RESEARCH ARTICLE **(Open Access)**

Evaluation of the Environmental State and WQI Variations in Waters of Tirana Artificial Lake

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Abstract

A study of the water quality due to nutrients concentration in waters of the artificial Lake of Tirana was conducted in six different stations of the lake, during the period 2011-2014. A total of 14 water quality parameters were measured, while Water Quality Index, WQI was calculated in order to classify the water quality. The physical and chemical variables were temperature, dissolved oxygen (DO), conductivity, pH, total dissolved solid (TDS), chlorophyll- a, biochemical oxygen demand (BOD), chemical oxygen demand (COD), total suspended solid (TSS), ammonia, nitrite and nitrate-N and phosphate Results show that based on WQI, the waters of Tirana Lake are mainly classified as "class II", which is suitable for recreational activities and allows body contact. With respect to the Water Quality Standard (WQS), parameters like DO, pH, turbidity, BOD, COD and ammonia-N are categorized under class II. Comparison with eutrophic status related to chlorophyll-a concentration, indicated that the lake appears to be on mesotrophic condition. In general, water quality indicators varied temporally and spatially in waters of Tirana Lake.

Keywords: Water quality parameters**,** nutrients, WQI, Tirana lake**.**

1. Introduction

The availability of water both in terms of quality and quantity is essential for the very existence of mankind. Water, though indispensable and plays a vital role in our lives, yet is one of the most badly abused resources. Lack of awareness and civic sense, use of inefficient methods and technology, lead to more than 50% of water wastage in the domestic, agriculture & industrial sectors. There is heavy extraction of water for domestic, industrial and agricultural purpose. The release of domestic waste water, agricultural runoff water & industrial effluents promote excessive growth of algae in water bodies, which results in their eutrophication [1].

Accurate information on the condition and trends of water resources quantity and quality is required as a basis for economic and social development, and for the development and maintenance of environmental quality.

There has been increased interest and work over the past few years on the use of indicators to monitor change. Water quality index is one of the most effective tools to communicate information on the quality of water to the concerned citizens and policy makers. It, thus, becomes an important parameter for the assessment and management of surface water.

The ecosystem and quality of lakes throughout the world are of primary concern in water quality management. Lakes are distinguished from wetlands by their size, area of open water and their generally greater depths. As with wetlands, they can be natural or artificial. Natural lakes are formed by geological and/or hydrological processes while artificial storages are mainly built in stream in a location where the surrounding geology lends itself to a dam wall and with sufficient upstream catchments to capture run-off [2]. Lakes, whether natural or artificial, provide habitat for plants and animals, act as drought refuges and maintain biodiversity and ecological processes. Lakes serve as a source of water for municipal, agricultural, and industrial purposes [3]. In addition, they are used for water quality control and fisheries management. Therefore, the lake water quality has been intensively studied under different hydrological

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and hydraulic conditions. Recreation, fishing, and water supply for municipal, agricultural, and industrial uses are all intimately related to the quality of these water bodies. The distinguishing physical features of lakes include relatively low flow-through velocities and development of significant vertical gradients in temperature and other water quality variables. Lakes therefore often become sinks for nutrients, toxicants, and other substances in incoming streams [4]. To maintain the ecologic balance in artificial lakes, great care must be taken both in excavation and in filling. Water quality degradation in these manmade lakes increases over time, often accelerating as projects are built. The lakes gradually accumulate pollutants and sediments and can become grossly polluted if not properly designed and maintained. Artificial Lakes should be deep enough to ensure that rooted aquatics such as cattails do not take over. Also, artificial Lakes should be shallow enough to permit the maintenance of acceptable water quality through wind turnover. At relatively great depths, wind turnover is unlikely to prevent an accumulation of polluting substances in the deeper water at the bottom [5]. They should also be wide enough to ensure maintenance of water quality through wind turnover (a several-foot-deep lake should have dimensions of more than 500 feet to provide for turnover). Artificial Lakes provide recreation, attract tourism, promote aquaculture and fisheries, and can enhance environmental conditions. Thus, dams and reservoirs have become an integral part of the engineered infrastructure, of the man-made basis of survival. Still more dams will be needed in the future for the adequate management of the world's limited, unevenly distributed and in many places acutely scarce water resources [6]. The artificial lake of Tirana is a well known fishing and also, swimming area. The lake was built from local waters in 1955 on volunteer work, in a 400 m long dam that holds the waters from overflowing onto Tirana. Situated in the south part of Tirana city, it covers an area of 0.55 km^2, with a depth of 4.5 m, [7,8]. Regarding its environmental situation, pollution in Tirana Lake appears to be high due to sewage and inert discharges on it, which has led to water depletion and its degradation. Significantly, this is the point where knowledge on water quality can provide important information on the level of disposed contaminants and the degree of its environmental deterioration.

The objective of the present research is to provide information on the physico-chemical characteristics of Tirana lake water based on computed water quality index values.

2. Materials and Methods

In the present study, the water quality of six selected sampling points of Tirana Lake, covering the entire area, was evaluated. In order to assess annual variations, sampling expeditions were conducted in four different seasons, during the period September 2011- December 2014. The main characteristics and the concentrations of major pollutants were measured in order to assess the actual environmental quality and the contribution of domestic and industrial pollutants to the overall environmental burden. All samples were collected at about 10 cm from the surface of the water lake using a horizontal PVC sample collector, placed in 1L acid-washed polyethylene bottles and stored at 4^oC prior to analyses.

