Original Research Article

Assessment of Hydrological Properties and Proximate Impact of Soakaway Leachate on Well-Water Quality in Two Residential Areas of Ibadan, Southwestern Nigeria.

ABSTRACT:

Aims: To determine the impact of leachate from soakaway on proximate well water quality in two different residential areas and the variation in the physico-chemical parameters of the well water that are associated with spatial geographical location.

Study design:

Randomized monthly collection and analysis of well water over four months in two chosen residential area.

Place and Duration of Study:

Residential houses at Abowo and Akobo, Ibadan, Nigeria between April and August, 2012.

Methodology: The well water samples was collected from 30 sites once every month from different wells located at various perimeters from the soakaway. The distance between the soakaway and the wells were measured and the water subjected to physico-chemical analysis and bacteriological assessment to evaluate their qualitative, spatial and temporal variations.

Results: Coliform count results showed a significant increase ($p<0.01$) between dry and wet season while significant decrease ($p<0.05$) was recorded in the concentration of phosphate, salinity, total dissolve solid and potassium. The distance from the well to soakaway exhibited a negative correlation with coliform count ($p<0.05$), as well as for phosphate, nitrate, chlorine and ammonia ($p>0.05$). The Discriminant Chi square (X^2 = 62.526, $p<0.01$) and Wilk's Lambda (0.058) revealed a significant discrimination between the two study site. Partial Eta Squared value of 0.740, 0.382 and 0.137 were reported for location, proximity of soakaway to well water site and well depth respectively, showing their degree of contribution to variation in parameters measured.

Conclusion: The results stresses the need to set standards with regards to the distance and location of well from septic tanks/soakaway, while considering spatial and temporal variation in hydrological environment of well water site.

Keywords: Well water quality; Water Quality Index; Physico-Chemical variation; Soakaway; Bacteriological assessment.

1. INTRODUCTION

As population grow and urbanization increases, more water is required and greater demand would be placed on ground and surface water [1]. The rate of urbanization in Nigeria is alarming and the major cities areas are growing at rates between 10-15% per annum [2]. The human activities associated with such growth including, soil fertility remediation, indiscriminate refuse and waste disposal, and the use of septic tanks, soak-away pits and pit latrines are on the increase, with concurrent increasing pollution of underground water.

Groundwater contributes only 0.6% of the total water resources on earth, yet, it remains the major source of drinking water in Nigeria and every part of the world [3]. Water sources available for drinking and other domestic purposes must therefore possess high level of purity, free from chemical and microbial contamination. However, this useful resource is under threat of pollution from anthropological activities evident in low level of hygiene practices [4-6], and lack of recommended 'safe distance' between well water/borehole and soakaway sitting in Nigeria. In view of this, monitoring the chemical, physical, and microbiological quality of groundwater is as important as assessing it quantity [7].

The two main contributors to the variations in the biogeochemical composition of groundwater are weathering processes and anthropogenic inputs [8]. Rapid increase in population, changes in life style, changes in living condition and domestic waste management system [9] in Nigeria have resulted in a dramatic increase in the potential infiltration of extraneous materials into the groundwater environment [10]. In recent times, the impact of leachates on groundwater and other water

resources has attracted a lot of attention because of its overwhelming environmental significance; hence, protection of groundwater is now an important environmental issue [11-12]. Leachates from soakaway and other municipal sewage contain variety of chemicals like detergents, germicides, complex organic ccompounds and metals beside human effluent composite [13-14]. Municipal sewage particularly contains human faeces, and water contaminated with these sewage effluents may contain pathogenic organisms, high load of nitrate, phosphate, ammonia, total dissolve solid and associated complex organic substances [13], consequently, this may be hazardous to human health if such water is consumed without treatment [13]. Additionally, uncontrolled microbial action may result in the release of more toxic substances due to cumulative or synergistic effect of previously free or non-reactive component of the waste. Hence, the discharge of wastes from municipal sewers is one of the most important water quality issues world-wide. It is of particular significance to drinking water sourced from shallow water table [13, 15]. During leachate percolation, water present in the waste and that generated by biodegradation serve as vehicle for leachates vertical and horizontal migration finding its way into the groundwater environment thereby contaminating the groundwater. Survival and dispersal of microbes in the groundwater environment also varies, for instance *Escherichia coli* have been reported to have moved 46 m vertically and 70 m horizontally in an aquifer under favorable conditions while enteroviruses have been reported in groundwater 183 m from a wastewater point source [15]. Most chemicals found in drinking water are of health concern but only few of these chemical contaminants have been shown to demonstrate adverse health effects in humans as a consequence of prolonged exposure through consumption [16]. Consequently, evaluation of the microbial, physical and chemical quality of water is an important weapon to the achievement of potable water for daily consumption. This study seeks to assess the proximate impact of soakaway leachates on physico-chemical and microbial quality of ground water in different hydrological settings, Agbowo (densely populated) and Akobo (sparely populated) residential areas of Ibadan, Nigeria and thus provided a base line information towards exploring a possible minimum distance that could be recommended for Nigeria, where well water is the most common of water source within the cities.

2. METHODOLOGY

Study area

This study was carried out in Agbowo and Akobo residential areas of Ibadan, South-West, Nigeria (Fig. 1).

