British Journal of Applied Science & Technology
10(6): 1-18, 2015, Article no.BJAST.12452
ISSN: 2231-0843

SCIENCEDOMAIN *international*
www.sciencedomain.org

SCIENCEDOMAIN

Assessment of Hydrological Properties and Proximate Impact of Septic Tank Leachate on Well-water Quality in Two Residential Areas in Ibadan, South-western Nigeria

Roseangela I. Nwuba[1*] and Amire O. Philips[2]

[1]*Department of Zoology, Cellular Parasitology Programme, Cellular Biology and Genetics Unit, University of Ibadan, Nigeria.*
[2]*Department of Zoology, Ecology and Environmental Biology Unit, University of Ibadan, Nigeria.*

Authors' contributions

This work was carried out in collaboration between both authors. Author RIN designed the study, wrote the protocol, corrected the manuscript and managed literature searches; while author AOP carried out the work, performed the statistical analysis, managed literature searches and wrote the first draft of the manuscript. Both authors read and approved the final manuscript.

Article Information

DOI: 10.9734/BJAST/2015/12452
Editor(s):
(1) Jian Guo Zhou, Centre for Engineering Sustainability, School of Engineering, University of Liverpool, UK.
(2) Ahmed Fawzy Yousef, Geology Department, Desert Research Center, Egypt.
Reviewers:
(1) K. Arumugam, Department of Civil Engineering, Anna University, India.
(2) Anonymous, University of Illinois, USA.
(3) Anonymous, Autonomous University of Morelos State, México.
(4) Anonymous, Al al-Bayt University, Jordan.
Complete Peer review History: http://sciencedomain.org/review-history/10280

Original Research Article

Received 2nd July 2014
Accepted 10th July 2015
Published 23rd July 2015

ABSTRACT

Aims: To determine the impact of leachate from septic tank 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 areas.
Place and Duration of Study: Residential houses at Agbowo and Akobo, Ibadan, Nigeria between April and August, 2012.

**Corresponding author: E-mail: r.nwuba@mail.ui.edu.ng, rnwuba@yahoo.com;*

Methodology: The well-water samples were collected from 30 sites once every month; from different wells located at various perimeters from the septic tanks. The distance between the septic tanks 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: A significant increase ($p<0.01$) was found in results from coliform counts between dry and wet seasons, while significant decrease ($p<0.05$) was recorded in the concentration of phosphate, salinity, total dissolved solids and potassium. The distance from the well to the septic tanks 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 sites. Partial Eta Squared value of 0.740, 0.382 and 0.137 were reported for location, proximity of septic tank to well-water site and well depth respectively, showing their degree of contribution to variation in parameters measured.
Conclusion: The results stressed the need to set standards concerning the distance and location of wells from septic tanks/septic tank, while considering spatial and temporal variations in hydrological environment of well-water sites.

Keywords: Well-water quality; water quality index; physico-chemical variation; septic tank; bacteriological assessment.

1. INTRODUCTION

As population grows 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 as the major cities 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 increase in under-ground water pollution.

Groundwater contributes only 0.6% of the total water resources on earth, yet, it remains the major source of drinking water in Nigeria, as in every part of the world [3]. Ideally, potable water sources must be highly pure and free from chemical and microbial contamination. However, this useful resource is under threat of pollution from human activities as evident in low level of hygiene practices [4-6], and lack of recommended 'safe distance' between well-water/borehole and septic tank sites in Nigeria. In view of this, monitoring the chemical, physical, and microbiological quality of groundwater is as important as assessing its 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 conditions 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 sources 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 septic tanks and other municipal sewage contain variety of chemicals like detergents, germicides, complex organic compounds and metals. Besides, human effluent composite 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 which may be hazardous to human health if such water is consumed without treatment [13,14]. Additionally, uncontrolled microbial actions 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 worldwide and it is of particular significance to drinking water sourced from shallow water table [13,15]. During leachate percolation, water present in the waste and those generated by biodegradation serve as vehicle for leachate's 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 favourable 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, though 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 means of securing potable water for daily consumption. This study seeks to assess the proximate impact of septic tank leachates on the physico-chemical and microbial quality of groundwater in different hydrological settings viz: Agbowo (densely populated) and Akobo (sparsely populated) residential areas of Ibadan, Nigeria. This will provide a baseline information towards exploring a possible minimum distance that could be recommended for Nigeria, where well-water is the most common water source within the cities.

2. METHODOLOGY

2.1 Location and Geology of the Study Area

This study was carried out in Agbowo and Akobo residential areas of Ibadan. Ibadan is located in south-western Nigeria, 160 km inland northeast of Atlantic coast of Africa, situated in-between rainforest and savanna. The study areas lie within latitudes 7°25'37"N and 7°26'26" N and Longitude 3°54'25" E and 3°56'50" E (Fig. 1). The climate of the study areas is tropically wet and dry, with the wet season from mid-March to October and dry period from November to March. The study was conducted within the Precambrian Basement Complex terrain of south-western Nigeria [17]. The main lithology of the rock unit include the amphibolites, migmatite gneisses, granites and pegmatites. Other important rock units are the schists, made up of biotite schist, quartzite schist talk-tremolite schist, and the muscovite schists [18].

The topography of the city is characterized by undulating terrain with general elevation between 180 m and 210 m above sea level, and is drained by rivers Omi, among others. Occurrence of groundwater is dependent on the extent of weathered units and development of secondary porosity, e.g. fractures, faults, joints [19]. Consequently, the weathered aquifers are generally discontinuous, with groundwater occurrences in localized disconnected phreatic weathered regolith aquifers, essentially under unconfined to semi-confined conditions [20].

