Environment Pollution and Climate Change

ISSN: 2573-458X

Majekodunmi Grace et al., Environ Pollut Climate Change 2022, 6:11

Research Article

Open Access

Groundwater Quality Assessment around Two Dumpsites: A Case Study of Ojota and Bariga Sites in Lagos, Nigeria

Majekodunmi Grace F[1], Akanmu James[2]*, Adenekan Kifaayah[2], Mayowa Adenekan[2] and Notiswa Libala[3]

[1]*Department of Chemistry, University of Lagos, Nigeria*
[2]*Department of Civil and Environmental Engineering, University of Lagos, Nigeria*
[3]*Rhodes University, South Africa*

Abstract

Many Nigerians does not have access to improved drinking water both in rural and urban area but more critical in urban areas of which can be linked to rapid urbanization leading to greater demand for water resource supply and municipal sanitation services in the country. This is particularly true for region experiencing exponential population growth such as the Lagos Metropolitan, the economic hub of Nigeria. Concurrently, waste generation increases at rates that municipalities cannot safely dispose of; which results in the rise of illegal waste dumping in unauthorised dumpsites.

The occurrence of these dumpsites in urban areas were identified as one of the sources of water pollution and poses a health risk to groundwater users as leachate and other contaminants generated from the dumpsites has the potential to migrate downwards into the underlying aquifers. This study assessed the groundwater quality near two dumpsites in the Lagos Metropolitan (The government controlled authorised Ojota the unauthorised Bariga disposal sites).

Samples were collected from boreholes and monitoring wells around the Ojota and Bariga dumpsites respectively between the period of June and August 2021 The pH, Temp, EC, Salinity, TDS, Calcium Hardness, Total Hardness, Chloride content, Alkalinity, Acidity, Heavy metals (Cr, Cu, Fe, Mn, Pb, and Zn) microbial parameters were analysed from the water and leachate sample collected. The results were analysed using the statistical tools in the R-package and compared against the World Health Organization (WHO-2017) and the Nigerian Standard for drinking water quality (NSDWQ-2007).

However, the concentrations of EC, TDS, Chloride, Fe and Zn levels of Bariga dumpsite were observed to be higher which means it contains some contaminants than that of Ojota dumpsite as compared with the standards used (WHO&NSDWQ). Although the result of analysis of EC, TDS on the leachate for Ojota dumpsite was discovered to be high beyond permissible limits showing a level of contamination in the groundwater quality.

From this study, it is evident that lack of well-constructed engineered environmental friendly landfills and indiscriminate dumping of wastes to water channels can possibly lead to high contamination of the groundwater quality, posing a serious threat to the human health and the environment at large. It therefore requires collective efforts between the community residents to avoid indiscriminate dumping of waste and the government ensuring that proper waste management and monitoring is put in place especially in areas where these landfills are currently situated.

Keywords: Physico-chemical parameters; Heavy metals; Water quality Standards; Water pollution

Introduction

The availability of adequate water resources underpins sustainable economic growth and is vital for the sustenance of life. Although water is available as a ubiquitous natural resource, the major problem is the quantity of fresh water available for use. The sustenance of life depends greatly on good quality water therefore; demand for potable water continues to rise in line with global population growth. Both surface water and groundwater are important water sources for water for human consumption in all aspects of life. In the Lagos Metropolitan, continuous population growth, and rapid migration into the metropolis increases the demand on water resources.

In Lagos, groundwater remains a major source of water supply for drinking and other uses such as domestic, recreational, commercial, industrial, and aesthetic purposes [1]. Waste disposal is a global problem, particularly in developing countries due to increase in population, economic growth, urbanisation, and industrialisation, coupled with poor waste management practices. However, solid waste dumpsites have been implicated as one of the major threats to groundwater resources in the country, especially in urban areas such as Lagos State. This is particularly true in areas such as Bariga, Iwaya, Alaba Rago, and Ilaje, where leachate infiltration from the dumpsites is known to be detrimental groundwater quality [1-4]. Groundwater pollution is a major problem, because contaminated leachate affects soil characteristics, surface – as well as groundwater quality around dumpsites. This is primarily due to lack of adequately constructed leachate treatment systems hence, the need for engineered landfills.

The reduced capacity to collect, process, dispose of, or re-use solid waste in a cost-efficient manner is often limited by available technological and managerial capacities [5]. As a result, the waste is disposed in depressions such as valleys, excavations, or selected portions of land within the residential- urban settlements. Accumulation of

***Corresponding author:** Akanmu James, Department of Civil and Environmental Engineering, University of Lagos, Nigeria, E-mail: jakanmu@unilag.edu.ng

Received: 09-Nov-2022, Manuscript No. EPCC-22-78600; **Editor assigned:** 11-Nov-2022, PreQC No. EPCC-22-78600 (PQ); **Reviewed:** 25-Nov-2022, QC No. EPCC-22-78600; **Revised:** 28-Nov-2022, Manuscript No. EPCC-22-78600 (R); **Published:** 05-Dec-2022, DOI: 10.4172/2573-458X.1000309

Citation: Majekodunmi Grace F, James A, Kifaayah A, Adenekan M, Libala N (2022) Groundwater Quality Assessment around Two Dumpsites: A Case Study of Ojota and Bariga Sites in Lagos, Nigeria. Environ Pollut Climate Change 6: 309.

groundwater contaminants and exposure of the nearby communities utilising groundwater may result to adverse human health impacts.

In Nigeria, like many other developing countries, open dumping has been the only management option of solid waste disposal. In previous years, management system has been based on collection and dumping out of the city boundaries in conformity with the concept of "out of sight out of mind" [6]. But recently in a mega-city like Lagos, the siting and development of residential quarters near waste sites are common due to shortage of building land to cope with the increasing rate of migration and consequent population [7]. Most dwellers in Lagos State have no access to pipe borne water from public water supply (Lagos Water Corporation) but solely depend on ground water through boreholes and wells constructed privately. Unfortunately, in Lagos State groundwater quality is threatened through uncontrolled industrial and commercial effluents discharges, indiscriminate municipal solid wastes disposal, residential sewage discharges, agricultural chemicals and fertilizers applied on farms as well as salt-water intrusion, urban surface runoffs, underground storage tanks and pipelines leakages etc.

The continual flow of leachate into the surface and groundwater, poses an environmental health risk to on and offsite receptors through direct contact (dermal contact, accidental ingestion etc.) and indirect contact (e.g., volatilisation of contaminants and inhalation of volatiles). Furthermore, such dumpsites are known sources of anthropogenic sources of methane (CH4), thus contributors to global warming [8].

