Environmental & Analytical
Toxicology

Elegbede et al., J Environ Anal Toxicol 2015, 5:5
http://dx.doi.org/10.4172/2161-0525.1000317

Research Article Open Access

Effect of Water Quality Characteristics on Fish Population of the Lake Volta, Ghana

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Abstract

This study examines the effect of physicochemical parameters on different categories of fish species; benthopelagic, pelagic and demersal on Lake Volta. The methods of this study were based on the estimation of hydrographic data, collection and analysis of physicochemical parameters of the water samples. Fish samples were collected from four sampling stations namely Oti River at Sabra, White Volta at Daboya, Black Volta at Bamboi and Lower Volta at Amedeka. This review work studies a study which was carried out between February 1995 and January, 1996. A statistical analysis was conducted. Water resource availability and mean annual rainfall of Lake Volta were highest in Black Volta and Oti River respectively. The results show pH 194-520, Conductivity (μS cm^{-1}), Dissolved oxygen 8.0- 11.2 (mg/L), Biological Oxygen Demand (BOD) 2.7-105 (mg/L), Alkalinity 35.3-53.8 (mg/L), Chloride 4.6-13.6 (mg/L), Calcium 4.8-10.1 (mg/L), Total Hardness 17.4-44.1 (mg/L), Magnesium 2.5-8.3 (mg/L), Ammonia-N 0.4-1.6 (mg/L), Phosphate 0.2-0.9 (mg/L), Nitrate 0.2-6.6 (mg/L), Nitrite 0.06-0.6 (mg/L) and Sulfate 1.2-8.9 (mg/L) respectively. The benthopelagic, pelagic and demersal fish population show 16, 6 and 11 number of different fish species respectively in the lake. The study concludes that the quality of the water is satisfactory when compared with other lakes. Anthropogenic activities is insignificant on the aquatic habitat and the appreciable fish population is an indication of good biological quality of the water body.

Keywords: Species; Fisheries; Pollution; Trophic level; Rainfall; Akomombo

Introduction

Lake Volta occupies about 4% of the area of Ghana. It is recorded as the largest man- made Lake, which is the largest of its kind and has provided enormous biological and socio economic benefit like generation of electricity (1060 MW) at Akosombo and Kpong dam [1]. The Lake Volta is a highly significant water body richly surrounded by Togo, Cote d´Ivoire, Mali, Benin and Burkina Faso distributing the largest drains in the Lake Basin [2]. It is drained by several major rivers: the Mouhoun (Black Volta), the Nakambe (White Volta) with the Nazinon (Red Volta) as its tributary, the Oti River and the Lower Volta [2]. The construction of the Lake in 1964 was purposely for hydroelectric power generation, which had necessitated the uprising of other West Africa lake like Koussou Lake in Cote D' Ivore, Kariba Lake in Zimbabwe and Kainji Lake in Nigeria [3]. All these lakes are promotional aquatic inland biodiversity with abundant species of flora and fauna particularly enhancing regional fisheries market. The lake is attributed to various prospects and opportunities such as transportation, regional fishery trade, enhancement of livelihood. The lake is an ecologically formed reservoir whose biological development is by any of these namely: deformation of the original flora and fauna abundance and further decolonization by other species; production of plankton which is from primary and secondary production and an establishment of non-permanent plant and animal communities which leads to a period of ecological stabilization [4].

Lake Volta contributes between 80 and 90% of fish catches from the inland fisheries of Ghana [5]. In order to meet consumer needs, maintenance of the quality, diversity and availability of fish in sufficient quantities must be promoted. The lake is influenced by numerous anthropogenic impact. The physicochemical characteristics is affected which has uploaded negative effect on fish population in the Lake. It is pertinent to critically evaluate the effect of water quality characteristics on the fish population of Lake Volta, Ghana for proper sustainability and decision-making process in the region [6]. This paper is based on review study which focuses on physicochemical parameters of Lake Volta and the evaluation of its fish population. The aim of this review study is to examine the biological, physical and chemical water quality parameters including composition and distribution of fish population in the lake.

