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IMPACT OF CONTINUOUS FARMING ON THE MICROBIAL AND PHYSIO-CHEMICAL CONSTITUENTS IN GROUNDWATER

Adegbola, Adedayo, Akeredolu, Damilare, Oyekanmi, Martins
Department of Civil Engineering, Ladoke Akintola University of Technology,
P.M.B 4000, Ogbomoso, Oyo State, Nigeria

ABSTRACT

Water is one of nature's most important gift all living things. The importance of this gift of nature is such that without it man could hardly exist. However, the major source of water is groundwater which agricultural activities contaminate through infiltration of organic and inorganic substances used on the farm. The aim of the study is to investigate the effect of agriculture on groundwater quality. Groundwater samples were collected from thirteen (13) wells in Oyo State Agricultural Development Farm (OYSADEP) in Ogbomoso South Local Government, Nigeria. The samples were taken to the laboratory for Physical, Chemical and Bacteriological analysis. The parameters determined include pH, temperature, BOD,COD, Iron (Fe^{2+}), Sulphate (SO_4^{2+}),Potassium, Phosphorous (PO_4^{3-}) and heavy metals like Lead (Pb^{2+}), Copper (Cu^{2+}) and Zinc (Zn^{2+}). Pb^{2+}, Cu^{2+} and Zn^{2+} concentrations in the samples indicated groundwater pollution but were below the WHO limits for consumption and USEPA Maximum Contaminant Level. The pH ranges from 5.57 to 6.65 indicating toxic pollution. In the same vein, Sulphate and Ammonia-Nitrogen concentrations ranges from 6.17mg/L to 37.23 mg/L, 1.03 mg/L to 6.96 mg/L respectively, only sample 1 contain 0.05mg/L of copper, no data for Zinc. Total Coliform Count ranges from 1.2×10^3cfu/ml in Sample 4 to 17.2×10^3cfu/ml in Sample 13 exceeding WHO standards. Moreover, Total Viable Count, Total Fungal Count and Total Coliform Count was high. Statistical analyses using non-parametric Spearmen correlation indicated significant differences at 0.05. A positive moderate relationship exists between Potassium and Iron. A very strong correlation exists between potassium and Electrical Conductivity, TFC and TVC also show strong correlation. It is concluded that the samples were polluted due to agricultural activities on the studied farms; the bacteriological constituents of the entire samples were high due to organic manure and require treatment before domestic use. Water treatment, groundwater monitoring and effective nutrient management in the study is recommended.

KEYWORDS: Infiltration, Groundwater, Correlation, Conductivity, Nutrient.

INTRODUCTION

The Blue planet consists 70% water (both groundwater and surface water) and the same percent in human body (World Health Organization, 1993). This fact reveals the essentiality of water to humanity. However groundwater is an extremely valuable resource and pollution of groundwater resources is a matter of serious concern (Jeyaruba and Thushyanthy, 2009). Among the major threats to groundwater from are agricultural activities. Studies have shown that agriculture is the one of the numerous activities that pollutes the environment, especially if the chemicals are used without control. As food production is increasing, the use of chemicals and fertilizer plummets. Therefore, pollution from animal wastes, pesticides, germicides, herbicides, fertilizers, improper dispose of the organic and inorganic substance and waste constitute a huge threat to groundwater. Numerous studies have associated agricultural activities to groundwater contamination for instance Anderson *et al.* (1999) linked surface water quality with agricultural land use. In a study by Forrest *et al.* (2006), the quality of some shallow groundwater selected in certain regions in Canada contained traces of contaminants. The study found relationships between water quality parameters, land use variables and aquifer vulnerability factors like well depth, water level and surficial geology (estimated using an Aquifer Vulnerability Index), described in Dash *et al.* (2002). Also, Bergstrom and Ritter (2001) affirmed that organic constituents' leaches into groundwater. A relationship between nitrogen compound in manure and fertilizer was studied by Thomas (2009) using California as a case study. The seasonal effect of climate on fresh and groundwater quality was considered by Aizebeokhai (2011) which stated that freshwater resources including groundwater are vulnerable to climate change and variability.