There have been many studies in different parts of the world including the study area of this paper, on the environmental impact of waste disposal on groundwater quality. Longe and Balogun-Adeleye (2010) observed the accumulated leachate at the base of the sanitary dumpsite can breakthrough into the groundwater with time, and gas emissions poses potential environmental and health risk. Coker showed that the pH, TDS and EC of some water samples collected around Ojota dumpsite are beyond the maximum permissible limits recommended by WHO and such boreholes should therefore be abandoned [9]. Moreover, there is also a strong correlation and efficacy in the assessment of leachate impact (emanating from solid waste) been demonstrated. Longe and Enekwechi showed that elevated concentrations of contaminants were detected predominantly in the downgradient locations but followed no specific migration or attenuation patterns [10]. It was deduced that soil stratigraphy beneath the landfill site signicantly contributes to the concentrations of the contaminants present in the groundwater.

Adeyi and Majolagbe discovered that 50 water samples around Ojota dumpsite are delineated as good – poor – very poor using the Water Quality Index [1]. In addition, almost all the groundwater collected around Ojota dumpsite showed level of nitrate higher than the WHO permissible limit of 10 mg/L. This situation is of great health risk as nitrate pollution has been linked to myth and sometimes death. Rapti-Caputo and Vaccaro evaluated the geochemical evidences of dumpsite leachate in groundwater in Ferrara Province, Northern Italy, and found that the propagation of the polluting fluids in the deeper aquifers can be attributed to the deeper propagation of the leachates [11]. Liu investigated the impact of Municipal Solid Waste dumpsite on the contamination of phthalate esters (PAEs) in nearby environment in Wuhan, China [12]. They found that the dumpsite had an obvious effect on the contamination of Phthalate Esters (PAEs) in groundwater. Han examined groundwater inorganic contamination around a municipal dumpsite site in Zhoukou city, Henan province, China, and found that the shallow groundwater (within 30 m depth) around the dumpsite is not suitable for drinking, and recommended improvement of pollution control [13].

This paper will complement initial studies carried out on groundwater quality in and around dumpsite areas.

Groundwater physicochemical parameters analysis near the Ojota dumpsite according to Ameloko and Ayolabi has indicated seasonal variations in the various elemental constituents [14]. Highly elevated concentrations were recorded during the drier season, and in closer proximity to the dumpsite [14]. It can therefore be inferred that the exposure to contaminated groundwater-to-groundwater users, increases significantly in the drier seasons. These variations have been historically interpreted to reflect the absence of rainfall during the dry season period, allowing contaminant accumulation in groundwater to increase as result of continuous breakdown of the biodegradables units with time.

Therefore, the aim of this study is to assess groundwater quality around the vicinity of selected dumpsites in Ojota and Bariga areas of the Lagos Metropolitan. The Ojota dumpsite is a government authorized whereas the Bariga dumpsite is an illegal one. In addition, the study is to determine how these dumpsites could lead to specific chemical and biological contaminants exposure in the selected communities. The key focus on the study is to determine the quality of the groundwater through physicochemical, heavy metals and some microbial parameters and compare the values with drinking water quality standards (WHO and NSDWQ). This investigation expands the knowledge of groundwater contamination trends in unauthorized dumpsites and compares the findings to those observed in an authorized site. The adaptive strategic approach (ASA), as described by Palmer was adopted for this study [15].

Materials and Methods

Study Area

The study was conducted in two sites located in the Lagos Metropolitan, south western part of Nigeria (Figure 1, 2). The region is classified as having a tropical climate, characterised by two principal alternating seasons-wet and dry season [9, 16]. The wet season generally commences in the April through to October, whereas the dry season is from October to March [16]. The average temperature for the city is 27°C, and the city receives rainfall of over 2,000 mm per annum [17, 18]. The highest rainfall volumes have been recorded in the months of June and July [10].

The Lagos Metropolis is located on a relatively flat and low lying plain and underlain by stratified sedimentary rocks within the Dahomey Basin [19]. The Dahomey Basin extends from the eastern portion of Ghana through the southern boundary of Nigeria, through to the western margin of the Niger Delta [20]. In age, these deposits range from the Cretaceous to the Quaternary [10]. The Cretaceous deposits are predominantly from the Abeokuta Group, whereas Quaternary sediments are generally alluvial, lagoon and coastal plain sand deposits [21, 22].

The main aquifer Lagos is the Coastal Plan Sand [19]. It comprises three main zones, which are separated by impervious clay horizons [22]. A semi-permeable silty clay unit, attaining 10m in thickness, separates the uppermost aquifer from the second underlying aquifer. This latter occurs between 20m and 70m, and predominantly serves as groundwater [22]. The third aquifer system occurs at further depth within the Benin Formation and reported at depths ranging between 118 and 166 m below sea level [22]. The calculated hydraulic conductivity of this water-bearing zone is in the order of 10-3cm/s [10].

Citation: Majekodunmi Grace F, James A, Kifaayah A, Adenekan M, Libala N (2022) Groundwater Quality Assessment around Two Dumpsites: A Case Study of Ojota and Bariga Sites in Lagos, Nigeria. Environ Pollut Climate Change 6: 309.

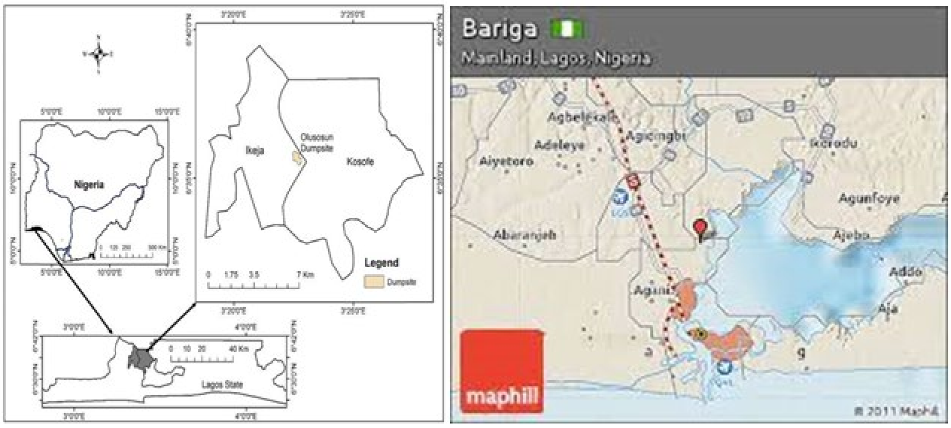

Figure 1, 2: Site Locality Map indicating the Ojota and Bariga Study Area.

