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Water Quality Assessment of Different Land Uses of Tugbo Watershed Forest Reserve and Downstream River

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Abstract

Changes in land use and management practices have been highlighted as one of the main driving forces behind risks to the quality of the water in the Tugbo watershed and downstream river in Masbate Island, Philippines. The purpose of the study is to evaluate and analyze pertinent data regarding the impact of various land uses on the tributary physicochemical properties of the river both on- and off-site using data from water quality monitoring and the DENR Administrative Order (DAO) No. 2016-08 classification guidelines for water quality. Six (6) types of land cover predominate in the watershed: pastureland, agroforestry farms, old-growth forests, coconut-based areas, built-up/quarry sites, and built-up/estuaries were identified. Significant differences at 0.05 level were observed based on Analysis of Variance (ANOVA) and post-hoc test results across different land uses are significantly different from each other between the inside and outside the watershed. The data show that pH and nitrate are significantly different water quality outcomes in comparison to the LULC of the test site, regardless of the land cover or land use adjoining the water system. Other than two land-uses differences, the temperature and dissolved oxygen do not differ greatly from one another. Analyses of the water quality were within the norm, and a positive correlation was found between several indicators and various land uses. The outcome is generally highly beneficial for developing and implementing watershed strategies to protect land and water resources and improve the overall state of the continuum.

Keywords: Land uses, Physicochemical properties, Sampling, Tugbo watershed, Water quality

Introduction

Global attention has been drawn to research on the connections between changing land use and cover and water quality which has significantly impacted environmental changes (Obubu et al, 2022). Vital resources like drinking water, irrigation water, fisheries-derived protein, and services like navigation, energy, tourism-based recreation, climate regulation, and flood control are all provided by lakes, rivers, and reservoirs (Bonansea et al 2021; Du Plessis et al. 2014). The main sources of nutrients and sediments entering rivers, lakes, and wetlands are caused by anthropogenic activity in the watersheds and atmospheric deposition (Fuentealba et al 2020). The loss of agricultural land, biodiversity, water, and soil quality, as well as global warming and deforestation, (Zhang et al 2021; Hassan et al. 2016) which affect rivers' hydrological processes and surface runoff, are all directly correlated with land degradation and fragmentation (Fernandes, et al 2020; Berihun et al 2019).

Land use and land cover (LULC) are important factors that have a direct impact on water quality and the ecosystem of river waters (Brontowiyono et al. 2022). The industrial, agricultural, and public health sectors all place an increasing emphasis on water quality (Shi et al. 2017).

However, the deterioration of water quality is a global issue that is mostly brought on by human activity (Zhang et al. 2021). Population growth, intensifying agriculture, growing industries, and rapid urbanization have all had a significant negative impact on the quantity and quality of water sources (Zhang et al. 2020). It has been discovered that the dense tropical forest aids in enhancing the watershed level's physicochemical quality (Aweng et al. 2021). These timberlands offer essential ecosystem services for the control and purification of water supplies in addition to other services (Chishugi et al. 2021). Aditya & William (2011) argue that the degradation of primary forest cover into other LULC types poses a threat to the long-term viability of watersheds as systems for controlling water quality. It is important to ascertain which characteristics of the river ecosystem are more essential for maintaining their functions than others.

Masbate is an island province in the Philippines, about in the center of the archipelago, between 11°43' north and 123°09' east and 124°5' east latitudes. The province was ranked 9th by the Forest Management Bureau (2010) with 6,678 hectares or 1.17 percent of its total land area with the least forest cover. Tugbo Watershed Forest Reserve (TWFR) was declared by Presidential Proclamation No. 369 on May 2, 1994, with a total area of 244.1299 and a length of 19.973 kilometers (DENR-CENRO Mobo Revised Briefer 2019). It is primarily timberland, with natural forests accounting for more than 50% (NAMRIA, 2015), while the remaining areas were converted into agricultural and rangeland areas. No comprehensive land-use study within the watershed's tributaries has been conducted except for the ongoing off-site water quality monitoring in the Tugbo River DENR-Adopt a Water Body Program conducted by the Department of Environment and Natural Resources-Environmental Management Bureau (DENR-EMB V) which started in 2014 to 2018.