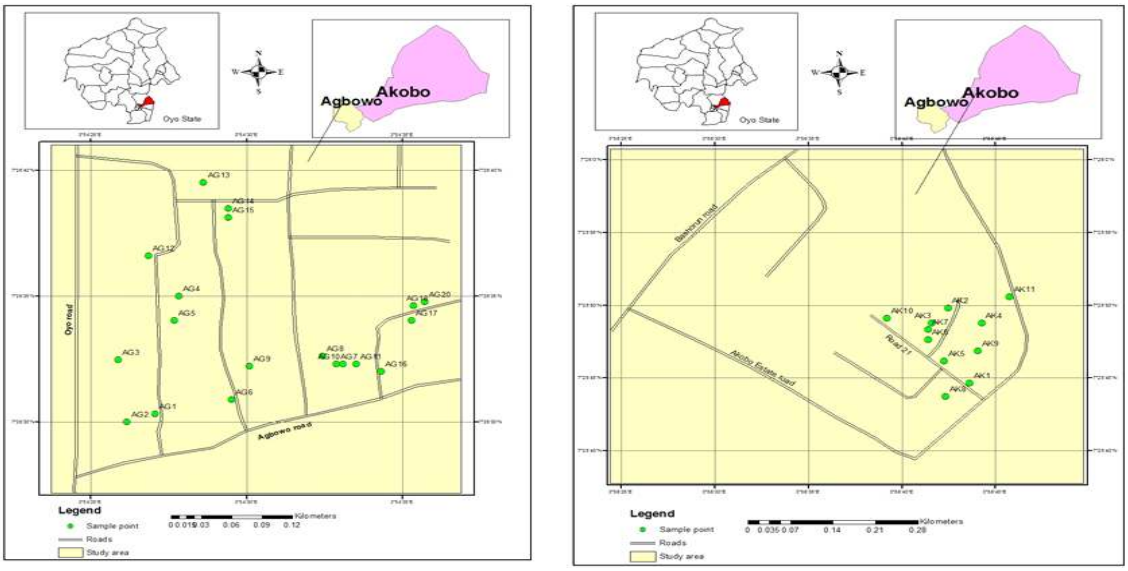

Fig. 1. Map of the study area [A: Agbowo (a densely populated area) and B: Akobo (a sparsely populated area)]

Sample Collection

This study was carried out between April and August, 2012 across wet and dry seasons. Well-water samples were collected from thirty one locations in the study site. Hand held Global Positioning System (GPS) receiver device with 12-channel tracking and differential correction capability was used to determine and identify location where the water samples were collected.

Quality Assurance Procedures

Samples were collected in plastics that were pre-washed with detergent water solution, rinsed with distilled water and soaked for 48 h in 50% HNO3, then rinsed thoroughly with distilled deionised water before air-dring. As part of the quality control measures, samples bottles were rinsed with sample well-water before filling. Samples for Calcium (Ca^{2+}), Magnesium (Mg^{2+}), Sodium (Na^{+}), Potassium (K^{+}), Ammonia (NH_4^{+}), Nitrate (NO_3^{-}), Chloride (Cl^{-}) and Phosphate (PO_4^{3-}) were refrigerated at $4^{o}C$ prior to analysis.

Well depth and water level determination

Well depths were determined using graduated tape with added weight and similar procedure was employed for water level determination.

Determination of physical and chemical parameters

Non-conservable parameters like, pH, Salinity and other parameters like Total Dissolved Solid (TDS), conductivity, temperature (^{o}C), Dissolve Oxygen (DO) and percentage Oxygen (%O2) were taken immediately at the sampling point using Consort CS-C933 Multi-Parameters Portable meter, Topac Instrument, Inc. USA. Total hardiness, Calcium (Ca) and Magnesium were determined by Ethylene Diamine Tetra-acetic Acid (EDTA) method. Flame photometric method was employed in the determination of Sodium (Na^{+}) and Potassium (K^{+}); Chloride (Cl^{-}) was measured by potassium chromate method. Nitrate (NO^{-3}) by Phenol disulphonic acid method, Phosphate (PO_3^{-4}) by Ascorbic Acid Method and Ammonia by Indophenols (Colorimetric).

Total Coliform Assessment

Sterile cornning tubes were used to collect well-water sample from various sampling site locations and they were transferred immediately to the laboratory where they were preserve at $4^{0}C$. Microbial analyses were carried out within 24 hours of collection. Borosilicate glasswares were used in microbiological testing in conformity with Section 9000 of "Standard Methods for the Examination of Water and Wastewater". Dilution bottles were made of resistant Borosilicate glass, with plastic screw caps which were equipped with liners that do not produce toxic or inhibitory compounds when sterilized. McConkey broth with incorporated Bromocresol purple as indicator (LAB M Ltd. UK) was used as the growth media. Sterile syringes were used to introduce 5mL of the broth media (3.5% w/v) into 160/15mm test-tube and small Durham tube inverted inside the test tube (totally submerge) to determine gas production in the sterilized fermentation tube. Series of 100%, 10% 1% and 0.1% of the stock solution of well water samples (1mL) were prepared with sterile distilled water. The prepared concentrations were introduced into sterilized fermentation tube.

Most Probable Number (MPN)/100 mL were estimated using MPN Index of Standard methods 9221 Standard Total Coliform fermentation technique [17]. A multiple-tube fermentation technique was used for total coliforms (McConkey Broth Medium) and various combinations of positive results from five tubes per dilution were used (10 ml, 1.0 ml and 0.l ml sample portions).

Data Analysis

The bacteriological data were log-transformed to meet the assumption of equal variance which were then subjected to student T-test to evaluate the impact of seasonal variation on coliform density. Correlational analysis were performed to evaluate the extent of the relationship between coliform density, well depth and distance between well and the nearest soakaway point for dry and wet season. Correlation analysis was performed on the parameters measured to evaluate their inter-relatedness. Principal Component Analysis (PCA) was also used to assess the concentration of physic-chemical and bacteriological data from well water samples, quantitatively determining the minimum number of new variables necessary to reproduce various attributes of the data. Discriminant analysis was performed on the parameters to identify variables that best differentiate the two sampling zone (Agbowo and Akobo). The Water Quality Index (WQI) was determined using the Weighted Arithmetic Index method [18].

3. RESULTS AND DISCUSSION

3.1 Variable Analysis of well-water samples

The descriptive statistical analysis data presented in Table 1 show the univariate summary statistic of well-water sample variable analyzed during the study period between the month of April and August, 2012. In this study the minimum

distance between well and soakaway ranges from 4 to 30.5m and well depth ranges from 0.25-15m. Well depth in Akobo study area ranges from 4 to 15 m while Agbowo recorded depth range of 0.25 to 5.5m indicating area with high aquifer level. Results for Water Hardness, coliform count, TDS, conductivity and chloride recorded large variances.

