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**Research Article**

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# Assessment of seasonal and spatial variation of water quality in a coastal Basin: case of Lake Togo Basin

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**Abstract** Togo is a Sub-Saharan country with tropical climate and a great potential in water resources but the lack of water quality monitoring, data base on water quality and tools for water management caused many damages such as water availability. Lake Togo basin is the third watershed of Togo with costal localization in the south of Togo. This watershed is composed of three main sub-basins supplied by many tributaries and its waters are used for many purposes. This study was undertaken to explore water quality variability, potential factors which control water quality variability and candidate parameters for a future water quality index development. Four sampling campaign were performed in seven sites of permanent running rivers, Notsè dam and in Lake Togo. Water quality analyzes were performed in Laboratory of Water Chemistry using standards methods described by AFNOR. Factor analysis, statistical tests, descriptive statistics and diagrams for evolution trends of parameters were executed by Statistica for window 7.0. Globally water chemical quality agree criterions and standards for surface water quality except EC (Max EC= 32200 µS/Cm) during the dry period in Lake water. The microbiological quality doesn't meet criterions and standards conditions for surface water in all sites and sub-basins. The target study had highlighted a seasonal variation (between dry season and rainy season) and spatial variation (between sub-basins) in the trends of evolution of parameters in Lake Togo Basin. Statistical tests confirmed at $p < 0.05$ a significant variability of fecal coliforms, E. coli, water Hardness, Temperature, pH and Electrical Conductivity according to seasons and sub-basins. Factor analysis has highlight four main factors (83.46% of total variance) which governed water quality variation in Lake Togo basin. The microbiological parameters (Total coliforms, fecal coliforms and E. coli) and water salinity parameters (EC, Hardness, Na, K and Cl) are strongly correlated (coef > 0.80) with the second and first principal component respectively. They are the most sensitive parameters for assessment of Lake Togo basin water quality. DO, CODMn, Turbidity and pH and water alkalinity are significantly correlated (coef > 0.5) with the third and fourth principal component and are other kind of sensitive parameters. At least ten water quality parameters are sensitively useful for a water quality index development in Lake Togo Basin

**Keywords** Variability, Water Quality, Factors, sensitive, Lake Togo Basin, sub-basin, water quality index

## 1. Introduction

Clean water is one of being essentials for life. Therefore, potable drinking water can be considered as a primary need for every human being [1]. Unfortunately, this foodstuff in spite of his well and natural availability is rare for many people in sub-Saharan countries. If the main reason is attributed to a weak mobilization of natural water for drinking water production, assessing spatial-temporal variations have become an important aspect of river water quality and its availability. Indeed, rainfall in Togo varies about 800 mm to 2000 mm and the average volume of rain water is estimated about 70 milliard $m^3$([Politique nationale de l'eau du Togo (PNET)], 2010). Surface water is characterized by three basins (Oti Basin, Mono Basin and Lake Togo Basin) and the main body of water inflows in these basins is the direct precipitation while the main output is the Real Evapo Transpiration (RET).

In Togo, the rate of effective access to drinking water (groundwater supply by hand pump) in rural and semi urban areas is 48%. So, people with no access to the Togolese drinking water network (TdE) drink the untreated surface water. This resource like many surface waters is under threat by contamination from natural sources and anthropogenic sources [2-3] such as bad hygiene practices, bad pesticides uses in agriculture and fishing, inorganic and organic fertilizers uses in agriculture, oxen drink during transhumance etc. Currently, the majority of diarrhoea-related deaths worldwide are explained by a lack of access to safe drinking water, or a deficiency in personal hygiene [4]. Furthermore, in developing countries, 17% of all children death below 5 years of age are due to diarrhea which usually follows ingestion of poor quality drinking water [5]. In Togo, despite efforts to improve the availability and accessibility of potable drinking water, problems regarding a lack of access to potable water still arise, particularly in rural and peri-urban settings.

In the wet season, it is evident that water is abundant however the quality of water is poor as the gravity flow water emerged with its colour greatly changed. In dry season, surface water becomes rare and due to RET and human practices, pollution is often increased affecting negatively population health. After all these hygiene and sanitation problems, there is not a full study at a watershed level or at national level which assess physicochemical and bacteriological quality of surface water. Nerverthless, there are some scarce studies regarding physicochemical quality of some surface water of Togo such as Boukari et al. [6] in some dams and rivers of Oti basin, Mono basin and Lake Togo basin, and Tampo et al. [7] in Zio river sub-basin. Boukari et al., [6] and Tampo et al., [7] reported that many surface waters in Togo is used mainly for drinking or domestic uses at all times of the year. Hence, it is necessary to obtain information on the temporal variation of physico-chemical and bacteriological characteristics of water resources in order to provide basic information for identification of candidate variables for water quality development and a monitoring program of water resources in Togo.

Lake Togo Basin was selected for surface water quality assessment because it is a major source of water for the inhabitants and the largest reserve of surface water near Lome (Capital of Togo). Due to a very low drinking water supply network insured by Togolese Water Network people in Lome and its around, usually supply water themselves by doing drilling in Continental Terminal aquifer for private or commercial purposes. As many drillings, usually are done manually in Lomé and near boring, this resource is under threat by contamination from natural sources and anthropogenic source [8]. Therefore an additional water resource is required to meet water needs in south of Togo.

This study generated basic data regarding the effect of seasonal variations in physicochemical and microbiological parameters on quality of surface water used for domestic purpose in Lake Togo Basin (LTB).

## 2-Material and Methods

### *2.1-Study area*

Lake Togo Basin (LTB) is located in a tropical climate type with two long seasons (one dry and one rainy) and two short seasons (one dry and one rainy). Because of South Togo climatic anomalies and overall climate change effects, some years the two short seasons or one of them can be absent or mixed up to one of the long seasons. LTB surface water is the major source of water for domestic and agricultural purposes in rural and semi-urban area of the basin. Moreover, the main activity in the basin is agriculture (Maize, cassava, bean, yams, rice etc). Fishing and some few industrial activities such gravel washing, cement production, limestone and phosphate extractions are noted. These activities are situated mainly at upstream of some sampling sites (especially phosphate extraction and it transportation for washing factory located at Kpeme village along Atlantic Sea).

LTB is composed of many rivers as tributaries or main rivers distributed mainly in three sub-basins (Sub-basin of Zio River; Sub-basin of Haho River and Sub-basin of the Lake). Some rivers have permanent running and others have intermittent running during the year. The water samples were collected in permanent rivers, in Notsè dam and in the Lake Togo as shown on the figure 1. The Table 1 presents GPS locations and the name of sampling sites and rivers.

**Table 1:** Surface water sample sites and its GPS positions

| Sample sites | River or Dam/Sub-basin | X | Y |
|---|---|---|---|
| Kpédomé | Notsè Dam/Haho Sub-basin | 1,16291 | 6,98347 |
| Yotokopé | Yoto river/Haho Sub-basin | 1,31935 | 6,73653 |
| Kati | Zio river/Zio Sub-basin | 0,82252778 | 6,87969444 |
| Gati | Gati river/Haho Sub-basin | 1,33765 | 6,50661 |
| Gbatopé | Lili river/ Haho Sub-basin | 1,25688 | 6,44298 |
| Togblékopé | Zio river /Zio Sub-basin | 1,21161 | 6,28346 |
| Kpémé | Lac Togo/ Lake Sub-basin | 1,49554 | 6,22661 |

***2.2-Water Sampling***

Water samples were collected from 7 sampling sites in the basin during four campaigns for physic-chemical and microbiological analysis. After in situ parameters measurement, the water samples were collected in a 1.5 L polyethylene plastic bottle for physicochemical analysis. For microbiological analysis, samples were collected in borosilicate glassware of 500 mL according to the standard procedure NF EN 25667-1 [9]. All samples were stored in ice during transport to the Laboratory. Sampling site selection criteria included natural conditions as well as catchments with human activities and they correspond to sampling stations of hydraulic department of Togo.