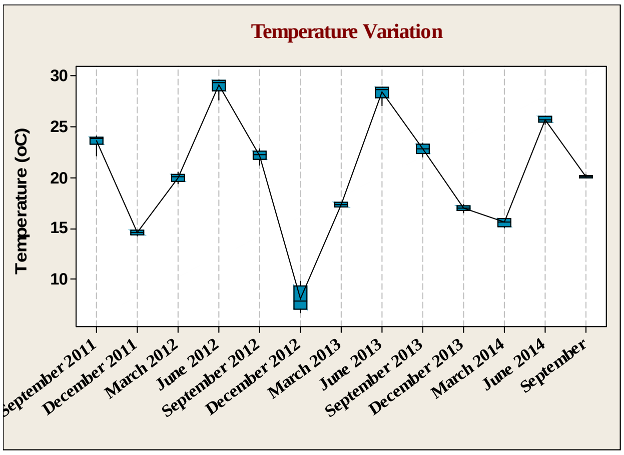
Measured parameters included dissolved Oxygen, COD, BOD_5, ammonia nitrogen, nitrite and nitrate nitrogen, phosphate phosphorus, heavy metals, pH, temperature, conductivity and redox potential. Water physic-chemical parameters were measured in situ, using a Multi meter model 340i/SET water checker. The concentration of nitrites, nitrates, ammonia and reactive soluble phosphorus were measured using the 419-NO_2^- Colorimetric Method, 418-NO_3^--C Cadmium Reduction Method, PO_4^{3-} 424-F Ascorbic Acid method and 417-N-NH_3 -C Phenate method of the ‘‘Standard Methods for the Examination of Water and Wastewater’’ [9]. All nutrients were determined by spectrophotometry using an UV-VIS Spectrophotometer. Biochemical oxygen demand was determined using the BOD measuring device, OxiTop IS 6, after 5 days of incubation in 20^oC. The sampling stations are numbered (1-6) and are shown in Figure 1.

Figure 1. Map of sampling stations

3. Results and Discussion

3.1 pH and temperature

Temperature is an important water quality parameter and affects the solubility and availability of dissolved gases such as oxygen and carbon dioxide in the water. Temperature in this study followed the expected seasonal fluctuation for all stations and the values ranged from 6.7 – 29.6°C.



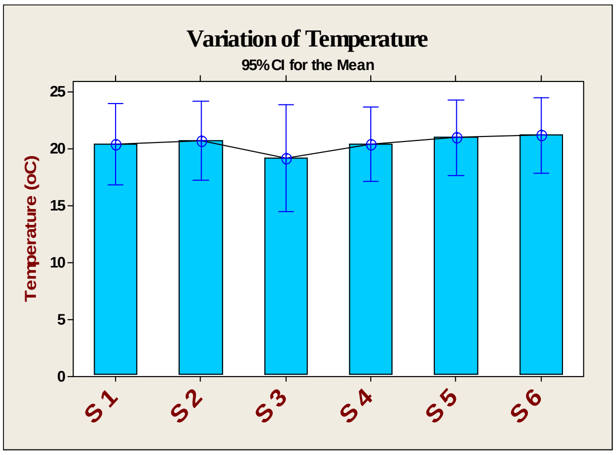
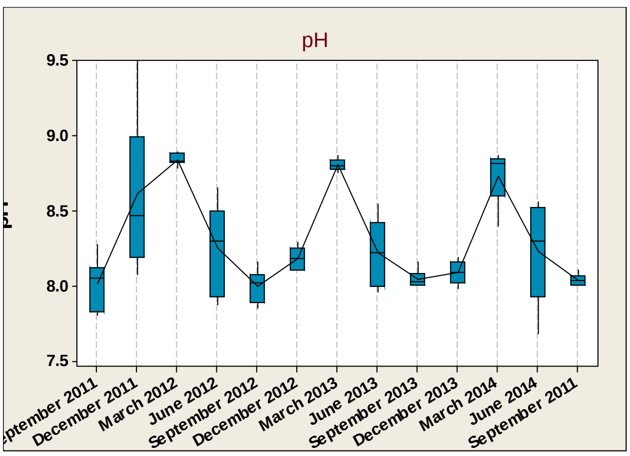


Figure 2. Temp. values for all sampling periods **Figure 3**. Temp. fluctuations in all sampling stations



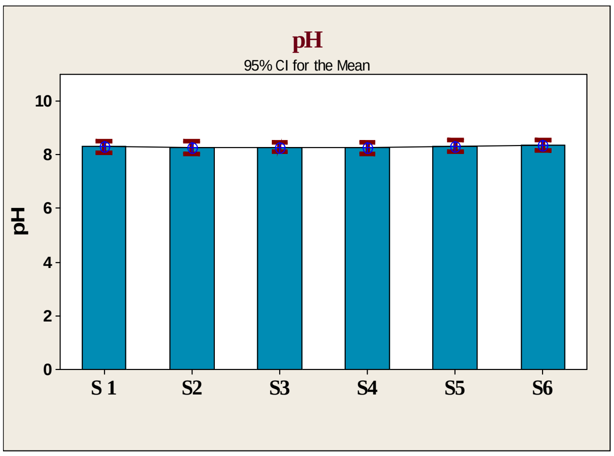


Figure 4. pH values for all sampling periods **Figure 5**. pH fluctuations in all sampling stations

Higher water temperature can reduce the dissolved oxygen concentrations in water and may thus affect the aquatic organism's life [10]. The pH of the samples varied from 7.8 – 8.9. The variations observed are not significant and the pH ranges obtained fall within the water quality range 6.5-8.5 for any purpose. The pH values also fell within the European Union standards for the support of fisheries and aquatic life (between 6 and 9), [11]. Results of our analysis are shown in Figures 4 and 5.

1) DO , COD and BOD_5

The DO levels in this study varied significantly between sampling points and seasons, ranging from 5.44-12.12 $mg.L^{-1}$. The DO levels in most stations resulted to be lower during summer and autumn, which implies that untreated sewage discharges lead to de-oxygenation of the water. These values are above the recommended limit according to EEC, 1989, for supporting life in surface waters. DO levels in water are well connected with temperature and decomposition of organic matter. High temperatures promote organic matter decomposition resulting in a decrease in DO levels.

Stations S2 and S3 are characterized by higher levels of DO, because of the highest depth found in respective stations. Station S3 is positioned near the damn of the lake, having the highest depth (about 10 m).