2.2 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.

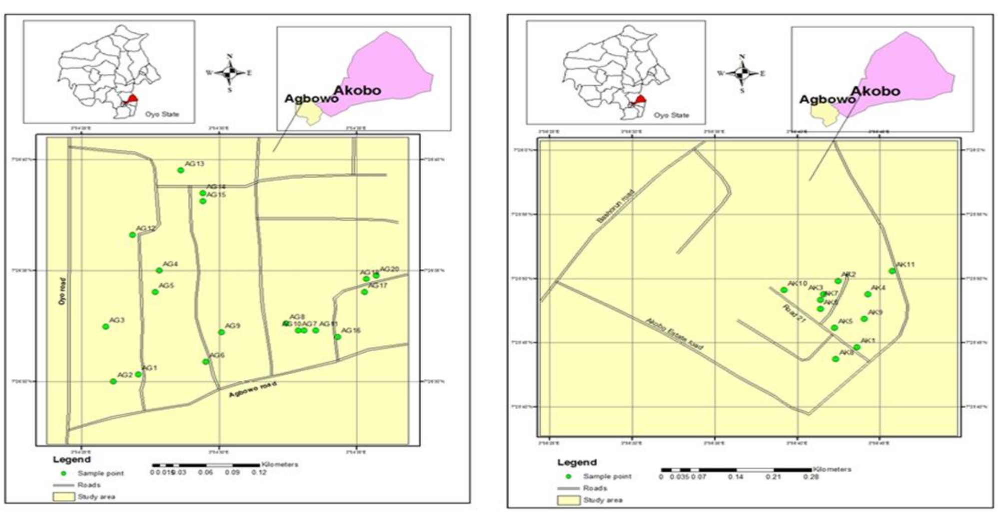

Fig. 1. Map of the study area [A: Agbowo (a densely populated area) and B: Akobo (a sparsely populated area)]

2.3 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-drying. 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°C prior to analysis.

2.4 Well Depth and Water Level Determination

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

2.5 Determination of Physical and Chemical Parameters

Non-conservable parameters like, pH, Salinity and other parameters like Total Dissolved Solid (TDS), conductivity, temperature (°C), Dissolve Oxygen (DO) and percentage Oxygen ($\%O_2$) 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 Phenoldisulphonic acid method, Phosphate (PO_3^{-4}) by Ascorbic Acid Method and Ammonia by Indophenols (Colorimetric).

2.6 Total Coliform Assessment

Sterile corning tubes were used to collect well-water samples from various sampling sites and were preserved at 4°C prior to microbial analyses. Microbial analyses were carried out within 24 hours of collection. Borosilicate glassware 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 5 mL of the broth media (3.5% w/v) into 160/15 mm 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 (1 mL) were prepared with distilled water. The prepared concentrations were introduced into sterilized fermentation tubes.

Most Probable Number (MPN)/100 mL were estimated using MPN Index of Standard methods 9221 Standard Total Coliform fermentation technique [21]. 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).

2.7 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 septic tank 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 physico-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 zones (Agbowo and Akobo). The Water Quality Index (WQI) was determined using the Weighted Arithmetic Index method [22].

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 of well-water sample analysed during the study period between the month of April and

August, 2012. In this study, the distance between well and septic tank ranges from 4 to 30.5 m and well depth ranges from 0.25-15 m. Well depth in Akobo study area ranges from 4 to 15 m, while Agbowo recorded depth range of 0.25 to 5.5 m, indicating an 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 source of water [23] because of the purification properties of soil [24]. 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 [25]. The result presented in Table 1 shows that the overall water hardness, DO, coliform, distance from nearest septic tank, 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 [26-27]. A 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 Akobo, a low density area (97.58, 181.98, 0.1, 111.50 respectively). The overall evaluation of most parameters however fell below the permissible limit of NESREA; except coliform count and chloride concentration [28].

3.2 Coliform Count in the Dry and Rainy Seasons

The presence of coliform was confirmed by lactose fermentation and concurrent gas production. There was a strong negative correlation ($r = -0.51$, $P < 0.05$) between coliform count and distance from septic tank for the 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 and that of well depth in wet season ($r = -0.16$, $P>0.05$).

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 °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/100 mL	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	

On the other hand, slightly positive but insignificant correlation (r = 0.1, P>0.05) existed between coliform count and well depth during dry season (Table 2). Well-water in Akobo study area recorded a low mean coliform count of MPN 674.14/100 mL with higher kurtosis (-1.85) compared with Agbowo which recorded a mean of MPN 1008.00/100 mL and -1.20 for kurtosis indicating that well samples coliform count in Akobo clustered less around high MPN value than Agbowo samples.

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

	Coliform count in dry season	Coliform count in wet season
Distance from well to septic tank	-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 shows 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 sanitation level and hygiene practices [28] and other environmental factors observed in the community [1] may have contributed to the high microbial assessment of Agbowo wells. It was observed that the layout of the buildings in Agbowo were highly clustered and not well planned, resulting in the close distance of well sites to septic tanks and refuse dumps. An extreme observation involved cases in fenced neighbourhoods where wells were ignorantly sited at close proximity to the septic tank of the neighbouring house. This might have affected the reported high value of Coliform density observed in site AG2 with > MPN1600/100 mL and it supports the report on human waste contamination of groundwater by USEPA [29].

