Effect of Sunlight on the Different Strata of Lake Water

Aneke Nwabueze Peter, Prof. Ademiluyi Joel Ojo

Abstract—Lake Water samples were collected from Nike Lake which is located in Enugu East Local Government Area of Enugu state, Nigeria. The lake water sample was poured into the experimental set-up. The samples were analysed for 13 physicochemical parameters and two microbial parameters according to standard procedures. Samples were tested at different time intervals for exposure to sunlight (day 1, day 7 and day 14). Turbidity, iron and dissolved oxygen exceeded the acceptable limits for surface water guidelines (NER, AUS-NZ and EQSSW). The results of the Water Quality Index (WQI) show an average value of 209.64, indicating that the water in the lake is excessively polluted and unsuitable for drinking. Correlation analysis was carried out to investigate the strength of relationship between the physicochemical and microbiological parameters of lake water. Multiple regression analysis was done to investigate the effect of sunlight on the different strata of lake water. The results indicates that the days of exposure of lake water sample to sunlight and the depth of lake water column influences the concentrations of iron and total hardness. Principal component analysis (PCA) and cluster analysis (CA) were carried out to investigate the sources of contaminant of the lake water samples. The results shows that the lake water is influenced by impact from faecal contamination (principal component 1, 53.288%), water hardness from rainwater which dissolves mineral matter and flows through the ground to the lake (principal component 2, 18.101%), impact from agricultural activity (principal component 3, 13.066%) and impact from domestic and industrial wastewater disposal (principal component 4, 8.640%).

Index Terms—Lake water, Stratification, Disinfection, Multiple Regression Analysis

I. INTRODUCTION

Thermal stratification is an important natural phenomenon in aquatic systems, which interferes significantly with their physical and chemical structure, creating complex gradients or simply leading to increased heterogeneity of the water column [28]. Latitude affects the stratification pattern and temperature of the upper mixed layer; therefore, stability changes are much more variable in the short term in the tropical than in the temperate lakes, especially if the winds are strong enough to cause vigorous motion in the upper water layer [7].

Lake thermal stratification occurs naturally due to the change in water's density with temperature [6]. Thermal stratification is as a result of solar radiation heating the lake's waters. In temperate lakes, stratification occurs annually as

the winter and summer months pass. Coupled with the effects of wind mixing, the water splits into three distinct layers in the summer. The warm upper layer is referred to as the epilimnion layer, the cool lower layer is referred to as the hypolimnion layer, and the shallow intermediate layer where the highest temperature drops occur is known as the metalimnion layer [16]. The amount of aquatic activity such as plant and animal growth is being determined by the thickness of the epilimnion layer [12].

Sunlight has been used to purify water for centuries. In India, around 2000 BC, water was filtered through charcoal and exposed to the sun [8]. The main objective of the study was to determine the effect of sunlight on various strata of lake water. The specific objectives are: to determine the physicochemical and microbial quality of the lake water samples and compare the results with established fisheries and recreational quality criteria standard, to evaluate the interaction between the water quality parameters (physicochemical and microbial) on the lake water quality and to determine the potential sources of contaminants on the lake water sample.

II. MATERIALS AND METHODS

A. Experimental Set-up

Fig. 1 shows the schematic diagram and pictures of the experimental set-up. The glass cylinder is made of borosilicate. The cylindrical glass was blown at the Scientific Equipment Development Institute, Enugu. The glass cylinder has a length of 0.92m and a diameter of 700mm to accommodate the lake water sample. The borosilicate glass has three glass tap with an opening for the collection of water sample. The glass taps are 300mm apart. A wooden casing was constructed to accommodate the borosilicate glass. The wooden casing was constructed in such a way that laterite will be placed round the borosilicate glass except the space that was given to accommodate the glass taps for the collection of lake water sample. The experimental apparatus was set-up at the National Water Quality Reference Laboratory, Federal Ministry of Water Resources, Enugu, Nigeria.

Lake water samples from Nike Lake which is located at Enugu east local government area, Enugu state, Nigeria were collected using sterilized sampling devices. These samples were transported to the National Water Quality Reference Laboratory, Federal Ministry of Water Resources, Enugu, where the experimental set-up is located within 24 hours of sampling. The method of sampling and sampling preservation as stated in the Standard Methods for the examination of water and wastewater, which was published jointly by

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Fig. 1 The schematic diagram and pictures of the experimental set-up.

American Public Health Association (APHA), American Water Works Association (AWWA), and Water Environment Federation (WEF) in 2005 was followed strictly. A total of 15 physicochemical and microbiological parameters were tested for each sample.