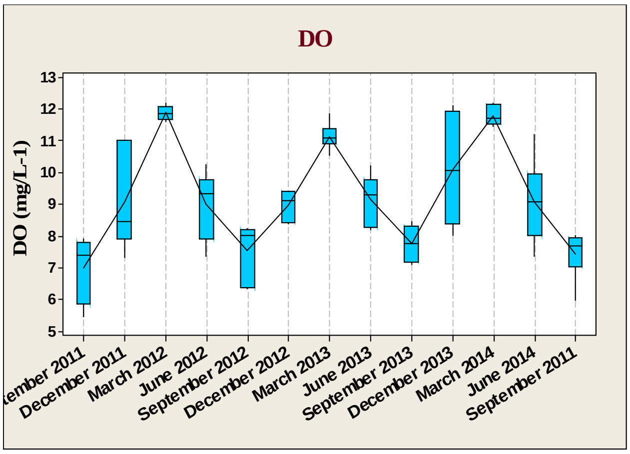


Figure 6. DO variations for all sampling periods

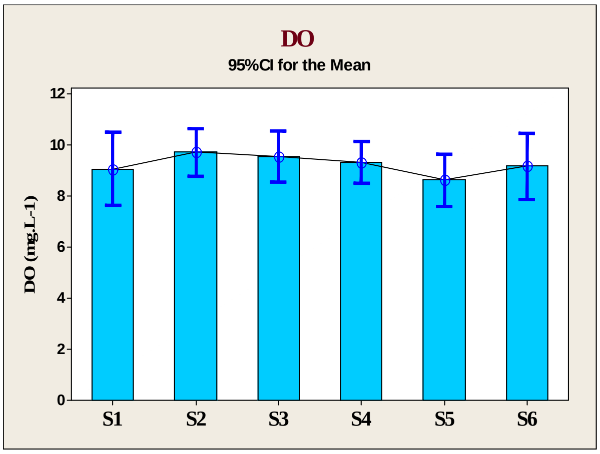


Figure 7. DO variations for all sampling stations

COD and BOD_5 levels express the content of organic matter. The drinking water quality standard for COD is 4 mg/l. This is exceeded in several stations in present study. Respective results of analysis are shown in Figures 8-11. BOD_5 values ranged from 0.1-11.1 $mg.L^{-1}$, recorded in station S1 and S5 respectively, while COD values ranged from 4.2-22.3 $mg.L^{-1}$, recorded respectively in the same stations. Station S5 suffers anthropogenic pressure because of some bars and restaurants developed near the lake shore. Higher levels of COD and BOD_5 are registered mainly during the hot months, where the temperatures are higher and the activity of chemical species present in the water is promoted.

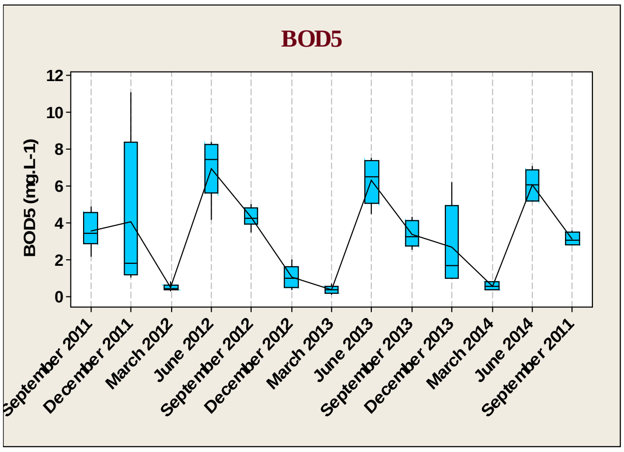


Figure 8. BOD_5 values in all sampling periods

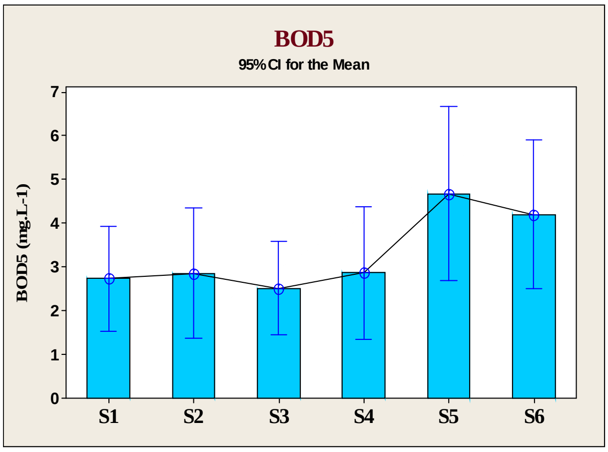
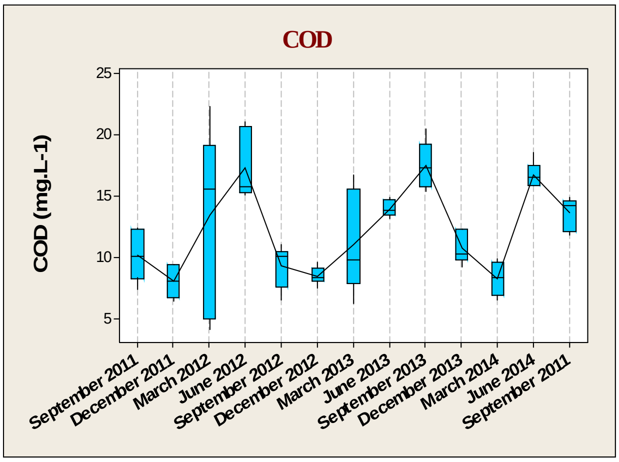