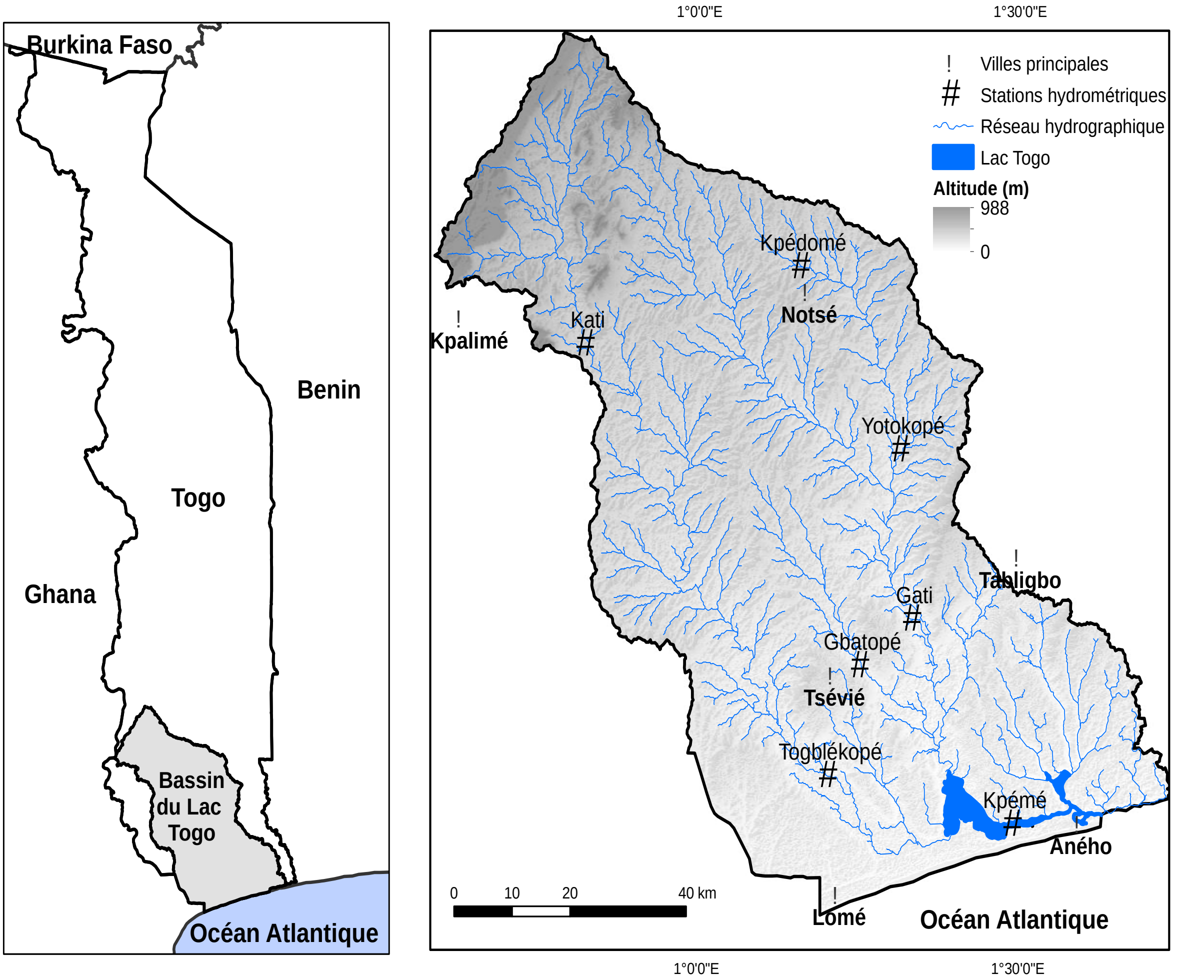



*Figure 1: Localization Map of Lake Togo Basin and sampling sites*

***2.3-Physico-chemical and Microbiological analysis***

Methods used for Physico-chemical and Microbiological parameters are summarized in table 2. In situ parameters such as Temperature, pH and Electrical Conductivity were measured at each site using WTW (Wissenschaftliche Technische Werkstätten) type instruments. Water samples were stored in a refrigerator at a temperature of 4°C and analyzed within 72 hours of sampling. All methods were based mainly on [Association Française de Normalisation [9]

**Table 2:** The water quality parameters and their analytical method in this study

| Parameters | Method | Method accuracy | Material |
|---|---|---|---|
| Turbidity – NTU | Nephelometry | ±0.01NTU | DRT100B, model 20012 turbidimeter |
| Temperature - °C | Thermomter | ±0.1°C | WTW Cond 330i Conductimeter |
| pH | Electrometry | ±0.01 | pH 330i pH-meter WTW |
| Electrical Condutivity 25°C - µs/cm | Conductimetry | ±0.5% | WTW Cond 330i Conductimeter |
| Alcalinity (TA) - °f | Acidimetry | | Glassware for Titration |
| Complete Alcalinity (TAC) - °f | Acidimetry | | Glassware for Titration |
| TH (Total Hardness) - °f | Complexometry EDTA | | Glassware for Titration |
| Sodium ($Na^+$) –mg/L | Atomic absorption spectrophotometry | ± 0.04 mg/L | PU 9200X Atomic absorption spectrometer |
| Potassium ($K^+$) –mg/L | Atomic absorption spectrophotometry | ± 0.02 mg/L | PU 9200X Atomic absorption spectrometer |
| Ammonium ($NH_4^+$) – mg/L | Spectrophotometry | 1 to 2% | 6705 UV/Vis spectrophotometer Jenway |
| Nitrates ($NO_3^-$ ) – mg/L | Spectrophotometry | 1 to 2% | 6705 UV/Vis spectrophotometer Jenway |
| Nitrites ($NO_2^-$) – mg/L | Spectrophotometry | 1 to 2% | 6705 UV/Vis spectrophotometer Jenway |
| Chlorures ($Cl^-$) – mg/L | Argentimetry | ± 0,5 mg/L | Glassware for Titration |
| Sulfates ($SO_4^{2-}$) – mg/L | Nephelometry | 1 to 2% | Glassware for Titration |
| Total Iron ($Fe^{2+}$ & $Fe^{3+}$) – mg/L | Spectrophotometry | | 6705 UV/Vis spectrophotometer Jenway |
| Manganese ($Mn^{2+}$) – mg/L | Spectrophotometry | | 6705 UV/Vis spectrophotometer Jenway |
| Dissolved Oxygen (DO) - $mgO_2/L$ | DO bottle method | ± 0.5 mg/L | DO bottles |
| COD - $mgO_2/L$ | Heat 200 °C/Titration | | Bloc Digest 6 |
| Total Germ (30°C)-nbr/mL | NF V08 051 | | Plate Count Agar (PCA), 30 °C |
| Total coliforms (30°C) - nbr/100mL | NF V08 016 | | VRBL, 30 °C |
| Faecal coliforms (44°C) nbr/100mL | NF V08 016 | | VRBL, 44 °C |
| Echerichia coli -nbr/100mL | NF T90-411 | | VRBL, 44 °C |

### *2.4- Data treatment and statistical methods*

Water quality data are often collected at different sites over time to improve water quality management. Water quality data usually exhibit the following characteristics: non-normal distribution, presence of outliers, missing values, values below detection limits (censored), and serial dependence. It is essential to apply appropriate statistical methodology when analyzing water quality data to draw valid conclusions and hence provide useful advice in water management [10].

In this study after exploratory analysis, we use univariate methods like descriptive statistics, hypothesis testing and multivariate methods like Principal Component Analysis (PCA) and Factor analysis (FA). All these analysis were translate mainly into useful graphical methods such as Box and whiskers plots for univariate analysis and scatter plots for multivariate analysis. Box and whiskers plots still called five-number summary are great tools for visualizing more than one statistic of a parameter on one graph, making the interpretation clearer. The boxes show the interquartile range and the black line in the box is the median. Two upright lines represent the data within the 1.5 interquartile range. The data between 1.5 and 3 times the interquartile range are indicated with a circle (outliers), and the ones with higher values than 3 times the interquartile range are considered to be extreme values indicated with an asterisk. They were used to highlight trend evolutions of parameters between season and sub-basins that cannot be detected by hypothesis testing.

A Scatter plots is a very useful summary of a set of bivariate data (two variables). It can be used to detect whether the relationships between two variables are linear or curved, and aids the interpretation of the correlation coefficient or a regression model. It was used to highlight and visualized correlations between variables (original variables and Factors or Principal components) and allowed to explore factors and processes which control water quality and its variation in LTB.

All data treatment and statistical methods were done using EXCEL and STATISTICA for Window software.

## 3-Results and discussions

### *3.1-Overall water quality of Lake Togo Basin*

The summary of main measured variables in the seven stations during the four campaigns is provided in Tables 3. Data analysis gives an overview of the variations in water quality during the four campaigns in Lake Togo Basin. There are some extreme values especially on Electrical Conductivity showing a notable dynamic in Togo Lake Basin.

Turbidity and Electrical Conductivity are characterized by high standard deviation indicating that the data is widely spread, due to the presence of temporal and spatial variations caused likely by natural and/or anthropogenic polluting sources [11]. The measured turbidity values are characterized by low to moderate values. The highest turbidity can be caused by the soil erosion of the prepared agricultural fields with loose top layer of the soil. Also, debris falling off due to the wind and rain could have contributed particles to the basin water. Regarding pH values, they ranged from 6.39 to 7.8 with the mean value varying to neutral toward alkaline. The mean pH values of water samples were within the pH standards range for drinking water (6.5 - 8.5) according to WHO limits. The temperature is among the physico-chemical parameters useful in evaluation of the drinking water quality as it influences the quality of water (physicochemical and biological characteristics) including the rate of chemical reactions in the water body and decrease in solubility of gases [12]. In the present study, temperature values recorded ranged between 25 and 28.33 °C.

