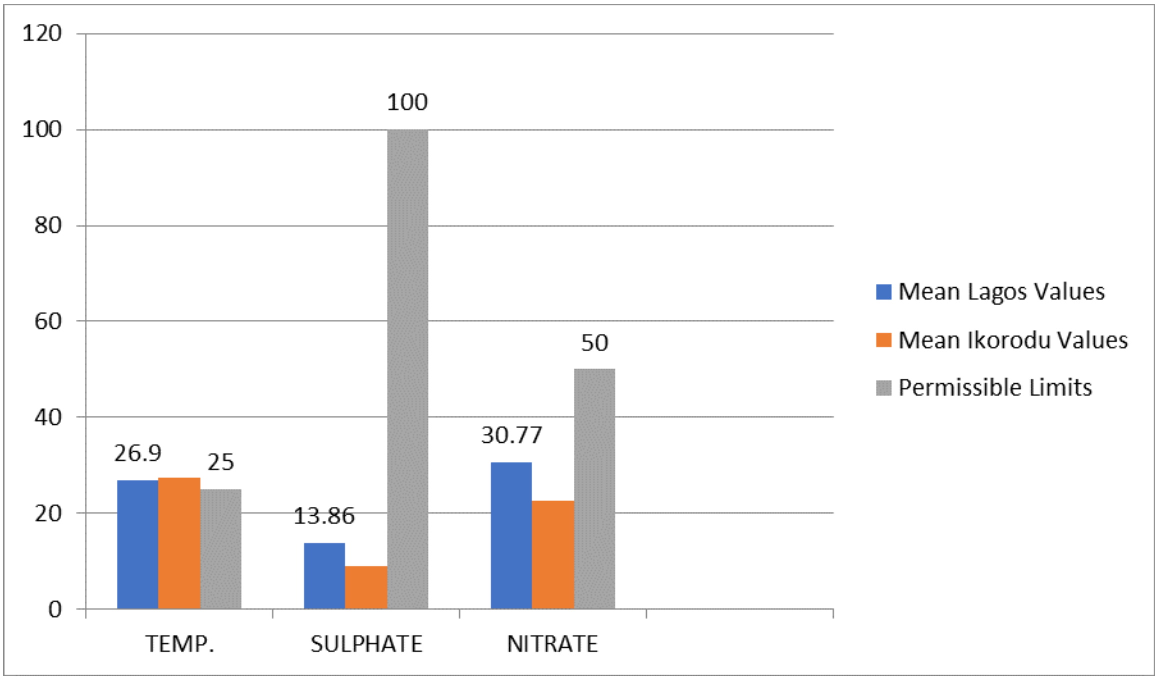

Fig. 2 Bar charts showing mean physicochemical characteristics of Water from different sources in comparison with the permissible Limits for Temp., Sulphate and Nitrate.