Generally, underground water is believed to be the purest known [19] because of the purification properties of the soil [20]. However, the amount and variation in the level of dissolved materials in underground water is a complex function of interaction between climate, land use patterns, human activity weathering and the geologic make-up of the hydrologic environment. These functions vary from one geographical area to the other [21]. The result presented in Table 1 showed that the overall water hardness, DO, coliform, distance from nearest soakaway, salinity, TDS, conductivity, ammonia, nitrate, phosphate cluster less around the mean, while, temperature, pH, potassium, calcium, well depth and Percentage Oxygen clustered more. The degree of variation observed in the data structure is in agreement with previous studies [22-23]. Wide variation was observed in the physico-chemical variables of well water collected from Agbowo and Akobo as shown in Table 1. The mean values for TDS, conductivity, salinity, water hardness recorded for Agbowo (408.01, 766.79, 0.35, 377.25 respectively) were significantly higher when compared with the mean values recorded for low density area of Akobo (97.58, 181.98, 0.1, 111.50 respectively). The overall evaluation of most parameters however falls below the permissible limit of NESREA; except coliform count and chloride concentration [23].

Table 1. Summary of the descriptive statistics of the entire variable evaluated in Akobo and Agbowo sites.

	Minimum	Maximum	Mean	Std. Deviation	Variance	Skewness	Kurtosis	NESREA
Temperature ^{0}C	28.6	31.2	29.3	0.5	0.2	1.8	6.5	
PO_4^{3-} mg/L	7.0	24.0	17.2	4.2	18.0	-0.4	-0.6	
NO_3^- mg/L	10.1	60.5	30.3	12.6	158.8	0.3	-0.6	45.0
NH_4^+ mg/L	11.6	80.9	42.4	19.7	386.6	0.2	-1.1	
Cl^- mg/L	75.0	475.0	2.2	126.9	16100.0	0.4	-0.8	200.0
pH	6.0	7.6	7.0	0.4	0.2	-0.8	1.2	6.5-8.5
Na^+ mg/L	0.8	4.1	2.3	0.8	0.7	0.3	-0.3	200.0
Mg^{2+} mg/L	0.8	3.5	1.8	0.6	0.4	0.9	1.5	150.0
K^+ mg/L	0.9	10.5	2.6	1.7	2.8	3.7	17.7	200.0
Ca^{2+} mg/L	2.0	37.1	10.2	6.9	47.0	2.0	6.9	200.0
Conductivity (µs/cm)	88.1	1340.4	559.0	340.2	116000.0	0.3	-0.7	1000.0
TDS mg/L	51.1	716.0	298.0	180.8	32700.0	0.3	-0.6	500.0
Salinity %	0.1	0.6	0.3	0.2	0.02	0.4	-0.7	
Hardness mg/L	50.0	610.0	283.0	154.7	23900.0	0.3	-0.7	500.0
DO mg/L	0.1	0.7	0.4	0.2	0.03	0.7	-0.8	4.0
$\%O_2$	1.1	10.3	4.4	2.0	4.1	1.0	1.2	
Coliform MPN/100mL	1.0	1600.0	890.0	633.9	402000.0	-0.2	-1.6	10.0
Distance m	4.0	30.5	16.0	8.0	63.3	0.5	-0.8	
Average well depth m	0.3	15.0	3.9	3.2	10.1	2.2	5.9	

3.2 Coliform count in the dry and rainy seasons

The presence of coliform was confirmed by lactose fermentation and concurrent gas produce. There was a strong negative correlation ($r = -0.51$, $P < 0.05$) between coliform count and distance from soakaway for dry season (Table 2) and the strength of correlation coefficient increased during the raining season ($r = -0.58$, $P < 0.05$) compared to dry season ($r = -0.51$, $P < 0.01$).

The correlation between coliform count and well depth was not significant ($r = -0.16$, $P > 0.05$) but there was an indication of a negative relationship between coliform count in wet season and that of well depth in wet season ($r= -0.16$, $P>0.05$). On the other hand, slightly positive but insignificant ($r = 0.1$, $P>0.05$) correlation existed between coliform count and well depth during dry season (Table 2). Akobo study area recorded a low coliform count mean of MPN 674.14/100mL with

higher kurtosis (-1.85) compared with Agbowo which recorded a mean of MPN 1008.00/100mL and kurtosis -1.20 indicating that Akobo coliform count for well sample cluster less around high MPN value than Agbowo sample.

Table 2. Correlation analysis showing relationship between soakaway and well distance and corresponding seasonal changes in coliform density

	Coliform count in dry season	Coliform count in wet season
Distance from well to soakaway	-0.51**	-0.58**
Well depth in dry	0.1	-
Well depth in wet	-	-0.16

**. Correlation is significant at the 0.01 level (2-tailed).

The result of the microbial analysis of well water sampled showed high levels of coliform contamination in well water collected in Agbowo. The low well-depth range recorded in Agbowo could account for the high level of groundwater contamination as against what recorded in Akobo. The low level of sanitation and hygiene practices [24] and other environmental factors observed in the community [1] may have contributed to the high microbial assessment of Agbowo well. It was discovered that the layout of the building in Agbowo were overcrowded and not well planned, resulting in the close distance of wells sites to soakaway and refuse dump. An extreme observation involved cases in fenced neighborhoods where wells were ignorantly sited at close proximity to the soakaway of the neighboring house. This might have affected the reported high value of Coliform density observed in site AG2 with > MPN1600/100mL and supports the report on human waste contamination of groundwater by USEPA [25].
The negative correlation obtained between total coliform count and distance from nearest soakaway and well-depth suggests that the total coliform decrease with increasing well distance and well depth. This is in agreement with Adekunle *et al.* [26] and Adetunji and Odetokun [1] findings. It also in agreement that soil filtration potential increased with distance both vertically and horizontally. However, the vulnerability of groundwater to particulate pollution is a function of the ease with which particulate and dissolve solutes can move with water and the attenuation capacity of the intervening materials [27]. The filtering capacity of soil as intervening materials will therefore depend on the soil properties and the distance between pollutant source and receiving water and also the properties of the pollutant. Previous study [28] revealed that coliform could travel distance of 70.7m from sewage trenches intersecting groundwater while covering a distance of 30.5m within 35hrs when travelling through sand and pea gravel aquifer. Francy *et al*. [28] also confirm an association between proximity of soakaway to well water site, well depth and coliform density.

