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Urban Well Characteristics and Groundwater Pollution in Ibadan, Nigeria

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Abstract:
In many countries around the world including Nigeria, access to adequate potable water has become a mirage. The supply of pipe-borne water in Nigeria has, over the years, become grossly inadequate or totally non-existent. This has led many people to seek alternative sources of water, especially from hand-dug wells. Most of the hand-dug wells are frequently polluted due to improper location and human anthropogenic activities around the wells. This study was carried out to investigate the physical characteristics of the sampled wells in Ibadan city and their vulnerability to pollutants. A multi-stage sampling technique was used to sample862buildings (4%) of existing buildings (21,391) using wells in six Local Government Areas (LGAs) (Ibadan North, Ibadan North-West, Ibadan South-East, Ido, Egbeda and Ona-Ara) of Ibadan sampled. Microbial analyses were carried out on water samples collected using graph method from 50 wells that were randomly selected in the six LGAs. The study revealed that 97.8% of the wells were shallow; 90.4% were ringed and covered; 91.1% fetched manually from of the wells; 60.1% had no fixed drawer and allowed individuals to bring and use various drawers to fetch water; 8.9% of the wells provided mechanical device to fetch water; 29.9% relied on electricity generator; 41.5% relied on electricity provided by the Power Holding Company of Nigeria (PHCN); while 28.6% relied on both generator and PHCN. About a half (47.8%) of the sampled wells were located down slope to the septic tank; 75.6% were situated at less than 25metres distance to septic facilities. Significant relationship was established between depth of the wells and groundwater pollution with bacterial count ($t=17.230$, $p \leq 0.000$); positive association exist between rings and bacterial count ($t=10.209$, $p \leq 0.000$); coliform count ($t=-6.764$, $p \leq 0.000$) and total suspended solid ($t=-13.023$, $p \leq 0.000$). The use of ring and cover on wells have been proved to be the best for proper hygiene while periodic water quality monitoring and incorporation of household water purification practices with hand-dug well water are recommended.

Keywords: *Well characteristics, groundwater, water quality, pollutants*

1. Introduction

Water is important for human survival, health and socioeconomic development (Akange, 2016). Water is an indispensable resource for the world economy as well as a precondition for human, animal and plant life, as there can be no stability of health and well-being without safe and adequate water supply (Ohwu and Abotutu, 2014). The social-economic life of a man can never be completed in the absence of assured water. Both in urban and rural areas, supply of water to meet increasing water demand is inadequate. Despite the effort of the past and present governments, there is increasing water pollution, especially in urban centres, as a result of diverse activities such as deforestation, improper land uses, indiscriminate waste dump, uncoordinated physical developments and inefficient institutional framework. Agricultural practices in peri-urban areas also often increase run-off that contaminates surface and groundwater.

Rapid population growth in developing countries has brought about increase in human activities and led to the high rate of organic and inorganic wastes generation into the environment (Ogbeibu and Edutie, 2005). Some other activities such as soil fertility remediation, indiscriminate refuse disposal, use of septic tanks, soak-away pits and pit latrines are on the increase and are potential sources of water pollution (Yusuf, 2007). Increase in population and urban physical development have accelerated the rate of human activities that have effects on environmental resources.

Inadequacy of pipe-borne water supplies in urban centres is a growing problem. As a result, people result to digging shallow and deep wells indiscriminately to supplement their daily water needs (Shittu, 2015). Most often, the wells are shallow and are located near sources of pollution and the quality is rather poor (Osibanjo, 1991). In the dry season, most of the shallow wells dry up for almost three months which aggravate water crisis in the affected areas.

Shortage of potable water is even more acute in the northern part of Nigeria. Women and children spend several hours daily in search of water from wells (Ishaku, 2011). In some communities, camels and donkeys are used to draw water from wells that could be as deep as 150 metres. Their problems are further compounded during the dry season as most of these wells dry up(ICRD, 2009). Low access to safe water in Nigeria has been attributed to the enormous socio-economic development, growing industrial base, poor planning, insufficient funding and haphazard implementation(Ayantobo, 2013). Consequently, the inhabitants have resulted into the use of hand-dug wells as major alternative source of water supply. Hand-dug wells also provide cheap and low-technology solution to the challenges of both rural and urban water supply.