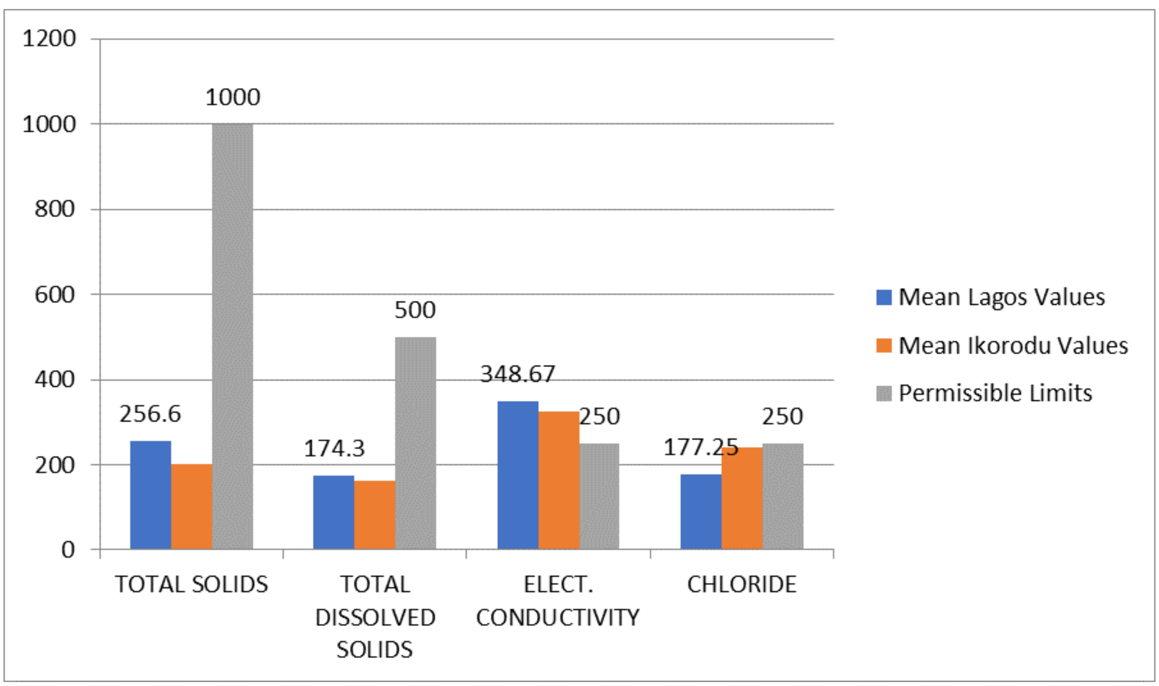

Fig. 3 Bar charts showing mean physicochemical characteristics of Water from different sources in comparison with the permissible Limits for TS, TDS, E.C and Chloride.

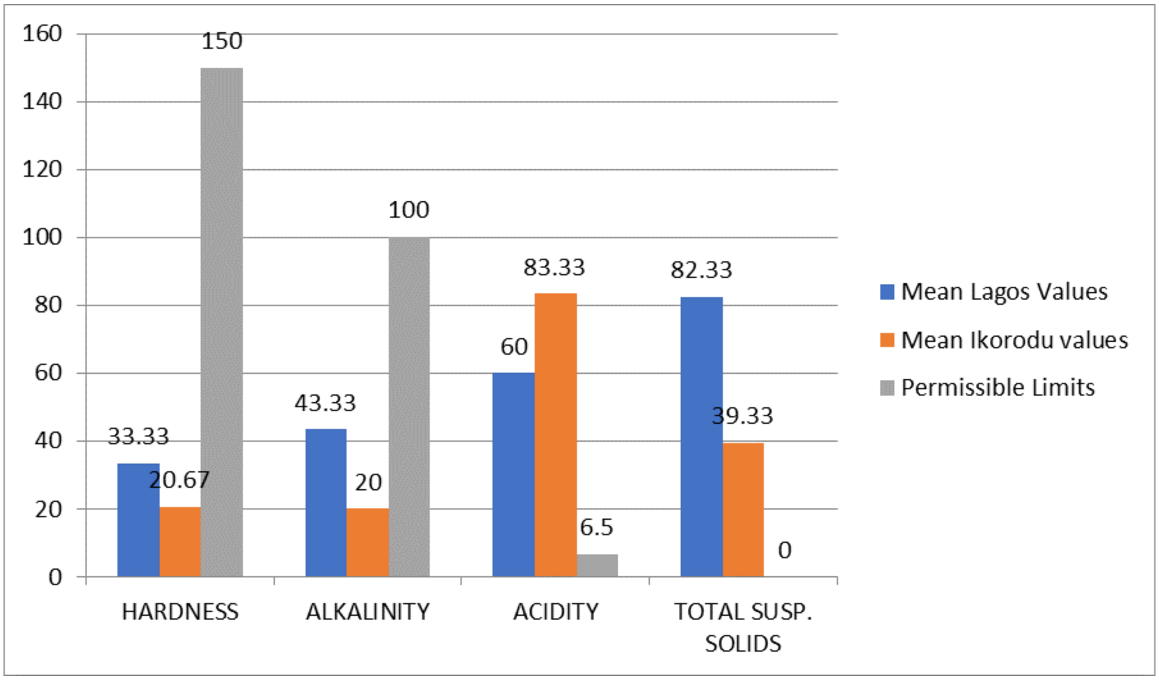

Fig. 4 Bar charts showing mean physicochemical characteristics of Water from different sources in comparison with the permissible Limits for TH, Alkalinity, Acidity and TSS.

Total Solids, Total Suspended Solids and Total Dissolved Solids (mg/L)

The values of the total solids ranged from 180mg/L for sample 2A (Ikorodu wells) to 263mg/L for sample 1C (Lagos centre tap water) (Table 3) with an average value of 256.7+6.5mg/L for representative Lagos Centre drinking water sources and an average value of 200.7+18.9mg/L for representative Ikorodu drinking water sources (Table 3) showing higher presence of solids in Lagos drinking water sources. The permissible limit for total solids is 1000mg/L for drinking water (Table 2). However, these values are within the limit (Fig. 2).