The negative correlation obtained between total coliform count and distance from the nearest septic tank and well-depth (Table 2) suggests that the total coliform decrease with increasing well distance and well depth. This is in agreement with the findings of Adekunle et al. [30] and Adetunji and Odetokun [1] and also in agreement with the fact 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 [31]. 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 studies [31] revealed that coliform could travel distance of 70.7 m from sewage trenches intersecting groundwater while covering a distance of 30.5 m within 35 hrs when travelling through sand and pea gravel aquifer. Francy et al. [32] also confirm an association between proximity of septic tank 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 exist in microbial and physico-chemical parameters of well-water sample in the dry season (April) and wet season (Average of value obtained between May and August) was determined (Table 3). The result shows that there was significant increase of coliform count between the dry season and wet season. (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).

The result of monthly variation observed in salinity, TDS and conductivity were as shown in Figs. 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 (Fig. 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 areas. 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 (Figs. 3 and 4).

The increased concentration of Salinity, TDS and Conductivity between the month of April to May as shown in Figs. 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 [26]. Precipitation also enhanced dissolution of materials naturally present in soil and the introduced water dissolved ionic and non-ionic minerals. The resulting water that moves through the soil to the underlying groundwater will then be enriched with high load of soluble salt [25] and consequently enhance the leaching of septic tank 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 [26] compounded by human withdrawal 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 [33] for Agbowo and Akobo study areas.

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 differences between dry season and wet season*

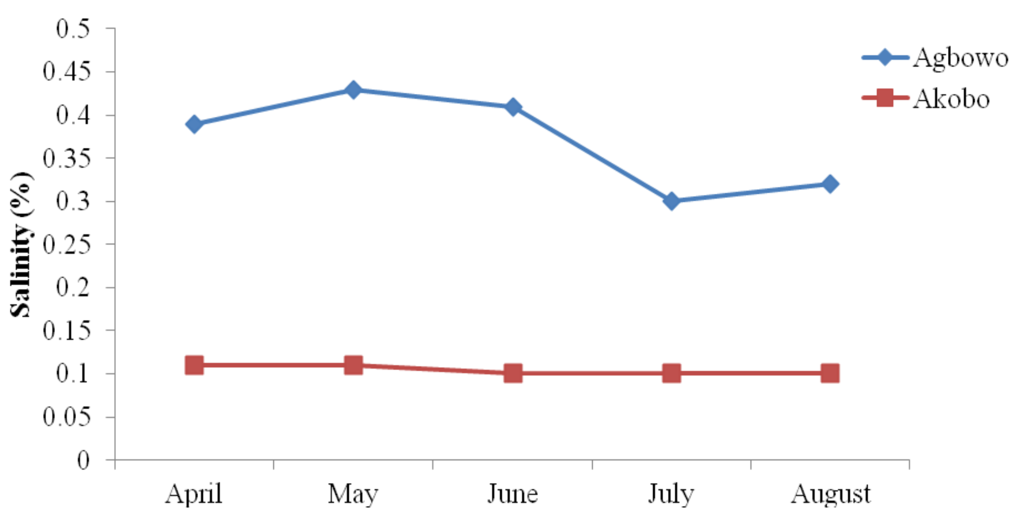

Fig. 2. Monthly variations in salinity of well water samples in Agbowo and Akobo

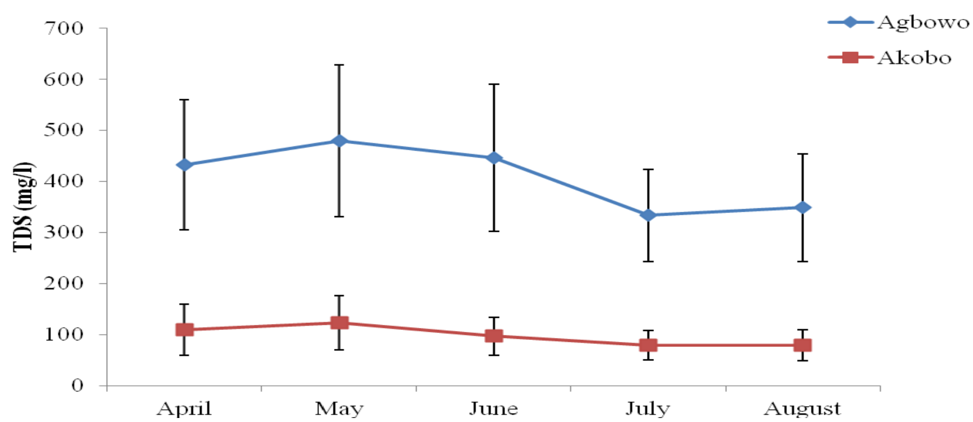

Fig. 3. Monthly variations in total dissolve solid (TDS) of well water samples in Akobo and Agbowo