2. Statement of Problem

Efficient water supply is very crucial to sustenance of socio-economic growth, poverty attenuation, food and health security. In most urban areas of developing countries including Nigeria, water supplies are not proportionate with demand, leading to a shortfall in water use and many people suffer from this scenario (Obeta and Nwankwo, 2015). Groundwater pollution has been attributed to the process of industrialization and urbanization that has progressively developed over time without any regard for environmental consequences (Longe and Balogun, 2010) which eventually results in the deterioration of physical, chemical and biological properties of water (Isikwe et al., 2011).Majority of urban well are vulnerable to pollution from sources which include domestic, commercial and industrial wastes and increased agricultural use of fertilizers and pesticides(Ofodile,2002). These pollutants may infiltrate into aquifers through seepage and thereby polluting groundwater. In the recent times, nitrate concentration of groundwater resources in most parts of Nigeria has increased due to rise in the construction of soak-away septic tanks in individual houses all over the country (Gbadebo, Oyedepo, and Taiwo, 2010). Also, physical characteristics of wells are vital factors that determine the quality of water in the well. Some wells are not properly constructed, absurdly located and are devoid of essential protective apparatus which encouraged pollution and consequently affecting the quality of water in them.

3. Review of the Literature

In a comprehensive study by Adelana et al (2003, 2004, 2005) on groundwater quality of the south eastern part of Lagos from 1999-2001 and the impact of urbanization, found that the concentrations of sulphate, nitrate and chloride were at intolerable proportion in all the wells sampled for the study. Nitrate particularly was noted to be very high and is linked with anthropogenic activities of residents. Groundwater in Lagos was found to be particularly susceptible to contamination due to shallow depth and the unconsolidated porous sand and gravel aquifer. In a similar study, Eni et al (2011) assessed the impact of urbanization on the sub-surface water of Calabar town and found the water to be acidic, with high concentration of nitrate and faecal coliform in sampled well water. Results of multiple regression established positive relationship between faecal coliform, pH, chlorine concentration and urbanization. High faecal coliform is often connected with the sanitary condition of the environment of the wells. Also, Amadi et al (2010) examined the effect of urbanization on groundwater quality of Makurdi metropolis. Results of analyses revealed that water samples collected within the vicinity of dumpsite have low pH, higher concentration of iron, manganese, calcium, total dissolved solids and total coliform when compared to those far away from the dumpsites suggesting leachate influence. Presence of coliform is traced to sanitary condition of the well.

Ayanboto et al (2012) discovered that exploitation of groundwater through the construction of hand-dug wells is a major source of drinking water for majority of the populace. They accentuated the need to assess the quality of water from this source because of the health impacts of water quality on individuals. The authors discovered that nitrate concentration, *E-Coli*and total coliform counts are more pronounced in wells that are installed close to domestic refuse waste, abattoir, pit latrine, stagnant water, and drainages. The pronounced concentrations decreased with increasing distance from the sources. Protected wells gave better water quality relative to semi-protected and unprotected wells. It was also disclosed that age of well can be an important indicator of its ability to keep out contaminants. Hand-dug well of more than 70 years old is more likely to be shallower, located at the centre of homestead, and surrounded by many potential contamination sources. Older well pumps are more likely to leak lubricating oils into the well. Similarly, older wells are more likely to have thinner casing that may be corroded and allow in contaminants (Ayantobo, 2013).