The Total Suspended Solids (TSS) value ranged from 37.0mg/L for 2C to 99.0 mg/L for 1C (Table 1) with an average value of 82.33±16.04mg/L for Lagos drinking water sources and 39.33± 2.08mg/L for Ikorodu drinking water sources (Table 3, Fig. 4). The values obtained from all the drinking water sources in Lagos are higher than those obtained for Ikorodu, indicating a higher pollution in Lagos. There are stated standards for TSS in drinking water.

Total Dissolved Solids (TDS) The TDS values obtained for all the samples ranged from 140 mg/L for 2A (representative Ikorodu wells) to 190 mg/L for 1B (representative Lagos borehole) with an average value of 174.3± 13.80mg/L for all the Lagos sample and an average value of 161.3± 20.13mg/L for Ikorodu water sample (Table 3 and 1). These values are within the **500**mg/L maximum permissible limit set by Nigerian Standards and WHO for drinking water (Table 2, Fig. 3). The higher mean TDS value observed in Lagos waters could also be linked to the higher level of industrialization and population density. The 2C (Ikorodu stream water) which has a high value of 180mg/L could be as a result direct discharge of chemicals, domestic waste waters, run-off from roads and dumpsites etc. which get finally washed into the natural water.

Dissolved Oxygen DO (mg/L)

The DO values for the entire sample analysed ranged from 2.20mg/L for 2A (Ikorodu wells) to 4.24mg/L for 2B (Lagos boreholes) (table 1) with a mean value of 3.50±0.46mg/L for Lagos sample and 3.41±1.07mg/L for Ikorodu water sample (Table 3). These values are however, within the permissible limits (Fig. 1). It should be noted that too much of DO in water can corrode pipelines and the value of DO obtained depends on temperature of the water, time of estimation, pressure and season also.

Biochemical Oxygen Demand, BOD (mg O_2/L)

The BOD values range from 1.01mgO_2/L for 1B, Lagos boreholes to 2.06mgO_2/L for 1A, Lagos wells (Table 1) with the mean value of 1.46±0.54 mgO_2/L for Lagos drinking water and 1.77±0.33 mgO_2/L for Ikorodu drink water (table 3). The highest values were observed in 1A (Lagos wells) with 2.06 mgO_2/L followed by 2B (Ikorodu boreholes) with 2.0 mgO_2/L.

BOD test is used to determine the pollution strength of water, waste water and quality of the receiving surface water. According to classification of surface water quality based on BOD values, water which has amount above 2.0mgO_2/L is said to be polluted, even though amount ranging from 3.0 and above is said to be much polluted. Hence, 1A and 2B waters are not fit for human consumption based on their BOD values.

Total Hardness (as mg $CaCO_3$/L)

In this study, the mean value of Total hardness for all the Lagos samples was 33.33±11.0 mg$CaCO_3$/L while for the Ikorodu water samples, the mean value was 20.67±2.31mg $CaCO_3$/L (Table 3). These values are far below the permissible limit (Fig. 4). Hence the water sources are all soft. Hardness of water causes disadvantages in domestic uses by producing poor lathering with soap, deterioration of cloths, scale forming, skin irritation, boiled meat and food becomes poor in quality (Pragathiswaran, *et al.*, 2008). Hard water is useful in the growth of children if within the permissible limit.

Total Alkalinity as mg $CaCO_3$/L

The alkalinity values ranged from 10.0 to 44.0 mg/L in the whole study area, with a mean value of 43.33±15.28 mg/L for Lagos water and 20.0±10.0 mg/L for Ikorodu water. Alkalinity is lowest in 2B (Ikorodu borehole) with a value of 10.0mg/L and highest in 1B (Lagos borehole water) with a value of 60.0mg/L as shown in Table 1.These values are below the acceptable limit of 100mg/L for drinking by WHO (2010) (Table 2, Fig. 4). Alkalinity leads to corrosion and influences chemical and biochemical reactions. (George *et al.*, 2010). Alkalinity is related to PH of the water and is objectionable in certain industrial processes (Egereonu and Odumegwu, 2006).