3.3. Variation in well water physico-chemical properties

A paired sample Student T-test (Two tailed) comparing mean differences that existed in microbial and physico-chemical parameters of well water sample between dry season (April) and wet season (Average of value obtained between May and August) was determined (Table 3). The result showed that there was significant increase between dry season and wet season for coliform count ($T = -3.401$, $P < 0.01$) and pH ($T= -3.566$, $P < 0.01$) while there was a significant decrease in the concentration of phosphate ($p < 0.01$), salinity ($P < 0.05$), TDS ($P < 0.01$), potassium ($P < 0.01$) and sodium ($P <0.01$), conductivity ($P <0.01$) and ammonia ($P <0.01$).

Table 3: Seasonal (Dry and wet season) changes in Physico-Chemical and Microbial Parameters

Parameters compared	Mean	T	Df	Sig. (2-tailed)
Coliform count	-328.27	-3.40**	30	0.00
Percent Oxygen	-0.73	-1.11	30	0.28
Dissolve Oxygen	-0.07	-1.38	30	0.18
Hardness	14.61	1.06	30	0.30
Salinity	0.02	2.50*	30	0.02
TDS	25.15	3.16**	30	0.00
Conductivity	44.54	2.86**	30	0.01
Calcium Dry	2.72	1.76	30	0.09
Potassium	0.90	8.11**	30	0.00
Magnesium	0.00	0.02	30	0.99
Sodium	0.57	4.40**	30	0.00
pH	-0.15	-3.57**	30	0.00
Chloride	18.45	1.95	30	0.06
Ammonia	8.33	2.33*	30	0.03
Nitrate	1.56	0.86	30	0.40
Phosphate	2.76	7.23**	30	0.00
Temperature	-0.07	-0.28	30	0.78

* P< 0.05 and ** P< 0.01 indicating significant difference between dry season and wet season

The result of monthly variation observed in salinity, TDS and conductivity were as shown in Fig 2, 3 and 4 respectively. There was a significant difference in Salinity (t = 8.234, df = 29, P <0.01) between samples collected from Agbowo to that of Akobo. The salinity of well water in Agbowo increased slightly from April to May and later declined through June and July and a slight increase in salinity was later observed in August. In Akobo there was no obvious fluctuation in the salinity of the well water (Figure. 2). A significant difference was also observed in the TDS (t = 8.175, df = 29, P< 0.01) and conductivity (t = 8.206, df = 29, P <0.01) between Agbowo and Akobo study area. The monthly variation in TDS and conductivity of Agbowo study area followed a similar pattern as that of Salinity. However, TDS and conductivity of well water in Akobo showed a slight decrease from the month of April through July before gaining stability (Figure. 3 and 4).

The increased concentration of Salinity, TDS and Conductivity between the month of April to May as shown in Fig. 2, 3, and 4 may have resulted from precipitation enhancing leaching of long term accumulated ionic and non-ionic particles (during dry season) on surface soil [22]. Precipitation also enhance dissolution of materials naturally present in soil and the introduced water dissolve ionic and non-ionic minerals. This resulting water that moves through the soil to the underlying groundwater is now enriched with high load of soluble salt [21] and consequently enhance the leaching of soakaway scum into the groundwater environment. The subsequent reduction in salinity, TDS and Conductivity, may have resulted from increased dilution from continuous rainfall during the raining season [22] compounded by human withdrawer of previous solute laden water for domestic use.

The trend in variation of average Salinity, TDS and Conductivity was taken as the prime parameter to focus on monthly variations [29] for Agbowo and Akobo study area.