Mile et al (2012) studied bacteriological contamination of wells in Makurdi town in Benue state, Nigeria. The study discovered that contamination of wells could be due to improper construction of wells, proximity to refuse dumping sites and various human activities around the wells. The authors recommended that soak-away pits, latrines and other potential sources of groundwater pollution must be situated at least 100m away from the site of shallow wells. They also suggest chemical sterilization or filtration or a combination of both for groundwater before use.Similarly, Idowu et al (2011) carried out a comparative study on covered and uncovered wells in Sagamu, Ogun state, Nigeria to determine their rate of contamination with microbial pathogens. The study revealed that uncovered wells were more highly contaminated with bacteria pathogens than the covered well especially in the highly populated areas. All the water samples exceeded the standard limit of the most probable number (MPN) per 100ml set for untreated drinking water. This result highlight the fact that most well water in Sagamu metropolis are not safe microbiologically for drinking without additional treatment such as boiling or disinfection and this could lead to outbreak of water borne diseases. Proper environmental and personal cleanliness must be maintained especially by the users of those wells to prevent their contamination with bacterial pathogens.

4. Study area

Ibadan is located between Longitude $7^{0}20^{1}$E and $7^{0}40^{1}$E and Latitude $3^{0}35^{1}$N and $4^{0}10^{0}$N of western Nigeria (Figure 1). As the crow files, it is 145 km north east of Lagos and 345 km southwest of Abuja, the Federal Capital. It is an inland city built on a ridge with latitude ranging from 150 – 275 meters (Adeniji and Ogundijo, 2009). Ibadan region is made up of eleven Local Government Areas (LGAs). Its population was estimated to be about 2,550,593 according to 2006 estimates by the National Population Commission (OYSG, 2011). Ibadan is continually growing in human population and this has resulted in continuous increase in water consumption demand. This situation has led to persistent water shortage in the city and its environs.

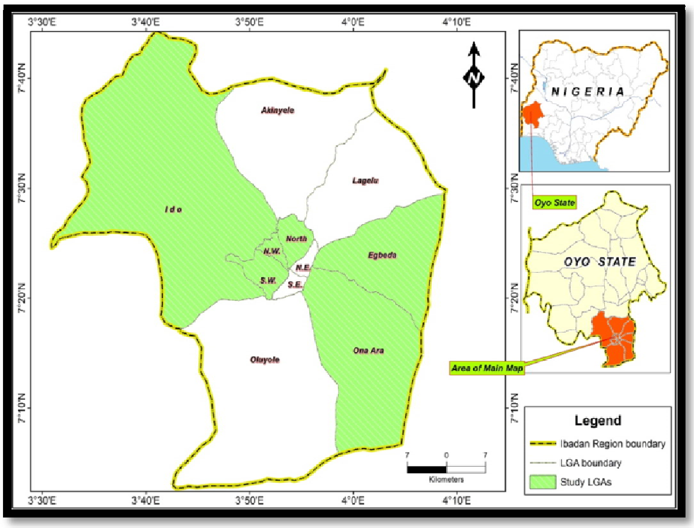


Figure 1: Map of Studied Lgas in the Context of Ibadan Region, Oyo State and National Setting

5. Materials and Methods

Survey research design was adopted. Both primary and secondary data were collected. Multi-stage sampling technique was employed to randomly select six Local Government Areas (LGAs) (Ibadan North, Ibadan North-West, Ibadan South-East, Ido, Egbeda and Ona-Ara) and three residential districts each (low, medium and high) from the LGAs. The study purposefully sampled 862 buildings (4%) of (21,391)existing buildings in the six selected Local Government Areas (LGAs) where households using well as a major source of water. Information on physical features of wells such as distance to soak away or pit toilet, well lid and water drawer were collected. The geographic position of selected wells was determined with Geographic Positioning System (GPS). Nearest Neighbour Analysis (NNA) was adopted using Arc GIS 10.4.1 software to determine the spatial pattern of coliform count in the groundwater. The study also carried out microbial analysis (coliform and bacterial count and total suspended solid) on water samples collected from the 50 wells randomly selected in the six LGAs during wet and dry seasons (Figure 2). Both descriptive and inferential statistics were used to analyse the data.