Total Acidity in mg/L

Total acidity varied from 40mg/L for (both 1B and 1C) to 100 mg/L for (both 1A and 2B), as shown in table 1 in the whole study area, with a mean value of 60.0±34.64 mg/L for Lagos centre drinking water sources and 83.33±15.28 mg/L for Ikorodu drinking water sources (table 3, fig. 4), indicating a higher acidic drinking water in Ikorodu. 1A and 2B with values as high as 100mg/L in each case are exceptionally high indicating much more presence of acidic substances leaching into and contaminating the groundwater sources.

Chloride (mg/L)

The chloride concentrations varied from 163.07mg/L for 1C (Lagos tap water) to 297.78 mg/L for 2C (Ikorodu stream) in the study area (Table 1). The mean value of the Lagos drinking water sources was 177.25±14.18 mg/L which was below the mean value for the Ikorodu drinking water sources of 241.06± 53.53 mg/L (Table 3). The permissible limit set by WHO, EU and Nigeria standards for chloride in potable water is **250**mg/L (Table 2). Almost all the sample from the different sources fell within the limit, except for 2C (Ikorodu stream) with chloride value of 297.78 mg/L. The high value of chloride in this drinking water source could be due to continuous usage of chloride salts in the nearby industries, ingress of saline water from backwater and the presence of soluble chlorides from salt bearing rocks (Geetha *et al.*, 2008; George *et al*., 2010). The appreciable lower chloride content obtained in 1C could be as a result of municipal treatment of tap water in Lagos.

Sulphates (mg/L)

The concentration of sulphates ranged between 3.96 mg/L and 20.1 mg/L for 2A (Ikorodu well water) and 1C (Lagos tap water) respectively (Table 1). The mean value obtained from all the sources of Lagos centre drinking water was 13.86±5.40mg/L and the mean value for the Ikorodu different sources of drinking water gave 9.07± 5.82mg/L (Table 3, Fig.2).

These values are all within the permissible limits given by WHO (1993), EU (1998) and Nigeria standards of **500, 250** and **100**mg/L respectively (Table 2). The general higher mean value of Lagos water could be linked with excess industrial and municipal waste as well as poor drainages and waste disposal culture. The high value of 15.40mg/L obtained in Ikorodu stream (2C) could be due to evaporative concentration of the dissolved ions during the dry season (Egereonu and Odumegwu, 2006) as well as agricultural run-off.

According to George *et al.*, (2010) High concentration of sulphate along with sodium and magnesium in drinking water can lead to gastrointestinal irritation and respiratory illness. Other studies have revealed that excess concentration of sulphate ions like Na_2S0_4 and $MgS0_4$ in water impacts a bitter taste, can form scale in water boilers and can produce unpleasant odour.

Nitrates (mg/L)

The permissible standard stated by WHO (1993), EU (1998) and Nigerian Industrial Standard (2007) for nitrates in portable water are all **50**mg/L (Table 2). However, from this study the concentration of nitrates ranged between 11.60mg/L and 35.60mg/L for 2A and 1C respectively (Table 1) with the average value for Lagos centre drinking water sources being 30.77±4.75mg/L and the average value for Ikorodu drinking water sources amounting to 22.53±9.56mg/L (Table 3). All the values for nitrates obtained from all the samples were all within the limit of the recommended standards (Fig. 2).

Most of these values are however high, especially in Lagos samples and therefore the possible sources of nitrates into the surface and groundwater need to be checked. The concentration of nitrate in drinking water causes adverse effects since it is a strong oxidizing agent and NO_2 can react with secondary amines present in human body, to form nitrosamines (George *et al.*, 2010). The primary adverse effect associated with human exposure to nitrate is methaemoglobinema. Nitrate converts haemoglobin to methaemoglobin by oxidizing the Fe^{2+} in haemoglobin to Fe^{3+} which cannot transport oxygen. High level of Fe^{3+}-haemoglobin in human blood can cause cyanosis, characterized by bluish skin and lips (Al-Dabbagh *et al.*, 1986).