The lake water sample was collected from the glass taps of the borosilicate glass. The three taps represents the top, the mid-point and the bottom layers of the Lake. In lake stratification, these layers are called the epilimnion (the top layer), the metalimnion (the mid-point) and the hypolimnion (the bottom layer). Lake water samples from the experimental set-up was collected and tested from the three different layers. Lake water sample was collected and transported to the laboratory on the 7th October, 2019. The sample was tested and poured into the experimental set-up. The experimental set-up with the Lake water sample was exposed to sunlight. Samples were collected from the three different layers and tested after 24 hours, 7 days and 14 days. Temperature, pH, turbidity, conductivity, total dissolved solids (TDS), phosphate, nitrate, iron, biochemical oxygen demand (BOD), chemical oxygen demand (COD), dissolved oxygen (DO), alkalinity, total hardness, total coliform, and Escherichia coli were measured according to standard procedures (APHA, 2005).

B. Analysis of results

A descriptive statistics of the physico-chemical and microbiological parameters was done and the test results were compared with three different surface water guidelines namely:
i. National Environmental (Surface and Groundwater Quality Control) Regulations, 2011 (Fisheries and Recreational Quality Criteria Standard).
ii. Australian and New Zealand (Guidelines for fresh and marine water quality) conservation council, 2000.
iii. China's environmental quality standard for surface water (EQSSW) (GB 3838- 2002).

The samples were tested for normality using the Shapiro-Wilks test for normality. After that, the parameters were correlated with each other using the Kendall's tau correlation to test if there is significant difference between any of the parameters. The water quality index (WQI) of the

lake water was calculated to ascertain its suitability for domestic, industrial and agricultural purposes. The Weighted Arithmetic index method was used for the calculation of water quality index (WQI) of the surface water.

The effect of sunlight on the physico-chemical and microbiological parameters of the lake water column was determined using multiple regression analysis. Principal component analysis and cluster analysis was used to investigate the potential sources of contamination of the lake water samples.

III. RESULTS AND DISCUSSION

A. Physicochemical and microbiological water quality in lake water samples

The results of the physicochemical and microbiological analyses of lake water sample collected from Nike Lake and exposed to sunlight are presented in Table 1. These results were compared with two surface water guidelines, namely the National Environmental (Surface and Groundwater Quality Control) Regulations, 2011 (Fisheries and Recreational Quality Criteria Standard) and the Australian and New Zealand (Guidelines for fresh and marine water quality) conservation council, 2000.

The physicochemical parameter such as temperature, pH, conductivity, total dissolved solids, phosphate, nitrate, biochemical oxygen demand (BOD), chemical oxygen demand (COD), alkalinity and total hardness were within the acceptable limit for fisheries and recreational water quality criteria standard according to NER (National Environmental Regulations). Turbidity, iron and dissolved oxygen exceeded the acceptable limits for fisheries and recreational water quality criteria standard. Sixteen water samples from two rivers (River Igbedi and River Nun) were tested by [2] and got dissolved oxygen values of 14.225±0.263 and 10.200±0.283 at the upstream and downstream of river Igbedi and dissolved oxygen values of 12.075±0.959 and 13.275±0.096 at the upstream and downstream of River Nun respectively. According to [25], turbidity values vary for two main reasons. One reason is physical such as heavy rains and fast-moving water which causes erosion. The other reason is biological due to algae growth and bacterial degradation of organisms in the water column.

Table 1. Descriptive statistics of physicochemical and microbiological parameters monitored.

Parameters	Method	N	Minimum	Maximum	Mean	Standard Deviation	NER 2011	AUS-NZ 2000
Temperature ($^{\circ}$C)	-	10	24.80	28.80	26.27	1.217511	-	-
pH @ 25.0°C	APHA 4500H^{+}B	10	5.39	8.74	7.093	1.072692	6.5-8.5	6.5-8.5
Turbidity (NTU)	APHA 2130B	10	2.44	34.60	12.884	11.32235	5	-
Conductivity (μS/cm)	APHA 2510B	10	81.30	88.20	82.81	2.056129	1000	-
Total Dissolved Solids (mg/L)	APHA 2510B	10	48.80	53.00	49.86	1.241146	500	-
Phosphate (mg/L)	APHA 4500-P	10	0.01	0.13	0.056	0.044522	3.5	-
Nitrate (mg/L)	APHA 4500-NO3E	10	1.40	6.00	2.74	1.613278	50	10
Iron (mg/L)	APHA 3500-FeB	10	0.33	1.30	0.657	0.309518	0.30	0.30
BOD (mg/L)	APHA 5210D	10	0.60	2.90	2.04	0.655235	3	-
COD (mg/L)	APHA 5220D	10	1.00	3.00	2.60	0.699206	30	-
Dissolved oxygen (mg/L)	APHA 4500-OC	10	5.70	8.80	8.01	0.864677	6.00	-
Alkalinity (mg/L)	APHA 2320B	10	4.00	20.00	13.60	4.427189	-	-
Total Hardness (mg $CaCO_3$/L)	APHA 2340C	10	10.00	28.00	18.20	6.356099	150	500
Total Coliform (cfu/100mL)	APHA 9222B	10	0	600	180.00	252.9822	10	-
E. coli	APHA 9222B	10	0	200	60.00	84.3274	0	-