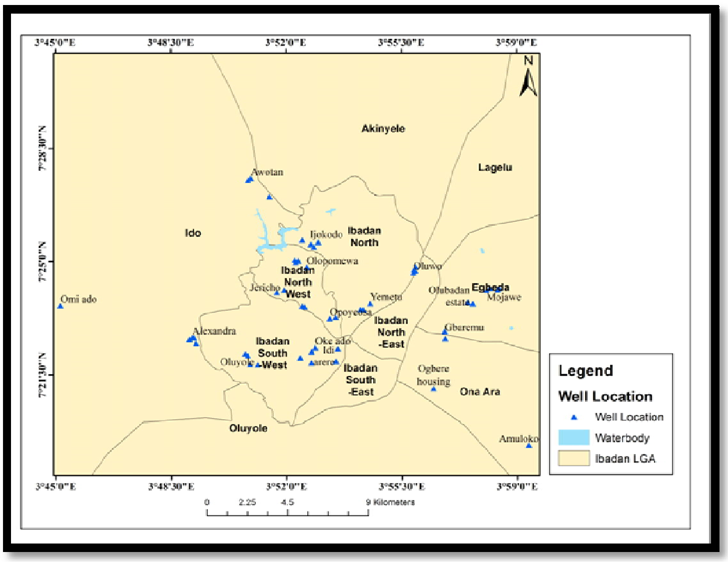


Figure 2: Location of sampled well in Ibadan Region

6. Findings and Discussion

6.1. Physical Characteristics of Wells

The physical characteristics of the wells are essential factors that determine the quality of water in the well. The study revealed that 97.8 % of the wells sampled were shallow type while 2.2% were machine dug. These kinds of wells were found in all residential districts. The machine-dug wells were mostly built by government, community associations and few individuals among the rich. The study revealed that 90.4% of the wells were ringed and covered, 5.7% were built without ring but covered while 3.9% were ringed without cover(Table 1). The study identified awareness of the importance of providing rings and cover for wells, ignorance, poverty and low level of concern for quality of water as factors responsible for some landlords not providing rings and cover for their wells.

The study also revealed spatial variations in the distribution of wells that had no rings but were well covered among the residential density zones. Of all the wells in this category 2.6% were in low-density areas, 5.6% were in medium density, and 7.7% were in high density areas. In the same vein, 3.9%, 2.6% and 5.8% of wells that had rings but did not have cover/lids were found respectively in the low, medium and high-density residential areas. The study revealed that higher proportion of wells that were not properly built were found in the high density residential zones, and could be attributed to the socio-economic status of the households in the zone.

Variables	**Residential density**			
	Low	**Medium**	**High**	**Total**
Type of well				
Shallow well	146(95.4)	441(98)	256(98.8)	843(97.8%)
Deep well (machine-dug)	7 (4.6)	9(2)	3(1.2)	19(2.2%)
Total	**153(100)**	**450(100)**	**259(100)**	**862(100.0)**
Physical condition of wells				
Ringed and covered	143(93.5)	413(91.8)	224(86.5)	780(90.4%)
Not ringed but covered	4(2.6)	25(5.6)	20(7.7)	49(5.7%)
Ringed but open	6(3.9)	12(2.6)	15(5.8)	33(3.9%)
Total	**153(100)**	**450(100)**	**259(100)**	**862(100.0)**

Table 1: The Types and Physical Appearances of Households' Wells
Source: Field Work, 2018