Figure 9. BOD_5 values in all sampling stations



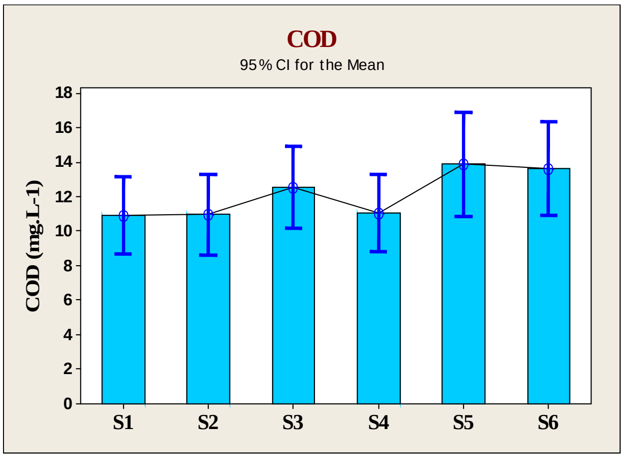
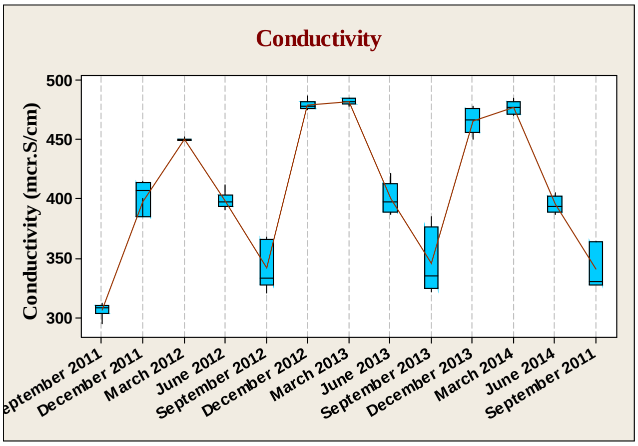


Figure 10. COD values in all sampling periods

Figure 11. COD values in all sampling stations

2) Conductivity and redox potential

The conductivity values ranged from 295 to 487 μS.cm^{-1} (Fig.12). Conductivity of water is a useful indicator of its salinity or total salt content, resulting to be higher during winter and lower during summer and autumn. The mean conductivity values of all sampling points were found to be lower than the WHO guideline values of 1000 μS.cm^{-1} for surface waters [11,12, 13]. The redox potential of water measures the availability of electrons for exchange between chemical species. The redox potential of the samples during the examination period varied between 295-580 mV which are typical values found in surface waters according to the European Union standards for the support of fisheries and aquatic life . Results are shown in Figures 12 and 13.



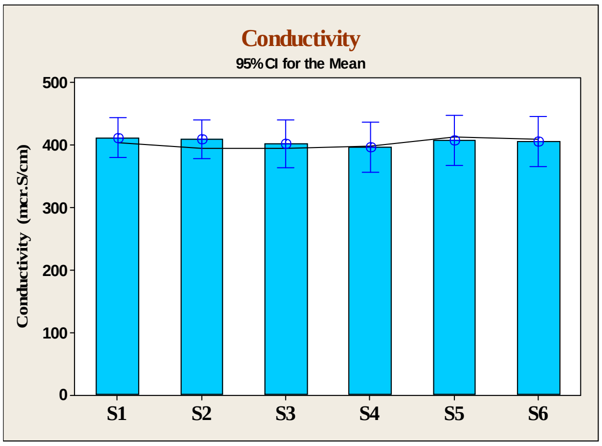


Figure 12. Conductivity values in all sampling periods

Figure 13. Conductivity values in all sampling stations

Redox potential of water samples varied from +295 to +508 mV. Lower values are registered during September 2011 as well as during June, September and December 2012. Higher values have resulted dring March (2012, 2013), September (2013, 2014).

Stations S1 and S2 are characterized by higher values. All measured values of Eh in waters of Tirana Lake are tipical for surface waters, falling within the recomanded values of the EU standard (300-600 mV).

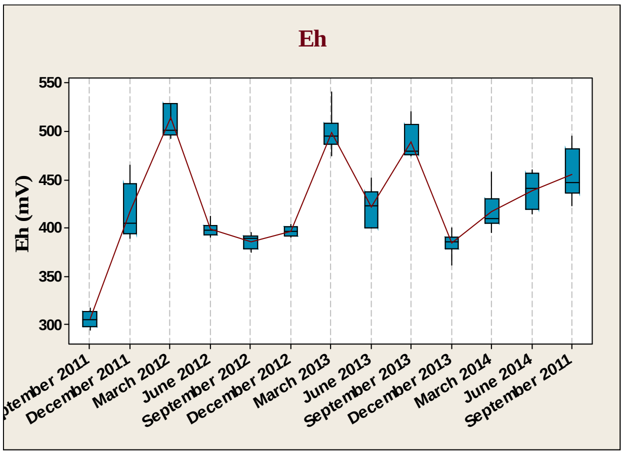


Figure 14. Eh values for all sampling periods

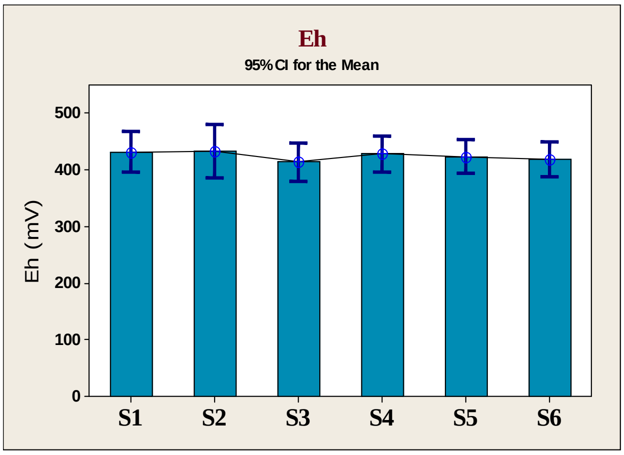


Figure 15. Eh fluctuations in all sampling stations

3) TDS and TSS

TS comprises the total solids present in the whole sample which is analyzed directly without filtration, while TDS represent the total sum of cations and anions being present in solution. Total solids varied between 218 mg.L^{-1} in station S6 and 394 mg^{-1}, recorded in station S4. Higher values of TS were recorded mainly during December 2011, 2013 and March 2014. Due to heavy precipitation, during wet months in water of Tirana Lake discharge all the waters from the hills around it, bringing high quantities of solid matter.

The same situation is evident for TDS as well, while wet months are characterized by higher values of dissolved solids. The values fell within acceptable limits (< 1000 mg/l TDS) for surface waters by the EEC standards [13]. The EPA recommends a maximal concentration of 500 mg/l TDS whereas the average levels of TDS in waters intended for domestic use is approximately 300 mg/l.