Concerning Electrical conductivity (EC), all its values (63 – 547 µS/cm) in the basin water were below the WHO maximum guideline limit (1500 µs/cm) except for some water samples related to mixture of Ocean Atlantic water with Lake Togo water sometimes mostly during the low water flow. In this area, EC varies from 238 to 32200 µS/cm, showing the temporary influence of the sea water as indicated in figure 1. Lake Togo Basin waters sampled during this study are characterized by a slight alkalinity confirmed by pH value slightly higher than neutral.

The chemical Oxygen Demand (CODMn) is a parameter used to quantify moderate organic contaminations load, easily oxidized by $KMnO_4$ [12]. CODMn shows contents between 1.9 and 13 mg/L. The high values could be related to the leaching and transport of natural material, domestic sewage, agricultural and industrial pollutant.

Dissolved Oxygen (DO) content is an essential parameter that maintains the equilibrium of aquatic ecosystems. It is commonly used to assess water quality and aquatic ecosystems health [13]. DO values vary from 3.4 to 13.1 mg/L and are similar to those obtained by Tampo et al., [14] in Zio River Sub-basin. Many values measured are higher or closer to 7 mg/L showing that water in Lake Togo Basin can be qualified as good to excellent quality according to surface water standards [9, 12]

The concentrations of other dissolved ions, cations ($Na^+$, $K^+$, $NH_4^+$) and anions ($NO_2^-$, $NO_3^-$, $SO_4^{2-}$, $Cl^-$) vary in the magnitude different to previous parameters with $NH_4^+$ and $NO_2^-$ under the detection limit value, very low values for $NO_3^-$ (0.5 to 2.4 mg/L). The range of concentration values of $Na^+$ (4.5 to 6600 mg/L), $K^+$ (1.2 to 268 mg/L) and $Cl^-$ (0.8 to 13415 mg/L) is similar to Electrical conductivity values and exhibit similar distribution as

Electrical Conductivity showing clearly that these parameters contribute greatly to the conductivity of Lake Togo basin water. Standard deviation of these parameters confirmed sea water intrusion above-mentioned.

Water related diseases are highly correlated with microbiological pollution of water used as drinking water. The presence of Fecal Coliforms and mostly E. *coli* is an indicator of the bacteriological contamination of water and conditioned water use for drinking or domestic purposes [15]. The concentrations values of Fecal Coliforms and E. *coli* ranged from 28 to 850 cfu/100ml and from 0 to 66 cfu/100 mL respectively. These results do not satisfy the standards of WHO for drinking water and are similar to those obtained by De Troyer et al. [15] in stream and wetlands of Ethiopia. Metallic elements analysis shows that the total iron (FeT) and Mn concentrations are very low (0.1 to 3.1 mg/L) and (0.05 to 1.2 mg/L) respectively or under detection value in water samples of LTB.

The exploratory and summary results of water quality in LTB reveal that some parameters present very low values or under detection limits (DL). These parameters had a very slight standard deviation (S-D) and showing their slight variability. The other parameters present values above DL with significant SD values expressing their variability.

**Table 3**: Descriptive statistics of parameters summarizing the results:
Mea: Mean value, Med: Median value, Min: Minimum value, Max: Maximum value, 25P: 25 percentile value, 75P: Percentile value, SD: Standard Deviation value

| Parameters | Mea | Med | Min | Max | 25P | 75 P | SD |
|---|---|---|---|---|---|---|---|
| Turbidity (NTU) | 38.46 | 40.7 | 0.3 | 152 | 4.4 | 59.1 | 35.91 |
| pH | 7.23 | 7.27 | 6.39 | 7.8 | 7.03 | 7.45 | 0.33 |
| T (°C) | 27.16 | 27 | 24 | 30 | 26 | 28.5 | 1.69 |
| EC (µS/Cm) | 2698.84 | 186.2 | 63.3 | 32200 | 127.4 | 322 | 7537.41 |
| Alcalinity (°f) | 8.52 | 7.5 | 1.5 | 24.5 | 5.5 | 10 | 5.08 |
| Hardness(°f) | 32.86 | 6.6 | 2.2 | 430 | 4.8 | 10.8 | 88.87 |
| Transp(Cm) | 35.6 | 25 | 1 | 168 | 5 | 35 | 43 |
| Sodium (mg/L) | 511.88 | 17.2 | 3.8 | 6600 | 8 | 29.6 | 1521.1 |
| Potassium (mg/L) | 24.28 | 3.7 | 1.2 | 268 | 2.4 | 7.2 | 62.14 |
| Chlorine (mg/L) | 991.73 | 15 | 0.8 | 13415 | 9 | 36 | 3035.18 |
| CODMn (mg/L) | 5.31 | 5.2 | 1.9 | 13 | 4.15 | 6.2 | 2.28 |
| DO(mg/L) | 6.66 | 6.6 | 3.4 | 13.1 | 5.6 | 7.4 | 1.83 |
| Total Germ (cfu/mL) | 14314.2 | 3900 | 250 | 203000 | 605 | 10700 | 40246.54 |
| Total Iron (mg/L) | 1.13 | 1 | 0.1 | 3.1 | 0.7 | 1.4 | 0.62 |
| Nitrates (mg/L) | 1.75 | 1.3 | 0.5 | 15 | 0.5 | 1.5 | 2.83 |
| Sulfates (mg/L) | 16.38 | 1 | 1 | 2.6 | 1 | 13.25 | 5.49 |
| Manganese (mg/L) | 0.4 | 0.1 | 0.05 | 1.2 | 0.08 | 1 | 0.5 |
| Total Col. (cfu/100mL) | 554.28 | 160 | 2 | 9000 | 40 | 260 | 1775.98 |
| Faecal Col. (cfu/100mL) | 84.12 | 28 | 0 | 850 | 6 | 50 | 178.14 |
| E. coli (cfu/100mL) | 7.8 | 1 | 0 | 66 | 0 | 8 | 16.78 |

***3.2-Seasonal variation of water quality in Lake Togo Basin***

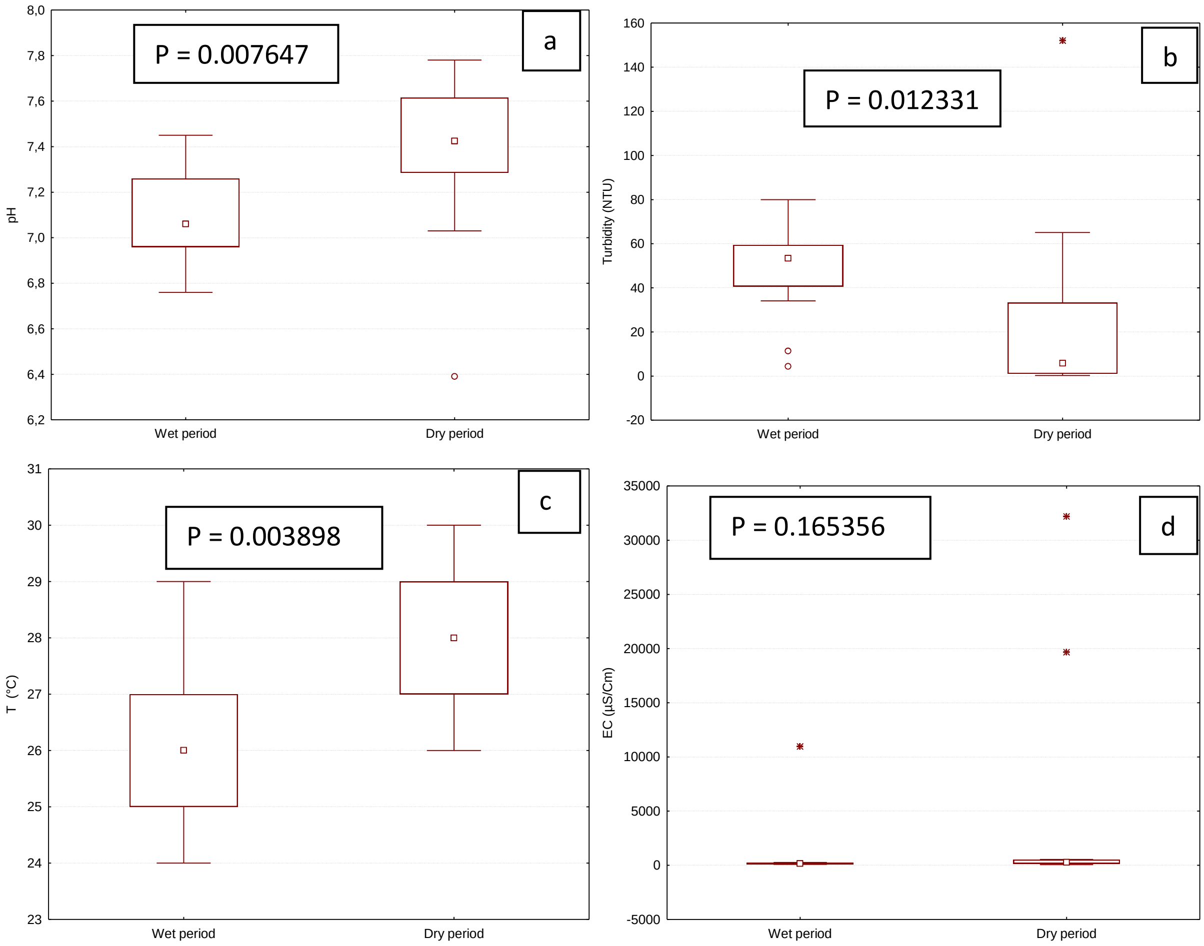
The summary of seasonal variation of main water quality indicators are represented by table 4 and the trend of seasonal variation of some parameters is represented by Whisker Box Plots in Figures 2 to 6.