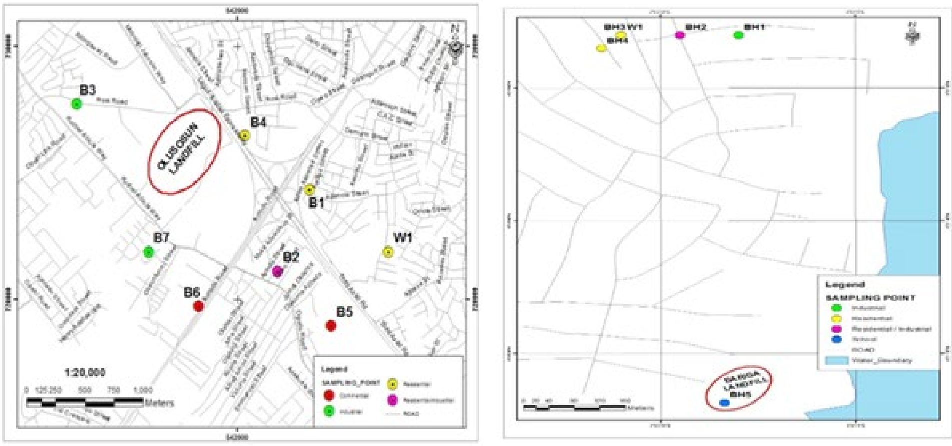

Figure 3, 4: Map indicating the distribution of the selected boreholes across the study sites.

The hydrogeological conditions near the Ojota Dumpsite are characterised red brown lateritic cover comprised of sand and clay. The area is characterised by 4m to 15m of clay rich / lateritic soils [23]. Longe and Enekwechi reported the water table depth between 4m in the northern portion and 10m in the southern portion of the dumpsite [10]. Several perennial and non-perennial streams are observed near the Ojota Dumpsite. The nearest major river is the Ogun River, located approximately 2.9km northeast of the site. The groundwater flow direction is expected to emulate topography, flowing southeast towards the Lagos Lagoon, and the Gulf of Guinea thereafter. The groundwater resources in Lagos are further threatened by saltwater intrusion into the aquifers [19].

Study site selection

Historical studies on water contamination due to leachate migration from dumpsites have predominantly focused on government-authorised dumpsites. This study evaluates how concentrations of chemical contaminants vary across authorised and unauthorised waste disposal sites. Furthermore, the investigation sought to undergo the controls on the migration patterns of the contaminant plume.

Two waste disposal sites were selected as primary investigation areas in this study. These include a government authorised Ojota dumpsite (6°35’46.79”N, 3°22’32.81”E) and an unauthorised disposal site in Bariga (6°31’54.00”N, 3°23’59.37”E). The Ojota dumpsite (6°35’46.79”N, 3°22’32.81”E) is the largest waste disposal site in Nigeria officially opened in November 1992 and occupies an area of approximately 42 ha in the Ikeja Local Government Area [10]. It was previously a burrow pit excavated to a depth of 12m [10]. The Bariga dumpsite (6°31’54.00”N, 3°23’59.37”E) is an illegal dumpsite downgradient of St Raphael Catholic Church and within 200m of the Lagos Lagoon.

The research design for the study was informed by the ASA framework as described by Palmer [20]. Predominantly, research in natural resources development historically resulted in inadequate nor sustainable real-world outcomes. By contrast, the ASA provides an integrative practical Trans disciplinary and community centred approach required to address issues in complex-ecological systems [20]. The first step of ASA (i.e., Bound) including desktop gathering of existing data, stakeholder mapping, and co-developing of the critical research questions with the stakeholders laid the foundation for this research. Through this stakeholder engagement process, the research team accessed groundwater sampling locations and established a community driven water quality monitoring program.

The dumpsites are in areas of mixed land use (i.e., residential, commercial, industrial). Property owners were engaged for permission to collect groundwater samples from boreholes in the two study areas. The boreholes were selected at varying distances from the contamination sources to deduce spatial trends of the contamination plume and assess contaminant exposure risk to different end-users (Figure 3, 4 and Table 1).

Table 1: Borehole Locality and Rationale for Monitoring Locations.

Borehole ID	Location	Current Use	Latitude	Longitude	Rationale for Sampling	Depth
Ojota Dumpsite						
BHO1	Oluyombo Street	Residential	6o35' 38''	3o 23' 08"	900m from the centre of the dumpsite	42m
BHO2	Olorunfunmi Street	Residential/industrial	6o 35' 17"	3o 22' 59"	1200m from the enter of the dumpsite	42m
BHO3	Billings Way	Industrial	6o 36' 00"	3o 22' 03"	1100m from the centre of the dumpsite	48m
BHO4	Bello Folawiyo Crescent	Residential	6o 35' 52"	3o 22' 50"	250m from the centre of the dumpsite	50m
BHO5	Ogunleti street	Commercial	6o 35' 03"	3o 23' 14 "	400m from the centre of the dumpsite	51m
BHO6	Kudirat Abiola Way	Commercial	6o 35' 08"	3o 22' 37"	250m for the centre of the dumpsite	42m
BHO7	Mobolaji Jonson Way	Industrial	6o 35' 22"	3o 22' 23"	400m from the centre of the dumpsite	51m
WO1	Ogunseinde Street	Residential	6o 35' 22"	3o 23' 30"	1000m from the centre of the dumpsite	16.2m
BHO -Borehole Ojota dumpsite						
WO -Well Ojota dumpsite						
Bariga Dumpsite						
BHB1	Pepsi	Industrial	6o31'54"	3o 23'54"	100m from the Lagoon	Nil
BHB2	Alhaji Alimi Jnc	Residential / Industrial	6o31'54"	3o 23'51"	150m from the Lagoon	Nil
WB1	Anike- Abu (W)	Residential	6o31'54"	3o 23'48"	200m from the borehole	Nil
BHB3	Anike- Abu (B)	Residential	6o31'54"	3o 23'48"	200m from the borehole	Nil
BHB4	Abeokuta	Residential	6o31'53"	3o 23'47"	250m from the lagoon	Nil
BHB5	F.O.D	School	6o31'54"	3o 23'53"	50m from the Lagoon	Nil

Groundwater sampling was conducted weekly in the period from June to August 2021. This coincides with the wet season when the water table is generally high. A total of nine (9 no) groundwater samples were collected in the vicinity of the Ojota Dumpsite. A composite surface leachate sample was collected near the Ojota dumpsite. In the Bariga study area, six (6 no.) groundwater samples were retrieved from privately owned boreholes. These samples collection is further illustrated in Table 1.