Akinro *et al.* (2012), Forrest *et al.* (2006), Divya and Bealgali (2012), Nosrat *et al.* (2009), Yanjun *et al.*, (2011), and other authors that have worked on the effect of agricultural activities on groundwater quality in various environments. Most of these researches used similar approach for the analysis of the samples but little difference in the geological testing methods.

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However, in Ogbomoso community, studies relating to groundwater had be carried out such as Investigating Pollution of Groundwater from Atenda Abattoir Wastes, Ogbomoso, Nigeria by Adegbola *et al.* (2012), Assessment of the Groundwater Quality in Ogbomoso Township of Oyo State of Nigeria by Adetunde *et al.* (2011), the Groundwater Potential Evaluation at Industrial Estate Ogbomoso, Southwestern Nigeria by Sunmonu *et al.*, (2012) and very few on nitrate contaminations. These studies had been carried out effectively using direct research using chemical, physical and biological analyses on the effect of other sources of pollution but effect of agriculture is yet to receive a proper nod. This present research will bridge the gap between all other sources of groundwater contaminant and the role agricultural activities plays.

Description of Study Area

The study area is in Ogbomoso which is located in Southwestern part of Nigeria (West Africa) along the guinea savannah belt of Nigeria but human activities such as exploitation are causing major changes. It is plodding into a Sudan savanna type of vegetation. The region is located in Geographical coordinates in decimal degrees (WGS84) Latitude: 8.133, Longitude: 4.267 and her coordinates in degrees minutes seconds is (WGS84) Latitude: 8 08' 00", Longitude: 4 16' 00" (Figure 1 and Figure 2). The town comprises of North and South Local Government Area (LGA). The study area is located in the South LGA which was carved out of the north. According to 2006 census figures, she has a population of 51,249 male, 49,566 female and a total of 100,815 people in her 18 square kilometers land area. Located in the North-Eastern part of Oyo State and is bounded in the north by Ogbomoso North LGA, in the south by Ogo-Oluwa LGA, in the east by Surulere LGA and in the west by Orire LGA. Her headquarters is situated at Sunsun /Arowomole, Ogbomoso (Adetunde et al., 2009). Figure 1 display the Map of Africa, Figure 2 is the Satellite Map showing Ogbomoso while Figure 3 is the geographical map of Nigeria.

Locally, Ogbomoso area experiences tropical rainfall which dominates most of Southwestern part of Nigeria and the area has two distinct seasons, the wet season usually between March and October, and the dry season which falls between November and February every year. The annual rainfall for the study area is 1247mm, but the amount varies from 1016mm to 1524mm, and is almost entirely concentrated in the wet season. The geology of Ogbomoso comprises migmatic and granitic, calcareous and granulitic rocks (Olafisoye *et al.*, 2012).

Oyo State Agricultural Development Programme (OYSADEP) has been in existence for about 53 years. It is made up of thousands acres of land equally distributed among the 180 inhabitant farmers. The government procured the land and divided it among the farms with subsidy. In addition, shelters are provided for the farmers. Various agricultural practices in the farm include field crops, horticulture, fishery, poultry and animal rearing. Chemicals and organic manure from poultry are continually applied to plants. Shallow and deep well are scattered around the farmland. The equipment and machinery used on the farm includes: Tractor, Generators, and Trucks.

Figure 1 Map of Africa showing Nigeria
Source: Modified from http://www.aveocrowracaps.com (2014)

Figure 2. Satellite Map Showing the Location of Ogbomoso
Source: http://www.tageo.com (2014)

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Figure 3. Map of Nigeria Showing Oyo State
Source: http://www.google.com (2014)