Also, [34] observed that the dissolved oxygen values of Kushiyara River in Bangladesh is 7.65±1.41 during the rainy season and 6.33±0.85 during the winter season. Since iron is one of the physicochemical parameters that exceeded the acceptable limit for the water quality standard in this study, this shows the excessive iron content makes the water turbid [35].

The microbiological analysis of the lake water was also reported in Table 1. Out of a total of 10 lake water samples tested, 6 (60%) had zero CFU/100mL while 4 (40%) had values above zero CFU/100mL for Total coliform and Escherichia coli. The reduction in total coliform and Escherichia coli of Lake Water samples tested in day 7 and day 14 on exposure to sunlight at different strata was observed. Escherichia coli (E. coli) is the most common member of faecal coliform bacteria, indigenous to the intestinal tract of humans or other warm-blooded animal [9]. The presence of E. coli in Lake Water indicates the potential for the presence of pathogenic organisms [4]. Municipal wastewater discharges, septic leachate, agricultural or storm runoff, wildlife populations, or nonpoint sources of human and animal waste are the various sources of E. coli contamination in surface water [4]. According to the US Environmental Protection Agency (EPA), it is recommended that E. coli is a better indicator of faecal pollution than faecal coliform for purposes of evaluating ambient fresh water quality [36]. The US Public Health Service used an

epidemiology study and observed detectable swimming associated health effects with total coliform levels of 2300 colony forming units (CFU)/100mL [10].

B. Correlation of the physicochemical and microbiological parameters of Lake Water samples

Correlation is a bivariate analysis that measures the strengths of association between two variables and the direction of the relationship ([13] and [38]). The physicochemical and microbiological parameters were tested for normality using Shapiro-Wilk's test for normality. Temperature, pH, phosphate, iron, BOD, alkalinity and total hardness are normally distributed or parametric because their significant values (sig. values) are greater than 0.05. Turbidity, conductivity, total dissolved solids, nitrate, COD, dissolved oxygen, total coliform and E. coli are not normally distributed or non-parametric because their significant values (sig. values) are less than 0.05. A non-parametric test called the Kendall's tau correlation was then used to correlate the physico-chemical and the microbiological parameters against each other. The Kendall's tau correlation coefficient is presented in Table 2. The correlation of the lake water parameters was done using SPSS (version 16.0) software. Temperature also affects biological activity and regulates the kind of organisms that can live in the Lake [25]. In this study, the Lake water temperature varied from 24.80°C to 28.80°C (Table 1).

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Table 2. A table showing the Kendall's tau correlation coefficients of all the parameters.
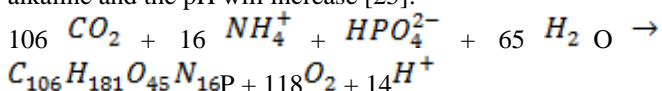
Correlations

	Temperature (°C)	pH @ 25.0 °C	Turbidity (NTU)	Conductivity (μS/cm)	Total Dissolved Solids (mg/L)	Phosphate(mg/L)	Nitrate (mg/L)	Iron (mg/L)	Biochemical Oxygen Demand (mg/L)	Chemical Oxygen Demand (mg/L)	Dissolved Oxygen (mg/L)	Alkalinity (mg/L)	Total Hardness (mg $CaCO_3$/L)	Total Coliform (cfu/100mL)	E. coli (cfu/100mL)
Temperature (°C)	1.000														
pH @ 25.0 °C	.494*	1.000													
Turbidity (NTU)	-.045	-.378	1.000												
Conductivity (μS/cm)	.138	.341	-.386	1.000											
Total Dissolved Solids (mg/L)	.460	.023	-.068	.674**	1.000										
Phosphate(mg/L)	.094	-.256	.675**	-.214	.119	1.000									
Nitrate (mg/L)	.659**	.135	.135	.184	.506*	.047	1.000								
Iron (mg/L)	-.045	-.378	.733**	-.250	.068	.861**	-.045	1.000							
Biochemical Oxygen Demand (mg/L)	.159	.674**	-.449	.230	-.092	-.141	-.114	-.270	1.000						
Chemical Oxygen Demand (mg/L)	-.031	.528	-.528	.382	-.064	-.293	-.094	-.466	.723**	1.000					
Dissolved Oxygen (mg/L)	-.414	.068	-.477	-.070	-.395	-.619*	-.368	-.568*	.046	.223	1.000				
Alkalinity (mg/L)	.341	.719**	-.180	.276	-.046	-.141	.159	-.180	.568*	.440	-.230	1.000			
Total Hardness (mg $CaCO_3$/L)	-.046	.205	.341	.023	-.163	.071	.046	.068	-.046	.032	-.209	.368	1.000		
Total Coliform (cfu/100mL)	.199	-.282	.732**	-.144	.202	.797**	.256	.789**	-.370	-.512	-.692*	-.085	.317	1.000	
E. coli (cfu/100mL	.199	-.282	.732**	-.144	.202	.797**	.256	.789**	-.370	-.512	-.692*	-.085	.317	1.000**	1.000