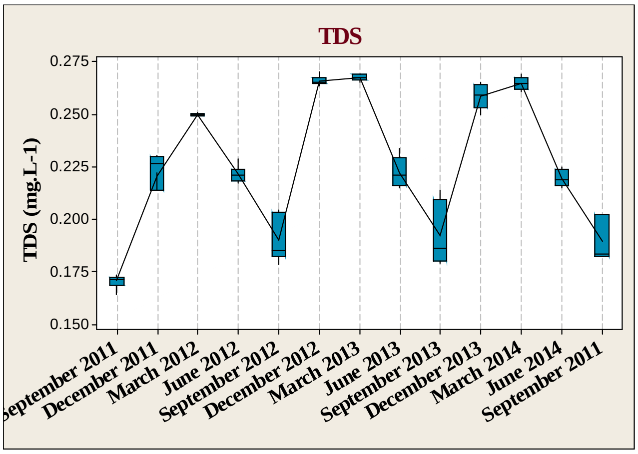


Figure 16. TDS values for all sampling periods

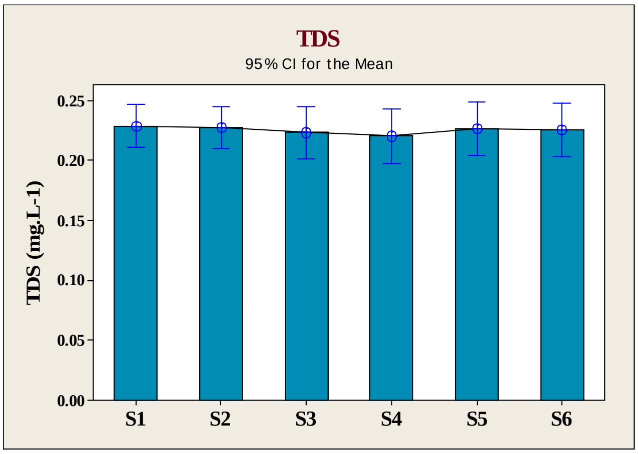


Figure 17. TDS variation in all sampling stations

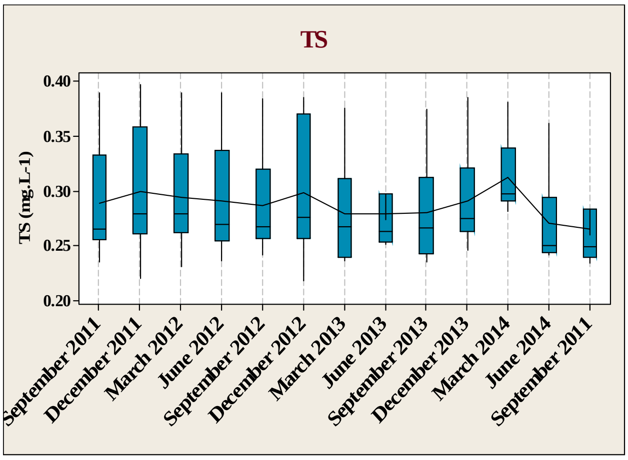


Figure 18. TS values for all sampling periods

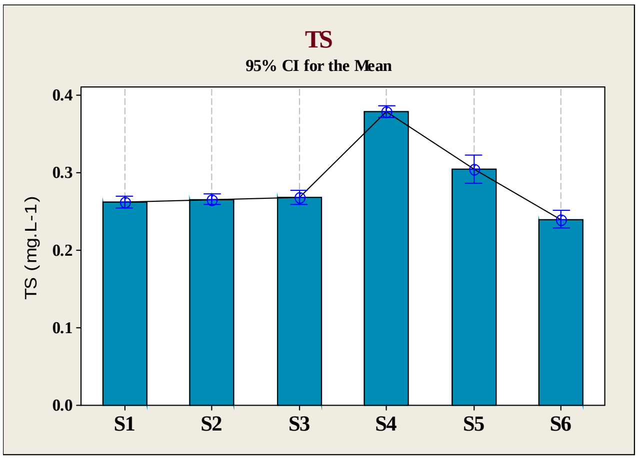


Figure 19. TS variation in all sampling stations

4) Nutrients (N, P)

Of particular interest in defining the eutrophication status of natural waters are the concentration levels of nutrients, nitrogen and phosphorus. The generally accepted upper concentration limits for waters free of algae is 0.3 mg/l of ammonia plus nitrate nitrogen and 0.02 mg/l of orthophosphate at the time of the spring overturn [14].

The presence of nitrites in water is an indicator of sewage pollution of waters. Levels of nitrites found in some sampling stations were higher compared to the EU standard, (EEC, [78/659/EEC] safety limit of salmonid waters 0.003 $mg.L^{-1}$. Nitrites in water of Tirana Lake varied from >0.005 $mg.L^{-1}$ (KD of the method), [9], to the maximum value 0.12 $mg.L^{-1}$.

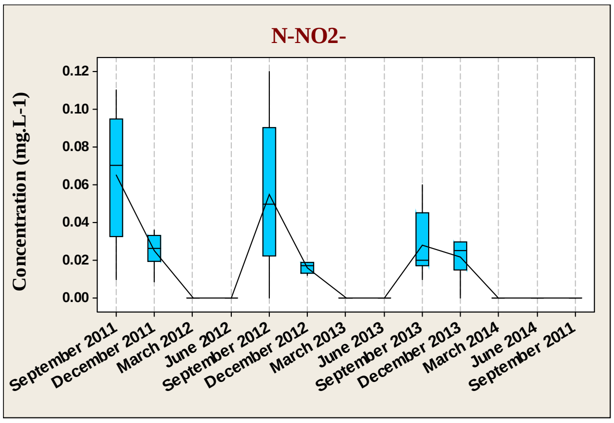


Figure 20. Nitrites values in all sampling periods

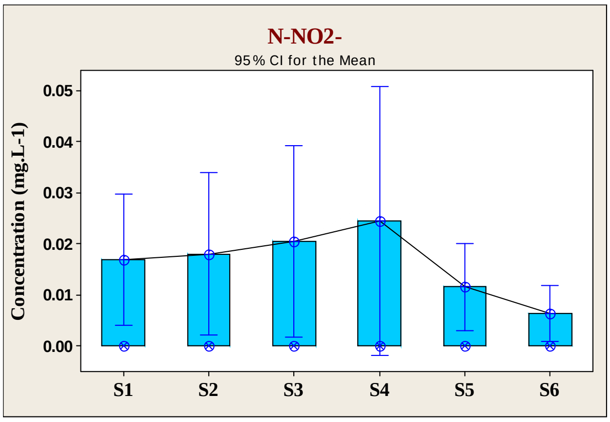


Figure 21. Nitrites values in all sampling stations

From the obtained results it be-comes obvious that in six sampling points, during winter (December, 2011, 2012, 2013) levels nitrates were found to exceed the EC guide values for high quality fresh water (<0.01 mg/l for Salmonid waters and <0.03 mg/l for Cyprinid waters). Although nitrates did not exceed the EU guideline value of 25 mg/l for surface water. Higher values were found in stations S1 and S5, which are known to suffer human activities.