MATERIALS AND METHODS

Water Samples Collection and Laboratory Analysis

The method adopted for this study includes issuing questionnaire to the farmers, reconnaissance survey to get the coordinates for the base map, and laboratory analyses of the groundwater samples. Thirteen (13) samples were collected from the main water well that supply the farm. The sampling was done in the month of October during the raining season although the effect of dilution may arise from precipitation during the season. It should the noted that samples were solely taken from agricultural fields early morning. During sampling, no particular spatial distance between samples was adopted as the well was randomly picked. The foregoing notwithstanding, sample locations were chosen on the basis of the intensity of agricultural practice. Sampling method is manual, 1.5Litres containers were used to take the samples. All samples were collected in sterilized plastic bottle and amber-coloured glass. The plastic and glass container was used to collect the samples; therefore, two samples were taken from each of the thirteen (13) wells. This is done because trace element to be tested for in some samples may be absorbed into the walls of plastic containers. Amber- colour glasses were used because some elements in water samples are light sensitive thus thereby eliminating photo degradation effect. Also, the sample containers were first rinsed thoroughly with the waters to be sampled. In addition, to ensure that no organisms were admitted into the bottle other than that which already exists in the water sample, the containers used to draw the water was also sterilized. Samples were securely covered and sealed in the Ice parked coolers, well labeled, and transported to the laboratory within 2 hours of collection. Physical and chemical parameters tested for include Temperature, pH, Colour, Turbidity, Total Hardness, Conductivity, Total Dissolved Solids (TDS), Total Suspended Solids (TSS) and Total Alkalinity. Dissolve Oxygen (DO), Chemical Oxygen Demand (COD), Biological Oxygen Demand (BOD), Iron (Fe^{2+}), Nitrogen-Ammonia (NH_4^{2+}), Phosphate (PO_4^{3-}),Sulphate (SO_4^{2-}), Zinc (Zn^{2+}), Lead (Pb^{2+}),Copper(Cu^{2+}),and Potassium(K^+) . Bacteriologically, analysis was performed to determine Total Coliform Count (TCC), Total Viable Count (TVC) and Total Fungal Count (TFC).

RESULTS AND DISCUSSION

Preluding the actual disussion of results, it important to put in perspective the conditions surround the thirteen (13) wells (Table 1) in OYSADEP Farm. It serves as the source of water in the farm and from which samples were collected. In addition to the farming purposes the wells serves, the principal use of the wells is domestic which ranges from washing to drinking. Moreover, the well 1-5 was located downstream south of the farmland which makes it very receptive to surface runoff during precipitation. Also, the rate of water withdrawal was very high making the well to be highly disturbed every day. Periodically, the wells were constantly desilted so that it can continue to serve the hundreds of inhabitants. It should also be noted that the samples were collected in the month of October during the rainy season when there would be high recharge to the groundwater aquifer through infiltration and leaching. Table 2 shows the physical and chemical characteristics of the groundwater samples analysed. In the same vein, bacteriological qualities are the hallmark of Table 3.

Physical, Chemical and Bacteriological analyses of the Samples.

From the result, Nitrogen ammonia is high is some samples. WHO specifies 1.5mg/L for Ammonium concentration in drinking water (Table 4) but NH_4 is higher in all the samples. Samples collected from well 1 and 3 contained 6.29mg/L and 6.96mg/L respectively. The intense use of fertilizer (Organic and inorganic) is responsible for this according to UNEP/WHO (1996). Also, the raw ammonia is converted into nitrites and then into nitrates in a process called nitrification by nitrifying bacteria. pH of groundwater samples ranges from a minimum from 5.46 in sample 5 to a maximum of 6.65 in sample 8 (Table 2 and Table 4) which were found to be within the permissible limits of WHO, USEPA, NSDWQ, IS and CDWQ standards, so also Temperature and Turbidity. The pH signifies the presence of calcium carbonate (calcareous) which is one of the geological structures of Ogbomoso (Olafisoye *et al.*, 2012). Increased Total Alkanity and hardness is attributed to it. Electrical conductivity of samples ranges from a minimum of 179uS/cm in sample 2 to a maximum of 874uS/cm in sample 4. Potassium is between 0.06mg/L in sample 2 to 0.86mg/L in sample 9. The USEPA secondary drinking water standard MCL is 0.3mg/L and WHO recommends 1mg/L. In all the samples analysed, the concentration of Iron is low.