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).

From Table 2, the correlation between temperature vs pH and temperature vs nitrate gave a correlation coefficient value of r = 0.494 and r = 0.695 respectively. The correlation between temperature vs pH is significant at p < 0.05 while the correlation between temperature vs nitrate is significant at p < 0.01. Temperature did not show a significant correlation with dissolved oxygen but negative correlation with dissolved oxygen (r = -0.414). This shows that when water temperature increases, the metabolic rate of microorganisms also increases and the amount of dissolved oxygen in water decreases [34]. The significant positive correlation between temperature and pH, nitrate indicates their rise with temperature.

The pH of a solution is a measure of the concentration of hydrogen ions (H^+) and it represents the negative logarithm of hydrogen ions concentration. The hydrogen ion concentration (pH) is an important factor that determines the suitability of water for various purposes, including toxicity to animals and plants [19]. In this study, the pH value of the Lake water varied from 5.39 to 8.74 and an average of 7.093±1.072692. About 40% of the tested Lake water samples had pH values within the NER (National Environmental Regulations) limit for surface and groundwater quality control. The pH showed positive and strong correlation with BOD (Biochemical Oxygen Demand) and alkalinity. The correlation between pH vs BOD and pH vs alkalinity gave a value of r = 0.674 and r = 0.719 respectively. All of them were significant at p < 0.01. This signifies that an increase in the pH of the Lake water sample will cause an increase in BOD and alkalinity. One of the reasons of pH change in water is the photosynthesis [25]. This process absorbs carbon dioxide from the water and uses the energy of the sun to convert it to simple organic carbon compounds and to produce oxygen (equation 1). Carbon dioxide in the solution has an acidifying effect as it reacts with water and forms carbonic acid (H_2CO_3). As long as it is removed by plants and algae, the water will become more alkaline and the pH will increase [25].

$$106\ CO_2 + 16\ NH_4^+ + HPO_4^{2-} + 65\ H_2O \rightarrow C_{106}H_{181}O_{45}N_{16}P + 118O_2 + 14H^+$$

(1)

The pH also showed negative and weak correlation with turbidity and total coliform. The correlation of pH vs turbidity gave r = -0.378 and that of pH vs total coliform gave r = -0.282 but they were insignificant.

Turbidity indicates the amount of suspended solids in the water, either mineral (such as soil particles) or organic (like algae). The turbidity analysis is a measure of the amount of light scattered in water and the more suspended particles cause greater scattering and thus high turbidity value [25]. In this study, turbidity was above the limit for surface water and groundwater control guideline.
Turbidity showed strong and positive correlation with phosphate, iron, total coliform and E. coli with correlations of 0.675, 0.733, 0.732 and 0.732 respectively. All of them were significant at p < 0.01. Also, the turbidity value varies due to algae growth and bacterial degradation of organics in the water column [29].

Phosphorous is essential for the growth of organisms and generally limits the primary productivity in water. In this study, the values of phosphate varied from 0.01 to 0.13mg/L and an average of 0.056±0.044522 mg/L (Table 1).
Phosphate showed strong and positive correlation with iron, total coliform and E. coli with a correlation coefficient of r = 0.861, r = 0.797 and r = 0.797 respectively. All of them were significant at p < 0.01.

Biochemical Oxygen Demand value indicates organic pollution in the aquatic systems, which adversely affect the river quality and biodiversity [33]. In this study, the values of BOD varied from 0.60 to 2.90 mg/L with an average of 2.04±0.655235 mg/L (Table 1).
BOD showed strong and positive correlation with Chemical Oxygen Demand (COD) and alkalinity with a correlation coefficient of (r = 0.723, p < 0.01) and (r = 0.568, p < 0.05) respectively. BOD showed a negative correlation with total hardness with a correlation coefficient of r = -0.046 and it is not significant.