6.2. Households' Methods of Fetching Water from Wells

Material and methods used by households to fetch water from wells could be a major contributory factor to water contamination. The study revealed that 8.9% of the wells were fetched with mechanical method powered by electricity/generator or both while 91.1% were fetched via the use of manual method (drawer). The study revealed that fetching water from most of the wells required expending a lot of energy which could have health and economic implications on the households (Table 2). The study revealed spatial variations in the use of mechanical devices to fetch water from the wells: 43.9% in low; 38.9% in medium density areas used electricity; 68.2% and 46.8% of wells in low-density and medium- density zones, respectively, were powered with both electricity and generator, while all (100%) of the wells in high-density areas relied on manual labour. Investigations on wells with fixed and unfixed drawers revealed spatial variations of the categories of wells in the residential density zones: 39.9% of the wells had fixed drawer while 60.1% did not have fixed drawer; the proportion of wells that had fixed drawers in low, medium and high density areas were 52.7%, 45.2% and 25.9% respectively; while proportion that did not have fixed drawers in the various residential density areas were 62.3%, 81.5% and 84.4% in low, medium and high density areas respectively(Table 2). The findings suggested that owners of these wells might have low awareness on the possibility of contamination that could occur to the water through drawer.

Variables	**Residential density**			
	Low	**Medium**	**High**	**Total**
Methods of fetching water				
Mechanical-pump	41(26.8)	36(8)	0(0.0)	77(8.9)
Hand pump/ manual	112(73.2)	414(92)	259(100)	785(91.1)
Total	**153(100)**	**450(100)**	**259(100)**	**862(100)**
Mechanical-pumping of well water				
Electricity power	18(43.9)	14(38.9)	0(0.0)	32(41.5)
Personal generator	8(19.5)	15(41.7)	0(0.0)	23(29.9)
Electricity/Generator	15(36.6)	7(19.4)	0(0.0)	22(28.6)
Total	**41(100)**	**36(100)**	**0**(0.0)	**77 (100)**
Fixed drawer on wells				
Had fixed drawer	59(52.7)	187(45.2)	67(25.9)	313(39.9)
Had no fixed drawer	53(47.3)	227(54.8)	192(74.1)	472(60.1)
Total	**112(100)**	**414(100)**	**259(100)**	**785(100)**
Wells without fixed drawer				
Drawer fixed	33(62.3)	185(81.5)	162(84.4)	380(80.5)
Drawer not fixed	20(37.7)	42(18.5)	30(15.6)	92(19.5)
Total	**53(100)**	**227(100)**	**192(100)**	**472(100)**

Table 2: Respondent's Methods of Fetching Water from Wells
Source: Field Survey, 2018

6.3. Location of Well In Relation to Pit Toilet/ Soak Away Pit

The location of well is a crucial factor that determine the life-span of the well and water quality. Locating a well in a safe place takes careful planning and consideration of surface drainage and possible contamination sources. This factor might not always be given adequate consideration especially in high density residential areas where there is limited space to situate well facilities. The study revealed that 75.6% of buildings sampled had their well and soak-away pits at distance less than 25 metres interval (Table 3). This distance is less than the minimum permissible interval of 25 metres by the World Health Organisation (WHO) that should exist between the two facilities. In addition, 13.3% of these wells were sited at distance between of 30 and 50 metres to soak-away pits, and 11.1% had soak-away pits located at distance more than 50 metres from wells. The analysis on residential densities revealed that 69.5%, 80.3% and 72.6% of the buildings in low, medium and high density zones respectively had their wells located at distance less than 25 metres to the soak-away pits (Table 3). The revelation underscored that indiscriminate location of wells and soak-away pits is not limited to a particular residential density but cut across the three residential densities.

The analysis of the relationship between the well and soak-away pit revealed that 52.2% of the buildings that had both well and toilet soak-away pit had their wells up-hill in relation to the soak-away pits, and 48.7% had their wells located down-hill in relation to the soak-away pits. The study showed that as high as 47.8% of the buildings had their wells wrongly sited as these wells could be easily contaminated and endanger the lives of the users. In addition, the analysis on residential densities revealed that 46.6%, 50.5% and 41.9% of the buildings in low, medium and high density zones respectively had their wells wrongly situated (Table 3). The situation showed that the groundwater in such buildings (47.8%) where wells location is down- hill to soak-away pit are grossly susceptible to pollution. In view of the above analysis, awareness on the risk of contamination of groundwater by soak-away pits should be increased through public enlightenment by the relevant authorities.