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For TDS, all analysed samples surpasses the WHO recommendation of 1000mg/L with the highest in sample 4, 7, 9 and 11. The lowest value of 1050mg/L was detected in sample 1. In addition, 47% of the sample exceed the standard of 500mg/L TSS set by Canadian Drinking Water Quality. Sample 1, 2, 8, 11, 12 and 13 were below. The maximum value of 995mg/L and minimum of 245mg/L was recorded in sample 9 and 11 respectively (Table 2). Desilting of wells and receptivity to runoff was responsible for the values of TDS and TSS. There was absence of Lead (Pb^{2+}) as it is normally caused by industrial discharges and mine both which is not in the study area. Little traces of copper was detected in sample 1. The 0.05mg/L is within the permissible limits of of WHO and USEPA. The concentration of Zn^{2+} ranges from 0.06mg/L to 0.2mg/L in all the samples. Sulphate anions (SO_4^{2-}) in the groundwater were not intolerable with 35.95mg/l the maximum of all the 11 samples (Table 2 and Table 4). The lowest value of SO_4^{2-} (6.17mg/L) was detected in sample 6. The oxygen content of the samples in term of BOD, COD and DO was moderate.

However, all the bacteriological parameters tested for exceeded the Maximum Contaminates Level of WHO (Figure 3). Highest Total Viable Count (TVC) of 12.2 x 10^3 cfu/ml in sample 2 and 6, Total Fungal Count (TFC) of 2.8 x 10^3 cfu/ml in well 13 and TCC of of 17.2 x 10^3 cfu/ml in sample 13 (Figure 4). Therefore all the samples are considered unsafe for drinking. The high values were as a result of excess use of animal wastes as manure to the farmland.

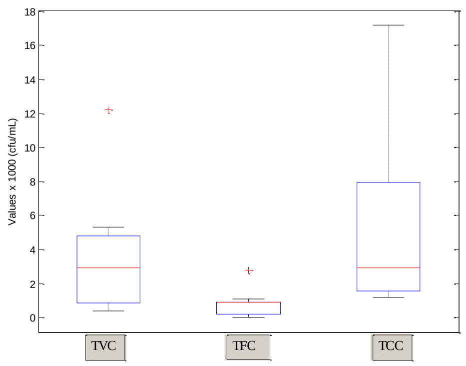

Figure 4: Boxplot of TVC, TFC and TCC

Statistical Analysis and Correlations

The Spearman Correlation (a non parametric) is used for the statistical analysis. The Spearman's correlation coefficient is a statistical measure of the strength of a relationship and direction between paired data as correlation coefficients measure the strength of association between two continuous variables while the p-value is also recorded. For this study, SPSS is used for the analyses and correlation is significant at the 0.05 level (2-Tailed)

H_o: $p \geq 0.05$ [Null Hypotheses]

H_A: $p \leq 0.05$ [Alternative Hypotheses]

From Table 5 and 6 there exist a strong positive correlation between TSS and Iron, which was statistically significant r_s (11) = 0.604, p =0 .029, a strong negative correlation between exist between Sulphate and Iron r_s (11) = -0.670, p =0 .012. Strong relationship also exist between TFC and TVC having r_s (11) = 0.711, p =0 .006, DO and BOD, Hardness and COD, Hardness and DO, Potassium and DO, Potassium and COD with r_s (11) =0.747, p=0.003. Moreover, There is a very strong correlation between Hardness and Electrical Conductivity r_s (11) =0.901, p=0.001, Potassium and Electrical Conductivity it r_s (11) =0.896, p=0.001, TSS and Hardness, TSS and potassium, TSS and EC with r_s (11) = 0.846, p =0 .001, thus Ho (Null Hypotheses) is refuted and H_A accepted.

A positive moderate correlation exists between TDS and Temperature r_s(11) = 0.454, p =0 .120, Phosphate and TFC, Potassium and Iron, Sulphate and pH. In addition, there were moderate negative correlation between COD and DO r_s (11) = -0.525, p =0 .065, TDS and Temperature r_s (11) = 0.454, p =0 .120, TA and PH, Zinc and Total Alkalinity, Sulphate and TSS, Nitrogen-Ammonia and Turbidity. Also there's a negative moderate correlation between Iron and TCC r_s (11) = -0.589, p =0 .034 thus significant, BOD and Iron r_s (11) = -0.415, p =0 .158, Zinc and Total alkalinity.

