Land-use and its implication on physicochemical parameters of groundwater: Evidence from Ikenne Local Government Area, Ogun State

[1*]Akinpelu O.P. & [2]Adewunmi A.A
[1]Department of Urban and Planning, Bells University of Technology, Ota, Nigeria,
[2]Gateway (ICT) Polytechnic Saapade, Remo North, Ogun State
*Corresponding author: olusegun_akinpelu@yahoo.com

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Groundwater is essentially the major source of fresh water and used widely for drinking purpose. In any given area, groundwater within an aquifer, or groundwater produced by a well, has some vulnerability to contamination from human activities. Therefore, information on human activities that leads to contamination of groundwater is important. Such information can aid in the choice of proper locations for certain activities, so that the adverse effects on groundwater are minimized and protection of groundwater achieved. Against this background, the study examines land-use and its implications on physiochemical properties of groundwater in Ikenne Local Government Area, Ogun State, Nigeria. The study obtains and analyses the existing land-use maps. Water samples were collected for laboratory test to benchmark physicochemical parameters based on World Health Organisation standards. Water Quality Index (WQI) was used to determine groundwater quality. Findings from analyses of land-use map show that residential land-use has highest percentage in Iperu (79.9%) and Ilishan (52.8%) towns, while industrial land-use constitutes the least, representing for 0.6% and 1.9% in Iperu and Ilishan respectively. The study found that WQI for Ilishan I (39.4), II (33.5), III (43.8) and Iperu I (32.9), II (31.4) was of good quality, while Iperu III (19.4) was excellent. ANOVA results of $F = 0.596$ and $p > 0.05$ established that there is no statistical significant variation in the physiochemical properties of groundwater. It can be concluded that absence of land-uses that generate contaminants reduce the likelihood of groundwater contamination. Therefore, strategies for effective implementation of zoning regulations should be put in place by relevant government agency.
Key words: Groundwater, landuse, parameter, physiochemical**,** water quality index (WQI)

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INTRODUCTION

Groundwater is a form of water occupying all voids within a geological stratum (Todd, 1980). It is estimated that groundwater represents about 30.1% of the global fresh water. Thus, it is one of the main sources of fresh water available for man's use. It is widely used for drinking and other domestic purposes. Generally, groundwater reservoirs are exploited to meet an increasing need of water for city dwellers, irrigation and industrial development. Therefore, in order to maintain an adequate supply of healthy and clean drinking water, the 30.1% groundwater resources must be carefully developed and managed (Ocheri *et al*., 2014). Groundwater sources can either be borehole or well. However, borehole is more reliable for human consumption compared to well (Okelola *et al.*, 2010). Groundwater can pose serious danger to public health if contaminated. Effects of contaminated groundwater or lack of access to quality water has been focus of many studies.

Fallahzadeh *et al***. (**2017) observed that contaminants from industrial, domestic, and agricultural wastewater discharge as well as leachate from waste and surface runoff have led to contamination of groundwater resources and have reduced their quality. It is documented that globally water-borne diseases kill more than 25,000 people per day and about 5,000 children die daily due to water related diseases (mainly diarrhoea) and as such, it represents leading cause of death mostly in developing nations (Davis, 2013). Contaminated water not only has the potential to pose immediate threat to human, but also affect an individual productive rate (Mpenyana-Monyatsi & Momba, 2012). Over 66 million Nigerians in the cities and rural areas lack access to drinking water of good quality. This has resulted to an increase in consumption of contaminated or polluted water (WHO, 2012; Ologbushere *et al*., 2016; Beshiru *et al*., 2018) with potential detrimental to public health effects. Studies investigating the spatial and seasonal variability of water quality have reported that water quality issues, such as eutrophication, are highly dependent on land-use pattern (Bridget & Reedy, 2005). Other studies have also identified the pollution sources and anthropogenic activities on spatio-temporal variations in water quality (Gambhir *et al.*, 2012).