Variables	**Residential density**			
	Low	**Medium**	**High**	**Total**
Distance of soak away to well water				
<25metres	82(69.5)	151(80.3)	45(72.6)	278(75.6)
25-50metres	15(12.7)	24 (12.8)	10(16.2)	49 (13.3)
>50metres	21(17.8)	13 (6.9)	7 (11.2)	41 (11.1)
Total	**118(100)**	**188(100)**	**62(100)**	**368(100.0)**
Relationship between soak-away and well				
Up-hill	63(53.4)	93 (49.5)	36(58.1)	192 (52.2)
Down-hill	55(46.6)	95 (50.5)	26(41.9)	176 (47.8)
Total	**118(100)**	**188(100)**	**62(16.8)**	**368(100.0)**

Table 3: Distance and Relationship of Soak-Away to Well Location
Source: Field Work, 2018

6.4. Well Characteristics and Pollutant Formation

Wells without lid/cover and those built with no ring are at greater risk of pollution. Proper location of hand-dug well is important to water quality. Locating a well in a safe place takes careful planning and consideration of surface drainage, slope and possible contamination sources. Generally, a well downhill of pollution source has a greater risk of contamination than a well uphill of pollution sources. Similarly, as expected and as shown in this study, the greater the distance a well is situated from a potential contamination source, the less likely the well will be contaminated.

The study revealed in wet season a strong association between depth of the wells and groundwater pollution with bacterial count ($t=17.230$, $p\leq 0.000$); coliform count ($t=-6.685$, $p\leq 0.000$); and total suspended solid ($t-12.919$, $p\leq 0.000$). Similarly, in dry season, the study showed significant relationship between depth of sampled wells and bacterial count ($t=10.046$, $p\leq 0.000$); coliform count ($t= -6.892$, $p\leq 0.000$) and total suspended solid ($t-12.919$, $p\leq 0.000$). The study further revealed in dry season strong association between distance of the soak away and bacterial count ($t=10.613$, $p\leq 0.000$); coliform count ($t=-6.833$, $p\leq 0.000$); and total suspended solid ($t=-9.123$, $p\leq 0.000$). While in wet season there was significant association between soak away and occurrence of bacterial ($t=13.817$, $p\leq 0.000$); coliform count ($t=-6.635$, $p\leq 0.000$); total suspended solid ($t=-12.816$, $p\leq 0.000$). This implies that water in the wells located closer to a soak away or pit latrine has potential of being contaminated. The study revealed that highest number of well in Ibadan are prone to the risk of pollution because about 75.6% were located at distance less than 25meter, the World Health Organisation standard setback between the well and soak away or pit latrine.

The study also examined the significant of lid/cover on wells to the water quality. Strong association exist between wells built without lid/cover and bacterial count ($t=-2.580$, $p\leq 0.013$); coliform count ($t=-6.957$, $p\leq 0.000$); and total suspended solid ($t=-9.403$, $p\leq 0.000$) in dry season. Similarly in wet season, there was strong association between wells built without lid/cover and bacterial count ($t=10.714$, $p\leq 0.000$); coliform count ($t=-6.766$, $p\leq 0.000$); and total suspended solid ($t=-13.024$, $p\leq 0.000$).

Ring or lining is another significant characteristic of urban wells. The study examined the impact of the rings on the quality of water in the wells. The dry season investigation showed significant association between rings and bacterial count ($t=-2.191$, $p\leq 0.000$); coliform count ($t=-6.955$, $p\leq 0.000$); and total suspended solid ($t=-9.403$, $p\leq 0.000$). Similarly in wet season, significant association exist between rings and bacterial count ($t=10.209$, $p\leq 0.000$); coliform count ($t=-6.764$, $p\leq 0.000$); and total suspended solid ($t=-13.023$, $p\leq 0.000$)

6.5. Spatial Dimension of Groundwater Pollution in the Studied Lgas

Nearest Neighbour Analysis (NNA) of Coliform count in the sampled wells was determined using Arc GIS 10.4.1 Software. GPS equipment was used to determine and record the locations of sampled wells. The result was processed in Microsoft excel as database for input into ArcGIS 10.4.1. The boundary of the study area was also extracted from the Political map of Ibadan. The coordinate system of the sampled location as well as the vector boundary shape files of the study area were projected to Universal Traverse Mercator projection (UTM Zone 31 N projected coordinate system) for accurate result of the analysis. Average Nearest Neighbour analysis in spatial analysis extension of ArcGIS 10.4.1was used to analyse the data.