A weak negative relationship exists between Iron and pH r_s (11) = -0.368, p =0 .216, Phosphate and TSS, Turbidity and Temperature, Zinc and BOD while a positive weak relationship exists between DO and Nitrogen-Ammonia r_s (11) = 0.278, p =0 .358, Hardness and Temperature, Potassium and Temperature. Furthermore, very weak positive correlation exists between DO and Sulphate r_s (11) = 0.327, p =0 .275, Hardness and Turbidity, BOD and Turbidity. However a very weak negative correlation was found between Zinc and COD r_s (11) = -0.152, p =0 .620, potassium and Nitrogen-Ammonia, Iron and TA r_s (11) = -0.0150, p =0 .626. Therefore we accept the Ho for these parameters.

Besides, no significances was discovered between the water depth and the values of elements of pollution tested (Table 7). This is due to the high precipitation in the study area resulting in dilution of the samples during the rainy season.

CONCLUSION

From the study, the following conclusions and recommendations were made:

1. Physical, chemical and bacteriological analyses results show high concentration of some trace elements which is in line with respect to studies by Adegbola *et al.*, (2012), Akinro *et al.*, (2012), Forrest *et al.*, (2006) and requires treatment.

2. Total coliform count, total fungal count and total viable count in the thirteen (13) sampled groundwater are high. While Zn^{2+}, SO_4^{2-},PO_4^{3-} and K^+ are still within the permissible limits of WHO and USEPA, their full impact may not be noted for a long period of time because they slowly moves through aquifers (Hamilton, 1995).
3. The study found very strong correlation between parameters and little relationship between water depth and the parameters.
4. Constant research on groundwater quality in the agricultural areas is essential so as to closely monitor this leaching rate of these contaminants.
5. Sample for future study can be collected twice i.e. during rainy season and dry season so as to ascertain the seasonal effect.

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Table 1: Field Logs

Sample Label	Location of Sampling Point	Condition of the Well	Vol. of Sample taken	Depth of Water (m)	Weather	Husbandry
1	OYSADEP	Covered	1.5L	12.33	Humid	Vegetables
2	OYSADEP	Covered	1.5L	10.32	Humid	Fishery, Banana plantation ,poultry
3	OYSADEP	Without Ring	1.5L	9.65	Humid	Vegetables
4	OYSADEP	Without Cover	1.5L	6.80	Humid	Maize and grasses
5	OYSADEP	Without Ring	1.5L	11.80	Humid	Yam, Cassava
6	OYSADEP	Without Ring and Cover	1.5L	12.30	Humid	Fishery, Bread fruit, Maize
7	OYSADEP	Half Cover	2.0L	12.60	Humid	Pawpaw, poultry
8	OYSADEP	Without Cover	1.5L	7.00	Humid	Poultry, cattle rearing
9	OYSADEP	Covered	1.5L	6.48	Humid	Poultry, Cashew plantation, pawpaw
10	OYSADEP	covered	1.5L	6.15	Humid	Poultry
11	OYSADEP	Covered	1.5L	6.48	Humid	Cocoa
12	OYSADEP	Covered	1.5L	12.35	Temperate	Grasses
13	OYSADEP	Covered	1.5L	12.00	Temperate	Tomatoes and other fruit crops

*Two samples were taken from each well, one in sterile amber coloured bottle glass and the other in plastic bottle.

*Sampling Method: Manual

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Table 2: Physical and Chemical Characteristics of the Groundwater Samples Analysed