Previous studies (Bello-Osagie & Omoruyi, 2012; Kwadzah & Iorhemen, 2015; Alabi, *et al.*, 2016; Alabi, *et al.*, 2017) have observed that indiscriminate location of land-uses that are potential sources of contamination to groundwater. The land-uses include abattoir, industry, agriculture and cemetery. It has also been established that effluents from industries such as pharmaceutical

(Bakare *et al.*, 2011); hospital (Iyekhoetin *et al.*, 2011), tobacco (Alabi *et al.*, 2016) and automobile (Alabi *et al.*, 2016) contained heavy metals and other chemical constituents in high concentrations that can contaminate groundwater, with harmful effects on public health. Against this backdrop, the study examines existing land-uses and its implications on the physiochemical properties of groundwater in the study area.

LITERATURE REVIEW

Water is an important environmental component which is an essential ingredient for sustainability and survival of living creatures on earth. Webster dictionary (2016) defines water as a transparent, tasteless, odourless, and nearly colourless chemical substance, which are the main constituent of earth's hydrosphere and the fluids of most living organisms. Its chemical formula is H_2O meaning that each of its molecules contains one oxygen and two hydrogen atoms. Water covers about 70 per cent of the earth's surface and in nature exists in liquid, solid and gaseous states. Water can be used for recreation, drinking, fisheries, agriculture or industry.

There are two major categories of water which are surface water and groundwater. On the one hand, surface water is water that is located on top of the earth's surface, the vast of which is produced by precipitation and run-off from high areas. This includes lakes, streams, rivers, creeks and reservoirs which are used for irrigation, livestock, hydropower, industrial uses and recreation. Moreover, there are three major types of surface water: permanent surface water (e.g. lakes, rivers and wetlands); semi-permanent- present at certain times of the year (for examples; lagoons, creeks and waterholes) and man-made surface water (for examples; canal, damned artificial lakes and ponds). On the other hand, groundwater is fresh water that soaks into the soil and is stored in tiny pores (spaces) between rocks and particles of soil. It comes to the surface as springs or be pumped from a well and could be found in two zones: saturated zones and unsaturated zones – this is where pores and rock fractures are filled with water and the top of this zone is called the water table.

While Hill (2004) stated that more than one quarter of the world population depends on groundwater for drinking and other basic needs, Henry and Heinke (2005) corroborated that groundwater is naturally replenished by surface water from precipitation, streams and rivers and generally not as susceptible to pollution as surface water; but once polluted it is difficult to restore back to its pristine state. Groundwater is generally abstracted as well water (open surface drilling) or as borehole (drilling with pipe). It provides a reasonably constant supply for domestic use, livestock and irrigation, which is not likely to dry up under natural conditions thereby buffering the effects of rainfall variability across seasons (Calow *et al.*, 2011; David, 2011). Consequently, it is considered as one of the purest forms of water available in nature as it meets the overall demand for people (Tyagi *et al.*, 2013).

It is documented in literature that there is association between land-use and physicochemical properties of groundwater. Tu (2011) noted that impact of land uses on water quality involves association of land use and water quality indicators. Researchers have shown that there are significant correlations between land use and water quality parameters (Buck *et al.*, 2004; Li *et al.*, 2008). Razali *et al.* (2018) reviewed case studies of land use change in highland areas and its impact on river water quality, and their study was limited to the river system network in the Cameron Highlands in Malaysia. However, current study examined the impact of land-uses on groundwater quality.

Chemicals are among the major groundwater contaminants affecting its quality. This is possible through vertical migration of chemical contaminants to the aquifer and extending to the borehole, or by horizontal migration through permeable soils to water supplies that are poorly constructed (Calow *et al*, 2011). Examples of heavy metals and organics which are major chemical contaminants of drinking water sources and potential threat to public health include polyaromatic hydrocarbon (PAH), polychlorinated biphenyls (PCB), polybrominated diphenyl ethers (PBDE) and among others. In Nigeria, abattoirs are located indiscriminately and usually near water sources since the process require a lot of water and for ease of disposal of wastes (Omoruyi, *et al.*, 2011). The impact of the abattoir effluents has been reported to markedly increase the amounts of nitrogen, phosphorus and total solids in contiguous water bodies (Bello-Osagie & Omoruyi, 2012). The high biochemical oxygen demand (BOD), nutrients and pathogen content in abattoir waste poses pollution risk to water bodies (Keskes *et al.*, 2012).