**Table 4:** Summary of variability of selected parameters during the four campaign periods

| | | Turd (NTU) | pH | T (°C) | EC (µS/cm) | Alc (°f) | COD (mg/L) | DO (mg/L) | E. Coli (cfu/100mL) |
|---|---|---|---|---|---|---|---|---|---|
| September | Mean± SD | 45.16±22.81 | 7.06±0.23 | 27.12±1.39 | 167.87±59.08 | 7.07±1.94 | 6.30±1.28 | 7.28±0.92 | 13.57±19.99 |
| January | | 4.23±7.74 | 7.24±0.49 | 28.00±1.26 | 3554.10±7902.25 | 12.58±8.43 | 3.91±1.92 | 8.18±2.51 | 11.66±26.62 |
| April | | 48.83±55.83 | 7.51±0.18 | 28.33±1.36 | 5528.88±130766;42 | 7.83±3.29 | 4.25±1.18 | 5.20±0.98 | 2.33±3.83 |
| June | | 52.18±24.35 | 7.12±0.18 | 25.16±075 | 1966.35±4406.64 | 6.83±3.25 | 6.60±3.19 | 5.88±1.04 | 2.66±4.08 |

The figures 2a, 2b, 2c and 2d show seasonal trend of pH, Turbidity, Temperature and Electrical Conductivity respectively in Lake Togo basin. The maximum values are recorded during dry season except Turbidity. Some extremes and atypical values are observed during the two seasons. These values can be explained by punctually modification of water characteristics lead to human or animal actions happened on some sites at the moment of sampling. The median value of these parameters and the statistical tests (U test) showed that there were a significant variation of pH, Turbidity and Temperature ($p < 0.05$) between dry and rainy seasons.

Electrical conductivity did not show a significant variation ($p > 0.05$) during the two seasons but it presents extremes values in dry season lead to contamination of sea water during this period [7]. This variation of Temperature, Turbidity and pH can mean that these parameters are influenced slightly by hydrochemistry processes but are perturbed by some outside phenomena. Indeed the Turbidity is related to hydrological flow which changes according to seasons with high values in rainy season. The temperature also follows seasonal variation because many days of rainy season are generally cold than dry season days in tropical climate of LTB. The pH modification is governed mostly in surface water by many factors such as: $pCO_2$; photosynthesis and stability of the different forms of carbonic acid [16]. The Temperature and pH can fluctuate in the same day according to the water sampling time [17]. But Electrical Conductivity in the majority is mainly governed by hydrochemical process such as dissolution of sells in water [18] and then it is very slightly impacted by seasonal regime in permanent running water.

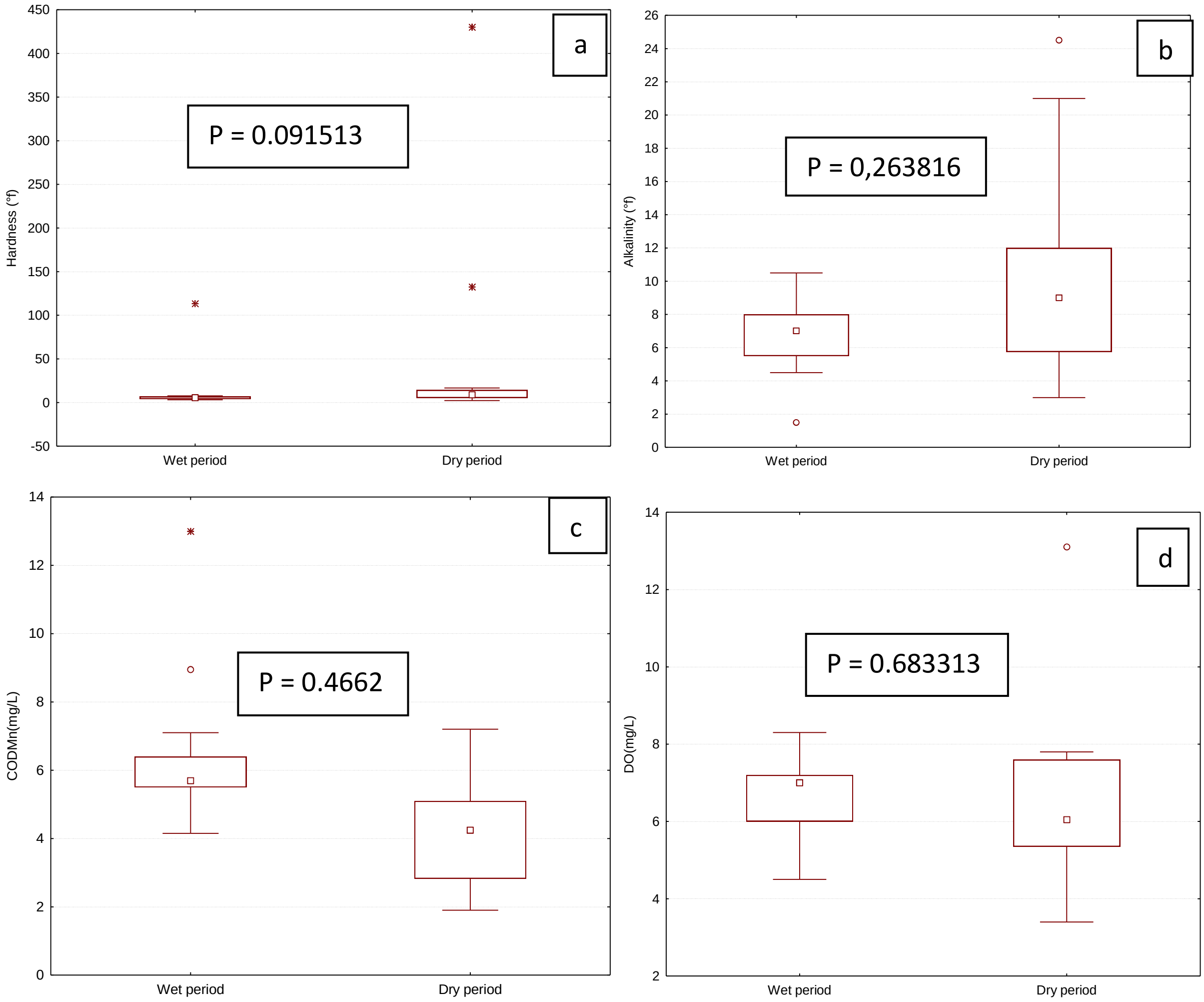



□ = Median. ☐ = 25P-75P. Ɪ = Non Atypical ○ = Atypical. ⁜ = Extremes

*Figure 2: Trend of seasonal variation of Temperature, pH, Turbidity and EC*

The figures 3a, 3b, 3c and 3d show seasonal variation of water hardness, water alkalinity, and chemical oxygen demand and dissolved oxygen respectively. High values of Hardness and Alkalinity in their majority are obtained during dry period but these parameters don't show a significant seasonal variation at Man Whitney test ($p > 0.05$). They represent the same trend of variation with EC and confirmed that they are linked to Electrical Conductivity. Generally EC or salinity in waters is dominated by Calcium and Magnesium ions which govern water hardness and by Bicarbonates ions which translate water alkalinity (Wurts and Durborow, 1992). Highest CODMn and DO are more recorded in the rainy season. CODMn and DO values don't show a significant variation according to the seasons. DO and CODMn are parameters which are very sensitive to organic pollution (Makhoukh et al., 2011).

Especially DO is a water quality indicator in surface water and contributes to natural purification. In the case of organic pollution DO values decrease while CODMn values increase. Among the reasons of their variation we have mainly organic matters load (Rodier et al., 2009) which variation is independent to seasonal regime because of the contribution of anthropogenic sources.




□ = Median. □ = 25P-75P. I = Non Atypical ○ = Atypical. ⁜ = Extremes

*Figure 3: Trend of seasonal variation of Temperature. Alkalinity. CODMn and DO*

The figures 4a, 4b, 4c and 4d indicate the trends of seasonal variation of Total Germs, Total Coliforms, Fecal Coliforms and E. *coli* concentrations respectively in LTB water. All microbiological parameters show some extremes values and can be explained by punctual contamination of water during the sampling time. Box and whisker Plots show similar median values of each parameter during dry and rainy season indicating a weak seasonal variability of microbiological parameters.