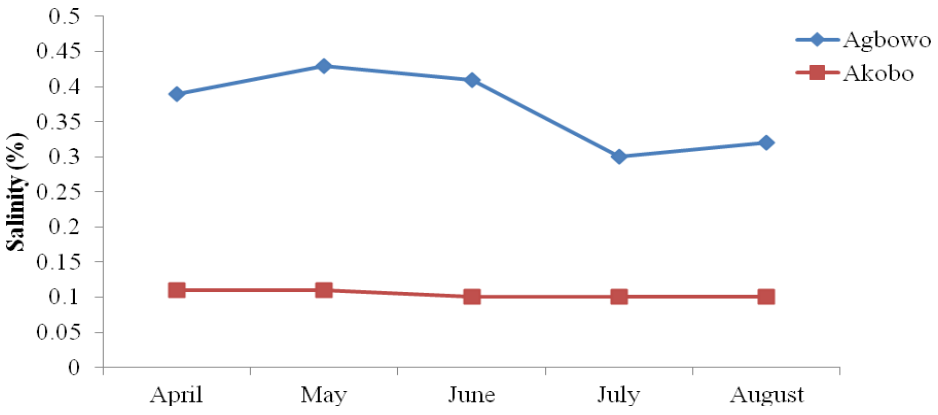

Fig. 2. Monthly Variation in Salinity of well water sample in Agbowo and Akobo

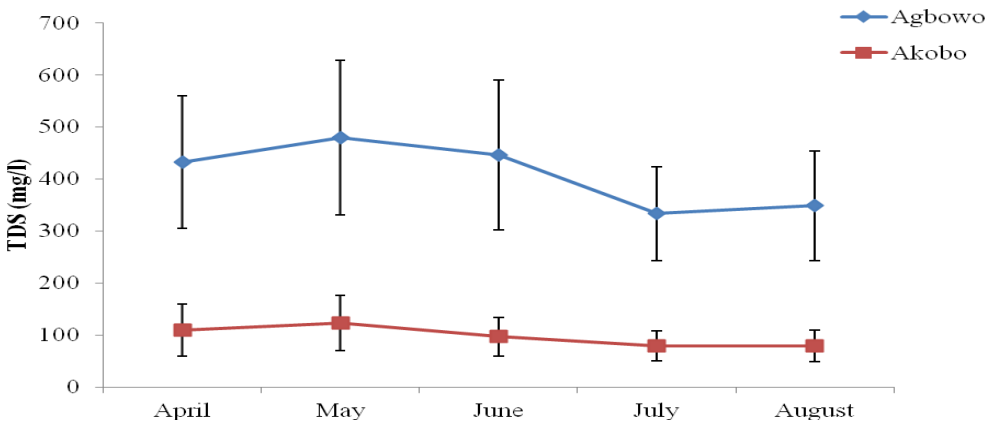

Fig. 3. Monthly variation in Total Dissolve Solid (TDS) of well water samples in Akobo and Agbowo

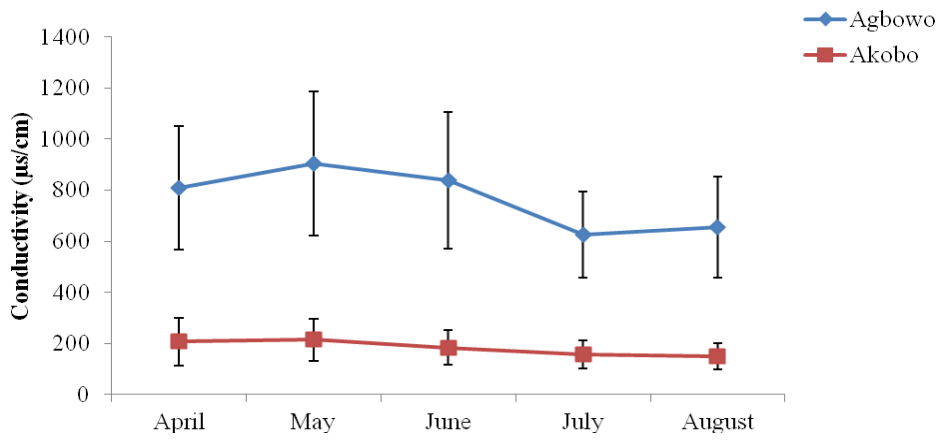

Fig. 4. Monthly variation in Conductivity of well water samples of Akobo and Agbowo

3.4. Interrelationships between Microbial, Physical and Chemical parameters.

The result of the correlation analysis perform to evaluate the extent of interrelationship that existed among the assessed variable is shown in Table 4. The correlation matrix revealed that strong positive relationship ($P<0.01$) existed between Phosphate and the following parameters; nitrate, ammonia, chloride, sodium, magnesium, calcium, conductivity, TDS, salinity, and hardness (Table 4). In addition, strong positive correlation ($P<0.01$) also existed between nitrate and the following; ammonia, chloride, sodium, magnesium, calcium, conductivity, TDS and salinity.

TDS and conductivity were perfectly correlated ($r = 1.00$) (Table 4). A significant positive correlation ($P < 0.05$) existed between log transformed coliform count and other parameters like phosphate, nitrate, ammonia, sodium, conductivity, TDS and salinity. Well distance from soakaway has a significant negative correlation ($P<0.05$) with average coliform count, and negative insignificant correlation ($P>0.05$) with phosphate, nitrate and ammonia (Table 4). Well depth recorded a significant negative correlation ($P< 0.05$) with parameters like phosphate, nitrate, ammonia, chloride, sodium, TDS, salinity and hardness (Table 4a & b).

The positive correlation observed between Coliform count, Phosphate, Nitrate, Chloride and Ammonia in ground water, is in line with previous work that had associated leachate from soakaway impacting on the concentrations of these variables concurrently [30-31]. The presence of coliform in the groundwater has been reported to indicate contamination by human and animal faeces [18, 32]. These pathogens may pose a health hazard for infants and people with weak immune system [32]. The significant variations in coliform count during wet and dry season; in relation to distance of well from soakaway and well depth showed that run-off and weathering resulting from precipitation during raining season impacted positively on the migration of coliform from different pollutions source to the receiving underground water.

The strong co-linearity that existed between salinity, TDS and conductivity as express in the correlation matrix showed that salinity as a measure of the amount of dissolved particles and ion in well water sample can account for TDS (measure of all dissolve substances) and conductivity (measure of charged ion or ionic particles) of the water sample. The negative correlation obtained between well distance from soakaway and soluble particles represented by salinity, TDS, conductivity show a possible contamination through leaching from proximate soakaway. This was justified by SWRC [21] findings that discharge from septic system increased the salinity of the receiving water body. Most salt resulting from these soluble particles does not naturally degrade, and can remain in groundwater for decade [21].

The weak negative correlation that existed between well proximity to soakaway and Nitrate; phosphate and ammonia concentration may suggest that leachate from soakaway contributed to the increased concentration of these parameters [33-35]. The strong negative correlation reported for nitrate concentration and well depth agreed with Piskin [36] findings who reported that Nitrate concentration decrease with increase in depth. Nitrate and Ammonia are by-product of natural break down of Nitrogen containing organic compounds from human and domestic waste accumulated in the septic tank and this reflected in the observed strong positive correlation between the above two variables.

The negative correlation that existed between well depth and the following variables: phosphate; nitrate; ammonia; chloride; sodium; magnesium; calcium; conductivity; TDS; salinity and hardness further establish the fact that areas with high aquifer levels were most predisposed to particulate contamination [36]. This may account for the reason why 73.9% of well sample at Agbowo study area, with well depth range (0.25 to 5.5m) were unsuitable for drinking; when compared to Akobo which recorded a well depth range of 4m to 15m with a lower percentage (54.55%) of unsuitable drinking water (Table 9),.

Table 4a: Correlation Matrix showing relationship between variables evaluated.