Effluents from the industries mostly contain heavy metals, hydrocarbons, and atmospheric deposition (Alam *et al.*, 2007). Findings established that industrial effluents when loaded with heavy metals and harmful microbes can be hazardous when it gets into the food chain through the soil and water bodies and can affect plants, animals and humans adversely (Deshmukh *et al.*, 2011; Bai *et al.*, 2012). Interestingly, many of these industrial effluents are not treated before being discharged into water bodies. This action consequently contaminates the receiving ground waters.

Wastewaters from most industries in Nigeria are disposed into water bodies (Kwadzah & Iorhemen, 2015). The following reports have shown that effluents from pharmaceutical industry (Bakare *et al.*, 2009; Bakare *et al.*, 2011), hospitals (Iyekhoetin *et al.*, 2011), universities (Alabi *et al.*, 2012), tobacco industry (Alabi *et al.*, 2016), automobile workshops (Alabi, *et al*, 2016) and cocoa industry (Alabi *et al.*, 2017) contained heavy metals and other chemical constituents in high concentrations capable of contaminating drinking water sources and lead to public health detrimental effects.

Moreover, analysing quality of water requires some form of calculations. Also, there are different methods of achieving this objective. However, weighted arithmetic water quality index will be adopted in this study. This method is adopted when most common quality variables are measured. The parameters or variables were analysed in the laboratory as per the standard procedures of American Public Health Association (1995). In order to calculate water quality index, the following equation were used:

First step: This is to calculate quality rating (Qn):

Quality rating (Qn) = $100 \times \frac{(Vn - Vi)}{(Vs - Vi)}$

Where,

Vn = actual value of particular parameter in water sample

Vi = ideal value of parameter (0 for all parameters except pH 7 Milligram per liter)

VS= standard value for the parameter

Second step: This is to find unit weight (Wn) of each parameter: Wn=K/ Vs

Where = $\frac{1}{1/vs\ 1 + 1/vs\ 2 + \ldots .1/vsn}$

Step3: To calculate water quality index (WQI):

WQI= $\frac{\Sigma QnWn}{\Sigma Wn}$

Where Qn is quality rating

Wn is relative weight

Table 1: Water quality index and Status of water quality

Water Quality Index Range	Water Quality status	Classification
0 – 25	Excellent quality	A
26 – 50	Good quality	B
51 – 75	Poor quality	C
76 – 100	Very poor quality	D
>100	Unsuitable for drinking	E

Source: International Journal of Engineering Research and Technology (Abhijeet, 2022)

MATERIALS AND METHODS

Ikenne is geographically located on Latitude $6^0 51'57''$N or 6.8658^0 and Latitude $3^0 42'55''$E or 3.7152^0 (Fig. 1, 2, 3). Ikenne Local Government Area (LGA) has its headquarter seated in Ikenne with about 144 square kilometre in size.

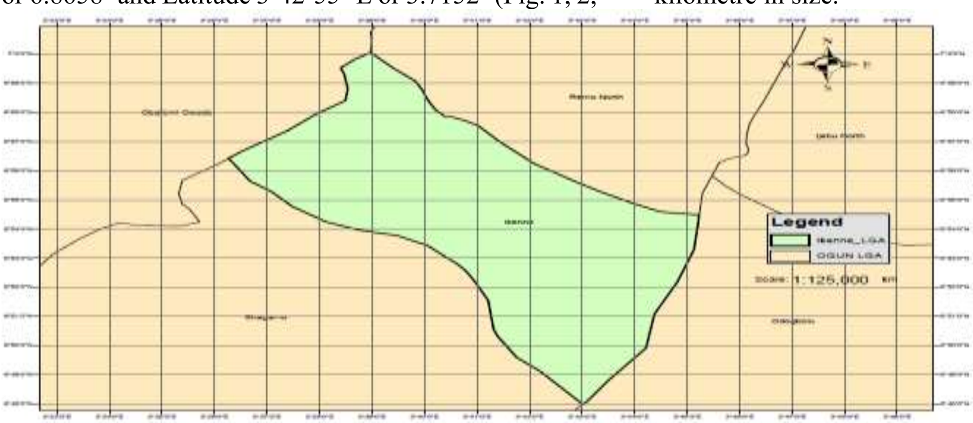

Figure 1: Map of Ikenne Local Government Area
Source: Department of Surveying and Geo-informatics, 2022

It is bounded in the west by Obafemi-Owode LGA, on the south by Sagamu LGA, while on the east and north by Odogbolu LGA. Being sub-urban, it comprises of four (4) major towns which are Iperu, Ilishan/Irolu, Ogere, and Ikenne. The local government is located along the transitional forest zone of southern Nigeria and Guinea savannah.