This slightly variation of microbiological parameters is confirmed by U test which presents p values lower than 0.05. The slight seasonal variation was expected because the bacteriological contamination is linked to anthropogenic sources as above-mentioned for DO and CODMn seasonal variability. For example the presence of Total Coliforms may indicate fecal contamination. Coliforms are interesting because a very large number of them live abundantly in the fecal matter of warm-blooded animals including humans and thus constitute fecal indicators of the highest importance [12, 15]. Elsewhere some studies showed some correlations between organic load, anthropogenic sources and Total Coliforms [20] or organic load, anthropogenic sources and Fecal Coliforms [15].

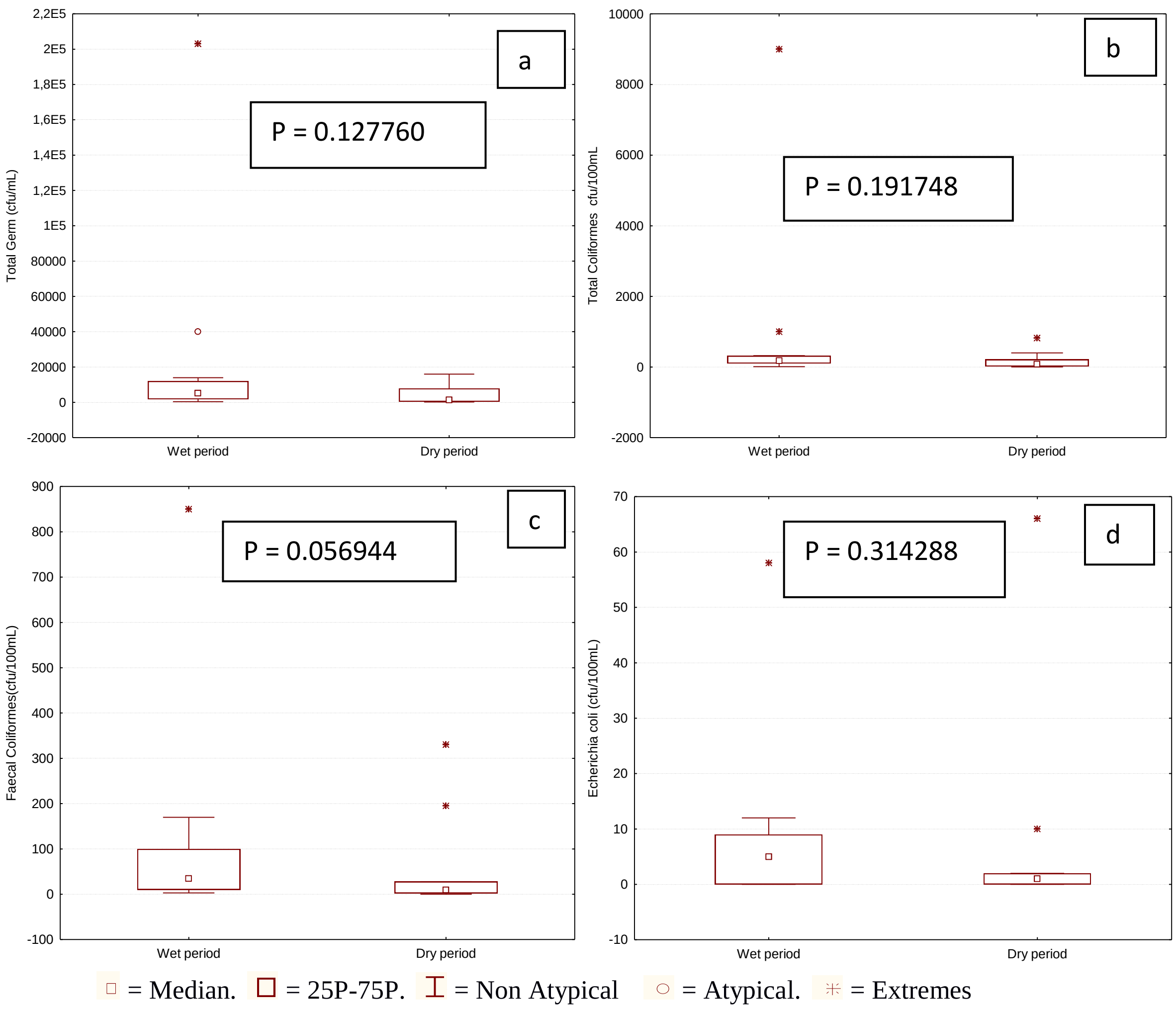



*Figure 4: Trends of seasonal variation of microbiological parameters*

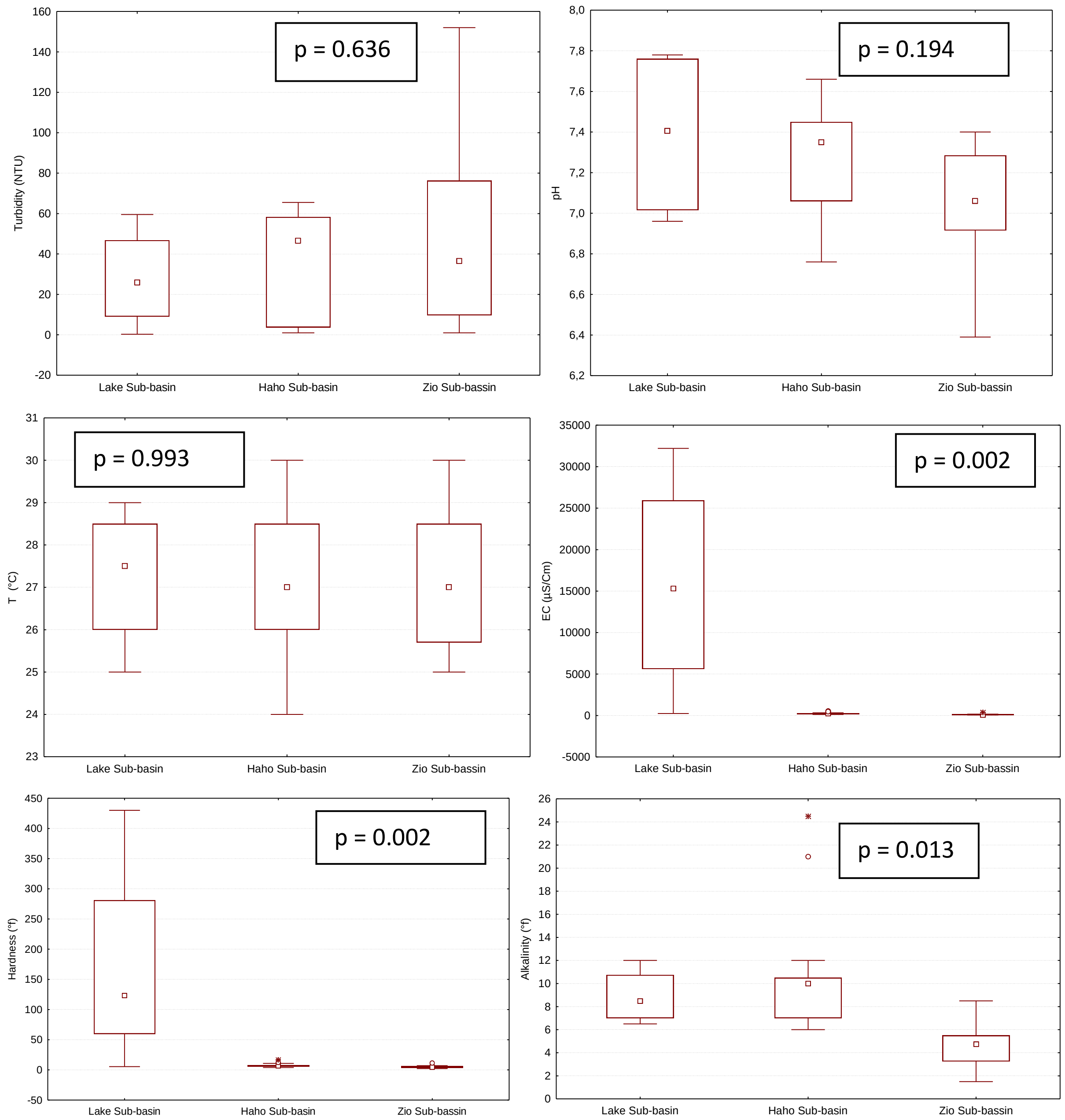
***3.3-Variability of water quality in sub-basins***

This spatial variation of water quality concerns evolution of some parameters in the three sub-basins of Lake Togo basin. The box and whisker plots show the trend of evolution of parameters in each sub-basin during the four sampling campaigns. The Kruskal Wallis test is associated to highlight significant variability of parameters between water quality of the three sub-basin. The median value of Turbidity, pH and Temperature in the three Sub-basins seem to be similar for each parameter (Figure 5). These trends are confirmed by the results of Kruskal Wallis for the three parameters ($p > 0.05$) which expressed non-attendance of significant variation. Nonetheless highest Turbidity, pH and Temperature are recorded in Zio sub-basin, in Lake sub-basin and in Haho sub-basin respectively. The lowest Turbidity, pH and Temperature are observed in Lake sub-basin, Zio sub-basin and Haho sub-basin respectively. The slight variation observed in box and whisker plots evolution can be imputable to external factors independently to chemistry processes in water.