Spls	pH	Copper	T	EC	TDS	Iron	TSS	TA	Sulphate	Phos	Turb.	NH3	BOD	COD	DO	Hards.	Zinc	Potassium	Lead	Odour
1	6.10	0.05	24.90	223	1050	0.0647	355	38	20.13	0.039	0.17	6.29	7.90	4.30	10.1	32	0.13	0.17	Nd	mild
2	5.57	Nd	22.10	179	1633	0.0714	405	15	19.65	0.37	0.15	2.53	3.10	4.90	4.70	0	0.15	0.06	Nd	mild
3	6.12	Nd	26.00	658	1900	0.139	598	58	19.60	0.104	0.10	6.96	2.30	5.15	5.01	803	0.11	0.41	Nd	mild
4	5.90	Nd	26.00	874	1925	0.0639	645	23	7.66	0.00	0.31	3.10	0.79	3.70	4.08	838	0.23	0.43	Nd	mild
5	5.46	Nd	25.70	423	1650	0.119	545	23	12.31	0.075	0.17	3.12	0.99	4.50	3.02	661	0.15	0.35	Nd	mild
6	6.40	Nd	25.10	718	1650	0.0916	848	43	6.17	0.00	0.14	1.09	1.66	7.60	3.61	1281	0.15	0.66	Nd	mild
7	5.80	Nd	25.60	689	1925	0.114	695	13	24.74	0.075	0.90	1.07	0.00	6.10	3.00	1042	0.26	0.54	Nd	mild
8	6.65	Nd	25.70	683	1625	0.0689	448	53	27.06	0.104	0.13	2.95	2.55	8.95	4.01	955	0.14	0.49	Nd	mild
9	6.06	Nd	25.10	758	1925	0.0666	995	58	29.83	0.036	0.16	4.05	1.10	5.30	2.22	1656	0.06	0.86	Nd	mild
10	6.20	Nd	25.60	703	1400	0.0864	680	73	13.85	0.074	0.21	1.03	1.31	5.10	2.66	924	0.20	0.48	Nd	mild
11	6.28	Nd	25.80	380	1925	0.0408	245	55	35.95	0.00	0.12	1.08	2.51	2.75	4.43	381	0.17	0.18	Nd	mild
12	6.21	Nd	25.60	359	1725	0.0442	295	58	21.17	0.172	0.25	2.04	2.40	3.10	5.01	201	0.11	0.11	Nd	mild
13	6.25	Nd	25.00	392	1700	0.0492	395	38	37.23	0.142	0.36	1.05	3.10	3.50	4.82	402	0.25	0.23	Nd	mild

All units in mg/L except T in degree celcius, EC in US/cm,Turbidity in NTU
Where T is Temperature, TA is Total Alkalinity
Turb. Is Turbidity, Phos. is Phosphorus
Hards. Is Hardness, Col. Is colour, Nd -No Data

Samples were collected at the site early in the morning using sterile containers and amber coloured bottles and was immediately transported to the Laboratory for Physical and Chemical analyses

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Table 3: Bacteriological Characteristics of the Groundwater Samples Analysed per mL

Samples	Total Coliform Count (cfu/ml)	Total Viable Count (cfu/ml)	Total Fungal Count (cfu/ml)
1	4.5	1.4	1.1
2	7.5	1.7	0.9
3	1.3	4.6	0.9
4	1.2	0.5	0.2
5	1.6	0.4	0.0
6	1.5	12.2	0.1
7	1.8	0.9	0.3
8	2.9	0.8	0.3
9	1.6	4.0	0.2
10	5.6	2.9	0.9
11	9.4	4.6	0.9
12	9.2	12.2	0.9
13	17.2	5.3	2.8

All Values in the table x 1000

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Table 4: Comparing Physical and Chemical characteristics with standards

Parameters	WHO	USEPA	NSDWQ	IS	UK	CDWQ	Present Report
pH	6.5-8.5	6.5-8.5	6.5-8.5	6.5-8.5		6.5-8.5	5.57-6.65
Copper	1.00	1.00	1.00	0.05	3.00	≤1	0.00-0.05
Temperature	24.5 – 39.7		Ambient			≤15	24.90-26.90
EC	2500		1000		1500		179-874
TDS	1000	500	500	500	1000	≤500	1050-1925
Iron	1.00	1.00	0.30	0.30	0.20	≤0.3	0.023-0.139
TSS	500						245-995
TA					30		13-73
Sulphate	400	250	100	200	250	≤500	6.17-29.92
Phosphate					2.2		0.00-0.37
Turbidity	5	≤5	5	5	4	1	0.11-0.90
NH_3	1.5				0.5		1.03-6.96
BOD	10						0.00-7.90
COD	10						2.75-8.95
DO	6						2.22-10.10
Hardness($CaCO_3$)	200		150	300	60		0.00-1656
Zinc	3	5	3	5	5	≤5	0.06-0.26
Potassium	12				12		0.06-0.86
Lead	0.01	0.015	0.01	0.1	0.05	0.01	Nd
Odour	U		U	U	A	I	mild
TCC	1		1		0		1.2-17.2
TVC					0		0.4-12.2
TFC					0		0.00-1.10