Materials and Methods

Study area

The Volta Lake is located in Ghana, West Africa. It lies between latitudes 5°30´N-14°30´N and longitudes 2°00´E-5°30´W, which stretches for a length of 520 km^2 from the Northern part to the southern part of Akosombo dam [7]. It is part of a river basin component which occupies 417,382 km^2 and follows a part of a basin which is elevated from sea level to a height of 920 m to an average elevation of 257 m

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Received March 05, 2015; **Accepted** August 21, 2015; **Published** August 24, 2015

Citation: Olalekan EI, Kies F, Omolara LAA, Rashidat SD, Hakeem EB, et al. (2015) Effect of Water Quality Characteristics on Fish Population of the Lake Volta, Ghana. J Environ Anal Toxicol 5: 317. doi:10.4172/2161-0525.1000317

between the lowest channel and the highest channel [8]. The Volta Lake is fed by some major appendages, from the Black Volta river, or Nakambe river, to the White Volta river or Nazinon river, Afram river and finally to the Oti river which drains 72,000 km^2 of northwestern Benin and Togo (Figure 1) [8]. These tributaries join in northern Ghana to form Lake Volta [7].

Sampling of chemical parameters

Data on the lake was collected between February 1995 and January 1996. It covered four sampling stations namely Oti River at Sabra, White Volta at Daboya, BlackVolta at Bamboi and Lower Volta at Amedeka, the sampling stations were chosen because they represent major parts of the lake. Sampling was done randomly at portions of the water course and each station was sampled in triplicate for 12 times from February 1995 to January 1996. All the water samples were taken with a water sampler. The lake was sampled under base flow conditions, about 20 - 30 cm deep from the surface [9]. Water samples for physicochemical analyses were collected into clean 1-litre plastic bottles. Temperature, conductivity, salinity and pH were measured *in situ* using a Horiba V-10 meter with combined electrodes [10]. Dissolved oxygen (DO) was measured using a DO meter, YSI Model 5I B [11]. Samples for Biochemical Oxygen Demand (BOD) were collected into dark painted glass bottles and were incubated at 20°C for 5 days before the remaining Dissolved oxygen was determined. All the samples were stored in cold boxes and, on return to the laboratory analyzed for physicochemical constituents [12]. Physicochemical parameters were determined at the sites and the collected water samples formed the basis for assessing the quality of the lake.

Laboratory analyses

The laboratory analyses were undertaken according to procedures outlined in Standard Methods for the Examination of Water and Wastewater, 20th edition [11]. The methods employed for the analyses were summarized as follows:

1. Suspended solids (SS): membrane filtration, followed by drying at 105°C and weighing.
2. Total phosphate: sulphuric acid/per sulfate digestion followed by reaction with ammonium molybdate and ascorbic acid to form a blue molybdate complex, whose intensity was measured at 880 nm using UV spectrophotometer.
3. Kjeldahl nitrogen: acid digestion in the presence of selenium catalyst followed by determination of ammonia-nitrogen.
4. Ammonia nitrogen: direct Nesslerisation and spectrophotometric determination.
5. Nitrate-nitrogen: reaction with Brucinesulfanilic acid, which produced a yellow color and measured spectrophoto- metrically at 410 nm.

Fish sampling

The fish species studied were collected from four sampling sites, namely Oti River at Sabra, White Volta at Daboya, Black Volta at Bamboi and Lower Volta at Amedeka during the year 1995 and 1996. Fish were captured with a battery of gill nets (2.5 m height × 25 m long) of 20, 25, 30, 35, 40 and 50 mm mesh size. Gill nets were set in the afternoon (17:00-21:00) and in the morning (5:00-9:00). Each site was sampled during one or two consecutive days, each individual, standard length (distance from the tip of the snout to the ultimate vertebrate) and weight were measured, sex was determined by gonad observation. The four sites are part of an interconnected river system and are not; therefore, strictly independent in space [13]. The fishes were preserved in 10% formaldehyde solution for taxonomic analysis. Identification and economic importance of fishes was carried [14].

Data analysis

The Statistical analysis of the research was performed using Microsoft Excel 2010 and Statistical Package for the Social Sciences (SPSS) (version 12.0, SPSS Incorporation, Chicago, II, USA) based on [8] statistical differences and significance in concentrations were also analyzed using non-parametric analysis of mean, standard deviation, standard error and Mann-Whitney U-test for the 3 sampling locations [8].