Improved water quality and decreased environmental deterioration within the zone can be achieved by integrated watershed management methods and their conservation policies, which incorporate social, economic, and ecological aspects. (Chishugi et al 2021). Thus, considering the relationship between water quality assessment and changes in land use might help inform scientific decision-making for the management of water resources in the future. In order to properly understand how the watershed was used in the past and the kinds of changes that may be discovered in this field work, baseline data is necessary. This study focused on measuring the on-site water quality in the installed sampling stations using a limited set of physico-chemical parameters, including temperature, pH, dissolved oxygen, and nitrate, across a wide range of land uses, and comparing the results to the current legal framework regarding updated government water classification standards.

Materials and Methods

Study Area

The research took place at the Tugbo Watershed Forest Reserve (N 120 18. 974' E 1230 37. 019') within the administrative boundaries of Tugbo, Mobo, Masbate, and Tugbo, Masbate City, Philippines between March to September 2019 (Figure 1). Land-use data of the watershed was secured from the Land Management Service (LMS) in Legaspi City, Philippines. The study area has a Type III climate, which is dry from November to April but wets the rest of the year. The average annual precipitation is 2,500 millimeters, with a mean ambient temperature of 28.3^0 degrees Celsius (Köppen and Geiger 2022). The Lamon Andesite formation –porphyritic andesite that occurs intrusively in the Mobo diorite and Lanang formations dominates the reservation's forest landscape. Later, the former invaded the Nabangig, Usab, and Lanang formations (Manalo et al. 2015). According to Mitchell and Balce's epithermal gold prospective studies (1990), streambank along the tributaries contains a large gold deposit. The soil textural classes in the area ranged from clay loam to clayey soil with light to medium brown tones (Regional Soil Laboratory V 2019). The landscape varied in elevation from mildly undulating to fairly steep slopes (5^0 to 35^0). The downstream portion of the watershed has a closed canopy, while the middle and upper sections have open fragmented secondary vegetation with pioneer species.

Sampling Stations, Parameters and Water Sampling

In assessing the actual physicochemical properties of TWFR, six (6) sampling stations were installed, three (3) were located inside the watershed and outer boundary was set for the remaining stations. In order to determine the exact locations of the Tugbo Watershed and downstream river sampling sites, the GPS was used to determine the upstream, midstream, downstream stations. In order to determine the water quality, each sampling point was classified and described based on current land use. Water quality monitoring was conducted twice a month of the first quarter of 2020 at the six sampling sites from the first sampling stream down to the last station of Tugbo River. The researcher took water samples from the river based on the guidelines of a specific parameter utilized.