	DISTANCE [FROM SOAK AWAY] (m)	TEMP (^{0}C)	PO_4^{3-} (mg/L)	NO_3^- (mg/L)	NH_4^+ (mg/L)	CL^- (mg/L)	pH	Na^+ (mg/L)	Mg^{2+} (mg/L)
Temp (^{0}C)	-0.26	1							
PO_4^{3-} (mg/L)	-0.31	-0.09	1						
NO_3^- (mg/L)	-0.33	0.04	0.96**	1					
NH_4^+ (mg/L)	-0.35	0.00	0.92**	0.95**	1				
Cl^- (mg/L)	-0.81	-0.10	0.90**	0.94**	0.91**	1			
pH	0.23	-0.05	-0.16	-0.17	-0.20	-0.18	1		
Na^+ (mg/L)	-0.29	-0.03	0.94**	0.95**	0.94**	0.92	-0.17	1	
Mg^{2+} (mg/L)	-0.30	0.14	0.90**	0.94**	0.90**	0.90**	-0.22	0.94**	1
PO_4^{3-} (mg/L)	0.13	0.09	0.15	0.247	0.236	0.242	-0.14	0.16	0.28
Ca^{2+} (mg/L)	-.013	-0.23	0.80**	0.78**	0.78**	0.83**	-0.16	0.80**	0.73**
Conductivity (µs/cm)	-0.35	-0.02	0.93**	0.95**	0.90**	0.95**	-0.17	0.94**	0.93**
TDS (mg/L)	-0.36	-0.0	0.92**	0.95**	0.91**	0.94**	-0.17	0.94**	0.93**
Salinity (mg/L)	-0.35	-0.02	0.92**	0.96**	0.90**	0.95**	-0.20	0.93**	0.92**
Hardness (mg/L)	-0.32	-0.00	0.96**	0.95**	0.95**	0.95**	-0.19	0.97**	0.96**
DO (mg/L)	-0.21	0.05	0.00	0.02	-0.04		-0.20	0.08	0.08
$\%O_2$	-0.22	0.04	0.01	0.02	-0.05	-0.03	-0.29	0.08	0.08
Log coliform	-0.61**	0.08	0.43*	0.43*	0.47**	0.37*	-0.30	0.44*	0.35
Well Depth (m)	0.51**	0.17	-0.57**	0.50**	-0.51**	-0.45*	-0.05	-0.43*	-0.38*

*. Correlation is significant at the 0.05 level (2-tailed). **. Correlation is significant at the 0.01 level (2-tailed). DO= Dissolve Oxygen, %O2= Percentage Oxygen, TDS= Total Dissolve Oxygen

Table 4b. Correlation Matrix showing relationship between variables evaluated.

	PO_4^{3+} (mg/L)	Ca^{2+} (mg/L)	CONDUCTIVITY (µS/CM)	TDS (mg/L)	SALINITY (mg/L)	HARDNESS (mg/L)	DO (mg/L)	$\%O_2$	LOG COLIFORM COUNT
PO_4^{3+}(mg/L)	1								
Ca^{2+} (mg/L)	0.18	1							
Conductivity (µs/cm)	0.25	0.78**	1						

TDS (mg/L)	0.25	0.78**	1.00**	1					
Salinity (mg/L)	0.24	0.78**	0.99**	0.99**	1				
Hardness (mg/L)	0.19	0.81**	0.97**	0.97**	0.98**	1			
DO (mg/L)	-0.13	0.02	0.09	0.1	0.12	0.06	1		
$\%O_2$	-0.13	0.01	0.09	0.10	0.12	0.06	0.96**	1	
Log coliform count	-0.25	0.39*	0.46**	0.46**	0.46**	0.45*	0.27	0.21	1
Well Depth (m)	0.34	-0.40*	-0.48**	-0.48**	-0.47**	-0.51**	-0.00	0.04	-0.51**

*. Correlation is significant at the 0.05 level (2-tailed). **. Correlation is significant at the 0.01 level (2 tailed). DO= Dissolve Oxygen, $\%O_2$= Percentage Oxygen, TDS= Total Dissolve Oxygen

3.5. Discriminant analysis (DA)

The result of a one-way ANOVA discriminant analysis for the variables in Table 5 showed that temperature DO, pH, K, $\%O_2$ and coliform count failed the tolerance test at 0.001 and did not contribute to the discriminant model classifying the two study area. The Eigenvalue value (16.1~~51~~) for the first discriminant function accounted for 100% of the variance that existed among the variables obtained from the two study area and the Chi square test (X^2 = 62.526, df=30, P<0.01) showed that the difference in the two group is not just due to chance. The strong canonical correlation of 0.970, low Wilk's Lambda value of 0.058 shows a strong relationship between the discriminant score and the group classification. Predicted group membership (Table 6) showed 100% perfect classification of sampling site based on discrimination between variables observed.

The low Wilk's Lambda value (0.058) revealed the strength of the variable at discriminating between the two study area in decreasing order as follows: phosphate > nitrate > salinity > conductivity >hardness>TDS > chloride > ammonia > magnesium > sodium > calcium. The standardized coefficients comparing variables measured on different scales downgraded the discriminative ability of phosphate to 5th position while promoting discriminant ability of conductivity, sodium, TDS and hardness above phosphate (Table 5).

Physical parameters like temperature, DO, and $\%O_2$ and coliform count did not contribute to the classification of the study areas. It may be that geographical location with respect to groundwater hydrological properties did not have an influence the variation in the physical and microbial properties of the groundwater between the two study sites.

The result of the discriminant analysis (Table 5 and 6) showed that differences which exist among variables in the study areas were not only limited to the proximity to soakaway or water level nor due to chance, therefore the significant difference in the hydrologic properties of the two locations might be a contributory factor [37-38].

Table 5. The Standardized Coefficients comparing Variables Measured in the Different Study Sites. ANOVA Tests of Equality of Group Means for Discriminant analysis.