Results

Hydrographic estimation of Lake Volta

Figure 2 shows water resource availability and Figure 3 shows mean annual rainfall of Lake Volta, between February 1995 and January 1996. Windows, since most concentrations were not normally distributed, non-parametric analysis was performed, a probability value of $P<0.05$ was considered as statistically significant in the study [8]. Black river has the highest water resources availability by area and the Lower River shows the lowest water availability by area in km^2. Average annual rainfall was highest in Oti River and lowest in Black River while White and Lower River almost show the same values.

Physicochemical characteristics of Lake Volta

Physicochemical parameters of water samples from the four sample stations of Lake Volta are presented. Mean values of physicochemical parameters in relation to different depth (m) (0, 2, 6 and 10) of Lake Volta, February 1995- January 1996 are presented in Table 1.

The physicochemical parameter presented is expressed based on the depth range of 0 to 10 m. The temperature ranges from 29.4 to 31.0°C. The pH shows ranges of 6.9 to 7.2, while the Dissolved Oxygen (DO) (mg/L) ranges between 6.5 and 8.1 (mg/L). O_2 saturation ranges between 85.2 and 108.9%. The BOD shows non availability in depth 2

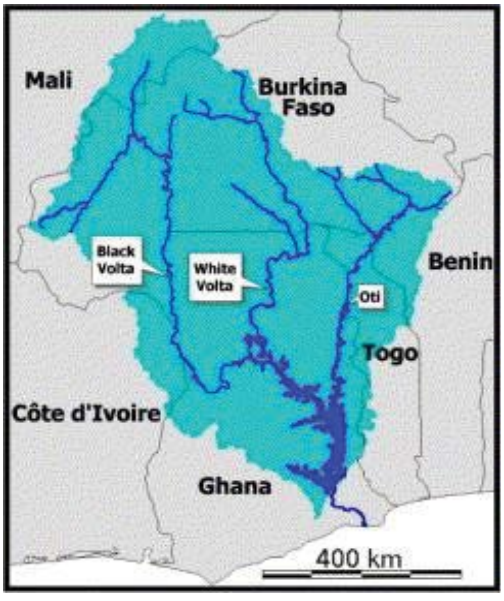

Figure 1: Map of Volta Lake.

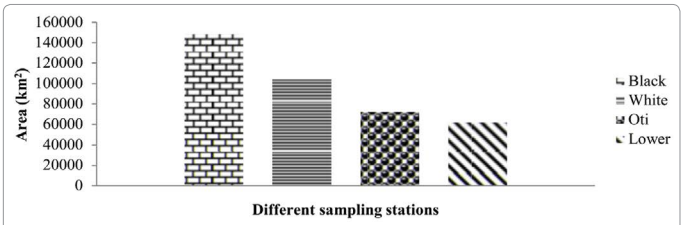

Figure 2: Water resources availability of Lake Volta, February 1995-January 1996.

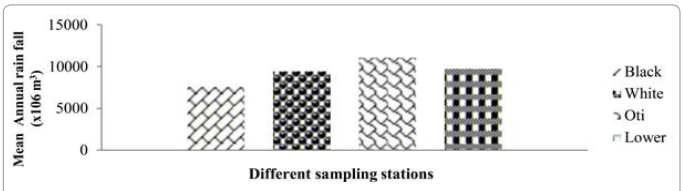

Figure 3: Mean annual rainfall of Lake Volta, February 1995- January 1996.

	Depth (m)			
Physicochemical factor	0	2	6	10
Temperature (°C)	31.0	30.0	29.5	29.4
pH	7.2	7.2	7.0	6.9
DO (mg/l)	8.1	7.9	7.2	6.5
O_2 saturation (%)	108.9	103.9	94.1	85.2
BOD(mg/l)	3.9	Na	Na	Na
Alkalinity (mg/l $CaCO_3$)	44.3	44.3	41.7	40.2
TDS (mg/l)	25.2	25.8	25.0	24.5
Conductivity (µS/cm)	84	79	76	76
Sodium (mg/l)	12.1	9.6	11.0	12.1
Phosphate (mg/l)	0.41	0.34	0.36	0.50
Nitrate (mg/l)	0.51	0.63	0.66	0.82
Nitrite (mg/l)	0.02	0.02	0.02	0.02
Ammonia-nitrogen (mg/l)	0.83	0.33	0.36	0.57
Secchi disc depth (cm)	50.2	0	0	0