Only Electrical Conductivity show a clear difference between Lake sub-basin and the two other sub-basins ($p = 0.002$). As above-mentioned, previously studies [7] show that the water of the Lake is often contaminated by sea water mainly during low water flow and increase EC of some parts of Lake Togo sub-basin water. Except this period of low water regime, EC is naturally low in all Lake Togo basin. These slight values of EC confirmed the idea of Gibbs [18] according to which waters of the tropical rivers in Africa present a very low rate of supply of dissolved salts to the rivers.

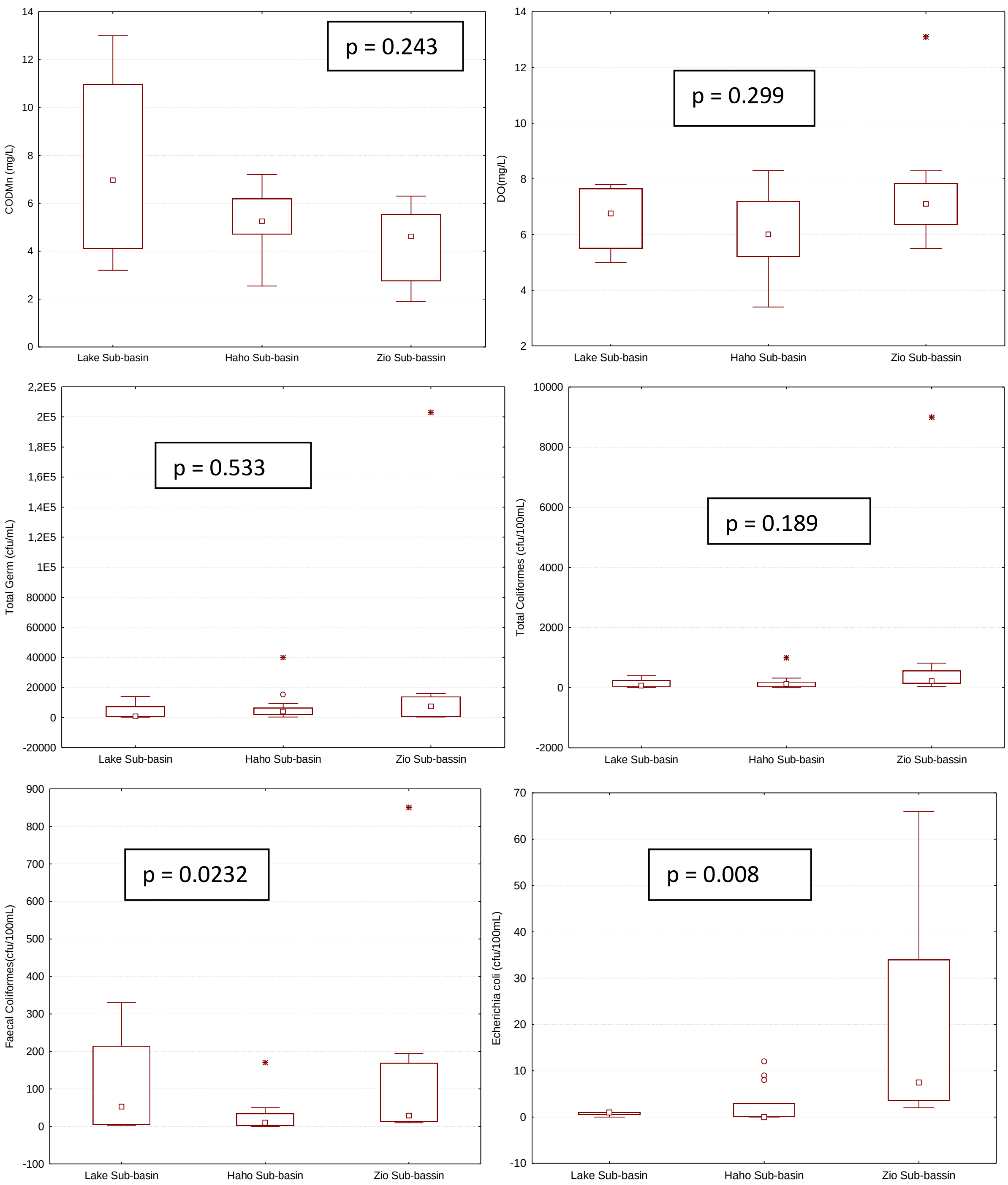
Alkalinity and Hardness show the same result for Kruskal Wallis test and in their evolution trends. This similarity was inspected because water hardness and alkalinity contribute in the majority to electrical conductivity of freshwater and are mainly governed in river water by the geological set up of the river catchment [21-22].

Median values of DO and CODMn in the three sub-basins are very close (Figure 6). This similarity is confirmed by the results of variability tests which revealed non-significant difference ($p > 0.05$). These results can translate that all the sub-basins are similarly affected by the same human activities because these parameters are more affected by anthropogenic activities than other factors and are influenced by point sources such as discharges from wastewater treatment plants, domestic wastewater and industrial effluents [23-24]. DO is a sensitive indicator for organic pollution in surface water and for hydrosytem health assessment with values over or near from saturation when natural processes are not disturbed [12, 25].




□ = Median. □ = 25P-75P. I = Non Atypical ○ = Atypical. ⁎ = Extremes

*Figure 5: Trends of spatial variation of Temperature, pH, Turbidity, EC, Hardness and Alkalinity*




□ = Median. ☐ = 25P-75P. Ɪ = Non Atypical ○ = Atypical. ✳ = Extremes

Figure 6: Trends of variation of DO, CODMn, Total germs, TC. FC and E. coli

Accordingly values of DO obtained in all sub-basins (Median of DO concentration > 6mg/L) indicated that Lake Togo Basin ecosystem health is in good state. The highest value of DO obtained in Zio Sub-basin is in agreement with Tampo et al., [14] who have recorded up to over saturation in this sub-basin. The results of DO in Zio sub-basin (5.7mg/L-13.1mg/L) can be interpreted by the degree of turbulence with an important velocity and permanent running of Zio water which allow an important mixing of water-air [12, 14]. CODMn is another indicator of organic pollution used for assessment of surface waters with moderate organic matter load [9]. In this study CODMn presents moderate values in the three sub-basins but high value is obtained in Lake sub-basin. In fact, Lake Togo receives running water from all the rivers of study area and constitutes an accumulation reservoir

of organic matters. In addition, sewage from Kpémé mining factory is also released into the Lake and may explain high load of oxidizable materials estimate by CODMn in the Lake sub-basin [26].
The bacteriological parameters show a variability in the sub-basins as indicated by their evolution trends in box and whisker plots (Figure 6). Total Germs (TG) and Total Coliforms (TC) median number in sub-basins showed non-attendance of significant variability but their extreme and maximum values are obtained in Zio sub-basin. Indeed Total Germs have no direct health effects but are indicators for the possible presence of bacteriological contamination [12]. The presence of Total Coliforms may indicate fecal contamination.
In extreme cases, a high count for the total coliform group is often associated with fecal coliforms [19]. Most of Fecal Coliforms (FC) constitute fecal and human pressures indicators. Accordingly some group of total germs and total coliforms can be associated with presence of nutrients or organic matters [27] and bring closer with DO and CODMn results when using Kruskal Wallis test. Fecal coliforms or E. coli are indicators for microbiological quality and indicate contamination of water by pathogens organisms of human origin. These parameters showed a significant variation between the three sub-basins and can be interpreted by point source pollution during sampling times.