	Wilks' Lambda	F	Standardized Coefficient
Temperature	0.98	0.51	0.20
Phosphate	0.23	95.25*	2.75
Nitrate	0.30	68.46*	-2.17
Ammonia	0.42	40.11*	0.27
Chloride	0.34	55.40*	-0.12
Ph	0.94	1.77	-0.40
Sodium	0.45	35.17*	-4.96

Magnesium	0.45	36.16*	-1.04
Potassium	0.99	0.35	-0.07
Calcium	0.52	26.72*	-0.01
Conductivity	0.30	67.35*	6.23
TDS	0.30	66.84*	-4.25
Salinity	0.30	67.79*	-0.48
Hardness	0.30	67.10*	4.25
DO	1.00	0.12	
$\%O_2$	1.00	0.09	
Coliform	0.93	2.04	

*Values do not have a significant contribution to the discriminant model. The higher the Wilk's Labda value to stronger the contributory strength of the variable.

Table 6. Predicted group membership.

			Predicted Group Membership		
		Grouping	Agbowo	Akobo	Total
Original	Count	Agbowo	20	0	20
		Akobo	0	11	11
	%	Agbowo	100.0	0	100.0
		Akobo	0	100.0	100.0
Cross-validated	Count	Agbowo	20	0	20
		Akobo	0	11	11
	%	Agbowo	100.0	0	100.0
		Akobo	0	100.0	100.0

3.6. Regression Analysis for Multiple Dependent Variables by General Linear Model (GLM)

The result of the GLM Multivariate procedure presented in Table 7 provided regression analysis for multiple dependent variables by factor variable (location of the study area) and the covariates (well closeness to soakaway and well depth) based on the model, in which location, distance and well depth are assumed to have linear relationships to the physico-chemical parameters and coliform count of the well water. The Pillar's trace for location presented the highest value of 0.74 showing location as the effect that contributed most to the model followed by distance. The closeness of Hotelling's trace (0.159) and Pillai's Trace (0.137) for Average well depth showed that well depth do not contribute much to the model. Roy's Largest Root showed the degree of contribution to the model as Location> Distance> Well depth. The equality of Roy's largest root and Hotelling's trace statistics revealed that the effect is predominantly associated with the strong correlation between the dependent variables. The GLM Partial eta squared presented the practical significance of effect based upon the ratio of the variation accounted for by the effect to the sum of the variation accounted for by the effect and the variation left to error. Partial Eta Squared value of 0.740, 0.382 and 0.137 were reported for location, Distance and well depth respectively (Table 7), showing their degree of contribution to the model in that order.

The multivariate GLM presented in Table 7 conclusively revealed that location contributed more to the variation that existed among physical and chemical parameters of the well water examined than soakaway proximity to well site and well depth; however, proximity to soakaway had a greater impact on the coliform count. Most of the well water quality in Akobo and Agbowo were below acceptable limit of NESREA [39] except for coliform count and chloride concentration.

Table 7. Regression Analysis for Multiple Dependent Variables by General Linear Model (GLM)

Pillai's trace is a positive-valued statistic. Increasing values of the statistic indicate effects that contribute more to the model. Wilks' Lambda is a positive-valued statistic that ranges from 0 to 1. Decreasing values of the statistic indicate effects that contribute more to the model. Hotelling's trace is the sum of the eigenvalues of the test matrix. It is a positive-valued statistic for which increasing values indicate effects that contribute more to the model. Roy's largest root is the largest eigenvalue of the test matrix. Thus, it is a positive-valued statistic for which increasing values indicate effects that contribute more to the model.

Effect		Value	F	Hypothesis df	Error df	Sig.	Partial Eta Square
Intercept	Pillai's Trace	0.93	74.28	4.00	22.00	0.000	0.93
	Wilks' Lambda	0.07	74.28	4.00	22.00	0.000	0.93
	Hotelling's Trace	13.51	74.28	4.00	22.00	0.000	0.93
	Roy's Largest Root	13.51	74.28	4.00	22.00	0.000	0.93
Distance	Pillai's Trace	0.38	3.39	4.00	22.00	0.026	0.38
	Wilks' Lambda	0.62	3.39	4.00	22.00	0.026	0.38
	Hotelling's Trace	0.62	3.39	4.00	22.00	0.03	0.38
	Roy's Largest Root	0.62	3.39	4.00	22.00	0.03	0.38
Average well Depth	Pillai's Trace	0.14	0.87	4.00	22.00	0.50	0.14
	Wilks' Lambda	0.86	0.87	4.00	22.00	0.50	0.14
	Hotelling's Trace	0.16	0.87	4.00	22.00	0.50	0.14
	Roy's Largest Root	0.16	0.87	4.00	22.00	0.50	0.14
Location	Pillai's Trace	0.740	15.70	4.00	22.00	0.00	0.74
	Wilks' Lambda	0.260	15.70	4.00	22.00	0.00	0.74
	Hotelling's Trace	2.852	15.70	4.00	22.00	0.00	0.74
	Roy's Largest Root	2.852	15.70	4.00	22.00	0.00	0.74

3.7. Water Quality Index (WQI)

All the Physico-Chemical and Microbial parameters analyzed were used to calculate the WQI in accordance with the procedure explained in methodology. The results of the WQI were presented in Table 8 and 9. Only 16.13% of the sampled well water fall within the excellent water quality range and 9.68% are within the very poor water while 74.19% of the sampled well waters were unsuitable for drinking. In Agbowo, 73.9% of the study area samples were unsuitable for

drinking while 54.55% of the Akobo were unsuitable for drinking. High coliform count was the predominant variable responsible for the poor quality of the water sample in Akobo, while high chlorine and coliform count were responsible for the poor well water quality in Agbowo.