Table 1: Mean value of physicochemical parameters of Lake Volta, February 1995-January 1996 (Na: Not available).

m, 6 m and 10 m but 3.9 (mg/L) in 0 m depth. Alkalinity value ranges from 40.2 and 44.3 mg/L for depth 10 m and 2 m respectively. The TDS values ranges from 25.0 and 25.8 mg/L in depth of 6 m and 2 m respectively. Conductivity shows the same values of 76 μScm^{-1} for depth 6 m and 10 m while depth 0 m shows a highest value of 84 μScm^{-1}. The highest value of 12.1 (mg/L) at 0 m depth and lowest value of 9.6 (mg/L) at 2 m was shown. Nitrate and nitrite have the highest values 0.82 and 0.02 (mg/L) and lowest values of 0.51 and 0.02 (mg/L) respectively. Ammonia-nitrogen ranges between 0.33 and 0.83 (mg/L) for 2 m and 0 m respectively while there is only clearness at 0 m depth of 50.2 cm based on the Secchi disc depth.

Mean pH value is 6.9 and 7.1 for Oti and lower Volta River respectively. Mean Dissolved oxygen is 8.0 at Lower Volta but 9.9 at Oti River. Alkalinity of 53.8 mg/L is highest in Black Volta and lowest in Oti River. Chloride of 13.6 (mg/L) is highest in White Volta and lowest value of 4.6 (mg/L) in Lower Volta is recorded, calcium was highest in Black Volta and lowest in Oti River. Total hardness value is highest in Black Volta 44.1 (mg/L) and lowest value of 17.4 (mg/L) in Lower Volta River. Phosphate, nitrate, nitrite and sulfate show values between 0.2, 0.2, 0.06, 1.2 mg/L and 0.9, 6.6, 0.6, 8.9 mg/L for Oti, White Volta, Black Volta and Lower Volta River respectively (Table 2).

Fish population in the benthopelagic, pelagic and the demersal region of Lake Volta

Table 3 shows fish population of the benthopelagic region of Lake Volta between February 1995 and January 1996. Table 4 shows pelagic fish species for the same region and period. *Clarias gariepinus* has the highest total length of 170 cm while *Barbus macrops* has the lowest maximum total length. *Malapterurus electricus* has the highest trophic level of 3.93 and *Synodontis eupterus* has the lowest trophic level of 2.88. The *Hemichromis fasciatus* shows a moderate trophic level, The *Arius gigas* also shows a higher trophic level.

For the fish population in pelagic region of Lake Volta, February 1995-January 1996 (Table 4). The pelagic fish species of Lake Volta *Brycinus leuciscus* shows the highest reproductive value of 1.20 whereas *Brycinus macrolepidotus* shows the highest maximum total length of 65 cm and *Brycinus luteus* shows the lowest maximum total length of 10 cm and the highest trophic level of 2.93. Table 5 shows fish population in demersal region of Lake Volta; it shows highest value of maximum total length of 204 cm for *Gymnarchus niloticus* and lowest value of 25 for *Ctenopoma kingsleyea* respectively. *Hepsetus odoe* shows the highest trophic level of 4.50 and lowest trophic level of 2.00 for *Citharinus citharus* respectively. The *Citharinus citharus* has the highest reproductive value of 0.33 while the *Heterobranchus longifilis* has the lowest resilience value of 0.11.

Discussion

Physicochemical characteristics of Lake Volta

Physicochemical parameters of dissolved oxygen level recorded in this study was higher compared to 3.0-0.7 (mg/L) recorded for water quality, abundance of fish and Plankton species of Ikwori Lake, Nigeria [15,16] explains that the possible reason for oxygen values in this study indicates an organic enrichment in the lakes. The values of dissolved oxygen fell within the ranges 5.0-9.0 (mg/L), which is in agreement with [17] for good water quality suitable for aquatic organisms. All pH values in this study agree with the work of of Trevidi and Kataria (2012) [18] for pH values of Shahpura Lake and pollution have effects on the ground water of its fringe areas. Total dissolve solid (mg/L) in this study was lower than the results of 96 - 109 (mg/L) [15] which was due to reduced anthropogenic and agricultural activities around Lake Volta. The conductivity observed was low due to the indication of the freshwater habitats for low salinity. The values are lower than 47,667