Values for TCC,TVC and TFC in the table x 1000

U-Unobjectionable, Nd- No Data, A-Acceptable, I-Inoffensive

Sources:

WHO - World Health Organisation(1993,2008)

USEPA- United State Environmental protection Agency(2012)

NSDWQ - Nigerian standard For Drinking Water Quality (2007)

UK-United Kingdom Drinkin Water Standard (1993)

CDWQ- Canadian Drinking Water Quality Guidelines (2008)

IS- Indian Standard(1993)

All in MCL (Maximum Contaminant Level and Health Based).

All units in mg/L except T in degree celcius, EC in US/cm,Turbidity in NTU

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Table 5: Spearman Correlation Coefficient (r_s) Matrix of the Physical and Chemical Characteristics of the Samples.

	TCC	TVC	TFC	pH	Temp.	EC	TDS	Fe^{2+}	TSS	TA	SO_4^{2-}	PO_4^{3-}	Turb.	NH_4^+	BOD	COD	DO	$CaCO_3$	Zn^{2+}	K^+
TCC	1.000																			
TVC	0.356	1.000																		
TFC	0.711**	0.375	1.000																	
pH	0.297	0.576*	0.241	1.000																
Temp.	-0.431	-0.25	-0.336	0.083	1.000															
EC	-0.682*	-0.157	0.646*	0.044	0.374	1.000														
TDS	-0.232	0.123	-0.269	-0.151	0.454	0.365	1.000													
Fe^{2+}	-0.589*	-0.287	-0.425	-0.368	0.111	0.264	-0.184	1.000												
TSS	-0.704**	-0.146	-0.643*	-0.225	0.036	0.846**	0.198	0.604*	1.000											
TA	0.101	0.531	0.184	0.54	0.213	0.155	-0.048	-0.150	0.014	1.000										
SO_4^{2-}	0.652*	0.035	0.547	0.429	-0.189	-0.418	-0.003	-0.670*	-0.577*	0.393	1.000									
PO_4^{3-}	0.423	0.085	0.426	-0.116	-0.270	-0.576*	-0.284	0.108	-0.360	-0.088	0.235	1.000								
Turb.	-0.158	-0.179	0.085	-0.349	-0.224	0.127	0.122	-0.184	0.094	-0.377	-0.226	0.118	1.000							
NH_4^+	-0.569*	-0.303	-0.213	-0.330	0.178	-0.033	0.006	0.220	-0.038	-0.008	0.000	-0.050	-0.413	1.000						
BOD	0.628*	0.323	0.735**	0.413	-0.483	-0.748**	-0.542	-0.415	-0.713**	0.090	0.655*	0.397	0.322	0.041	1.000					
COD	0.523	-0.187	-0.476	0.060	-0.061	0.500	-0.184	0.698**	0.731**	-0.006	-0.407	-0.030	-0.256	0.121	-0.275	1.000				
DO	0.303	0.295	0.673*	0.171	-0.085	-0.704*	-0.182	-0.355	-0.754*	-0.033	0.327	0.376	-0.132	0.278	0.705**	-0.525	1.000			
Hard.	0.575*	-0.061	-0.641*	0.159	0.222	0.901**	0.290	0.390	0.868**	0.186	-0.335	-0.44	0.006	-0.077	-0.655*	0.731**	-0.776**	1.000		
Zn^{2+}	0.180	-0.227	0.046	-0.089	-0.057	0.166	0.138	-0.036	0.055	-0.519	-0.307	-0.14	0.548	-0.711*	-0.255	-0.152	-0.235	0.050	1.000	
K^+	-0.591*	-0.102	-0.624*	0.143	0.194	0.896**	0.251	0.407	0.874**	0.155	-0.341	-0.48	-0.008	-0.044	-0.627*	0.747**	-0.768*	0.995**	0.058	1.000

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Table 6: Significance Matrix of the Physical and Chemical Characteristics of the Samples.