Primary data such as land-use and physiochemical parameters of groundwater were obtained for the study. Information on land-use was collected through land-use map of the area, while data on physicochemical properties were obtained through water sample from groundwater. Out of four major towns, two (Iperu and Illishan) were purposively selected. This is because of their size and proximity to each other that gives room for logical comparison. The two towns selected consist of three wards each, making six wards altogether. Land-use map of the two towns were used to analyse different uses to which land is put. Six water samples were collected from each of the ward, with priority on groundwater at the centre. This is based on the assumption that centrally located groundwater shares properties of surrounding groundwater. Groundwater samples collected were analysed through laboratory test, while water quality index (WQI) was arrived at by summation of relative weight, multiply by water quality rating and divided by relative weight.

RESULTS AND DISCUSSION

Under this section, findings on analysis of land-uses and physiochemical properties of groundwater through the use of Water Quality Index (WQI) are discussed.

Land-use Analysis

The analysis of land-uses in the study area becomes imperative, if objective conclusion pertaining to groundwater quality of the area under study will be made. This is because, studies have established that types of land-use within an area do have impact on the quality of groundwater in such community (Keskes, *et al*., 2012; Alabi, *et al*., 2016; Alabi, *et al*., 2017). The analysis was done based on the two communities that were selected from the study area; namely Iperu and Ilishan towns.

As shown in Figure 2, findings on land-use analysis of Iperu town show that residential constitute highest percentage. Residential land-use alone covers 692.24 hectares, representing 78.87% of the total land area in the town. In order of magnitude, open spaces ranked second. It has a total area of 56.04 hectares (7.50%). This consists of both organised and un-organised spaces. Public land-use is the third in position in terms of size after open spaces.

It covers a total area of 44.42 hectares, accounting for 5.13%. Public land-use comprises churches, mosques, cemetery, civic centres, water corporation office, police training centre, theological seminary and motor parks. Circulation land-use ranked fourth. The total space for different categories of road in the area summed up to 35.96 hectares, representing 4.14%. The total land area for institutional land-use is 19.87 hectares (2.29%). Land-use categories under the institutional land-use are schools, including nursery, primary, secondary and/or higher institution. Other land-uses with significant percentage are industrial and commercial. The respective hectares of each of these land-uses are 5.00 and 4.14, with percentage contributions of 0.58 and 0.48.