	Oti River at Sabra	White Volta at Daboya	Black Volta at Bamboi	Lower Volta at Amedeka
pH	6.9+0.5	6.9+0.4	7.0+0.5	7.1+0.3
Conductivity (µS/cm)	280+213	194+156	201+154	520+245
Dissolved Oxygen (mg/l)	9.9+2.4	10.6+3.8	11.2+3.1	8.0+2.0
Alkalinity (mg/l)	35.3+11.5	42.6+16.5	53.8+23.6	44.8+6.4
Chloride (mg/l)	5.4+2.8	13.6+8.6	7.0+0.8	4.6+2.5
Calcium (mg/l)	4.8+2.0	6.8+2.0	10.1+2.9	5.3+1.4
Total Hardness (mg/l)	22.9+10.8	30.4+2.8	44.1+18.6	17.4+7.3
Magnesium (mg/l)	4.3+2.2	5.8+0.8	8.3+4.1	2.5+1.9
Ammonia-N (mg/l)	1.0+1.5	1.6+2.9	1.5+2.4	0.4+0.5
Phosphate (mg/l)	0.9+0.4	0.7+1.0	0.6+1.9	0.2+0.3
Nitrate (mg/l)	0.2+0.1	0.5+0.6	0.2+0.1	6.6+10.9
Nitrite (mg/l)	0.08+0.02	0.06+0.08	0.1+0.1	0.6+1.3
Sulfate (mg/l)	5.7+6.6	8.9+10.7	7.0+8.4	1.2+0.8

Table 2: Summary of water quality at the sampling stations on Oti, White, Black and Lower Volta.

Species	Maximum total length (cm)	Trophic level
Alestes baremoze	43	3.05
Arius gigas	165	3.86
Bagrus docmak	71	4.08
Barbus macrops	12	3.04
Brienomyrus niger	16	3.25
Clarias gariepinus	170	3.15
Ctenopoma petherici	18	3.16
Emichromis bimaculatus	17	3.93
Hemichromis fasciatus	25	3.18
Malapterurus electricus	149	2.93
Synodontis clarias	44	2.98
Synodontis eupterus	37	2.65
Synodontis filamentosa	32	2.88
Synodontis membranaceus	61	3.11
Synodontis nigrita	22	2.89
Synodontis ocellifer	49	3.12

Table 3: Benthopelagic fish species of Lake Volta, February 1995-January 1996.

Species	Maximum total length (cm)	Trophic level
Alestes dentex	55	2.93
Brycinus leuciscus	15	2.91
Brycinus longipinnis	15	2.18
Brycinus luteus	10	2.93
Brycinus macrolepidotus	65	2.34
Brycinus nurse	25	2.44

Table 4: Pelagic fish species of Lake Volta, February 1995-January 1996.

Species	Maximum total length (cm)	Trophic level
Chrysichthys auratus	43	3.66
Chrysichthys nigrodigitatus	80	2.58
Citharinus citharus	71	2.00
Ctenopoma kingsleyea	25	3.19
Gymnarchus niloticus	204	3.71
Hepsetus odoe	70	4.50
Heterobranchus bidorsalis	150	3.69
Heterobranchus isopterus	90	3.61
Heterobranchus longifilis	183	3.72
Hyperopisus bebe	63	3.60
Lates niloticus	200	4.48

Table 5: Demersal fish species of Lake Volta, February 1995-January 1996.