Sampling and laboratory analysis

Prior to sampling, the depth to groundwater and bottom of the well was gauged using a dipping meter. The dipping meter was decontaminated between each well/borehole to militate against cross-contamination.

The groundwater samples were collected into sterilised 75cl plastic sampling containers, to minimise impurities prior to using the containers. The samples were accurately labelled, stored in cool conditions, and analysed within 5 hours of collection to ensure they are within laboratory holding times to maintain sample integrity.

The samples from the deep boreholes were collected from point of use taps while the well were sampled using a plastic fetcher methodology until all physico-chemical parameters had stabilised. The leachate samples were collected directly by lowering sterilized sampling bottles. Temperature (°C), Total Dissolved Solids (TDS) (mg/L), salinity (ppt) and Electrical Conductivity (EC) (µS/cm) were measured in-situ per sampling location.

The laboratory testing was conducted in accordance with the Standard Methods stipulated in the 20th Edition of the American Public Health Association, APHA (2005). The tests were undertaken in the Water Quality Laboratory at the University of Lagos, Akoka.

The samples selected for total coliform analysis were prepared in the microbiology laboratory. In addition, samples were collected for heavy metals analysis concentration of Fe, Cu, Cr, Mn, Pb and Zn.

Data and statistical analysis

The data collected were analysed using averages, range, standard deviation, the Multivariate analysis of variance (MANOVA), Analysis of Variance (ANOVA), and the linear discriminant analysis (LDA), used as a Post-Hoc test. The statistical computing environment 'R' (version 4.1.1) access through the Comprehensive R Archive Network (CRAN), a free software environment platform for statistical computing and graphics with interface R Studio, an integrated development environment for R, was utilised.

The univariate (ANOVA) was used to show the significant variations between each physico-chemical properties in the boreholes and well, that is to test whether there are significant differences between the means, variances, and medians of water quality parameters between Ojota and Bariga dumpsites while the multivariate (MANOVA) was applied to further confirm the descriptive analysis carried out on the samples collected and to test whether physicochemical variables differ statistically between the two dumpsites.

Invariably the ANOVA and the linear discriminant analysis (LDA) were used as part of the analysis for post-hoc test. The linear discriminant method in statistics uses pattern recognition and machine learning to find a linear combination of features, which characterizes or separates two or more classes of objects or events. The resulting combination may be used as a linear classifier or, more commonly, for dimensionality reduction before later classification. The LD further shows the significant variations between the sample locations.

The Nigerian Standard for Drinking Water Quality (NSDWQ, 2007) and World Health Organisation (WHO, 2017) guideline values for drinking water were used as the benchmark for quality assessment.

Results

In this study Tables 2-5, and Figure 5, 6 shown below illustrates the descriptive statistics analysis and summarized result of the measured groundwater parameters.

The minimum and maximum pH values of Ojota dumpsite are 5.00 and 8.50 respectively given a mean value of 6.05 with a standard deviation of 0.6372. Similarly, the minimum and maximum pH values of Bariga dumpsite are 4.00 and 7.3 respectively given a mean value of 6.16 with a standard deviation of 0.987 as compared to the standard permissible limits of WHO (6.10-8.0) and NSDWQ (6.5-8.5).

Table 2: Descriptive analysis for physico-chemical parameters for Ojota dumpsite.

Descriptive Stat.	pH	Temperature	Electrical Conductivity	Salinity	Total Disolved Solid	Calculated Hardness	Total hardness	Chloride	Alkalinity	Acidity
		(0C)	(uS/cm)	(ppt)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)
Minimum	5	23	120	60	22.7	6	16	52	4	10
Maximum	8.5	25.9	8930	4800	7970	158	238	838	579	366
Mean	6.05	24.69	853.4	396.1	687.3	40.57	68.38	199	81.96	111
Standard Deviation	0.6372	1.052	1715	890	1632	33.17	56.03	203.8	102.5	91.3
NSDWQ (2007)	6.5 - 8.5	NV	1,000	NV	500	150	NV	250	NV	NV
WHO (2017)	6.10 - 8.00	NV	900	NV	500	NV	NV	NV	NV	NV

Table 3: Descriptive analysis for physio-chemical parameters for Bariga dumpsite.

Descriptive Stat.	pH	Electrical Conductivity	Salinity	Total Disolved Solid	Calculated Hardness	Total hardness	Chloride	Alkalinity	Acidity
		(uS/cm)	(ppt)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)
Minimum	4	559	280	378	40	44	224	34	48
Maximum	7.3	5660	8800	3570	155.7	592	3712	149.3	248
Mean	6.164	2819	2423	1888.9	288	336.4	1962	428	119.2
Standard Deviation	0.987	1468	2315	1076	66.7	166.8	1199	100.8	48.52
NSDWQ	6.5 - 8.5	1,000	NV	500	150	NV	250	NV	NV
WHO (2017)	6.10 - 8.00	900	NV	500	NV	NV	NV	NV	NV

Table 4: Mean value for site location of samples for Ojota.

Site Mean	pH	Temperature	Electrical Conductivity	Salinity	Total Disolved Solid	Calculated Hardness	Total hardness	Chloride	Alkalinity	Acidity
		(ºC)	(uS/cm)	(ppt)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)
Borehole	5.889762	24.7	428.2667	211.89524	287.1571	31.285719	51.238095	211.38095	68.261905	110.0476
Well	6.116667	24	613.1667	299.16667	414.1667	101.66667	164.66667	150	54	66.33333
Leachate	7.32	25.6	4712.4	2059.6	4376.4	45.2	96.8	154	230.6	172.8
NSDWQ (2007)	6.5 - 8.5	NV	1,000	NV	500	150	NV	250	NV	NV
WHO (2017)	6.10 - 8.00	NV	900	NV	500	NV	*NV*	*NV*	NV	NV

Table 5: Mean value for site location of samples for Bariga.