The result of the analysis is as shown below:

Observed Mean Distance=597.6233 Meters
Expected Mean Distance =3813.8020 Meters
Nearest Neighbour Ratio (Rn): 0.156700
Z Score= -11.964492
p-value: 0.00000
Area of Study= 3199918932 m^2
Number of Sampled coliform locations (N) =50
Nearest Neighbour Statistics is calculated using the formula below:

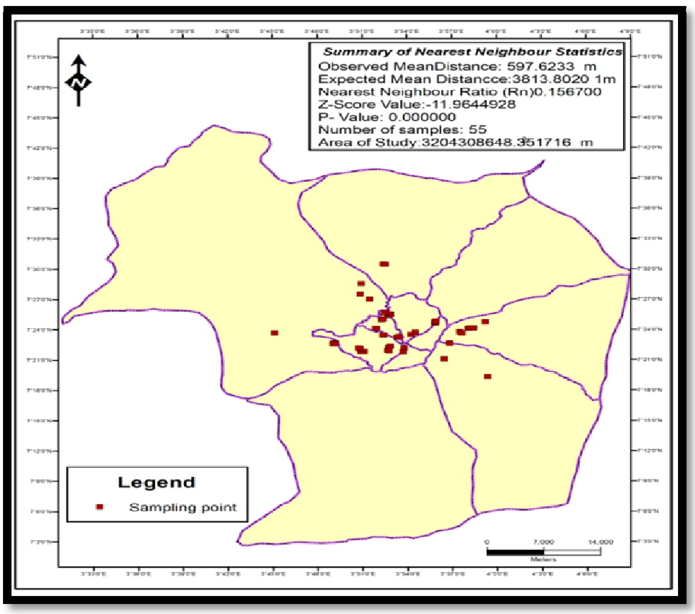
RN $=\frac{OD}{ED}$Where RN= Nearest Neighbour Ratio;
OD= Observed Mean Distance
ED=Expected Mean Distance.

The general rule for applying the method is based on the fact that Nearest Neighbour statistics (Rn) has a range value between 0 and 2.15

R-Value	Cluster tendency
Rn=1	Implies that the distribution is random
Rn 0 →	Implies that the distribution is clustering
Rn=2.15	Implies that the distribution is regular

The result of the analysis shows that Rn 0.156700 which exhibits a cluster pattern of distribution (Rn<1) while the ZScore-11.9644920055 (Figures 3 and 4). The Z score was used to test whether the result of clustering occur by chance at 0.01 significance level. This was found to be significant. Thus the distribution of Coliform count in the study area is not random but clustered (Rn<1.0). However, this result also shows that the Rn value of 0.156700 tends more towards clustering than randomness therefore there is high degree of clustering.

The severity of coliform count was more in high density residential areas (urban core). This revelation is instructive because majority of the wells in core areas of Ibadan such as Opoyeosa, Idi Arere, Oke Ado, Ijokodo and Yemetu were built very close to source of contaminants such toilet soak away, refuse dumping site and animal waste. The pattern of coliform concentration is most clustering particularly in areas where houses were fully built, least plot size is obtainable, required setbacks were compromised and sanitation is grossly lacking. The concentration of coliform in wells in each of the selected locality is relatively uniform because of common physical and environmental attributes such as proximity of septic tanks, improper construction of wells, particularly as some wells have no cover/ rings, position of refuse dumping site to well, inimical human activities around the wells, unhygienic usage of the wells thus making the water unfit for use except some form of treatment is undertaken.