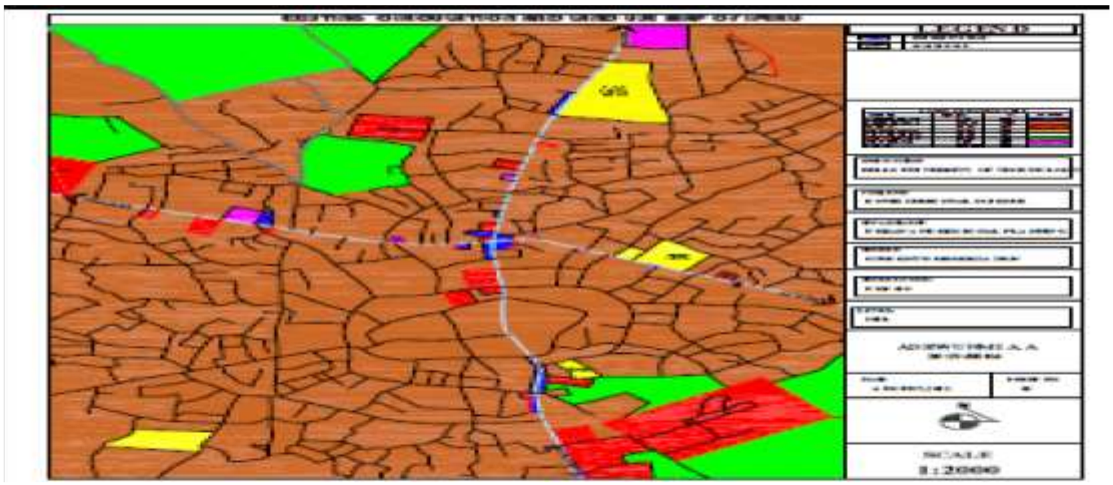

Figure 2: Land-use Map of Iperu Town

Figure 3 represents the findings on land-use analysis of Ilishan town. As shown in the figure the major land-use is residential (1,053.16 hectares), constituting 52.82% of the total land area. area. Open spaces ranked second. It covers an area of 666.96 hectares, representing 33.45%. Institutional land-use covers the total area of 214.22 hectares. It accounts for 10.74%. The next in rank is circulation land-use. It has a total land area of 38.23 hectares, constituting 1.92%. The town also has a number of public land-use. It covers a total of 10.22 hectares. This accounts for 0.51%. Commercial use occupies a space of 9.33 hectares, with proportion of 0.42%, which makes it second to the last in terms of total land area. The least land-use is industrial occupying an area of 1.93 hectares. It has a percentage of 0.10% of the total land area. The analyses of land-uses from the two towns do not show much variation in terms of land-uses. Residential land-use was predominant in the two towns. This might have significant impact on the quantity of contaminants generate and quality of groundwater in the area.

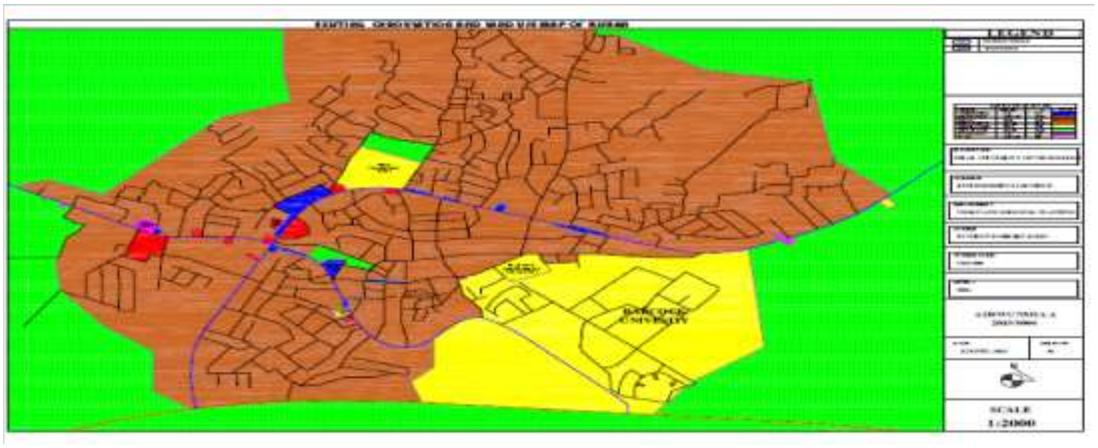

Figure 3: Land-use Map of Ilishan Town, 2022

Analysis of Physiochemical Parameters of Groundwater

Both physical and chemical parameters of water samples collected were subjected to laboratory test as depicted in Table 2. Important physical parameters that were tested included Total dissolved solids (TDS), temperature, turbidity, Electrical conductivity (EC), and pH of water. While important chemical parameters which were tested included Dissolved Oxygen (DO), chloride, sulphate, magnesium, calcium, hardness, Biochemical Oxygen Demand (BOD), Feacal coli form, Total Suspended Solids (TSS) and nitrate. The results were then harmonized and discussed with World Health Organization standards. It was found that groundwater pH in the study area ranges from 5.0 – 6.5. According to WHO standards pH should be between 6.5 and 8.5. The groundwater pH in Iperu ward I, II and III are 5.32, 5.3 and 5.0 respectively. In Illishan ward I, II and III the respective pH was 6.0, 5.62 and 6.5.

Turbidity is the measure of relative clarity of a liquid Though WHO gave no guideline for turbidity of drinking water quality however, maximum permitted according to Standard Organization of Nigeria (SON) (NSDWQ, 2007) is 5 NTU. Hence, water samples in Iperu wards and Ilisan wards are all within permissible limit. WHO standards the permissible range of magnesium in water should be 150 mg/l. In study area, magnesium values in Iperu wards range from 1.08 – 3.89mg/l and it ranged from 1.19 – 5.48mg/l in Ilisan wards. The values of it still fall within the prescribed standard limit. The quantity is significantly low in all the six wards. The values show a low concentration which could affect health of residents as it is essential for human body. The WHO (2017) allows maximum permissible limit of nitrate in drinking water is 50 mg/l. The results of the water samples in Iperu and Ilisan wards are 2.98, 5.01, 4.98, 3.06, 4.32 and 2.46mg/l. These outcomes indicate that the quantity of nitrate in study locations is acceptable.