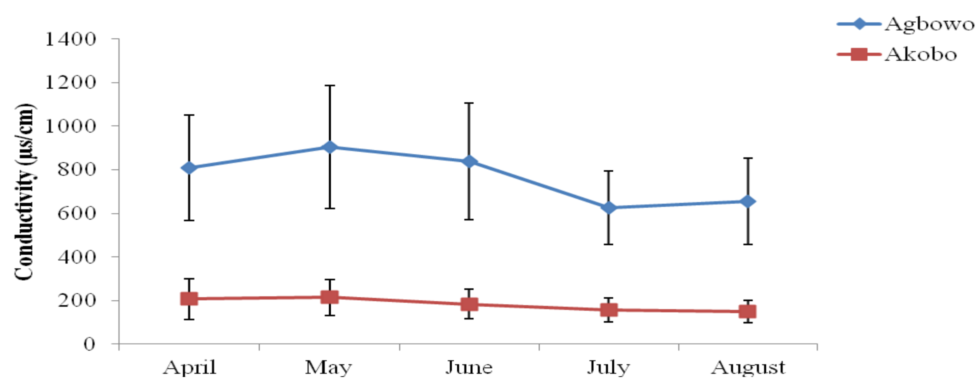

Fig. 4. Monthly variations in conductivity of well water samples of Akobo and Agbowo

3.4 Inter-relationships of Microbial, Physical and Chemical Parameters

The result of the correlation analysis performed to evaluate the extent of the interrelationship that exists among the assessed variables 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.

Conductivity and TDS were perfectly correlated ($r = 1.00$) (Table 4). A significant positive correlation ($P<0.05$) was found between log transformed coliform count and other parameters like phosphate, nitrate, ammonia, sodium, conductivity, TDS and salinity. Well distance from septic tank had 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, was in line with previous work that had associated leachate from septic tank impacting on the concentrations of these variables concurrently [34-35]. The presence of coliform in the groundwater had been reported to indicate contamination by human and animal faeces [22,36]. These pathogens may pose a health hazard to infants and people with weak immune systems [36]. The significant variations in coliform count during wet and dry seasons; in relation to distance of well from septic tank and well depth show that run-off and weathering resulting from precipitation during raining season had a positive impact on the migration of coliform from different pollution sources to the receiving underground water.

The strong co-linearity that existed between salinity, TDS and conductivity as expressed in the correlation matrix shows 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 septic tank and soluble particles represented by salinity, TDS, conductivity show a possible contamination through leaching from proximate septic tank. This was justified by SWRC [25] findings that discharges from septic systems increased the salinity of the receiving water body. Most salt resulting from these soluble particles do not naturally degrade, and can remain in groundwater for decades [25].

The weak negative correlation that existed between well proximity to septic tank and Nitrate; phosphate and ammonia concentrations may suggest that leachate from septic tank contributed to the increased concentrations of these parameters [37-39]. The strong negative correlation reported for nitrate concentration and well depth agrees with Piskin [40] whose findings indicates that Nitrate concentration decrease with increase in well-depth. Nitrate and Ammonia are by-products of natural break-down of Nitrogen containing organic compounds from human and domestic wastes that accumulate in the septic tank and this is reflected in the observed strong positive correlation between the above two variables.

The negative correlation that was found to exist between well depth and the following variables: phosphate; nitrate; ammonia; chloride; sodium; magnesium; calcium; conductivity; TDS; salinity and hardness further establishes the fact that areas with high aquifer levels are most predisposed to particulate contamination [40]. This may account for the reason why 73.9% of well samples at Agbowo study area, with well depth range (0.25 to 5.5 m), were unsuitable for drinking; when compared to Akobo which recorded a well depth range of 4 m to 15 m 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 (°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, $\%O_2$= 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 shows 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 (16.151) for the first discriminant function accounts for 100% of the variance that exists among the variables obtained from the two study areas and the Chi square test (X^2 = 62.526, df=30, P<0.01) shows that the difference in the two groups was 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) shows 100% perfect classification of sampling site based on discrimination between variables observed.

The low Wilk's Lambda value (0.058) reveals the strength of the variable at discriminating between the two study areas in decreasing order: 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 on the variation in the physical and microbial properties of the groundwater between the two study sites.

The result of the discriminant analysis (Tables 5 and 6) shows that differences which exist among variables in the study areas were not only limited to the proximity to septic tank or water level nor due to chance, therefore the significant difference in the hydrologic properties of the two locations might be a contributory factor [41-42].

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

The result of the GLM Multivariate procedure presented in Table 7 provides regression analysis for multiple dependent variables by factor variables (location of the study area) and the covariates (well closeness to septic tank and well depth) based on the model, in which location, distance and well depth were 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 the average well depth showed that well depth does 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 degrees of contribution to the model in that order.

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.*

The multivariate GLM presented in Table 7 conclusively reveals that location contributes more to the variation that exist among physical and chemical parameters of the well water examined, than septic tank proximity to well site and well depth. However, proximity to septic tank has a greater impact on the coliform count. Most of the well water quality in Akobo and Agbowo were below acceptable limit of NESREA [43] except for coliform count and chloride concentration.

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 on the other hand, 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.

3.7 Water Quality Index (WQI)

All the physico-chemical and Microbial parameters analysed were used to calculate the WQI in accordance with the procedure explained in the methodology section. The results of the WQI were presented in Tables 8 and 9. Only 16.13% of the sampled well water fall within the excellent water quality range and 9.68% were within the very poor water range; while 74.19% of the sampled well waters were unsuitable for drinking. The quality of the well water collected from the two different study areas have shown that in Agbowo, 73.9% of the water samples collected were unsuitable for drinking, while 54.55% of that collected from 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 6. Predicted group membership

		Grouping	Predicted group membership		Total
			Agbowo	Akobo	
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

Table 7. Regression analysis for multiple dependent variables by General Linear Model (GLM)

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

Table 8. Water quality index (WQI)