Figures 3: Spatial Pattern of Coliforms in the Selected Lgas

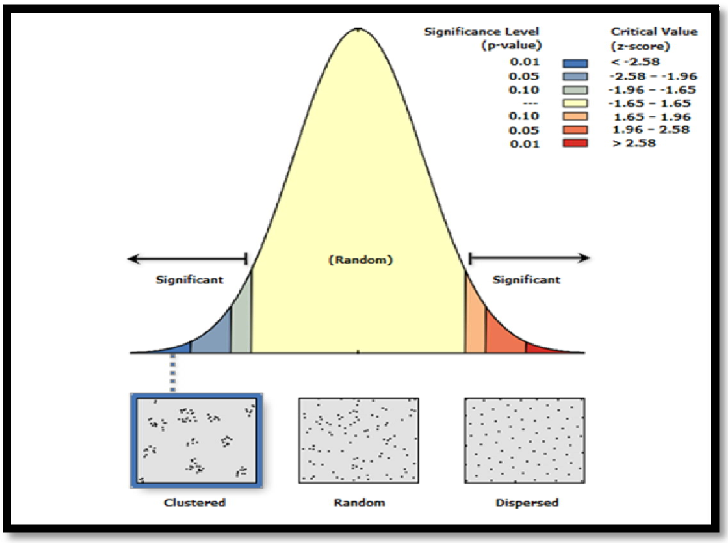


Figure 4: Average nearest Neighbor Summary

Given the z-score of -11.9644920055, there is less than 1% likelihood that this clustered pattern could be the result of random chance.

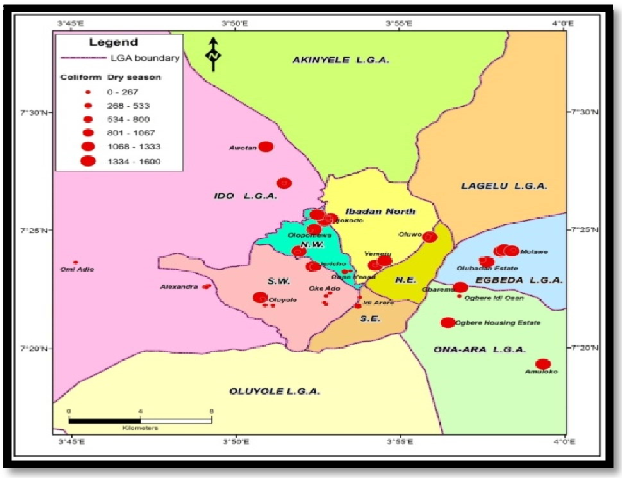


Figure 5: Coliforms Count in Selected Wells in Ibadan Region

7. Conclusion and Recommendation

The paper revealed that the use of hand dug well is the major source of water in Ibadan. The location of wells was not properly considered in relation to the source of pollutants. The quality of water from wells was not given proper priority by providers particularly the landlords (house owners). Majority of respondents shared water drawer which is a potential source of water contamination irrespective of the well classification. Wells built with ring and covered has been proven to be the best design for proper hygiene. However, the combined effects of installing wells close to sanitary facilities and soak away contribute significantly to high pollution of wells, resulting in the deterioration of water quality and could be a potential public health risk. The situation is not peculiar to the study areas but rather a nationwide problem because of lack of proper physical planning which has generally encouraged groundwater contamination via latrine.

The study recommended community education on proper location of well which should be champion by Local Planning Authorities personnel and enforces standards for siting of wells from latrines or soak away in order to limit the risk of groundwater pollution. Consequently, Site Analysis Report is recommended as part of requirements for building approval document to indicate the site slope, locations of soak away and proposed well. Public enlightenment on water quality is also necessary to forestall potential public health threats to water consumers. Therefore, both the government the relevant ministry and rich philanthropists should help to support the non-governmental organisations that focus on water and health campaign with fund. Similarly, the study appeal to government and private rich developers to build more community deep wells with adequate pumping facilities to cushion the effects of water shortage and enhanced easy access to groundwater supply.

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