According to [18], dissolved oxygen can be defined as the concentration of oxygen molecule in water which depends on temperature of the water and biochemical oxygen demand of the system. As a very important water quality parameter, the recommended minimal value of dissolved oxygen for domestic use and to maintain good fish population is 5 mg/L [14]. The amount of diffusing oxygen in the aquatic environment is dependent very much on temperature [24].
Dissolved oxygen showed negative and strong correlation with phosphate and iron with correlation coefficients of (r = -0.619, p < 0.05) and (r = -0.568, p < 0.05) respectively. Dissolved oxygen also showed negative and strong correlation with total coliform and Escherichia coli with correlation coefficients of (r = -0.692, p < 0.05) and (r = -0.692, p < 0.05) respectively. This shows that the activities of microorganisms cause a reduction in the amount of dissolved oxygen in the water.

Alkalinity in a solution means the solution is capable of buffering acidic solutions with higher concentrations of hydrogen ions. Alkalinity in water comes from a high concentration of carbon-based mineral molecules suspended in the solution [29]. Guideline values were not provided for alkalinity by National Environmental Regulations (NER). This is because they believe that alkalinity are not found in concentrations harmful to the humans in surface water and groundwater. Alkalinity showed positive correlation with total hardness and negative correlation with E. coli with correlation coefficients of r = 0.368 and r = -0.085 respectively.

Total Hardness is a very important property of water from its domestic application point of view. Total hardness is made up of calcium and magnesium concentrations. Total hardness had a range of 10 to 28 mg/L with a mean value of 18.20±6.36mg/L which is well below the NER guideline for surface and groundwater. Total hardness showed positive correlation with total coliform (r = 0.317) and E. coli (r = 0.317) respectively.

B. Water quality index
The water quality index was calculated using three different surface water quality guidelines. They are the National Environmental Regulations (NER) guidelines for surface and groundwater quality control, the Australian and New Zealand

(Guidelines for fresh and marine water quality) conservation council and the China's environmental quality standard for surface water (GB 3838- 2002). The weighted arithmetic water quality index method was used.

The water quality index value for the NER guidelines for fisheries and recreational quality criteria standard was gotten as 216.76, that of the Australian and New Zealand conservation council was gotten as 206.02, while that of the China's environmental quality standard for surface water (GB 3838- 2002) was gotten as 206.14. The results of the Water Quality Index (WQI) show an average value of 209.64, this shows that the status of the Lake is excessively polluted and unsuitable for drinking.

C. Multiple linear regression analysis of Lake Water parameters

According to [20], multiple linear regression is a statistical method for understanding the relationship between an outcome variable (dependent variable) and several independent variables that best represent the relationship in a population. The method is used for predictive and explanatory purposes, both experimental and non-experimental. Multiple linear regression was applied on surface water quality data by [22] with the aim of identifying

their contribution toward water quality variation. 150 bore well water samples were analysed by [26]. They conducted a multiple regression analysis and observed that 99.9% of the variability in electrical conductivity could be attributed to the combined effect of Cl^-, HCO_3^-, NO_3^- and SO_4^{2-}. They also noted that the multiple regression model can predict ground water quality parameters with 5% level of significance [26].

Multiple linear regression analysis was performed by using the SPSS (version 16.0) software. It was used in predicting the effect of sunlight on the physicochemical and microbiological parameters of lake water. Shapiro-Wilk's test for normality was conducted on the lake water parameters. Temperature, pH, phosphate, iron, biochemical oxygen demand (BOD), alkalinity and total hardness were normally distributed or parametric. Multiple linear regression was performed on the parameters that were normally distributed. Table 3 shows the contribution of two independent variables (days of exposure to sunlight and the depth of lake water column) on predicting its effect on the dependent variables (lake water parameters).

Table 3. Individual contribution of various independent variables to predict its effect on lake water sample.

Dependent variable (R^2)	Independent variables			
	Days of exposure of lake water sample to sunlight		Depth of lake water column	
	p-value	t-stat	p-value	t-stat
Temperature (0.110)	0.998	-0.002	0.397	-0.903
pH (0.535)	0.042	2.490	0.504	0.704
Phosphate (0.789)	0.004	-4.225	0.119	-1.775
Iron (0.839)	0.003	-4.538	0.029	-2.742
BOD (0.482)	0.077	2.070	0.376	0.945
Alkalinity (0.420)	0.374	0.949	0.124	1.749
Total hardness (0.718)	0.010	-3.473	0.016	3.171

From Table 3, the multiple R^2 value (0.110) indicates that 11.0% of the variability in water temperature could be attributed to the combined effect of the days of the exposure of lake water sample to sunlight and the depth of lake water column. With p-values of 0.998 and 0.397 for the days of exposure of lake water sample to sunlight and the depth of lake water column at t-stat of -0.002 and -0.903 respectively. This signifies that the independent variables (days of exposure of lake water sample to sunlight and the depth of lake water column) is not significant and has no effect on the lake water temperature.