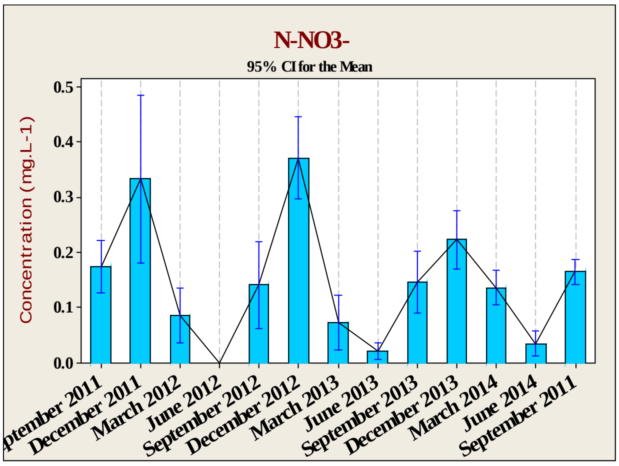


Figure 22. Nitrates values in all sampling periods

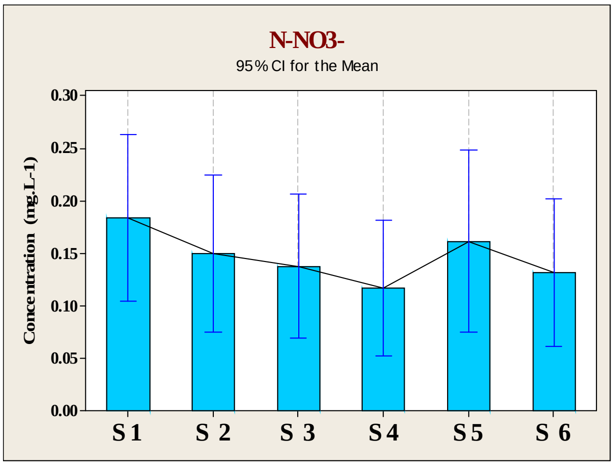
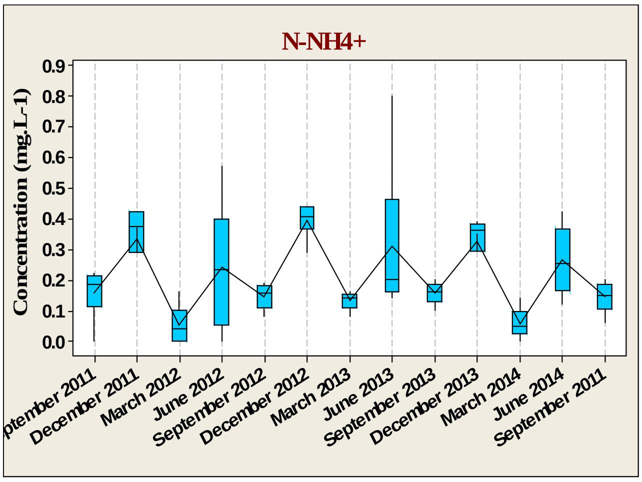


Figure 23. Nitrates values in all sampling stations

Values of ammonia in waters of Tirana Lake varied from >0.01-0.57 $mg.L^{-1}$. Moreover, ammonia values were in high levels and exceed the ammonium limit of 0.16 mg/l $N\text{-}NH_4^+$ of ECC Directive for cyprinid waters, except for results obtained in spring (Figures 24, 25) . Higher values are recorded in stations S1 and S6 while station S4 is characterized by lower values of the parameter.



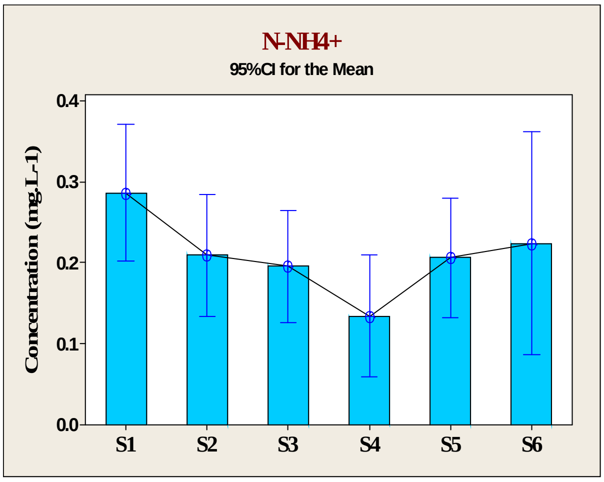
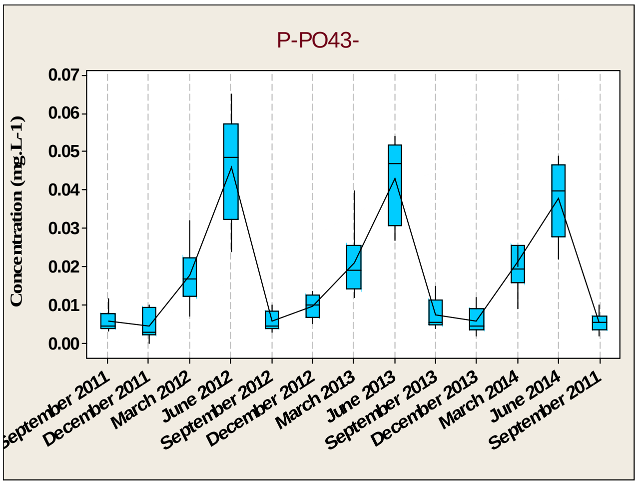


Figure 24. N-NH_4^+ values in all sampling periods

Figure 25. N-NH_4^+ values in all sampling stations

The fluctuations of the total soluble P were lower than the limit of 65.3 µg/l P-PO_4^{3-} of the ECC Directive for salmonid waters [12]. All respective results are shown in Figures 24-25.Higher values are recorded mainly during June (2012, 2013, 2014) while the lowest levels are measured during months September and December, in all years of monitoring. Levels of phosphates varied in a wide range within each station, being higher mainly in station S3.