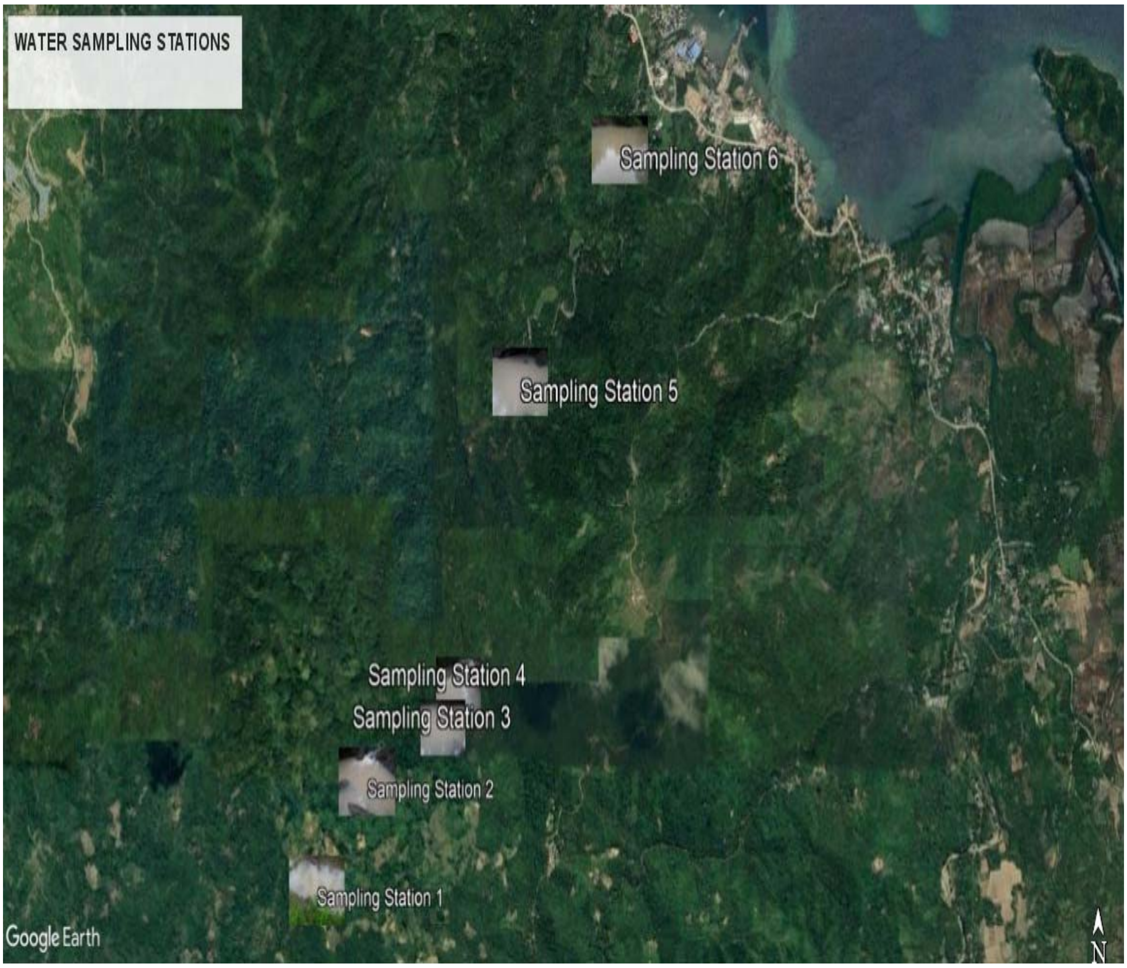

Figure 1. Sampling stations at different land uses of Tugbo Watershed Forest Reserve

Water Sampling Stations and Their Description

The HORIBA multi-parameter probe was used to measure on-site analysis of water quality parameters such as temperature and pH while HORIBA compact water quality meter for dissolved oxygen (DO) and nitrate. From January-March 2020, water sampling was conducted in the six sampling stations. Data collection was completed within 3 consecutive months with an interval of 2 weeks.

Table 1. Sampling stations in the conduct of water sampling at TWFR

Sampling Station	Location	Coordinates	Altitude
On-site			
Station 1	Upstream	12^0 18.714"N 123^0 36.809"E	238m
Station 2	Midstream	12^0 19.000"N 123^0 37.030"E	214m
Station 3	Downstream	12^0 19.145"N 123^0 37.364"E	194m
Off-site			
Station 4	Upstream	12^0 19.257"N 123^0 37. 432"E	167m
Station 5	Midstream	12^0 20.057"N 123^0 37.705"E	50m
Station 6	Downstream	12^0 19.67" N 123^0 38. 146"E	9m

The triplicates of all samples were analyzed. Afterward, all results were compared if conformed to DAO 2016-08 under specific water classification.

In this study, six (6) sampling stations were installed, three (3) were found within the watershed and the remaining stations were established on the outside boundary (Table 1). The GPS was used to install the actual positions of TWFR and downstream river sampling sites (upstream, midstream, downstream) and to reconfirm the site's location during successive sampling periods. In order to determine the water quality, each sampling point was classified and described based on current land use. The upstream was found to be a grazing area for livestock; the midstream is used for agriculture and covered with less vegetation; the downstream was covered with old-growth forest. Sampling stations outside the watershed catchment area were classified upstream as a coconut-based production area; midstream mainly used for residential /sand and gravel quarry/small-scale mining/ and; lower downstream as built-up/open piggery raising/waterways.

Table 2. Physical description of the water sampling stations

Land-use Type	Description
Pasture-agriculture area (PAA)	Marginally hilly; bare land; grazing area for domesticated animals; adjacent agricultural cultivation; planted with coconuts; colonized by weeds and perennial pioneer species
Agroforestry area (AFA)	Irregular hilly terrain; shrubland reopened for annual crop production; patches of native forest vegetation aligned along the streambank
Old-growth forest (OGF)	Steeply rolling gradient; no clearings on both sides; cogonal upper portion (70 m from the transition forested area); intact original floral vegetation
Coconut-agriculture area (CAA)	Slightly inclined area; predominantly an agriculture area; coconut plantation with undergrowth ranging from small to medium-sized trees.