and 24,100 μS cm^{-1} for water quality characteristics at the estuary of Korle Lagoon in Ghana [12] also gave possible reasons for the lower conductivity value, which could be ascribed to the low primary source of domestic water and sewage in the lake to most of these towns [19]. BOD value of more than 8 mg/L is an indicative of moderate pollution (Martin, 1970). BOD values of 12 mg/L or more are considered grossly polluted [12]. The higher value of BOD in White Volta at Daboya is attributed to increased human induced impact of the area. BOD therefore is an important parameter of water, which expresses the health scenario of freshwater bodies [20]. The alkalinity level of the present study was in agreement with the values of [21] on the effect of rain on aquatic physicochemical parameters. Chloride content in River Usuma varied from 0.05- 2.18 (mg/L) which is very much higher than the values of this work. The values of chloride observed in this study are not significant when compared to tolerable values posted by United States Environmental Protection Agency (USEPA) though chloride contents in water are not harmful. Chloride concentration at different sampling sites did not exhibit a clear trend with respect to point or non-point pollution sites [22]. Magnesium values of the present study were lower than the values of magnesium of 10.1 (mg/L) for Weija Reservoir [9]. The nitrate and nitrite in form of N in this present study are within the range of values considered favorable for lifetime consumption which is between 6 and 9 (mg/L) based on the World Health Organization (WHO) guidelines for tropical South Africa, [23]. The phosphate in this study is high at 10 m depth. Lakes deepest depth sinks phosphorous and settles to the strata then covered with sediments. At high temperature the phosphorus are released back, which enhance phytoplankton multiplication including aquatic vegetation, hence provide nutrients for demersal herbivore fish [24,25]. The sulfate values of this study are lower than the sulfate values of 101.4 to 344.1 (mg/L) of water quality parameters of River Usuma in Nigeria due to the fact that sulfate [22]. This is due to the fact that the area of study does not have major industrial activites around, salt from ocean are not accounted for. For most lakes, sulphate concentrations is range between 2 and 30 mg/L. the value of study fall within the these range which is also favorable for survial of aquatic organism [26].

The sulfate values of a Plankton-Based Assessment of the Trophic State of Three Tropical Lakes in Cross River, Nigeria in ref. [15] are higher than the values of this study based on the circumstance that low sulfate concentrations occur in organic rich water especially at time of low water discharge and high temperature of summer season [27]. The nitrate, phosphate and sulfate in this study are important parameters of aquatic water bodies, they show the pollution status and anthropogenic load in the water habitat [28]. The populations of fish in the lake Volta survive well as its shown in the values of the physicochemical parameters and their abundance are shown below.

Fish population of Lake Volta

The lake is rich in fish fauna [2]. About 121 species have been recorded on Lake Volta, during pre-impoundment phase and filling stage. The species list recorded during the filling stage is likely to change mostly due to the upgraded taxonomy of the species attributed to the region and also to the disappearance of some fish species as a consequence of the change from riverine to lacustrine conditions [29-35]. 41 different fish species were observed in this study, which is very low compared to the original fish species of the lake. The reduction in current estimate is due to over exploitation of the fish resources, [2] and particularly the fluctuations in the physicochemical characteristics of the fish. Diversification is observed in the trophic level, fish species with the highest trophic level indicates increased feeding in different regions of habitat.

Conclusions

Aquatic habitats of Lake Volta are a large expanse of water, the largest part of the lake is the Lower River. The maximum amount of annual rainfall is recorded and observed at the Oti River of the lake in Ghana. Water quality of Lake Volta is generally safe and within the recommended limit of freshwater and similar lakes around the world. There are some sampling locations with altered physicochemical parameters. The most dominant fish species with high trophic level in the benthopelagic habitat are *Bagrus docmak*, *Arius giga* and *Emichromis bimaculatus*, while *Alestes dente*, *Brycinus leucisc* and *Brycinus luteus* are dominant in the pelagic region. *Hepsetu odoe*, *Lates* niloticus, Bagrus *bajad* and *Heterobranchus bidorsalis* were dominant in the demersal region of Lake Volta. The trophic level abundance of these species is related to their resistance to uniform aquatic degradation. Effective monitoring and frequent assessment of the lake is highly

crucial and controlling of anthropogenic activities around the lake. This research work is a great tool for decision making by the Ghanaian government especially in water resource management for limnological purpose. Lake Volta is an important resource for the Africa community especially Ghana, adequate monitoring and controlling of the habitat is required to maintain the diversity and richness of fish species and other economically important species. Likely anthropogenic activities around the water environment should be discouraged and proper enlightenment and education of the dwellers of the Lake Basin environment should be encouraged.

Acknowledgement

Our appreciation is directed to some of the staff of the Brandenburg University of Technology, Cottbus-Senftenberg, Germany, who supported this study research. We acknowledge the support of the colleagues in the academic community who added value to the success of this work. Our thanks are deeply directed to the reviewers and the editorial board for their constructive peer reviewed job.

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Citation: Olalekan EI, Kies F, Omolara LAA, Rashidat SD, Hakeem EB, et al. (2015) Effect of Water Quality Characteristics on Fish Population of the Lake Volta, Ghana. J Environ Anal Toxicol 5: 317. doi:10.4172/2161-0525.1000317