Location	Coliform count	NO_3^-	Cl^-	Ca^{2+}	pH	Distance (m) between well and septic tank	Water depth in dry season (m)	Water depth in wet season (m)	WQI	Water quality
AG1	290.00	30.54	199.50	9.72	6.96	13	4	2	305.32^{ν}	Unsuitable for drinking
AG2	1600.00	40.48	245.00	14.05	7.00	4	4	3	1619.31*	Unsuitable for drinking
AG3	535.00	26.27	150.00	8.04	7.23	16	3	2	551.13^{ν}	Unsuitable for drinking
AG4	1600.00	44.82	355.00	15.30	7.52	10.5	3	2.5	1620.18*	Unsuitable for drinking
AG5	1600.00	35.06	235.00	11.06	7.16	12.3	3	2.5	1617.02*	Unsuitable for drinking
AG6	815.00	27.37	235.00	7.57	6.78	29	5	2.2	831.23^{ν}	Unsuitable for drinking
AG7	950.00	32.08	295.00	11.08	7.14	7.5	3	2	966.49	Unsuitable for drinking
AG8	260.00	27.08	215.00	8.14	7.02	7.6	3	1.5	275.97^{ν}	Very poor water
AG9	825.00	33.82	255.00	11.39	6.89	4.4	1.5	0.2	840.80^{ν}	Unsuitable for drinking
AG10	625.00	35.38	325.00	12.67	7.11	12	4	2.3	641.20^{ν}	Unsuitable for drinking
AG11	1050.00	42.41	295.00	14.98	7.01	10	4.5	2.3	1066.71*	Unsuitable for drinking
AG12	1600.00	60.54	430.00	16.09	7.27	5	6	5	1619.22*	Unsuitable for drinking

AG13	1600.00	48.92	475.00	16.81	7.46	15.5	4.5	1.5	1620.72*	Unsuitable for drinking
AG14	1600.00	42.39	430.00	37.11	7.61	25	6	2	1618.79*	Unsuitable for drinking
AG15	1600.00	47.46	465.00	14.61	7.56	24	6	2	1617.44*	Unsuitable for drinking
AG16	1600.00	42.30	315.00	14.66	6.65	24	4	2	1616.51*	Unsuitable for drinking
AG17	8.60	32.92	245.00	9.91	6.72	18	2	0	24.07$^{\flat}$	Excellent
AG18	1050.00	34.87	220.00	12.45	7.50	11	1	0.25	1066.25*	Unsuitable for drinking
AG19	920.00	37.13	250.00	13.13	7.27	11	0.5	0	936.83$^{\flat}$	Unsuitable for drinking
AG20	31.00	39.16	340.00	13.97	6.63	18	1.5	0	48.66$^{\flat}$	Excellent
AK1	7.50	17.45	75.00	5.01	6.89	30	13	12	21.08$^{\flat}$	Excellent
AK2	1600.00	18.56	95.00	5.12	6.87	14	6	2.5	1613.83*	Unsuitable for drinking
AK3	1600.00	18.38	75.55	5.11	7.05	8.2	6	2.3	1615.15*	Unsuitable for drinking
AK4	185.00	18.03	75.00	3.83	6.97	22	4	3	201.90$^{\flat}$	Very poor water
AK5	360.00	10.06	75.00	2.44	6.01	14.2	8	8	374.75$^{\flat}$	Unsuitable for drinking
AK6	1150.00	16.38	80.00	3.47	7.03	13	5	4	1166.62*	Unsuitable for drinking
AK7	900.000	15.41	100.00	2.98	5.99	15	5	4.4	913.29*	Unsuitable for drinking
AK8	1600.00	15.87	75.00	4.08	7.17	16	15	14	1616.83*	Unsuitable for drinking
AK9	2.000	15.82	80.00	2.00	6.77	30.5	15	13	15.75$^{\flat}$	Excellent
AK10	10.000	18.42	95.00	4.00	6.45	26	4	3	255.20$^{\flat}$	Very poor water
AK11	1.000	15.33	136.00	4.61	6.96	30	15	14	15.80$^{\flat}$	Excellent

*WQI= Water Quality Index, $^{\flat}$Below zone average, *Above zone average. AK= Akobo, AG=Agbowo.*
Akobo Average=710.0179, Agbowo Average=1025.191

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%)

Nitrate level exceeding the recommended standard (45 mg/L) as observed in Wells AG4, AG12, AG13 and AG15 sampled and this has been reported to cause methemoglobinemia in infants [35,36,44-45], thereby rendering the water in these wells unsafe for infant consumption.

High level of Chloride observed in all Agbowo sample site (Average 299 mg/L against 200 mg/L NESREA Standard) has been associated with sewage pollution [22]. 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 dissolved solute taken from surface and subsurface soil. From observation of 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 [46].

4. CONCLUSION

In this study, various statistical techniques were used to evaluate quality and variation in physical, chemical and microbial parameters of well-water (underground water) in Agbowo and Akobo in relation to their proximity to septic tank. The results have shown that leachates from septic tank owing to proximity to well-water impact on physic-chemical properties such as nitrate, Ammonia, chloride, Sodium, Magnesium, Conductivities, TDS, Salinity, water hardness, and microbial qualities of the well-water. 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 a well in any location. The results suggest that the minimum standard distance between septic tank and well water will vary with different hydrologic environments and recommend a restriction on digging wells for domestic use in areas of high aquifer levels; rather, boreholes should be an alternative for the provision of potable water in such areas.