From Table 3, a multiple R^2 value of 0.535 indicates that 53.5% of the variability in pH could be attributed to the combined effect of the days of exposure of lake water sample to sunlight and the depth of lake water column. For the days of exposure of lake water sample to sunlight, the p-value of 0.042 indicates that the independent variable (days of exposure of lake water sample to sunlight) is significant at t-stat value of 2.490. The independent variable (depth of lake

water column) has a p-value of 0.504 and it indicates that it is not significant at a t-stat value of 0.704. The p-values of the independent variables indicates that the days of exposure of lake water samples to sunlight has an effect on the pH of the lake water sample while the depth of the lake water column has no effect on the pH of lake water sample.

From Table 3, a multiple R^2 value of 0.789 indicates that 78.9% of the variability in phosphate could be attributed to the combined effect of the independent variables. The days of exposure of lake water sample to sunlight has a p-value of 0.004, which signifies that the independent variable is significant at t-stat value of -4.225. Also, the depth of lake water column has a p-value of 0.119 which indicates that the independent variable (depth of lake water column) is not significant at t-stat value of -1.775. From the p-values, the days of exposure of lake water sample to sunlight has an effect on phosphate but the depth of water column has no effect on phosphate of the lake water sample.

Multiple R^2 value of 0.839 indicates that 83.9% of the variability in iron could be attributed to the combined effect

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of the independent variables (days of exposure of lake water sample to sunlight and the depth of lake water column) (Table 3). The independent variables (days of exposure of lake water sample to sunlight and the depth of lake water column) gave p-values of 0.003 and 0.029 at t-stat values of -4.538 and -2.742 respectively. This indicates that the independent variables are significant and that they have an effect on iron of lake water sample. The multiple regression equation was given as:

Iron = 1.139 – 0.038 [days of exposure to sunlight] – 0.429 [depth of lake water column]

(2)

From Table 3, with p-values of 0.077 and 0.376, this indicates that the days of exposure of lake water sample to sunlight and the depth of lake water column are not significant at t-stat values of 2.070 and 0.945 respectively. Also, from Table 3, a multiple R^2 value of 0.482 indicates that 48.2% of the variability in BOD could be attributed to the combined effect of the independent variables (days of exposure of lake water sample to sunlight and the depth of lake water column). From the p-values, the independent variables have no effect on the BOD of lake water sample.

The p-values of the independent variables (0.374 and 0.124) indicates that the independent variables (days of exposure of lake water sample to sunlight and the depth of lake water column) are not significant at t-stat values of 0.949 and 1.749 respectively (Table 3). A multiple R^2 value of 0.420 indicates that 42.0% of the variability in alkalinity could be attributed to the combined effect of the days of exposure of lake water sample to sunlight and the depth of lake water column. From the p-values, the days of exposure of lake water sample to sunlight and the depth of lake water column has no effect on alkalinity of lake water sample.

From Table 3, a multiple R^2 value of 0.718 indicates that 71.8% of the variability of total hardness could be attributed to the combined effect of the days of exposure of lake water sample to sunlight and the depth of lake water column. The p-values of the independent variables (0.010 and 0.016) indicates that they are significant at t-stat values of -3.473 and 3.171 respectively. From the p-values, the independent variables (the days of exposure of lake water sample to sunlight and the depth of lake water column) has an effect on the total hardness of lake water sample. The multiple regression equation was given as:

Total hardness = 16.129 – 0.789 [days of exposure to sunlight] + 13.477 [depth of lake water column]

(3)

D. Principal component analysis of the physicochemical and microbiological parameters of Lake Water samples

According to [30], principal component analysis (PCA) is a multivariate statistical approach designed to turn the complexity of input variables with a large amount of information into new non-correlated variable called principal components, which are linear combinations of the original variables. And it is supposed to provide a clearer understanding of the original variables. Principal component analysis offers details on the essential parameters with minimal data loss [32]. Principal component analysis was performed using SPSS (version 16.0) software.