The results of dissolved oxygen (OD) are in the range 6.2 – 7.6mg/l as shown in Table 2. This showed that the values obtained from the study areas exceeded the WHO standard limit of 5mg/l. This can be due to the infiltration of oxygen demanding waste. The value of biological oxygen demand (BOD) obtained shows that Iperu and Ilisan wards range from 2.28-3.17mg/l and 2.55-3.5mg/l respectively. According to WHO (2017) standards, its allowable range of calcium in drinking water is 150 mg/l. In study areas, results show that the concentration of calcium in Iperu wards range from 9.37- 19.03 mg/l whereas in Ilisan wards, the range is between 9.55 – 25.25mg/l. Hence, all values are within the acceptable standard limit. The values for total suspended solids (TSS) ranged from 6.66 – 15.55mg/l in Iperu and 7.15 – 12.79mg/l in Ilisan wards. The WHO (2017) maximum allowable limit of total solids in drinking water is 500 mg/l. The results indicated that the values are below the WHO recommended values which means that the sampled groundwater are free from suspended solids.

The temperatures of the sampled water vary from 25.2 to 25.7 Celsius. The temperature range falls within the recommended standard of WHO (2017). According to WHO standards concentration of chloride should not exceed 250 mg/l. In Iperu, chloride value ranges from 18.99-39.72 mg/l, while in Ilisan, the value ranges from 20.11 – 35.13mg/l. Thus, all the samples have lower concentration of chloride. The WHO has established 250 mg/l as the highest desirable limit of sulphate in drinking water. In study areas, values of sulphate in Iperu range from 44.29 – 56.33mg/l and Ilisan range from 44.89 – 60.78mg/l. The results show that concentration of sulphate in the study localities are below the maximum standard limit which makes the water suitable for domestic uses. With reference to World Health Organization (WHO, 2017) hardness of water should be 300 mg/l. The hardness values obtained in the study areas range between 11.89 – 38.45mg/l. It means the areas had lower values of total hardness within the permissible limit by WHO standards. It is not harmful and does not require treatment with chlorine to remove hardness of water.

From the results in Table 2, total dissolved solids (TDS) of water sampled in Iperu ranges from 20.3 – 90.1mg/l and that of Ilisan ranges from 14.4 – 72.6mg/l. Hence, the TDS values were far negligible compared to the maximum standard level of 500mg/l and concentration of TDS is not harmful. WHO standards limit, established that electrical conductivity (EC) value should not exceeded 300 μS/cm. EC values in Iperu ward I II and III were 31.3, 135.4 and 92.8 μS/cm, respectively. While in Ilisan wards I, II and III the respective EC values were 22.2, 109.9 99.8 μS/cm. Hence, the values obtained were lower than the standard limit. The microbiological analyses of the water indicate that faecal coliform microbial loads were not found in all the groundwater sampled. This indicates minimal level of microbial load in all the groundwater which makes the water suitable for drinking purpose.

Table 2: Laboratory Analysis of Physio-chemical Parameters of Groundwater

Wards	pH 6.5-8.5	Temp.0 C 24-30	Turb. NTU 5	Conductivity 300 µS/cm	Chloride 250 mg/L	Total hardness 300 mg/L	SO_4 250 mg/L	NO3 50 mg/L	TDS 500 mg/L	E.Coli cfu/ML	Mg^{2+} 150 Mg/L	Ca 150 Mg/L	TSS 500 mg/L	DO 5	BOD - 50
Iperu ward I	5.32	25.5	2.78	31.3	18.99	11.89	56.33	2.98	20.3	0	1.08	9.37	8.59	6.7	3.17
Iperu ward II	5.3	25.2	4.63	135.4	45.24	20.01	44.29	5.01	90.1	0	3.89	13.83	15.55	7.0	2.94
Iperu ward III	5.0	25.3	2.41	92.8	39.72	25.32	55.79	4.98	60.5	0	3.44	19.03	6.66	7.6	2.28
Ilishan ward I	6	25.5	2.04	22.2	35.13	12.22	60.78	3.06	14.4	0	1.19	9.55	7.15	6.4	3.25
Ilishan ward II	5.62	25.4	2.78	109.9	29.22	38.45	44.89	4.32	72.6	0	5.48	27.73	8.65	7.2	2.55
Ilishan ward III	6.5	25.7	3.15	99.8	20.11	34.95	51.55	2.46	64.6	0	3.86	25.25	12.79	6.2	3.5