Table 8. Water Quality Index (WQI)

Location	Coliform count	NO_3^-	Cl^-	Ca^{2+}	Mg^{2+}	pH	WQI	Water Quality
AG1	290.00	30.54	199.50	9.72	1.85	6.96	305.32^{p}	Unsuitable for drinking
AG2	1600.00	40.48	245.00	14.05	2.18	7.00	1619.31*	Unsuitable for drinking
AG3	535.00	26.27	150.00	8.04	1.67	7.23	551.13^{p}	Unsuitable for drinking
AG4	1600.00	44.82	355.00	15.30	2.27	7.52	1620.18*	Unsuitable for drinking
AG5	1600.00	35.06	235.00	11.06	1.94	7.16	1617.02*	Unsuitable for drinking
AG6	815.00	27.37	235.00	7.57	1.64	6.78	831.23^{p}	Unsuitable for drinking
AG7	950.00	32.08	295.00	11.08	1.95	7.14	966.49	Unsuitable for drinking
AG8	260.00	27.08	215.00	8.14	1.75	7.02	275.97^{p}	Very poor water
AG9	825.00	33.82	255.00	11.39	1.90	6.89	840.80^{p}	Unsuitable for drinking
AG10	625.00	35.38	325.00	12.67	2.10	7.11	641.20^{p}	Unsuitable for drinking
AG11	1050.00	42.41	295.00	14.98	2.19	7.01	1066.71*	Unsuitable for drinking
AG12	1600.00	60.54	430.00	16.09	3.51	7.27	1619.22*	Unsuitable for drinking
AG13	1600.00	48.92	475.00	16.81	3.45	7.46	1620.72*	Unsuitable for drinking
AG14	1600.00	42.39	430.00	37.11	2.41	7.61	1618.79*	Unsuitable for drinking
AG15	1600.00	47.46	465.00	14.61	2.23	7.56	1617.44*	Unsuitable for drinking
AG16	1600.00	42.30	315.00	14.66	2.24	6.65	1616.51*	Unsuitable for drinking
AG17	8.60	32.92	245.00	9.91	1.95	6.72	24.07^{p}	Excellent
AG18	1050.00	34.87	220.00	12.45	2.08	7.50	1066.25*	Unsuitable for drinking
AG19	920.00	37.13	250.00	13.13	2.13	7.27	936.83^{p}	Unsuitable for drinking

AG20	31.00	39.16	340.00	13.97	2.29	6.63	48.66[p]	Excellent
AK1	7.50	17.45	75.00	5.01	1.15	6.89	21.08[p]	Excellent
AK2	1600.00	18.56	95.00	5.12	1.45	6.87	1613.83*	Unsuitable for drinking
AK3	1600.00	18.38	75.55	5.11	1.33	7.05	1615.15*	Unsuitable for drinking
AK4	185.00	18.03	75.00	3.83	1.34	6.97	201.90[p]	Very poor water
AK5	360.00	10.06	75.00	2.44	0.84	6.01	374.75[p]	Unsuitable for drinking
AK6	1150.00	16.38	80.00	3.47	1.22	7.03	1166.62*	Unsuitable for drinking
AK7	900.000	15.41	100.00	2.98	1.12	5.99	913.29*	Unsuitable for drinking
AK8	1600.00	15.87	75.00	4.08	1.26	7.17	1616.83*	Unsuitable for drinking
AK9	2.000	15.82	80.00	2.00	1.26	6.77	15.75[p]	Excellent
AK10	10.000	18.42	95.00	4.00	1.09	6.45	255.20[p]	Very poor water
AK11	1.000	15.33	136.00	4.61	1.67	6.96	15.80[p]	Excellent

WQI= Water Quality Index, [p]Below within zone average, *Above within zone average. AK= Akobo, AG=Agbowo. Akobo Average=710.0179, Agbowo Average=1025.191

Nitrate level exceeding the recommended standard (45mg/L) as observed in Wells AG4, AG12, AG13 and AG15 sampled and this has been reported to cause methemoglobinemia in infants [31,32,40-41], thereby rendering the water unfit for infant consumption.

Table 9. Standard water quality classification scheme based on WQI value

WQI value	Water Quality	Water sample	Location	Water Sample
<50	Excellent	5 (16.13%)	Agbowo	2 (10%)
			Akobo	3 (27.27%)
50 – 100	Good water	0 (0%)	Agbowo	0 (0%)
			Akobo	0 (0%)
100 – 200	Poor water	0 (0%)	Agbowo	0 (0%)
			Akobo	0 (0%)
200 – 300	Very poor water	3 (9.68%)	Agbowo	1 (5.00%)
			Akobo	2 (18.18%)
>300	Unsuitable for drinking	23 (74.19%)	Agbowo	17 (73.9%)
			Akobo	6 (54.55%)

High level of Chloride observed in all Agbowo sample site (Average 299mg/L against 200mg/L NESREA Standard) have been associated with sewage pollution [18]. Chloride is often chemically bonded with sodium naturally present in soil to form Sodium Chloride which impact salty taste on water. The simultaneous fluctuation in the concentration of some variables may be accounted for by infiltration of rainwater through the porous and permeable unconfined aquifer into shallow water table that enriches the groundwater with dissolve solute taken from surface and subsurface soil. From observation water conductivity, TDS and salinity decreased immediately after rainfall.

Slightly Low pH level in AK5, AK7 and AK10 well water (below recommended standard 6.5 to 8.5)) observed in some sample points in Akobo may be accounted for by the low level of calcium and magnesium concentration in the study area [42].

4. CONCLUSION

In this study various statistical techniques were use to evaluate quality and variation in physical, chemical and microbial parameters of wellwater (underground water) in Agbowo and Akobo in relation to their proximity to saokaway and in different geographical environment of Ibadan Metropolis. The result showed that leachates from soakaway owing to proximity to wellwater impact on physic-chemical properties such as nitrate, ammonia, chloride, sodium, magnessium, conductivity, TDS, salinity, water hardness, and microbial qualities of the wellwater. Precipitation also contributes significantly to the migration of coliforms from various sources to the underground water.

There is therefore a need for biogeochemistry assessment of hydrologic environment before considering siting of well water in any location. The results suggest that the minimum standard distance between soakaway and well water will vary with different hydrologic environment and recommend a restriction on digging wells for domestic use in area of high aquifer level rather; borehole should be an alternative for the provision of portable water in such areas.

COMPETING INTERESTS

“We declare no conflict of interest”.

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