ACKNOWLEDGEMENTS

The authors wish to thank Dr. Aina O. Adeogun and Prof. E. O. Fagade for their suggestions and allowing us use their laboratory equipment.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Adetunji VO, Odetokun IA. Groundwater contamination in Agbowo community, Ibadan Nigeria: Impact of septic tanks distances to wells. Mal. J. Microbio. 2011;7:159-166.
2. Yusuf KA. Evaluation of groundwater quality characteristics in Lagos-City. J. Appl. Sci. 2007;7:1780-1784.
3. Eluozo SN, Ademiluyi JO, Ukpaka PC. Development of mathematical models to predict the transport of *E. coli* on groundwater influence by arsenic in Port Harcourt, Rivers State, Nig. J. Environ. Sci. Water Res. 2012;1:39-45.
4. Punmia BC, Jain AK. Wastewater engineering 2nd Edition, Laxmi Publications (P) Ltd, New Delhi; 1998.

5. Akujieze CN, Coker SJ, Oteze GE. Groundwater in Nigeria- a millennium experience distribution, practice, problems and solutions. Hydrol. J. 2003;1:259-274.
6. Ahmed MI. Microbiological physio-chemical analysis of groundwater and its biological effect on population in Saint Katherine, protectorate Egypt. Thirteenth International Water Techno-logical Conference IWTC; 2009.
7. Khodapanah I. Groundwater quality assessment for different purposes in Eshtehard District, Tehran Iran. Eur. J. Sci. Res. 2009;364:543-553.
8. Chan HJ. Effect of land use and urbanization on hydrochemistry and contamination of groundwater from Taejon Area, Korea. J. hydrol. 2001;253:194-210.
9. World Population Monitoring. Population, environment and development. Department of Economic and Social Affairs Population Division, ST/ESA/ SER.A/203. United Nations, New York; 2001.
10. Lanning A, Peterson EW. Evaluating subdivisions for identifying extraneous flow in separate sanitary sewer systems. J. Water Resour. Prot. 2012;4:334-341.
11. Longe EO, Balogun MR. Ground water quality assessment near a municipal landfill, Lagos, Nigeria. Res. J. Appl. Sci. Eng. Technol. 2010;2:39-44.
12. Jothivenkatachalam K, Nithya A, Chandra-Mohan S. Correlation analysis of drinking water quality in and Perur block of Coimbatore District, Tamil Nadu, and India. Rasayan J. Chem. 2010;3:649-654.
13. UNEP/WHO. Water quality monitoring - A practical guide to the design and implementation of freshwater quality studies and monitoring programmes. ISBN; 1996.
14. Code of practice onsite wastewater management. Guidelines for Environmental Management. Publication, EPA Victoria, 200 Victoria Street, Carlton; 2013.
15. McCarthy TS, Gumbricht T, Stewart RG, Brandt D, Hancox PJ, McCarthy J, et al. Wastewater disposal at safari lodges in the Okavango Delta, Botswana. Water SA. ISSN; 2004.
16. WHO Guidelines for drinking-water quality. 4th ed. ISBN; 2011.
17. Rahaman, MA. Recent advances in the study of the basement complex of Nigeria. Precambrian Geology of Nigeria, A Publication of Geological Survey of Nigeri., 1988;11-41.
18. Akindele OO. Geology and geotectonic setting of the basement complex rocks in south western nigeria: Implications on provenance and evolution. Earth and Environmental Sciences. Dr. Imran Ahmad Dar (ed.), Intech, ISBN; 2011.
19. Asseez LO. Hydrogeology of southwestern Nigeria. The Nigerian Engineers. 1972;7(1):22–44.
20. Tijani MN. Hydrogeochemical assessment of groundwater in Moro area, Kwara State, Nigeria. Environ. Geol. 1994;24:194–202.
21. Standard Total Coliform Fermentation Technique, Standard Methods 9221B, 20th Edition; 2003.
22. Amadi AN, Olasehinde PI, Yisa J, Okosun EA, Nwankwoala HO, Alkali YB. Geostatistical assessment of groundwater quality from coastal aquifers of Eastern Niger Delta, Nigeria. Geosciences. 2012; 2:51-59.
23. Gordan M, Fair J, Gever G. Water supply and waste removal. In: Waste Engineering Vol. John Wiley and Sons; 1996.
24. Shittu OB, Olaitan JO, Amusa TS. Physico-chemical and bacteriological analyses of water used for drinking and swimming purposes in Abeokuta, Nigeria. Afr. J. Biomed. Res. 2008;11:285–290.
25. State Water Resources Control Board [SWRC]. Groundwater information sheet salinity, Division of Water Quality GAMA Program; 2010.
26. Ali M, Salam A, Ahmed N, Khan BYA, Khokhar MY. Monthly variation in physico-chemical characteristics and metal contents of Indus River at Ghazi Ghat, Muzaffargarh, Pakistan. Pakistan J. Zool. 2004;36:295-300.
27. Kaur R, Singh RV. Assessment for different groundwater quality parameters for irrigation purposes in Bikaner City, Rajasthan. Journal of Applied Sciences in Environmental Sanitation. 2011;6:385-392.
28. Bai S, Lung WS. Three-dimensional modeling of fecal coliform in the Tidal Basin and Washington Channel, Washington, DC. Part A, Toxic/Hazardous Substances and Environmental Engineering. J. Environ. Sci. Health. 2008; 41:1327-1346.
29. USEPA. National primary drinking water regulations. Washington, D.C. EPA 816-F-09-004; 2009.