Land-use Type	Description
Built-up area/ quarry/small-scale mining area (BQMA)	Slanting topography; eroded streambank; settlement area; sand and gravel excavation zone; mining spot along the riverbank; animal pool; mixed vegetation of native and exotic species
Built up zone/ estuary/ transport route animal domestication (BETDA)	Undulating landscape; estuary; residential area; busy transport zone; open hog raising; grasses and selected fruit trees and forest species.

The water quality indicators were compared and analyzed at the upstream and downstream sites and between the on-site and off-site stations. In order to assess if they were within the recommended acceptable limits based on the DENR administrative order 2016- 08, physicochemical findings were compared with various water quality requirements for freshwater.

Data Analysis

Kolmogorov-Smirnov and Shapiro-Wilk normality tests were used in comparing the different water quality parameters among the existing land uses and elevation within and outside the watershed area. Different sampling station's land-uses such as pasture and open agriculture area; agroforestry area and old-growth forest found inside the watershed; while coconut-based area; built-up area/ quarry/small scale mining area and built-up zone/ estuary/transport route/open hog raising area situated outside the watershed were characterized. To assess substantial variations across the sites for the study variables, one- way analysis of variance (ANOVA) and post-hoc Tukey's test were used. Variance Analysis (ANOVA) and post-hoc analysis (Tukey's HSD) was used to assess the significant difference between sites.

Further, the water quality indicators were compared and analyzed at the upstream midstream and downstream sites and between the on-site and off-site stations. In order to assess if they were within the recommended acceptable limits based on the DENR administrative order 2016- 08, physico-chemical findings were compared with various water quality requirements for freshwater (Table 3).

Table 3. Standard recommendations on water quality key parameters

Parameter	Unit	Level		
		Class A	Class B	Class C
Temperature	^{0}C	26-30	26-30	26-30
pH		6.5-8.5	6.5-8.5	6.5-8.5
Dissolved Oxygen	mg/L	5	5	5
Nitrates	mg/L	7	7	7

Results and Discussion

Physicochemical Analyses

*Temperature***.** The average mean water temperature of the three months sampling ranged from 26.85^{0}C to 28.06^{0}C on the basis of the results obtained. The lowest average water temperature recorded in February 2020 was 25.580C and 25.650C, respectively within Station 3 (OGF) and Station 2 (AFA) of the watershed to Station 2 and Station 3 outside the watershed. The lowest average temperature was a maximum average temperature of 29.050C and 28.70C in March 2020, respectively confirmed in Station 3 (OGF) inside the watershed, while the highest average temperature was found in Station 2 (BQMA) outside the watershed. For the 2014-2018 DENR-EMB V Adopt a Water Body Program in the downstream Tugbo river, data ranged between 27.86^{0}C to 29.32^{0}C, and the average water temperature currently collected off-site at stations 2 and 3 was almost comparable to the output of this study. The overall findings show that the temperature inside the watershed is marginally lower than outside the continuum, which also indicates substantially higher values. Therefore, as per DENR DAO 2016-08 for class C water, the numerical value is within the norm.

Table 4. Tukey's multiple comparisons of means on temperature

Station	Diff	Lower	Upper	P-adj
B-A	-0.9133333	-3.000654355	1.1739877	0.6879017
C-A	-1.3566667	-3.443987688	0.7306544	0.3118440
D-A	-0.3600000	-2.447321021	1.7273210	0.9906152
E-A	1.0033333	-1.083987688	3.0906544	0.6050618
F-A	0.7233333	-1.363987688	2.8106544	0.8451860
C-B	-0.4433333	-2.530654355	1.6439877	0.9765580
D-B	0.5533333	-1.533987688	2.6406544	0.9417104
E-B	1.9166667	-0.170654355	4.0039877	0.0788863
F-B	1.6366667	-0.450654355	3.7239877	0.1620249
D-C	0.9966667	-1.090654355	3.0839877	0.6112313
E-C	2.3600000	0.272678979	4.4473210	0.0238637*
F-C	2.0800000	-0.007321021	4.1673210	0.0509960
E-D	-1.3633333	-0.723987688	3.4506544	0.3073512
F-D	-1.0833333	-1.003987688	3.1706544	0.5316680
F-E	-0.2800000	-2.367321021	1.8073210	0.9970510