In general, the results revealed a general acidic pH of less than 7 ranging from 6.29 to 6.90 for all the samples and an average of 6.62±0.31 for Lagos centre samples and an average of 6.49±0.18 for samples from Ikorodu. The WHO and Nigerian Industrial Standards stipulated a permissible limit of (6.5-8.5). Most of the samples are however within the limit. The mean Temperatures were 26.9±0.1°C and 27.4±0.76°C for Lagos centre and Ikorodu respectively. Almost all the samples have high Conductivity values above the WHO and EU standards (which is 250µS/cm) with a mean value of 348.67±143.10µS/cm and 332.50±115.18µS/cm for Lagos centre and Ikorodu samples respectively. The acidity values obtained for all the samples were too high above the WHO (of 6.5mg/L) standard limit with an average of 60.0±34.64mg/L and 83.33±15.28mg/L for Lagos centre and Ikorodu samples respectively. The values for TS, TDS, TSS, DO, TH, and Nitrate were high in the whole samples but significantly higher in Lagos centre samples. This could be linked to the influence of industrial effluents, refuse dumps and population density which is higher in Lagos centre. However, the values of Turbidity, BOD and Chloride were higher in Ikorodu, largely due to much contribution from the polluted stream (surface water) at Ikorodu which the people still used for domestic purposes.

Conclsions

The result obtained in this study revealed that all the samples analyzed were slightly acidic for both Lagos metropolis (centre) and all Ikorodu drinking water sources. The Electrical Conductivity and Acidity of all the samples exceeded the World Health Organisation and European Union standards for drinking water.
The higher presence of Total Solids, Total Dissolved Solids, Total Suspended Solids, Dissolved Oxygen, Total Hardness and Nitrate value in Lagos centre samples were reflective of the influence of industrialization, urbanization, population density, dumpsite etc in the area. The values are however, still within the acceptable limits.

Turbidity, BOD and Chloride content are higher in Ikorodu samples than in Lagos centre samples. This could be due to presence of soluble salt from salt bearing rocks or continuous usage of chloride salt in a nearby industry in Ikorodu. Water with high BOD values is not safe for drinking purposes. The values for these parameters are however within the permissible limit. Other physiochemical parameters are low enough in the entire samples.

The heavy metals presence showed that Lead, Nickel and Magnesium values exceeded the WHO, NIS and EU standards for all the representative samples for both areas of study which makes the water unfit for drinking. The value of Iron for Ikorodu sample exceeded the limits set by all the regulatory bodies but have value within the permissible limits for Lagos centre samples. This could be caused by factors such as geology of the place, iron peels and rusts from bailers used in fetching the water, rusted pipe channels for the bore holes which are not cared for, etc.
Cadmium was not detected in any of the whole sample. Cu, Cr, Zn, Na, and Ca all have values within the acceptable limits.

The concentration of some heavy metals and physicochemical properties of water above the WHO standard makes water unpalatable for human consumption if not purified prior to use and affect the stability of the water for other forms of domestic use.
Bar charts were also used to depict the relationship between the physiochemical parameters as well as the heavy metal values with the standard permissible limits.

Recommendations

The use of the surface water at Ikorodu “etunrenren” stream for drinking and other domestic purposes should be stopped, because of the high extent of pollution as discovered from this study except if adequate treatment is carried out before use.
Regular monitoring of the wells/boreholes (groundwater) and the quality of all other drinking water sources should be practiced since these supplies are used for washing, drinking, cooking and irrigation purposes.

Indiscriminate and unhealthy disposal practices should be abolished as well as introduction of modern techniques of waste disposal.
Regular treatment of water as to meet up to standards should be practiced to avoid water borne diseases. Appropriate treatment techniques/ methods should be taught to the people since in most cases wells and boreholes when pumped out are not treated in any form at all, or when treatment is attempted, it is arbitrary, involving random dosage of such chemicals as alums, sodium chloride, lime and hypochlorite.

Awareness should be created among the people on the possible danger of polluted water consumption and the associated diseases if not treated.Drinking Water Quality Surveillance Agency should increase the frequency of sampling for drinking water facilities considering the ever-increasing population in Lagos state as a whole since such periodic monitoring of water quality will ensure future sustainability.

Further studies should be carried out on the level of the physicochemical parameters, Microbial parameters and Heavy metals concentration in more areas and from different sources. This will serve as baseline data and determine the source of future groundwater pollution.

1. Industries should adequately treat their effluents before discharge to the environment and nearby surface water bodies.
2. Dumpsites should be sited away from residential areas.
3. Well and boreholes should be sited away at least 30 meters from soak away.
4. A proper landfill site should be designed to minimize the adverse effects associated with solid waste disposal.
5. The government should enact and enforce environmental laws to protect the different drinking water sources from vulnerable practices that could lead to pollution.

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