Location	pH	Electric	Salinity	TDS	Calcium Hardness	Total Hardness	Chloride	Alkalinity	Acidity
		Conductivity	(ppt)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)
		(uS/cm)							
Borehole	6.003333	2775.0333	2595.333	1808.033	143.46667	325.23333	1909.7	114.13333	120.6
Well	6.966667	3038.3333	1561.667	2293.333	217	392.33333	2226	325	112.3333
NSDWQ (2007)	6.5 - 8.5	1,000	NV	500	150	NV	250	NV	NV
WHO (2017)	6.10 - 8.00	900	NV	500	NV	*NV*	*NV*	NV	NV

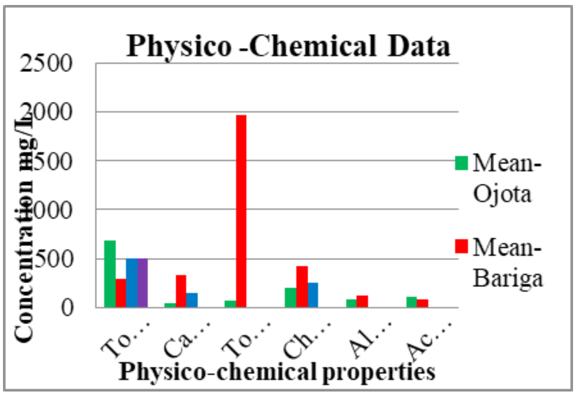

Figure 5: Showing the Physico-Chemical properties of Ojota and Bariga dumpsites.

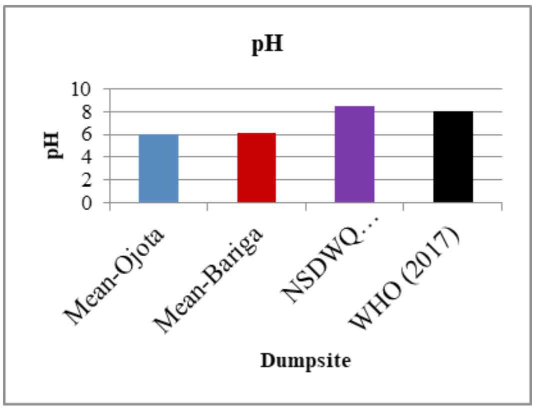

Figure 6: Showing the Mean pH of Ojota and Bariga dumpsites.

Table 2 and 3 shows the mean values of the EC, Salinity, TDS and Chloride for Ojota dumpsite are 853.4 uS/cm, 3961ppt, 687.3mg/L and 199mg/L respectively while that of Bariga dumpsite are 2819 uS/cm, 2423ppt, 1888.9 mg/L and 1962mg/L respectively.

Table 4 shows the EC (4712.4 u S/mg), Salinity (2059.6 ppt), TDS (4376.4 mg/L) and Chloride (154mg/L) in the Leachate sample for Ojota dumpsite.

Table 4 shows the heavy metals analysis for Ojota dumpsite. The Fe ranges from 0.003mg/L to 0.140 and Zn ranges from 0.004mg/L to 0.023mg/L for all boreholes (BHO1 to BHO7) and well (WO) as compare to the standards of NSDWQ as (0.03mg/L and 3.00mg/L) and WHO as (0.30mg/L and 15mg/L) for Fe and Zn respectively.

Table 5 shows the heavy metals analysis for Bariga dumpsite. The Fe ranges from 0.057mg/L to 0.401mg/L and Zn ranges from 0.001 to 0.25867mg/L for all boreholes (BHB1 to BHB5) and well (WB) as compare to the standards of NSDWQ as (0.03mg/L and 3.00mg/L) and WHO as (0.30mg/L and 15mg/L) for Fe and Zn respectively.

Discussion

The results of the mean values of the pH of both dumpsites shows that the concentration are slightly acidic compared with the standards (WHO and NSDWQ). Slightly acidic in nature, can be said to be within the stipulated water quality standards under the WHO but not within the permissible limit of NSDWQ according to tables 2, 3 and figure 6 .While the EC, TDS, Salinity and Chloride for Bariga dumpsite exceeds the permissible limit for both standards (WHO and NSDWQ) which shows a level of contamination in the groundwater as a result dissolved ions increase in the water see table 2, 3 and Figure 5, 7 and 8.

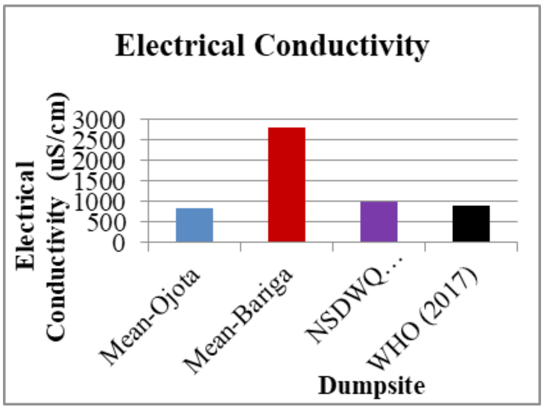

Figure 7: Showing the EC of Ojota and Bariga dumpsites.

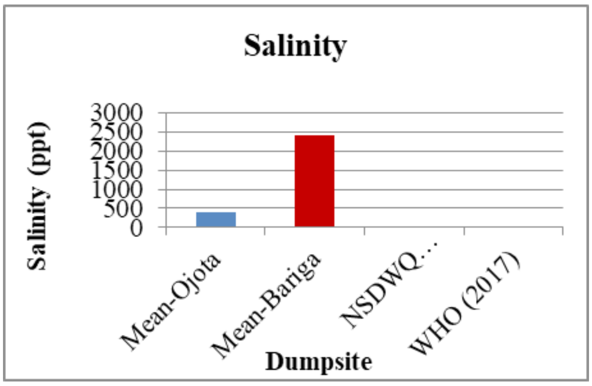

Figure 8: Showing the Salinity of Ojota and Bariga dumpsites.

The statement above can also be attributed to the fact that Bariga area is located close to the Lagoon. According to a research done by Oyedele and Momoh on the evaluation of seawater extrusion in fresh water aquifers in a lagoon, (https://www.researchgate.net/publication/338491017) which deduced that the salinity problem may exist due to upward movement of water and salts from groundwater [24]. For coastal aquifers, the influence of seas, oceans, and lagoons are predominant. One of the potential causes of subsurface salinity which does not require too geologically long a time, has been reported by Achari et al. (2005) was the inundation of an entire barrier by the surface influx of seawater where the tsunami impact on groundwater quality was assessed. They preferred an explanation for the process that led to groundwater salinization thus: when seawater ingresses over the surface, by waves with heights ranging from 4 to 7m, it carried along some dissolved salts, which were lodged in the soil. The salts brought by the mighty waves sink into the soil and with the first rains of the year, the absorbed salts leach down to the groundwater aquifer and contaminated it.

The high level of chloride in groundwater quality also suggest pollution from the lagoon. This also increases the potential corrosively of the water, which affects infrastructure, and drinking water quality and invariably affects mortality and aquatic plants and animals as a result of acidification of streams around the area. But for Ojota dumpsite, the level of chloride may suggest that there is the possibility of a level of control measure that is adopted being an authorized dumpsite as compared to Bariga dumpsite that is unauthorized.