Note: Pairs of means with * are significantly different at 0.05

ANOVA result and post-hoc test at 0.05 level of water temperature across different land uses are not significantly different from each other except pair of means in Stations 5 and 3. Intact forest presence plays a major role in water quality control within a watershed (Duxbury et al. 2012). If water is cold, it holds more oxygen which supports more aquatic organisms as claimed by Touchart et al. (2012). On the other hand, the smaller number of trees around the water associated with an open area directly exposed to sunlight and the various destructive human-led activities increase the degradation of the point source and non-point source of water (Labajo, 2014; Juahir et al., 2011).

pH. For aquatic life, pH is a significant limiting chemical factor. With the exception of Station 3 (OGF) situated inside the watershed boundary with the slightly acidic pH value of 5.55, the collection time was below the minimum quality level of DENR. The mean pH of all sampling sites is between 6.45 and 7.58 Mg/L, which is within the tolerable range of 6.5-9.0 Mg/L. A descending pattern within the watershed was shown by pH data from upstream to downstream, while an ascending pattern was observed separating the boundary by TWFR based on the monthly data set. All sampling sites are considered to be neutral and fall within the optimum pH range for fish to thrive, except for the OGF zone. However, according to the forest guards who are regularly crossing the area, living organisms such as fishes and mollusks are thriving in the river zone. This was confirmed by Baker et al (1990) that some may live beyond the pH range. Overall, a healthy pH level of all stations follows the DENR DAO 2016-08 national quality standard for Class A and C water. Significant differences observed based from ANOVA resulted in post-hoc test results on pH across different land-uses that are mostly significantly different from each other. Important differences (p < 0.05) between six stations suggest that there were differences between the inside and outside watershed values sampled: PAA and OGF (P=0.0031396) and OGF and AFA (P=0.0274258); within and outside the watershed: BETO and PAA (P=0.0458637), BQMA and AFA (P=0.0110208), BETO and AFA (P=0.0051568), BQMA and OGF (P=0.0000448) and BETO and OGF (P=0.0000254) and; outside the watershed: BQMA and CAA (P=0.0048168) and BETO and CAA (P=0.0023008).

Table 5. Tukey's multiple comparisons of means on pH

ation	Diff	Lower	Upper	P-adj
-A	-0.3133333	-1.12095029	0.49428363	0.7782757
-A	-1.2066667	-2.01428363	-0.39904971	0.0031396*
-A	-0.4333333	-1.24095029	0.37428363	0.4988651
A	0.7100000	-0.09761696	1.51761696	0.0977500
A	0.8200000	0.01238304	1.62761696	0.0458637*
-B	-0.8933333	-1.70095029	-0.08571637	0.0274258*
-B	-0.1200000	-0.92761696	0.68761696	0.9952504
B	1.0233333	0.21571637	1.83095029	0.0110208
B	1.1333333	0.32571637	1.94095029	0.0051568*
-C	0.7733333	-0.03428363	1.58095029	0.0634256
C	1.9166667	1.10904971	2.72428363	0.0000448*
C	2.0266667	1.21904971	2.83428363	0.0000254*
D	1.1433333	0.33571637	1.95095029	0.0048168*
D	.2533333	0.44571637	2.06095029	0.0023008*
E	0.1100000	-0.69761696	0.91761696	0.9968326

Note: Pairs of means with * are significantly different at 0.05

The extent of variation between OGF, BQMA and BETO highlighted based from ANOVA results at <0.005 level of significance. The slightly acidic OGF water is due to the plant residues and logs found on the bank of the river (Labajo, 2014). Organic acids are produced when these logs decompose, resulting in water pH decreasing. While the pH value of human-led activities within the tolerable range of 7.47 to 7.58 Mg/L is opposed in the Egereonu & Emezium (2006) investigation on the physicochemical analysis of selected groundwater in River State, Nigeria. In their results, residues from bathing, washing, latrines brought organic material along the water bodies and decomposed by microorganisms decreasing the pH content. Yet, the results of Milisa et al (2010) backed this research, pH increased significantly with 7.94-8.13 Mg/L and Abroampah et al. (2015) with a mean value induced by downstream quarry between 8.9-9.9 Mg/L. Low pH values reported in Duncan (2020) findings, however, showed a mean pH range of 5.3-6.38 Mg/L measured in all mining sites in a river in Ghana.