### *3.4-Factor analysis and typology of water quality*

Factor analysis reduces the contribution of less significant variables obtained from PCA and the new group of variables known as factors is extracted through rotating or no the axis defined by PCA [20]. PCA of variables (water-quality data set) was performed to extract two significant factors and to further reduce the contribution of variables with minor significance [28]. Figure 7 show the results of factors analysis after exploratory analysis. The scatter plot of variables according to the two principal factors (61.1% of total variance) presents four groups of parameter. The first group is represented by parameters which express degree of water salinity/mineralization. This group is mainly composed of Hardness, Electrical Conductivity, Potassium, Sodium and Chloride. The second group expresses microbiological quality of Lake Togo basin water and composed of bacteriological parameters such as Total Germs, Total Coliforms, Feacal Coliform and Escherichia *coli*. The third group is represented by parameters which express organic pollution or organic load in Lake Togo basin water and is composed of CODMn, DO and Turbidity. In the same way Wan Abdul Ghani et al [29] identified Chemical Oxygen Demand, Dissolved Oxygen and Total Suspended Solids as significant and sensitive indicators of organic pollution and showed their strong correlation with the first axis of PCA and with some biotic indices known to be most sensitive organic load indicators. The fourth group is represented by parameters which express degree of alkalinity or carbonate ions balance and consists of Temperature, Alkalinity and pH. The group one and two are identified as significant parameters in assessment of Lake Togo basin water quality and its variability. The group three and four are identified as less significant parameters but having an influence on indication of Lake Togo basin water quality and its variability. These results are confirmed by factor matrix which showed a very strong correlation of group one parameters with the first factor which expresses degree of water mineralization or water mineralization processes in the study area. The variables of group 2 are strongly correlated with factor 2 which expresses microbiological features in Lake Togo basin water. This strong correlation between these groups of parameter and the main two factors (60.1% of total variance) can mean that variability of water quality in the study area were influenced mainly by microbiological and mineralization features. Many studies have used the first and second axis in the factor analysis to discriminate sampling sites, to identify significant variables and phenomena which govern water chemistry processes and water quality variability [10, 24, 22, 30. Some authors show that cumulative variance of the two principal components explained the most variability of water quality and are strongly correlated with parameters having significant influences on water quality [20, 23, 24, 30, 31]. The ideas of these authors confirmed the results of our study. The variables of group three are significantly correlated with the fourth factor which represents 10.31% of total variance. This factor expresses organic load and conditions having a significant influence on Oxygen Demand of water. In most of study case, it was demonstrated that COD, DO and Turbidity/Total Suspended Solids are significantly correlated with the first factor or second factor [20, 29, 31] or each parameter is correlated with one of the first four factors [24, 30]. This relationship shows the influence of these parameters on water quality, on its variability and generally on the health of aquatic ecosystems. The variables of group four are significantly correlated with the third factor which represents 12.05% of total variance and translate water alkalinity and carbonate ions balance. Indeed it has been demonstrated that pH, Temperature, Carbonate ions and carbon dioxide are correlated in most of freshwater [16, 18, 32]. This relationship within variables and between variables and the first and second principal components discriminate rivers of Lake Togo Basin in three types which represent the three sub-basins waters. The figure 8 indicates the three groups of water when we used above-mentioned selected variables recorded in the different rivers during the four sampling campaigns. These results related that in Lake Togo basin four factors mainly control variability of water quality and all rivers water can be categorized in three types corresponding at each sub-basin respectively.

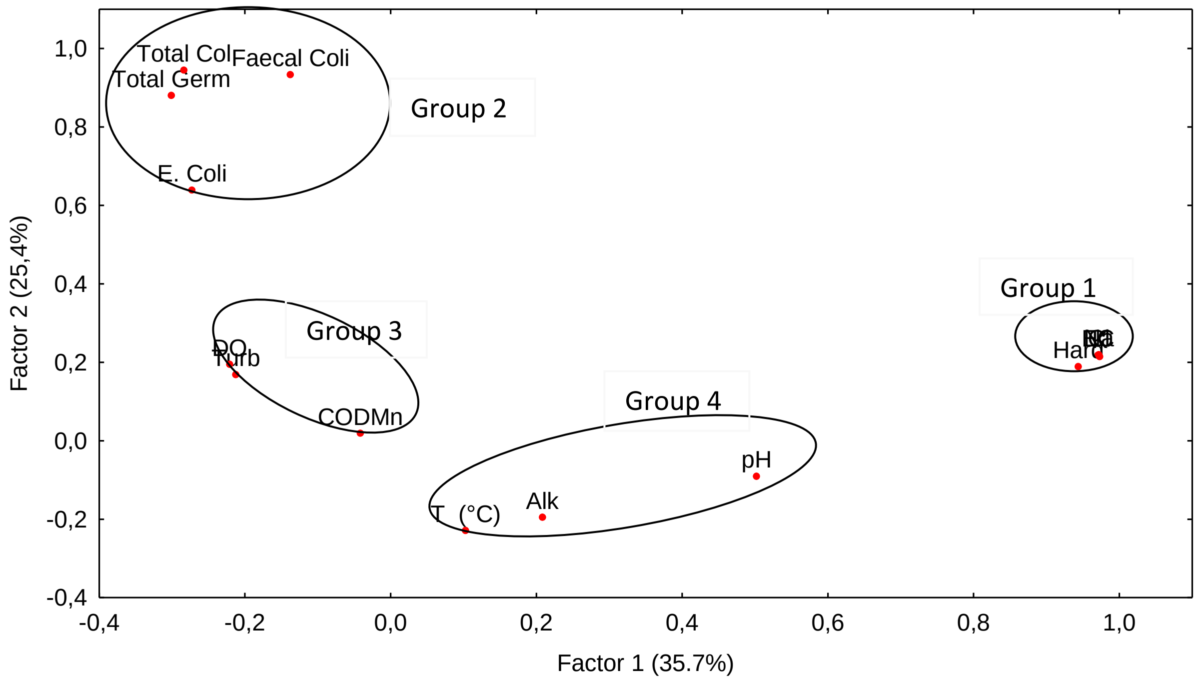



*Figure 7: Variables scatter plot in factor 1 and factor 2 plans*

**Table 5:** Varimax rotated factor matrix

| Variables | Factor 1 | Factor 2 | Factor 3 | Factor 4 |
|---|---|---|---|---|
| Turb | -0.26 | -0.21 | -0.10 | **0.71** |
| pH | 0.49 | 0.11 | **0.66** | 0.31 |
| T (°C) | 0.14 | 0.30 | **0.53** | -0.28 |
| EC | **0.95** | -0.27 | -0.13 | -0.03 |
| Alk | 0.27 | 0.26 | **0.65** | 0.02 |
| Hard | **0.94** | -0.24 | -0.11 | -0.02 |
| Na | **0.95** | -0.27 | -0.12 | -0.04 |
| K | **0.96** | -0.26 | -0.10 | -0.04 |
| Cl | **0.95** | -0.27 | -0.12 | -0.04 |
| CODMn | -0.06 | -0.04 | -0.44 | **0.58** |
| DO | -0.28 | -0.25 | -0.34 | **-0.77** |
| Total Germ | -0.33 | **-0.86** | 0.23 | 0.09 |
| Total Col | -0.31 | **-0.91** | 0.17 | 0.05 |
| Faecal Coli | -0.17 | **-0.93** | 0.14 | 0.03 |
| E. Coli | -0.32 | **-0.70** | 0.28 | -0.17 |
| % Variance | 35.7 | 25.4 | 12.05 | 10.31 |
| Cumulative % | 35.7 | 61.1 | 73.15 | 83.46 |

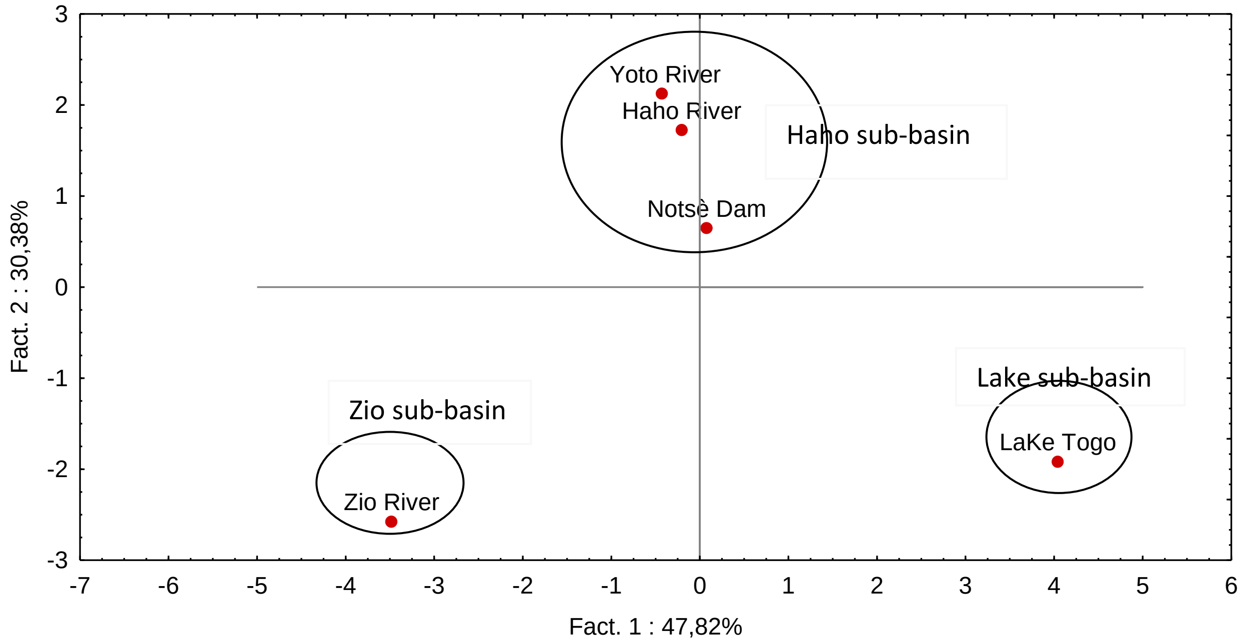



*Figure 8: Scatter plot of sub-basin samples on PC1 and PC2 plan*

**4- Conclusion**

This study found that physicochemical quality of Lake Togo Basin water was acceptable according to physico-chemical parameters but water salinity increased up to over the standards for surface water in Lake Togo during low water flow or dry season. The microbiological quality was perturbed by fecal contamination of some samples in the majority of water samples collected. The exploratory analysis with descriptive statistics revealed that some parameters present slight variation with some values under detective limit. These exploratory analysis help to select some parameters with significant and sensitive values for studies of seasonal and spatial variability of water quality. The results reveal that there are seasonal and spatial variation in the evolution trends of parameters indicated by box whisker and plots. The U tests confirmed significant seasonal variability of Hardness, EC, Turbidity, Temperature and Fecal Coliforms while Kruskal Wallis tests confirmed significant spatial variability of EC, Hardness, Alkalinity, Fecal Coliforms and E. coli. The Factor analysis identified four types of variables with significant sensitivity in indication of variability of water quality. These sensitive variables are strongly correlated with the first four PC axis and mainly influenced water quality variability and discriminate Lake Togo basin water in three types of water corresponding to the three sub-basins waters (Haho, Zio and Lake sub-basins).