Coker showed that the pH, TDS and EC of some water samples collected around Ojota dumpsite are beyond the maximum permissible limits recommended by WHO and such boreholes should therefore be abandoned [9]. Moreover, there is also a strong correlation and efficacy in the assessment of leachate impact (emanating from solid waste) been demonstrated. But in this study, The EC, TDS of the water samples collected are beyond the permissible limits of both the WHO and NSDQW standards for Bariga dumpsite (illegal site).

This study also revealed a slight degree of contamination of heavy metals (Fe and Zn) in the groundwater quality around the Bariga dumpsite compared to that of Ojota dumpsite .The heavy metals according to Figure 9 and tables 4-6 shows that Iron (Fe), and Zinc (Zn) are higher in values compared to other heavy metals especially in the boreholes and well of Bariga dumpsite beyond the permissible limits. This implies the groundwater around the Bariga dumpsite is not fit for drinking purposes. The main source may be drawn to its proximity to the lagoon and surface run-off, which can negatively affect the health of individual.

However, the EC (4712.4 u S/mg) and TDS (4376.4 mg/L) in the

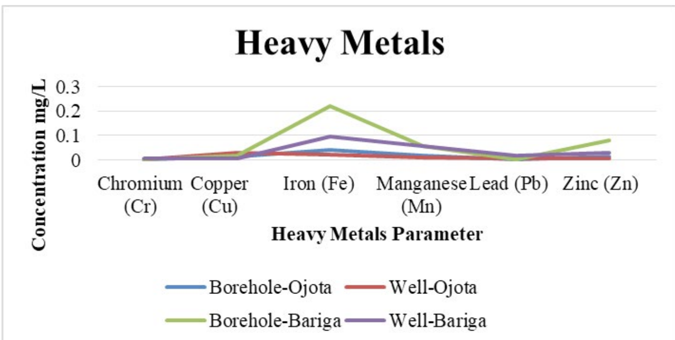

Figure 9: Showing the Heavy Metals Properties between Ojota and Bariga sites.

Table 6: Mean values for heavy metals and microbial analysis for Ojota dumpsite.

Site	Cr	Cu	Fe	Mn	Pb	Zn	E-Coli
	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	
BHO1	0.003	0.017	0.03	0.009	0.003	0.004	14.667
BHO2	0.002	0.013	0.028	0.039	0.004	0.022	TNTC
BHO3	0.007	0.019	0.074	0.012	0	0.005	TNTC
BHO4	0.006	0.011	0.003	0.005	0.002	0.009	TNTC
BHO5	0.003	0.012	0.14	0.01	0.003	0.009	4.6
BHO6	0.003	0.01	0.008	0.026	0.009	0.017	3.167
BHO7	0.002	0.026	0.007	0.016	0.004	0.023	TNTC
WO1	0.001	0.029	0.02	0.009	0.005	0.005	TNTC
Leachate	0.025	0.049					33.3
NSDWQ 0.05 1 0.30 0.20 0.01 3.00 10							
-2007							
WHO 0.05 2 0.30 0.05 0.01 15 NA							
-2017							

Table 7: Mean values for heavy metals for Bariga Dumpsite.

	Chromium (Cr)	Copper (Cu)	Iron	Manganese (Mn)	Lead	Zinc
	(mg/L)	(mg/L)	(Fe)	(mg/L)	(Pb)	(Zn)
			(mg/L)		(mg/L)	(mg/L)
BHB1	0.0017	0.010667	0.208333	0.088667	0.003333	0.258667
BHB2	0.003	0.023	0.057	0.015	0.002	0.001
BHB3	0.000667	0.008333	0.248	0.094	0.001667	0.135333
BHB4	0.005	0.016	0.401	0.065	0.008	0.012
BHB5	0.002	0.024	0.190667	0.021	0.004667	0.003667
WB	0.00425	0.007	0.09625	0.05775	0.0165	0.029
NSDWQ	0.05	1	0.3	0.2	0.01	3
WHO	0.05	2	0.3	0.05	0.01	15

Table 8: Analysis of Variance for Heavy Metals in Ojota and Bariga Sample sites.

Source of Variation	SS	Df	MS	F	P-value	F crit
Sample	0.007735	1	0.007735	9.564795	0.009315	4.747225
Heavy Metals	0.022493	5	0.004499	5.563031	0.007027	3.105875
Interaction	0.012925	5	0.002585	3.196605	0.045982	3.105875
Within	0.009704	12	0.000809			
Total	0.052857	23				

Leachate sample for Ojota are higher in values above the permissible limit of 1000 and 500 (NSDWQ and WHO) respectively according to table 4.This shows a level of contamination in the groundwater quality and also supports the work done by Longe and Enekwechi that showed that elevated concentrations of contaminants were detected predominantly in the down gradient locations but followed no specific migration or attenuation patterns [10]. It was deduced that soil stratigraphy beneath the landfill site signicantly contributes to the concentrations of the contaminants present in the groundwater. Table 6 shows a reasonable presence of E-coli contained in the leachate.

Comparison between Ojota and Bariga dumpsites

The mean value of the physiochemical properties for Bariga site shows higher levels of the pH, EC, TDS and Chloride in both the well and borehole samples which indicates a level of water contamination compared as discussed earlier in text.

The MONOVA in Table 9 carried out signifies the significant variations in the physiochemical properties of both dumpsites showing of a 50% value for Bariga higher than that of Ojota of 38% value which further justifies the descriptive analysis carried out above. The one-way ANOVA was carried out as a post hoc test which shows significant statistical difference in the mean concentrations of the physico-chemical properties as shown in Tables 4 and 5.

Table 9: MANOVA Results of Physiochemical Properties for Bariga and Ojota Dumpsites.

Dumpsite	Partial Eta Square	P-value
Bariga	0.5	<.001
Ojota	0.38	<.001

For heavy metals, Iron (Fe) and Zinc (Zn) are higher in concentration in the Bariga dumpsite than that of Ojota according to Figure 9.

The Tables 10 and 11, shows the analysis of variance, as a post hoc test on the MANOVA to test which of the location shows significant difference. This shows the different variations in their mean and implies that the mean of the two dumpsites are about the same, hereby indicating that the distribution of sampling locations across the two sites is comparable.