30. Adekunle IM, Adetunji MT, Gbadebo AM, Banjoko OB. Assessment of groundwater quality in a typical rural settlement in Southwest Nigeria. Int. J. Environ. Res. Public Health. 2007;4:307-318.
31. Schmoll O, Howard G, Chilton PJ, Chorus I. Protecting groundwater for health: Managing the quality of drinking water sources. WHO/IWA, London; 2006.
32. Francy DS, Helsel DR, Nally RA. Occurrence and distribution of microbiological indicators in groundwater and stream Water. Water Environ. Res. 2000;72:152-161.
33. Kudaravalli SP, Kuchipudi RKP. Hydrogeological variations of ground water in different geomorphic units of Krishna Eastern Delta, Andhra Pradesh. Int. J. Eng. Sci. Technol. 2010;2:4007-4012.
34. Entry J, Farmer N. Ground water quality: Movement of coliform bacteria and nutrients in ground water flowing through basalt and sand aquifers. J. Environ. Qual. 2001;30:1533-1539.
35. WHO. Guidelines for drinking water quality. 3rd. Ed. Recommendation, Geneva. 2004;1.
36. Osuinde MI, Eneuzie NR. Bacteriological analysis of ground water. Nigeria J. Microbiol. 1999;13:47-54.
37. Spalding RF, Exner ME. Occurrence of nitrate in groundwater- A review. J. Environ. Qual. 1993;22:392-402.
38. Wilhelm SR, Schiff SL, Robertson WD. Biogeochemical evolution of domestic waste water in septic systems 2. Application of conceptual model in sandy aquifers. Groundwater. 1996;34:853-864.
39. Wakida TF, Lerner DN. Non-agricultural sources of groundwater nitrate: A review and case study. Water Res. 2005;39:3-16.
40. Piskin R. Evaluation of nitrate content of ground water in Hall County, Nebraska. Groundwater. 1973;11:4-13.
41. Dimitrov D, Velikov B, Machkova M. Cluster and discriminant analyses of groundwater, hydrochemical data in North-east Bulgaria, In: Water down under 94: Groundwater Papers; Preprints of Papers. Barton, ACT: Institution of Engineers; 1994.
42. Steinhorst RK. Discrimination of groundwater sources using cluster analysis, MANOVA, canonical analysis and discriminant analysis. Water Resour. Res. 1985;21:1149.
43. NESREA (National Environmental Standards and Regulations Enforcement Agency), National Environmental (Surface and Groundwater Quality Control) Regulations. Federal republic of Nigeria official gazette, government notice no. 136. The Federal Government Printer, Lagos, Nigeria. FGP 71/72011/400 (OL 46). 2011; 49:98.
44. USEPA. National Standard for Drinking Water. United States Environment Protection Agency; 2002.
45. Farrell-Poe K, Jones-McLean L, McLean S. Nitrate in private water wells. Arizona Cooperative Extension SUA; 2010.
46. Adegbenro PD, Oladele O. Water quality issues in developing countries –A case study of Ibadan Metropolis, Nigeria; In Water Quality Monitoring and Assessment. Edt. Kostas Voudouris and Dimitra Voutsa. InTech Janeza Trdine 9, 51000 Rijeka, Croatia; 2012.