Firstly, the standardized principal component analysis was used to analyze the data. This method was useful because the parameters have a wide variety of units and magnitudes. In addition, the standardization process reduces the effect of the various measurement units and makes the data dimensionless [37]. This approach consists first of standardizing the data by turning the covariance matrix into a correlation matrix before the principal component analysis is carried out [23]. Various standardization approaches exist, but in this study, standardization was accomplished by subtracting the group mean from each variable and dividing it by the group standard deviation to allow all the data to have zero mean and a unit variance. Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy and Bartlett's test of sphericity were used to check the suitability of the data for principal component analysis [30]. The data is not suitable for principal component analysis.

From Table 4, the first principal component (PC1) had high positive loading on temperature, turbidity, phosphate, nitrate, iron, total coliform and E. coli. The first principal component indicates sewage discharge and faecal contamination of the lake water. Coliform bacteria are excreted in large quantities in human faeces and in other warm-blooded animals [17]. As a result, water polluted with faecal matter is identified as potentially harmful due to indicator organisms co-existing with E. coli that causes cholera. Examples of diseases caused by drinking or bathing in faecal polluted water include diarrhea, cholera, dysentery and skin, eye, ear, nose and throat infections [39].

The second principal component (PC2) had high positive loading on pH, conductivity, total dissolved solids, alkalinity and total hardness (Table 4). Therefore, the second principal component represent water hardness. Sources of water hardness could be the result of rainwater that dissolves mineral matter as it flows through the ground on its way to rivers, lakes and springs [1]. Limestone (which introduces calcium to the water) and dolomite (which introduces magnesium) are the most common sources of water hardness [28]. According to [28], water hardness on the basis of dissolved concentrations of calcium and magnesium can be categorized as soft (0-60 mg/L), moderate (61-120 mg/L), hard (121-180 mg/L) and very hard (over 180 mg/L). From Table 1, the lake water samples can be categorized as very soft water.

The third principal component (PC3) has high positive loading on temperature and nitrate and a negative loading on dissolved oxygen (Table 4). PC3 represents the nutrient factor. This indicates that there was a high degree of agricultural activity in the lake environment and that this has resulted in nutrient pollution from fertilizers [17]. Large amounts of dissolved organic matter in lake water consumes large amount of oxygen which results in decrease in the amount of available dissolved oxygen [21]. The nutrient component reflects effects from non-point sources such as agricultural run-off and atmospheric deposition [21].

The fourth principal component (PC4) has high positive loading on pH and weak positive loading on temperature, phosphate, BOD and alkalinity (Table 4). PC4 may indicate organic pollution from domestic and industrial wastewater disposed to the lake. Elevated concentrations of dissolved organic matter and biological organic matter arise from waste disposal practices or runoff of solids [40]. Influences from

municipal and industrial point-source wastes, non-point agricultural sources, agricultural sources, livestock and/or domestic sources can be identified with organic and nutrient variables [31].

E. Cluster analysis of the physicochemical and microbiological parameters of Lake Water samples.

Cluster analysis is a method used to identify related and close objects within a data set and to group these objects into clusters based on their characteristics ([5] and [15]).

Table 4. Loadings (Coefficients) of the first four principal components.

Component Matrix[a]

	Component			
	1	2	3	4
TEMPERATURE	.627	.180	.659	.351
PH	-.637	.455	.332	.482
TURBIDITY	.941	.214	-.211	.054
CONDUCTIVITY	-.042	.822	.255	-.490
TDS	.322	.698	.399	-.482
PHOSPHATE	.875	.293	-.219	.201
NITRATE	.560	-.082	.695	-.024
IRON	.945	.130	-.153	.170
BOD	-.826	.344	.040	.385
COD	-.819	.386	.027	.038
DISSOLVED OXYGEN	-.895	.078	-.336	-.194
ALKALINITY	-.648	.554	-.092	.390
TOTAL HARDNESS	.091	.686	-.600	-.084
TOTAL COLIFORM	.908	.230	-.233	.156
E-COLI	.908	.230	-.233	.156

Extraction Method: Principal Component Analysis.

a. 4 components extracted.