The Linear Discriminant for the sample sites were further carried

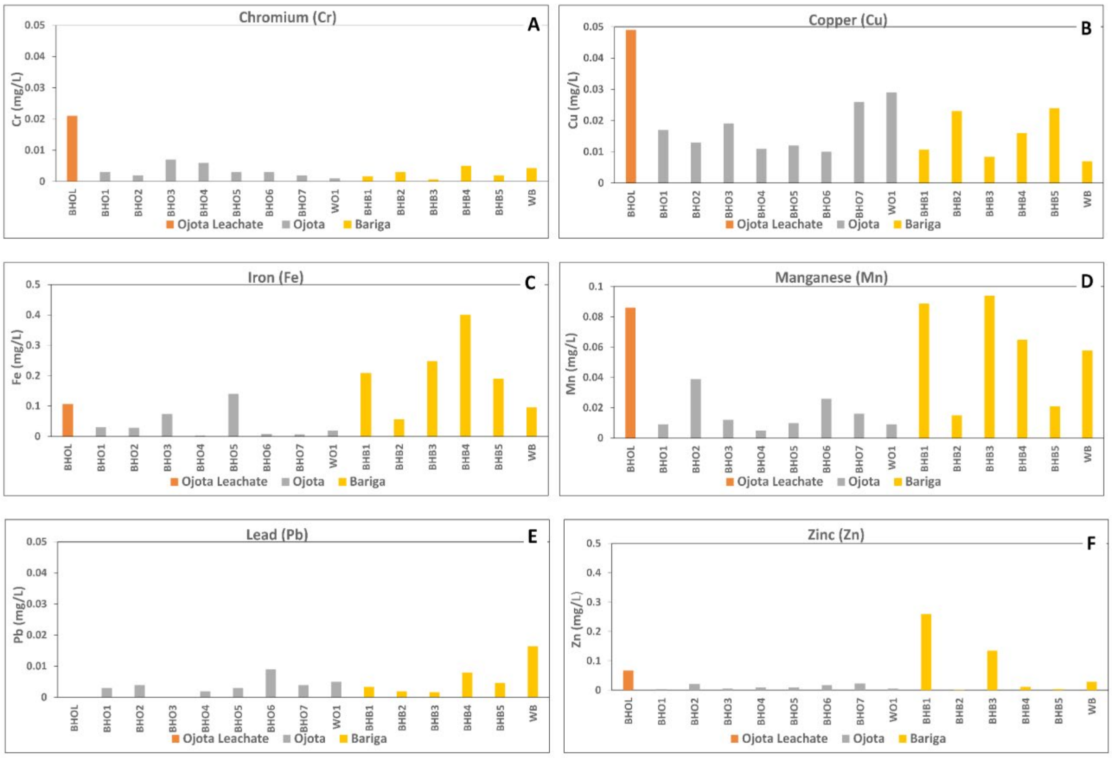

Figure 10: Showing the comparison of Heavy Metals for both dumpsites.

Table 10: Analysis of Variance (ANOVA) Test of Physiochemical Properties for Bariga Dumpsite.

Physiochemical Properties	F value	P-value	Inference
pH	2.4425	0.04922	Significant
Electric Conductivity	6.349	<.001	Significant
Salinity	1.5223	0.2061	Not Significant
TDS	178.86	<.001	Significant
Cal_ Hardness	5.5968	<.001	Significant
Total Hardness	27.495	<.001	Significant
Chloride	704.85	<.001	Significant
Alkalinity	10.477	<.001	Significant
Acidity	6.4617	<.001	Significant

out to test which of the site location shows the highest significant difference. The higher values of 0.9707 and 0.7936 of both dumpsites according to table 6 shows level of contamination around those areas not too far from the dumpsites (Tables 7,8).

Statistical analysis for physiochemical parameters

Heavy metal and microbial analysis

Table 9 shows the result of the multivariate analysis of variance tests for Bariga and Ojota dumpsites in Lagos state Nigeria collected randomly from six locations for Bariga dumpsite and nine locations for Ojota dumpsite. From the result, it is seen that both Bariga dumpsite and Ojota dumpsite had significant variations in the physiochemical properties of the water samples collected from these sites at 5% level of significance with a P-value less than .001. To know which of the physiochemical properties of the water samples were significant, analysis of variance (ANOVA) tests was conducted as a post-hoc for each of the physiochemical properties. The result is seen below (Figure 10).

Table 11: Analysis of Variance (ANOVA) Test of Physiochemical Properties for Ojota Dumpsite.

Physiochemical Properties	F value	P-value	Inference
pH	8.4967	<.001	Significant
Temperature (0C)	269.96	<.001	Significant
Electric Conductivity	7.5037	<.001	Significant
Us/mg			
Salinity (ppt)	3.7747	<.001	Significant
TDS (mg/L)	7.1629	<.001	Significant
Cal_ Hardness (mg/L)	5.43	<.001	Significant
Total Hardness (mg/L)	8.5197	<.001	Significant
Chloride (mg/L)	73.241	<.001	Significant
Alkalinity (mg/L)	6.4532	<.001	Significant
Acidity (mg/L)	9.7083	<.001	Significant

The analysis of variance test for Bariga dumpsite in table 10 shows that all physiochemical properties except Salinity were significant at 5% level of significance. This means that there were significant variations in the mean values of the physiochemical properties based on the various samples collected on these locations.

The analysis of variance test for Ojota dumpsite in table 11 shows that all physiochemical properties were significant at 5% level of significance. This means that there were significant variations in the mean values of the physiochemical properties based on the various samples collected from these locations.

Since the physiochemical properties were significant, it is important to know which of samples collected at various areas in these locations had significant variation.

A linear discriminant analysis was further conducted to see the variations in these areas where those samples were collected.

Post-hoc test for the dumpsites

Linear discriminant analysis (LDA) and the related Fisher's linear discriminant are methods used in statistics, pattern recognition and machine learning to find a linear combination of features, which characterizes or separates two or more classes of objects or events. The resulting combination may be used as a linear classifier or, more commonly, for dimensionality reduction before later classification. Since the LDA can characterize between two or more groups, it is employed in this article as a post-hoc test for the MANOVA test. The proportion of trace value is the percentage separation achieved by each discriminant function. The proportion of trace value is seen in the table.

Conclusion

Ground water sources are under increasing threat from various contaminants resulting from the indiscriminate solid waste disposal; wastewater discharge and possibly storm water run-off potentially deteriorate drinking water quality, which invariably threatens the global gains made to improve access to drinking water. The level of physico-chemical parameters in groundwater samples around Ojota dumpsite shows no significant deviation from the standards (WHO and NSDWQ) except the EC (4712.4 u S/mg) and TDS (4376.4 mg/L) in the Leachate sample for Ojota which are found to be higher in values as against the standards.