Appendix 1. Mean of raw data

Site	Temp	PO_4^{3-}	NO_3^-	NH_4^+	Cl^-	pH	Na^+	Mg^{2+}	K^+	Ca^{2+}	Conductivity	TDS	Salinity	Hardness	DO	$\%O_2$	Coliform
AG1	28.900	18.345	30.535	42.575	199.500	6.956	2.310	1.845	2.330	9.715	606.200	322.600	0.280	300.000	0.220	2.870	290.000
AG2	28.800	21.415	40.480	54.770	245.000	6.996	2.930	2.175	2.850	14.050	882.600	472.400	0.420	380.000	0.730	10.340	1600.000
AG3	29.900	17.405	26.265	31.820	150.000	7.234	1.910	1.670	1.720	8.035	426.400	226.800	0.200	240.000	0.344	4.040	535.000
AG4	29.300	21.495	44.815	63.960	355.000	7.516	3.420	2.265	3.300	15.295	1014.600	540.000	0.500	455.000	0.640	6.780	1600.000
AG5	29.400	19.340	35.055	32.605	235.000	7.160	2.515	1.940	2.655	11.055	787.600	419.800	0.380	330.000	0.376	4.200	1600.000
AG6	29.400	17.305	27.370	31.365	235.000	6.780	1.910	1.635	1.910	7.565	581.800	309.400	0.280	245.000	0.430	4.760	815.000
AG7	29.360	17.720	32.075	47.275	295.000	7.142	2.385	1.945	2.440	11.080	708.600	378.000	0.360	305.000	0.302	3.240	950.000
AG8	29.000	16.470	27.075	41.415	215.000	7.018	2.040	1.745	2.075	8.140	594.800	316.000	0.280	255.000	0.334	4.020	260.000
AG9	29.700	18.215	33.820	40.835	255.000	6.886	2.250	1.895	2.300	11.390	636.600	338.600	0.300	315.000	0.264	3.660	825.000
AG10	29.600	18.705	35.380	53.440	325.000	7.108	2.630	2.095	2.550	12.665	802.400	428.200	0.360	340.000	0.218	2.440	625.000
AG11	29.400	21.370	42.410	62.405	295.000	7.014	3.140	2.185	3.200	14.980	812.000	432.400	0.380	420.000	0.274	3.200	1050.000
AG12	31.200	23.990	60.535	80.945	430.000	7.272	3.825	3.510	3.895	16.085	1170.000	624.600	0.560	600.000	0.378	4.600	1600.000
AG13	29.200	23.125	48.920	73.285	475.000	7.460	4.110	3.445	4.045	16.810	1340.400	716.000	0.620	610.000	0.632	7.300	1600.000
AG14	28.600	21.910	42.385	63.505	430.000	7.610	3.340	2.405	3.505	37.110	939.800	501.000	0.440	465.000	0.376	4.240	1600.000
AG15	28.600	21.815	47.460	73.140	465.000	7.560	3.160	2.225	3.365	14.610	957.400	493.800	0.460	465.000	0.128	1.060	1600.000
AG16	29.100	21.440	42.300	62.550	315.000	6.650	3.150	2.240	3.140	14.660	726.700	380.400	0.340	415.000	0.338	4.204	1600.000
AG17	29.000	18.255	32.915	40.905	245.000	6.724	2.215	1.950	2.200	9.910	547.260	288.800	0.300	310.000	0.272	3.860	8.600
AG18	29.200	18.635	34.865	53.450	220.000	7.502	2.185	2.080	2.415	12.450	557.040	296.800	0.280	335.000	0.180	2.020	1050.000
AG19	28.900	20.035	37.125	54.150	250.000	7.272	2.675	2.125	2.690	13.130	590.200	322.800	0.300	365.000	0.300	3.420	920.000
AG20	29.300	21.140	39.160	61.755	340.000	6.630	2.815	2.290	2.985	13.970	653.460	351.800	0.320	395.000	0.546	5.850	31.000
AK1	29.200	12.715	17.445	19.670	75.000	6.886	1.670	1.145	1.600	5.010	144.880	73.460	0.100	125.000	0.152	3.560	7.500
AK2	29.800	13.485	18.555	40.895	95.000	6.870	1.950	1.450	1.910	5.115	186.200	97.160	0.100	150.000	0.174	2.020	1600.000
AK3	29.660	13.500	18.380	40.730	75.550	7.046	1.890	1.325	1.870	5.110	343.800	195.800	0.140	150.000	0.340	4.160	1600.000
AK4	29.600	13.065	18.030	20.015	75.000	6.970	1.405	1.335	1.660	3.825	132.780	73.360	0.100	120.000	0.656	7.460	185.000
AK5	29.600	6.960	10.060	11.560	75.000	6.014	0.760	0.835	0.890	2.435	88.140	51.140	0.100	55.000	0.638	7.340	360.000
AK6	29.100	12.325	16.375	19.575	80.000	7.034	1.550	1.215	1.460	3.465	184.720	91.740	0.100	110.000	0.604	5.920	1150.000
AK7	29.000	13.365	15.410	17.635	100.000	5.992	1.360	1.115	1.335	2.975	137.340	74.240	0.100	90.000	0.352	3.980	900.000
AK8	29.700	13.010	15.865	19.205	75.000	7.168	1.625	1.255	1.670	4.075	157.080	87.480	0.100	125.000	0.608	7.060	1600.000
AK9	29.600	10.330	15.820	19.060	80.000	6.766	0.925	1.255	10.540	1.995	186.900	101.700	0.100	50.000	0.222	2.680	2.000
AK10	29.200	13.285	18.415	19.955	95.000	6.45	1.540	1.085	1.400	4.000	239.640	125.040	0.100	117.500	0.190	2.280	10.000
AK11	29.200	13.035	15.325	19.305	136.000	6.960	1.910	1.665	2.130	4.610	200.280	102.300	0.100	134.000	0.316	3.460	1.000

Appendix 2. Coliform count of the well sample (MPN/100ml)

Site code	Distance (m)	Water depth in dry season (m)	Water depth in wet season (m)	Dry season coliform count (MPN/100ml)	Wet season coliform count (MPN/100ml)
AG1	13	4	2	280	300
AG2	4	4	3	1600	1600
AG3	16	3	2	170	900
AG4	10.5	3	2.5	>1600	>1600
AG5	12.3	3	2.5	>1600	>1600
AG6	29	5	2.2	30	>1600
AG7	7.5	3	2	300	>1600
AG8	7.6	3	1.5	1600	240
AG9	4.4	1.5	0.2	50	>1600
AG10	12	4	2.3	350	900
AG11	10	4.5	2.3	500	>1600
AG12	5	6	5	>1600	>1600
AG13	15.5	4.5	1.5	>1600	>1600
AG14	25	6	2	>1600	>1600
AG15	24	6	2	1600	>1600
AG16	24	4	2	1600	>1600
AG17	18	2	0	8	9.2
AG18	11	1	0.25	500	>1600
AG19	11	0.5	0	240	>1600
AG20	18	1.5	0	13	49
AK1	30	13	12	7	8
AK2	14	6	2.5	1600	>1600
AK3	8.2	6	2.3	>1600	>1600
AK4	22	4	3	130	170
AK5	14.2	8	8	220	500
AK6	13	5	4	900	1600
AK7	15	5	4.4	900	900
AK8	16	15	14	1600	1600
AK9	30.5	15	13	<2	2
AK10	26	4	3	7	13
AK11	30	15	14	0	2

Ag= Agbowo, AK= Akobo

Peer-review history:
The peer review history for this paper can be accessed here:
http://sciencedomain.org/review-history/10280