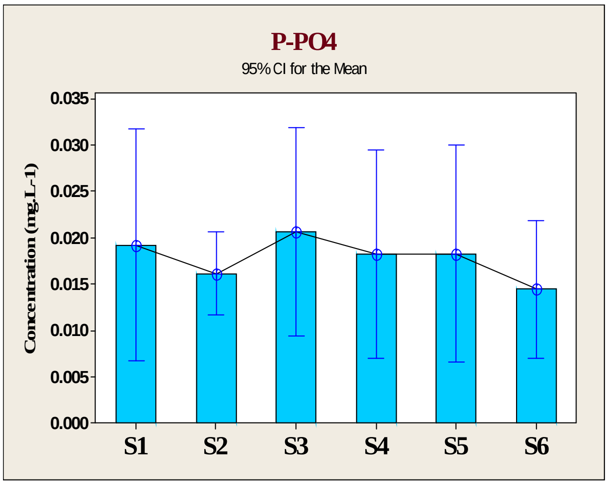
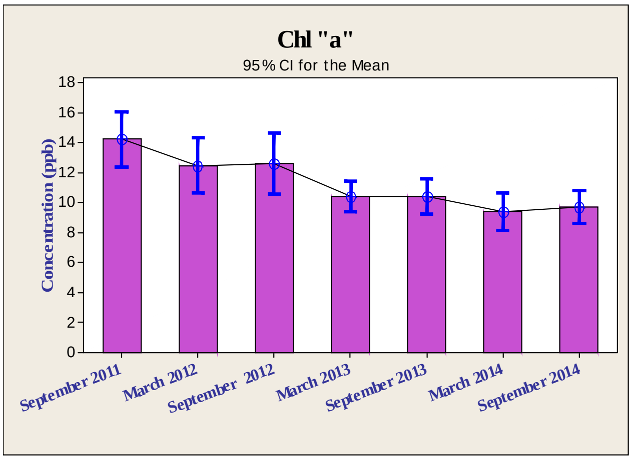


Figure 26. Phosphates values in all sampling periods

Figure 27. Phosphates values in all sampling stations



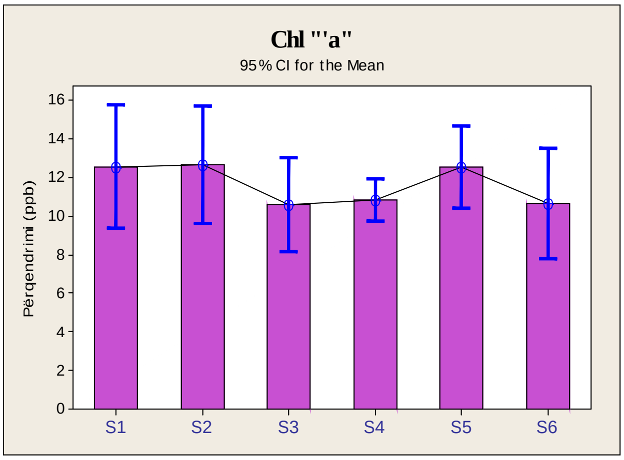


Figure 28. Chl a values in all sampling periods

Figure 29. Chl a values in all sampling stations

Chlorophyll is perhaps the single most important parameter in the assessment of the water quality of lakes, particularly in regard to their trophic quality (i.e. whether or not, or to what degree, they are enriched due to the presence of nutrients such as phosphorus and - to a much lesser extent - nitrogen in the form of nitrate}. Excessive nutrient presence in lakes promotes the growth of algae which in overabundance cause serious environmental problems.

Chlorophyll levels in water of Tirana lake varied between 9-16 $\mu g.L^{-1}$. Concentration of Chl'a" decreased during the years of monitoring, while station S1, S2 and S5 are characterized by higher values. According to classification of the trophic state of waters [12, 15], Chl "a" for mesotrophic state is 8-25 $\mu g.L^{-1}$), Tirana lake can be considered in a mesotrophic condition.

Water Quality Index, WQI, of Tirana Lake

The water quality index is a single number that expresses the quality of water by integrating the water quality variables. Its purpose is to provide a simple and concise method for expressing the water quality for different usage. The present work deals with the monitoring of variation of seasonal and spatial water quality index in water of Tirana Lake. The index improves the comprehension of general water quality issues, communicates water quality status and illustrates the need for and the effectiveness of protective practices. It is found that in all cases the change in WQI value follow a similar trend throughout the study period. However, it is found that water quality of lake deteriorates slightly from winter to summer season on account of the increase in microbial activity as well as increase in pollutants concentration due to water evaporation.

In the table below, the calculation of WQI in waters of the lake during September 2011 is presented.

Calculation of WQI:

The Water Quality Index (WQI) was calculated using the Weighted Arithmetic Index method. The quality rating scale for each parameter qi was calculated by using this expression:

Quality rating, Qi = 100 [(Vn -Vi) / (Vs -Vi)]

Where, *Vn*: actual amount of nth parameter

Vi: the ideal value of this parameter

Vi = 0, except for pH and D.O. Vi = 7.0 for pH; Vi = 14.6

mg/L for D.O.

Vs: recommended WHO standard of corresponding parameter

Relative weight (*Wi*) was calculated by a value inversely proportional to the recommended standard (*Si*) of the corresponding parameter:

Wi = 1/ *Si*

Water Quality Index (WQI) =Σ(Qi)Wi /ΣWi (WQI)

In the table below, the calculation of WQI in waters of the lake during September 2011 is presented.