However, some levels of concentration of the physico-chemical parameters for Bariga dumpsite were found to be higher than that of Ojota especially in the EC, TDS, and Salinity and Chloride parameters. The nature (not controlled), volume of the solid waste deposited and the area being close to a lagoon could be some of the factors responsible for that observation.

The high level of chloride in groundwater quality suggest pollution from sewage sources. This also increases the potential corrosively of the water, and affects infrastructure, drinking water quality and invariably affects mortality and aquatic plants and animals because of acidification of streams around the area. However, for Ojota dumpsite, the level of chloride may suggests that there is the possibility of a level of control measure that is adopted being an authorized (controlled) dumpsite as compared to Bariga dumpsite being unauthorized (uncontrolled).

The pH analyzed in the ground water samples from the study areas shows slightly acidic concentrations in nature. This might be attributed to high population density and commercialization in those areas. Another form of groundwater contamination can be drawn from the heavy metals (Fe and Zn) in Bariga dumpsite.

From this study, it is evident that lack of well-constructed engineered environmental friendly landfills and indiscriminate dumping of wastes to water channels can possibly lead to high contamination of the groundwater quality, posing a serious threat to the human health and the environment at large. It therefore requires collective efforts between the community residents to avoid indiscriminate dumping of waste and the government ensuring that proper waste management and monitoring is put in place especially in areas where these landfills are currently situated.

Acknowledgement

We wish to thank the UKRI through ARUA Water Centre of Excellence for providing supports to this study; we quite appreciate our undergraduate students Mayowa Adenekan, David Akanmu and David Jefferson for data collection and stakeholders' engagement.

Declaration of Interest Statement

The authors reported no potential conflict of interest.

References

1. Adeyi AA, Majolagbe AO (2014) Assessment of Groundwater Quality around two major Active Dumpsites in Lagos, Nigeria. GJSFR14.
2. Ogbaran N, Uguru H (2021) Assessment of Groundwater Quality Around an Active Dumpsite using Pollution Index. Civ Eng Res J 11: 555814.
3. Longe EO, Balogun MR (2010) Groundwater Quality Assessment near a Municipal Land_ll, Lagos, Nigeria. Res J Appl Sci Eng Tech 2: 39-44.
4. Osibanjo O, Majolagbe AO (2012) physicochemical quality assessment of groundwater based on land use in Lagos city, southwest, Nigeria. Chem J 2: 79-86.
5. Oyeku OT, Eludoyin AO (2010) Heavy metal contamination of groundwater resources in a Nigerian urban settlement. Afr J Environ Sci Technol 4: 201-214.
6. Arukwe A, Eggen T, Möder M (2012) Solid Waste Deposits as a Significant Source of Contaminants of Emerging Concern to the Aquatic and Terrestrial Environments-A Developing Country Case Study from Owerri, Nigeria. Sci Total Environ 438: 94-102.
7. Ikem A, Osibanjo O, Sridhar M, Sobande A (2002) Evaluation of Groundwater Quality Characteristics near Two Waste Sites in Ibadan and Lagos, Nigeria. Wat Air & Soil Poll 140: 307-333.
8. Balogun-Adeleye RM, Longe EO, Aiyesimoju KO (2019) Environmental assessment of municipal solid waste (MSW) disposal options: A case study of Olushosun landfill, Lagos State. IOP Conf Ser: Mater Sci Eng 640: 012091.
9. Coker J, Alausa SK, Odunaike RK, Alabi AA, Ogunpola AE (2019) The Impact Assessment of Solid waste on Groundwater Quality in Ojota Dumpsite, Lagos, Nigeria.
10. Longe EO, Enekwechi LO (2007) Investigation on potential groundwater impacts and influence of local hydrogeology on natural attenuation of leachate at a municipal landfill. IJEST 4: 133-140.
11. Rapti-Caputo D, Vaccaro C (2006) Geochemical Evidences of Landfill Leachate in Groundwater. Eng Geol 85: 101-121.
12. Liu H, Liang Y, Zhang D, Wang C, Liang HC, et al. (2010) Impact of MSW landfill on the environmental contamination of phthalate esters. Waste Manag 30: 1569-1576.
13. Han DM, Tong XX, Currell MJ, Cao G, Jin M, Tong C (2014) Evaluation of the impact of an uncontrolled landfill on surrounding groundwater quality, Zhoukou, China. J Geochem Explor 136: 24 -39.
14. Ameloko AA, Ayolabi EA (2018) Geophysical assessment for vertical leachate migration profile and physicochemical study of groundwater around the Ojota dumpsite Lagos, south-west Nigeria. Appl Water Sci **8:** 142.
15. Palmer T, Akanmu J, Alamirew T, Bamutaze Y, Banadda N, et al. (2020) The Adaptive Systemic Approach: research that enables just and sustainable natural resources development.
16. Ige OO, Adewoye FO, Obasaju DO (2021) Hydrochemical evaluation of groundwater quality - a case study from parts of North-Central, Nigeria. SWAM 7: 101.
17. Shiru MS, Shahid, D, Shiru S, Chung ES, Alias N, et al. (2020) Challenges in water resources of Lagos mega city of Nigeria in the context of climate change. J Water Clim Chang11: 1067-1083.
18. Longe EO (2011) Groundwater Resources Potential in the Coastal Plain Sands Aquifers, Lagos, Nigeria. EESRJ 3: 1-7.
19. Yusuf MA, Abiye TA, Ibrahim KO, Ojulari BA (2021) Assessment of saltwater–freshwater interactions using water samples and borehole logging information in the Lagos coastal region, Nigeria. Environ Earth Sci 80: 679.
20. Ayolabi EA, Folorunso AF, Obende PW (2010) Integrated Assessments of Possible Effects of Hydrocarbon and Saltwater Intrusion on the Groundwater of Iganmu Area of Lagos Metropolis, Southwestern Nigeria. ESRJ 14: 45-97.
21. Jones HA, Hockey RD (1964) The Geology of Part of Southwestern Nigeria. Bull US Geol Surv 31: 1-101.
22. Longe EO, Malomo S, Olorunniwo MA (1987) Hydrogeology of Lagos metropolis. J Afr Earth Sci 6: 163-174.

23. Popoola LT, Yusuf AS, Aderibigbe TA (2019) Assessment of natural groundwater physico-chemical properties in major industrial and residential locations of Lagos metropolis. Appl Water Sci 9: 191.

24. Kayode Oyedele K, Momoh (2009) Evaluation of Seawater intrusion in freshwater aquifers in a Lagoon Coast: a case study of the University of Lagos Lagoon, Akoka, Nigeria.