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**References**

[1]. Fatombi, K. J., Ahoyo, T. A., Nonfodji, O., Aminou, T., (2012). Physico-chemical and bacterial characteristics of groundwater and surface water quality in the Lagbe town: treatment essays with Moringa oleifera seeds, Journal of Water Resource and Protection, 4, 1001-1008.

[2]. Bawa, L.M., Djaneye-Boundjou, G., Boyode, B.P., Assih, B.T. (2007). Water quality evaluation from Lomé's lagoon: Effects on heavy metals contamination on fishes. Journal of Apply Sciences Environnement. Management 11(4), 33–36.

[3]. Effebi, K. R., N'tain, Y. J., Dabissi, N. D., Diallo, S., Tra Bi Zamblé, A., Nguetta F., Hela K., Kamagaté, B., Goné Droh, L., Jean Louis, P., Luc, S. (2017). Activities and Uses of Aghien Lagoon (South-East of Côte d'Ivoire) Journal of Water Resource and Protection, 9, 11-19.

[4]. WHO (2011). Guidelines for Drinking-Water Quality. 4th edition. Geneva, 569 p.
[5]. Clasen, T., Schmidt, W.P., Rabie, T., Roberts, I. and Cairncross, S. (2007). Interventions to Improve Water Quality for Preventing Diarrhoea: Systematic Review and Meta-Analysis, BMJ, 334, 782-785. http://dx.doi.org/10.1136/bmj.39118.489931.BE
[6]. Boukari, Y., Bawa, L.M., Djeneye-Boundjou, G. (1999). Characterization of some Togo surface waters. Bull. Chem. Soc. Ethiop. 13 (1), 11:21.
[7]. Tampo, L., Gnazou, D.T.M., Kodom, T., Oueda, A., Bawa, L.M. (2015a). Suitability of groundwater and surface water for drinking and irrigation propose in Zio River basin (Togo). J.Rech.Sci.17(3): 35-51
[8]. Ahoussi, K.E., Soro, N., Soro, G., Lasm, T., Oga, M.S., and Zade, S. (2008) Groundwater Pollution in Africans Biggest Towns: Case of the Town of Abidjan (Cote d'Ivoire). European Journal of Scientific Research 20, 302-316.
[9]. AFNOR, 1997. "Qualité de l'eau: Terminologie. Echantillonnage et Evaluation de Méthodes" 2nd Edition. Tome 1. Paris.
[10]. Fu, L., and Wang, YG. (2012). Statistical Tools for Analyzing Water Quality Data chapter 6 of Water Quality Monitoring and Assessment eds K. Voudouris and D. Voutsa. Intech book.
[11]. Ahmed, B., Mohamed, E.B., Jamila, R., Brahim A., Mohamed S. (2016). Assessment of spatial and seasonal water quality variation of Oum Er Rbia River (Morocco) using multivariate statistical techniques. International Soil and Water Conservation Research 4, 284–292.
[12]. Rodier J., Legube B., Merlet N., 2009. L'Analyse de l'eau, 9e édition entièrement mise à jour 1579p.
[13]. Sanchez. E.. Colmenarejo. M. F.. Vicente. J.. Rubio. A.. García. M. G.. Travieso. L.. & Borja. R. (2006). Use of the water quality index and dissolved oxygen deficit as simple indicators of watersheds pollution. Ecological Indicators. 7(2). 315–328.
[14]. Tampo, L., Oueda, A., Nuto, Y., Kaboré, I., Bawa, L. M., Djaneye-Boundjou, G., and Guenda, W. (2015b). Using physicochemicals variables and benthic macroinvertebrates for ecosystem health assessment of inland rivers of Togo. International Journal of Innovation and Applied Studies 12 (4), 961-976
[15]. De Troyer, N., Mereta, S. T., Goethals, P. L.M., and Boets P. (2016). Water Quality Assessment of Streams and Wetlands in a Fast Growing East African City. Water, 8, 123 doi:10.3390/w8040123.
[16]. Sarin, M. M., Krishnaswami, S., Dilli, K., Somayajulu, B. L. K., and Moore, W. S. (1989). Major ion chemistry of the Ganga-Brahmaputra river system: Weathering processes and fluxes to the Bay of Bengal. Geochim. Cosmochim. Acta 53, 997: 1009.
[17]. Nisbet, M., and Verneaux, J. (1970). Composantes chimiques des eaux courantes. Discussion et proposition de classes en tant que bases d'interprétation des analyses chimiques. Ann. Limnol 6, 61-190.
[18]. Gibbs, R. J., (1972). Water chemistry of the Amazon River. Geochim. Cosmochim. Acta, 30, 1061-1066
[19]. Bartram, J., Pedley, S., Balance, R. (1996). Water Quality Monitoring - A Practical Guide to the Design and Implementation of Freshwater Quality Studies and Monitoring Programmes. UNEP/WHO.
[20]. Singh, K. P., Malika, A., Mohan, D., Sinha, S., (2004). Multivariate statistical techniques for the evaluation of spatial and temporal variations in water qualityof Gomti River (India)—a case study. Water Research 38, 3980–3992
[21]. Aziz-ur-Rahman and Chughtai, M.O. (2014). Regional interpretation of river Indus water quality data using regression model, African Journal of Environmental Science and Technology 8(1): 86-90.
[22]. Jayawardana, J.M.C.K., Jayathunga, T.R., and Edirisinghe, E.A. (2016). Water quality of Nilwala River. Sri Lanka in relation to land use practices. Sri Lanka J. Aquat. Sci. 21, 77-94.
[23]. Simeonov, V., Stratis, J. A., Samara, C., Zachariadis, G., Voutsa, D., Anthemidis, A., Sofoniou M., and Kouimtzis, T., (2003). Assessment of the surface water quality in Northern Greece. Water Research 37, 4119- 4124.
[24]. Li, Y., XU, L., Li, S. (2009). Water Quality Analysis of the Songhua River Basin Using Multivariate Techniques. J. Water Resource and Protection 2, 110-121.

[25]. Chapman, D., Kimstach, V. (1996). Selection of water quality variables. Water quality assessments: a guide to the use of biota, sediments and water in environment monitoring, Chapman edition, 2nd ed. E and FN Spon, London, pp. 59-126.
[26]. Ayah, M., Bawa, L.M., Djaneye-Boundjou, G., DONI, S.K., Nambo, P. (2012). Spéciation du Cadmium. du Chrome. du Cuivre et du Plomb dans les sédiments des déchets de phosphate de Kpémé (Sud-Togo). Int. J. Biol. Chem. Sci.. 6(1), 479-492.
[27]. Soo, C.L., Ling, T.Y., Lee, N., Apun, K. (2016). Assessment of the characteristic of nutrients. Total metals. and fecal coliform in Sibu Laut River. Sarawak. Malaysia. Appl. Water Sci. 6, 77–96.
[28]. Vega, M., Pardo, R., Barrado, E., Deban, L. (1998). Assessment of seasonal and polluting effects on the qualityof river water by exploratory data analysis. Water Res 32, 3581–3592.
[29]. Wan Abdul Ghani, W. M. H., Abas Kutty, A., Mahazar, M. A., Al-Shami, S. A., Ab Hamid S. (2018). Performance of biotic indices in comparison to chemical-based Water Quality Index (WQI) in evaluating the water quality of urban river. Environ Monit Assess 190:297-301
[30]. Shrestha, S., Kazama, F. (2007). Assessment of surface water quality using multivariate statistical techniques: A case study of the Fuji river basin. Japan. Environmental Modelling & Software 22, 464-475.
[31]. Kumar, V., Sharma, A., Chawla, A., Bhardwaj, R., Thukral, A. K. (2016). Water quality assessment of river Beas. India. using multivariate and remote sensing techniques. Environ Monit Assess 188, 137:2047.
[32]. Wurts, W.A., and Durborow, R. M. (1992). Interaction of pH. Carbon Dioxide. Alkalinity and Hardness in Fish ponds. SRAC 466, 1-4.