Information from Table 3 indicates Water Quality Index (WQI) for each of the ward sampled. The WQI for Iperu I, II and III are 32.9, 33.5 and 19.4 respectively. Furthermore, the respective WQI for Illishan I, II and III are 39.4, 31.4 and 43.8. as recommended by American Public Health Association (1995) as shown in Table 1, the WQI of sample of groundwater from Iperu I, II and; Illishan I, II and III was found to be of good quality (Category B). It was only in Iperu III where WQI was found to be excellent (Category A). This is in agreement with the finding of Okelola, *et al*., (2010), in which they established that water from borehole is more reliable. The results of ANOVA of F = 0.596 and p > 0.05 established that there is no statistical significant variation in the physiochemical properties of groundwater in the surveyed wards. The findings might be attributed to two major factors. One is the fact that most of the residents' source of groundwater is borehole, which is deep enough to be contaminated by human activities. The other is that most of land-uses in the studied towns might not have by-products that will have significant negative impact on land that might lead to contamination of groundwater. It is clear from the study that groundwater; especially borehole might not be easily contaminated by anthropogenic activities of man, unlike surface water. Previous studies (Kwadzah & Iorhemen, 2015, Alabi *et al*., 2017) corroborate this assertion.

Table 3: Estimation of Water Quality Index (WQI)

Parameter	Iperu ward I	Iperu ward II	Iperu ward III	Ilisan ward I	Ilisan ward II	Ilisan-Irolu ward III	Relative weight (Wn)
pH	-24	-24.3	-28.6	-12.5	-19.2	-7.2	0.1429
Temperature	2.78	2.74	2.75	2.78	2.76	2.80	0.0333
Turbidity	11.12	18.52	9.64	8.16	11.12	12.6	0.2000
Conductivity	0.034	0.149	0.102	0.024	0.121	0.110	0.0033
Chloride	0.030	0.072	0.064	0.056	0.047	0.032	0.0040
Total Hardness	0.013	0.022	0.028	0.013	0.042	0.039	0.0033
Sulphate	0.090	0.071	0.089	0.097	0.072	0.083	0.0040
Nitrate	0.119	0.200	0.199	0.122	0.173	0.098	0.0200
TDS	8.12	0.036	0.024	5.76	0.029	0.026	0.0020
Magnesium	0.005	0.017	0.015	0.005	0.025	0.017	0.0067
Calcium	0.042	0.062	0.085	0.043	0.124	0.113	0.0067
TSS	0.003	0.006	0.003	0.003	0.004	0.005	0.0020
DO	26.0	28.0	30.4	25.6	28.8	24.8	0.2000
BOD	0.127	0.118	0.091	0.13	0.102	0.14	0.2000
∑WnQn	25.28	25.8	14.9	30.3	24.2	33.7	
∑Wn	0.7688	0.7688	0.7688	0.7688	0.7688	0.7688	
$WQI = \frac{\sum WnQn}{\sum Wn}$	32.9	33.5	19.4	39.4	31.4	43.8	

CONCLUSION

The study has examined land-use and its impacts on physiochemical properties of groundwater in the two major towns in Ikenne LGA. It was found that land-uses in the area do not contribute to contamination of groundwater, especially boreholes. It was also established that there is no significant variation in the physiochemical parameters of groundwater in the sampled wards.

It is therefore, recommended that land-use zoning should be promoted in Nigerian settlements. This will not only enhance considerable improvement in health of the community, but also see to sustainable land-use. It will guide use of land and/or buildings and of the height and density of buildings in specific areas, with the aim of securing convenience, health, safety and general welfare of a community. Since boreholes are less contaminated by human activities, priority should be given to sinking of boreholes by individuals, private and corporate organisations and governments in communities where groundwater is lacking or not adequate.

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