Table 1. The calculation of WQI for September 2011

Parametri	Njësia	(V_{eksp})	(V_{rek})	Wi	Qi	WiQi
DO	mg/L	6.98	8	0.125	87.23	10.90
Ph	njësi pH	8.01	8.5	0.118	94.25	11.09
Eh	V	0.310	0.450	0.002	68.89	151.19
Temp	^oC	23.62	25	0.040	94.47	3.78
$N-NH_4^+$	ppb	158.00	160	0.006	98.75	0.62
$N-NO_2^-$	ppb	65.00	15	0.067	433.33	28.89
$N-NO_3^-$	mg/L	0.18	11.3	0.088	1.55	0.14
$P-PO_4^{3-}$	ppb	6.00	100	0.010	6.00	0.06
COD	mg/L	10.13	5	0.200	202.67	40.53
BOD	mg/L	3.60	5	0.200	72.00	14.40
Cond	S/cm	306.67	1000	0.001	30.67	0.03
LNT	mg/L	170.00	500	0.002	34.00	0.07
LNP	mg/L	288.00	500	0.002	57.60	0.12
				ΣWi = 3.08	ΣWiQi = 261.81	
					WQI =84.97	

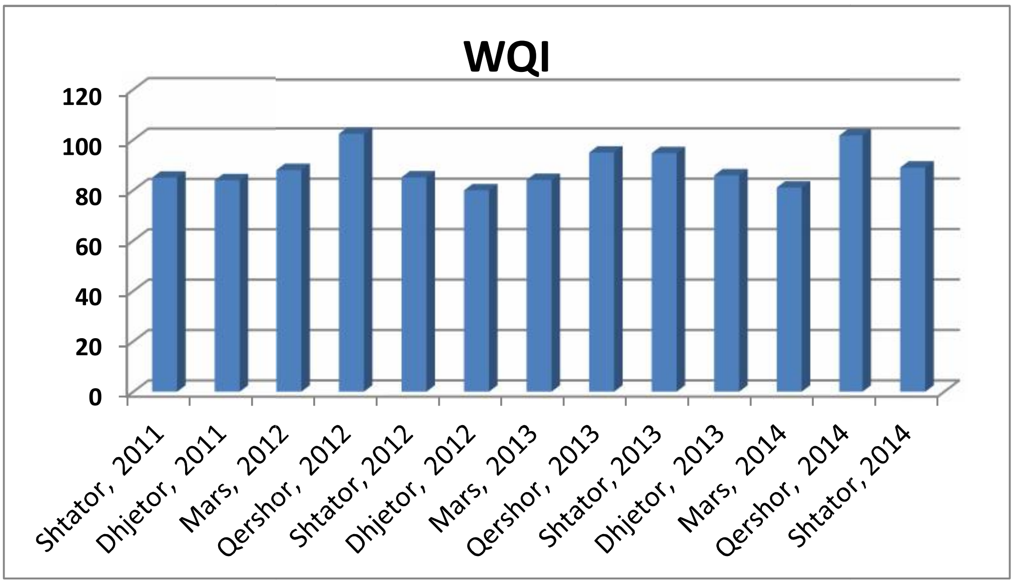


Figura 30. WQI variation in different months

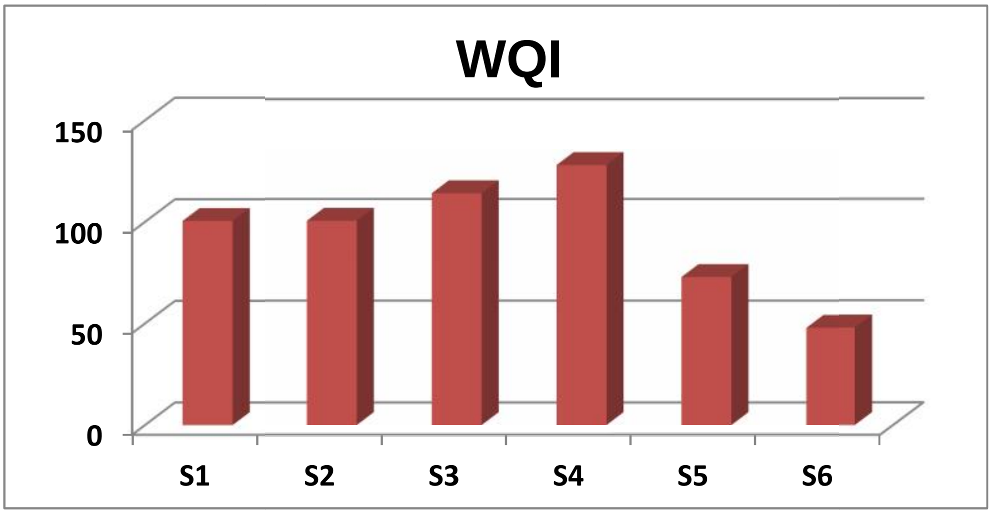


Figura 31. Variation of WQI in each station

Table 2. Water quality classification based on WQI value.

WATER QUALITY CLASSIFICATION BASED ON WQI VALUE

WQI Value	Water Quality
<50	Excellent
50-100	***Good water***
100-200	Poor water
200-300	Very poor water
>300	Water unsuitable for drinking

4. Conclusions

At the outset, the study clearly indicates that the lake water can be used for public consumption without any treatment. From the WQI values obtained during the study, there seems to be no significance change in water quality from upstream location to downstream location, which in turn, reveals that lake water is of good quality (WQI – 50 to 100). Further, the seasonal values of WQI indicate that during summer season, lake water is more affected than during winter. This could be due to the fact that the microbial activity get reduced due to low temperature, thereby keeping DO level at a very satisfactory range during entire winter season. Also during summer, the water quality deteriorated on account of the increase in microbial activity as well as increase in pollutants concentration due water evaporation.

Application of Water Quality Index (WQI) in this study has been found useful in assessing the overall quality of water and to get ride of judgment on quality of the water. This method appears to be more systematic and gives comparative evaluation of the water quality of sampling stations. It is also helpful for public to understand the quality of water as well as being a useful tool in many ways in the field of water quality management.

5. References

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