	TCC	TVC	TFC	pH	Temp.	EC	TDS	Fe^{2+}	TSS	TA	SO_4^{2-}	PO_4^{3-}	Turb.	NH_4^+	BOD	COD	DO	$CaCO_3$	Zn^{2+}	K^+
TCC	1.000																			
TVC	0.233	1.000																		
TFC	0.006**	0.207	1.000																	
pH	0.324	0.039*	0.428	1.000																
Temp.	0.142	0.409	0.261	0.787	1.000															
EC	-0.010*	0.608	0.017*	0.887	0.207	1.000														
TDS	0.446	0.689	-0.374	0.623	0.120	0.219	1.000													
Fe^{2+}	0.034*	-0.343	0.148	0.216	0.718	0.384	0.547	1.000												
TSS	0.007**	0.634	0.018*	0.459	0.907	0.000**	0.517	0.029*	1.000											
TA	0.742	0.062	0.547	0.057	0.486	0.613	0.877	0.626	0.964	1.000										
SO_4^{2-}	0.016*	0.241	0.053	0.144	0.537	0.156	0.993	0.012*	0.039*	0.184	1.000									
PO_4^{3-}	0.150	0.783	0.147	0.705	0.372	0.039*	0.347	0.725	0.227	0.775	0.439	1.000								
Turb.	0.605	0.558	0.782	0.242	0.463	0.680	0.692	0.547	0.761	0.204	0.459	0.701	1.000							
NH_4^+	0.042*	0.314	0.486	0.271	0.562	0.915	0.986	0.471	0.901	0.979	1.000	0.871	0.161	1.000						
BOD	0.022*	0.282	0.004**	0.161	0.0.94	0.003**	0.056	0.158	0.006**	0.770	0.015*	0.180	0.283	0.894	1.000					
COD	0.067	0.540	0.100	0.845	0.843	0.082	0.547	0.008**	0.005**	0.986	0.168	0.921	0.399	0.694	0.363	1.000				
DO	0.314	0.328	0.012*	0.577	0.783	0.007*	0.553	0.234	0.003*	0.914	0.275	0.206	0.667	0.358	0.007**	0.065	1.000			
Hard.	0.040*	0.884	0.018*	0.603	0.4.66	0.000**	0.336	0.188	0.000**	0.544	0.263	0.129	0.986	0.803	0.015*	0.005**	0.002**	1.000		
Zn^{2+}	0.556	0.455	0.882	0.774	0.853	0.588	0.654	0.907	0.858	0.069	0.307	0.653	0.052	0.006	0.401	0.620	0.439	0.872	1.000	
K^+	0.033*	0.740	0.023*	0.642	0.525	0.000**	0.408	0.168	0.000**	0.613	0.255	0.095	0.979	0.887	0.022*	0.003**	0.002*	0.000**	0.850	1.000

* Correlation is significant at the 0.05 level (2-Tailed)

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

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AUTHOR BIBLIOGRAPHY

	**Adegbola, Adedayo Ayodele** He is a professor of Civil Engineering. A former dean of the faculty of Engineering and Technology in LAUTECH, Nigeria. His international repute cut across his field. He is a corporate member of International Association of Hydrological Sciences (IAHS) and America Society of Civil Engineers (ASCE). Email: **aaagbola@lautech.edu.ng**
	**Akeredolu, Damilare Alaba** A graduated of Civil Engineering from Ladoke Akintola University of Technology, Ogbomoso, Nigeria. He is a practicing engineer with experiences garnered over the years of study. His career objective is to contribute his quota to the development of the society. Email: **akerelabala@yahoo.com**
	**Oyekanmi, Martins Olalekan** With B. Tech honours in Civil Engineering, he is building a career in Water Resources and Environmental Research with other branches of Civil Engineering also in view. He has attended local and international conferences within the shore of Nigeria and also graduate member of Nigeria Society of Engineers (NSE). Email: **mooyekanmi@student.lautech.edu.ng**