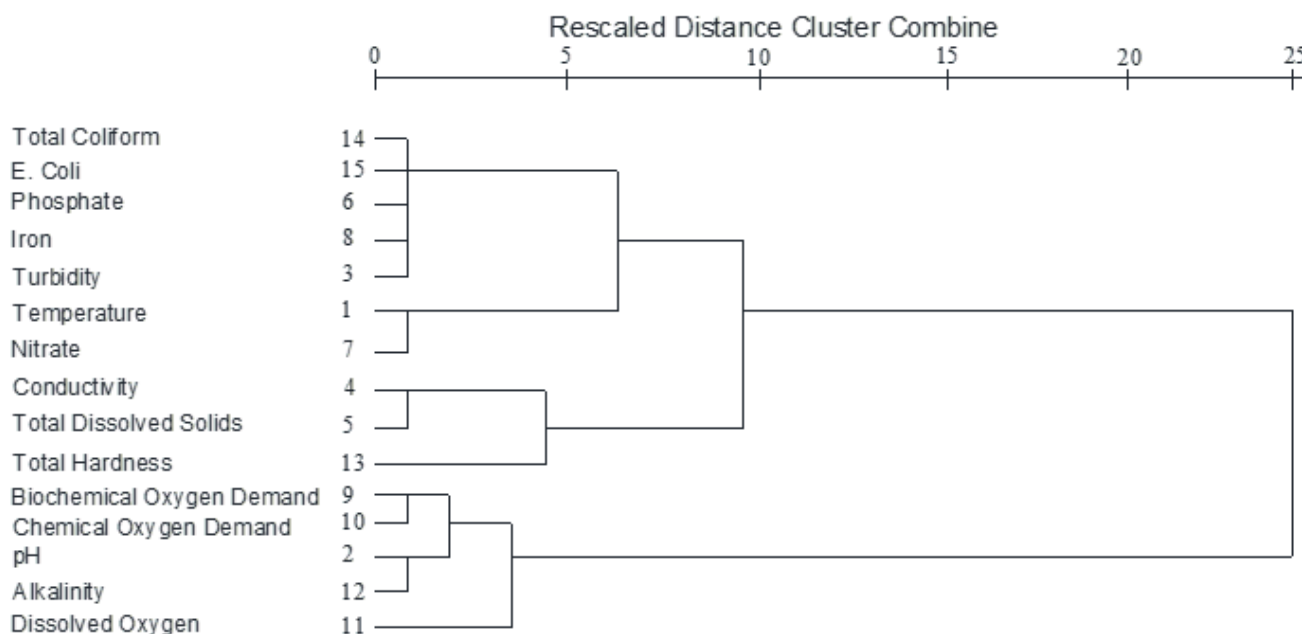**Fig. 2** Dendrogram based on hierarchical method (Ward's method) for the physico-chemical and microbiological parameters of lake water.

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Hierarchical clustering is the most common method in which clusters are arranged successively, beginning with the most similar pair of objects and generating clusters step by step, which is generally represented by a dendrogram [11]. The data sets produced in this study were treated by a cluster method known as Ward's method of linkage using squared Euclidean distance as its measure of similarity.

The dendrogram of the lake water parameters obtained by Ward's method is shown in Fig. 2. The outcome of the principal component analysis was fairly replicated by the cluster analysis. Cluster analysis was performed using SPSS (version 16.0) software.

Fig. 2 shows a cluster groupings of the physico-chemical and microbiological parameters of lake water. Group A consists of total coliform, E. coli, phosphate, iron and turbidity and thus corresponds with PC1. Group B is made up of temperature and nitrate which corresponds with PC3. Group C comprises of conductivity, total dissolved solids and total hardness which corresponds with PC2. Group D consists of BOD, pH and alkalinity which corresponds with PC4. Table 4.8 shows how the principal component analysis (PCA) results correspond with cluster analysis (CA).

IV. CONCLUSION

The physicochemical and microbiological properties of Nike Lake water sample on exposure to sunlight were well within the National Environmental Regulation (NER) guideline for surface and groundwater except for turbidity, iron, dissolved oxygen, total coliform and Escherichia coli. The results of water quality index (WQI) calculations shows that the lake water is excessively polluted and unsuitable for drinking.

The multiple linear regression analysis shows that the days of exposure of lake water sample and the depth of lake water column influences the concentration of iron and total hardness from the lake water sample. The multiple linear regression model gives good accuracy for forecasting the concentrations of iron and total hardness where R^2 values are 0.839 and 0.718 respectively (Table 3). The model indicates that 83.9% and 71.8% variability of the concentrations of iron and total hardness is attributed by the two independent variables used in the model. The principal component analysis and cluster analysis shows that the lake water was contaminated as a result of agricultural or storm runoff, wildlife populations, and non-point sources of human and animal wastes, water hardness from rainwater as it dissolves mineral matter as it flows through the ground to the lake and industrial wastes disposed on the lake. Correlation of lake water parameters shows that temperature affects biological activity and regulates the kind of organisms that can live in the lake. Also, turbidity value indicates the algae growth and bacterial degradation of organisms in the water column. E. coli and Total coliform indicates the presence of faecal contamination of water and it can happen when faeces of animals or humans is deposited on the lake water.

Sunlight has a disinfecting effect and it helps in improving water quality. From this study, it is recommended that intake works can be constructed to a required depth. The intake works should be constructed at the epilimnion layer of Lakes. Sunlight has a maximum disinfecting effect at the epilimnion layer (top layer).

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