Dissolved Oxygen. Dissolved oxygen (DO) is the oxygen content in the water that is dissolved. Its presence in water is important for sustaining a variety of biological life forms and the impact of waste discharge in a water body is largely determined by the system's oxygen balance (Saksena, 2008). Water temperatures usually have an inverse association with dissolved oxygen, according to Chu et al. (2013); dissolved oxygen decreases as temperatures rise. The dissolved oxygen pattern across the watershed indicates that, with an average of 8.62mg/L, Station 6 (BETDA) has the lowest at an average of 5.78mg/L and Station 3 (OGF) with the highest DO with an average of 8.62mg/L. Additional organic matter sources downstream off-site are anthropogenic water contaminants from local human settlements and farm runoff (Samantray et al., 2009). The low DO level reported in March (4.52Mg/L) was below the normal level as mainly affected by the bulky discharge of sewage polluting the water body, the more oxygen consumed to decompose these materials the DO content in the water decreases so low (Ling et al., 2012; Labajo-Villantes, 2014). The average value of dissolved oxygen at all watershed sites is 5 mg/L above the Class A and C DENR DAO 2016-08 water quality levels. Therefore, a good measure for the survival of aquatic life indicates the overall result of DO in the watershed.

Table 6. Tukey's multiple comparisons of means on dissolved oxygen

Station	Diff	Lower	Upper	P-adj
B-A	1.4866667	-1.06918871	4.0425220	0.4185575
C-A	2.4833333	-0.07252205	5.0391887	0.0586290
D-A	2.0133333	-0.54252205	4.5691887	0.1590042
E-A	0.8300000	-1.72585538	3.3858554	0.8759810
F-A	-0.3566667	-2.91252205	2.1991887	0.9964519
C-B	0.9966667	-1.55918871	3.5525220	0.7748438
D-B	0.5266667	-2.02918871	3.0825220	0.9794141
E-B	-0.6566667	-3.21252205	1.8991887	0.9484943
F-B	-1.8433333	-4.39918871	0.7125220	0.2225664
D-C	-0.4700000	-3.02585538	2.0858554	0.9874963
E-C	-1.6533333	-4.20918871	0.9025220	0.3162135
F-C	-2.8400000	-5.39585538	0.2841446	0.0266523*
E-D	-1.1833333	-3.73918871	1.3725220	0.6392237
F-D	-2.3700000	-4.92585538	0.1858554	0.0750422
F-E	-1.1866667	-3.74252205	1.3691887	0.6367085

Note: Pairs of means with * are significantly different at 0.05

The vertical distribution of pH values in TWFR differed between various land-uses although only Stations 6 and 3 were significantly different from each other and the rest were not significantly different (p-value > 0.05). Due to the cold temperature that retains more oxygen, high levels of DO were observed in forested areas (Touchart et al., 2012) therefore, DO is greater at high altitudes than at low altitudes as suggested by Effendi et al. (2017). The low DO in the downstream station which is closest to human habitation was responsible for other different controlling factors, such as increasing temperature, low topography and estuarine inflow (Li et al., 2020).

Nitrate. Environmental nitrates are present in soil fertilizer salts of ammonium, sodium, potassium and calcium during agricultural runoff, wastewater treatment, enclosed agricultural area (Station 4). Domesticated animals such as hogs, carabao and horses were present in the vicinity of the river at the time of sampling. Water flows over the surface of the soil as runoff during rains and carries the untreated waste that is an essential source of nitrates (Asriningtyas and Rahayuningsih, 2012). The data further indicates that was no clear pH trend observed in the vertical distribution across different stations.

Important difference ($p < 0.05$) between the six stations is significantly different from each other between the inside and outside watershed (Table 28). Values sampled were within the watershed between OGF and AFA (P=0.0188174); within and outside the watershed between BQMA and OGF (P=0.0021775), BETO and OGF (P=0.0008591) and; outside the watershed between BQMA and CAA (P=0.0249290) and BETO and CAA (P=0.0090947). A low pH value indicates the active decomposition and nitrification process in the reservoir in Stations 3 and 4 conforms to the findings of Ling et al. (2017). Opposing to this, the use of fertilizers and animal manure in the upper part of the watershed drained (Chimwanza et al., 2006) and Stations 5 and 6 in built-up areas raises the amount of nitrates into the rivers due to domestic sewage, and soil erosion due to river bank mining (Quan and Yan, 2002; Ayebo et al., 2006).

Table 7. Tukey's multiple comparisons of means on nitrate

Station	Diff	Lower	Upper	P-adj
B-A	0.1833333	-0.8259175	1.19258415	0.9881594
C-A	-1.0000000	-2.0092508	0.00925082	0.0526435
D-A	-0.5566667	-1.5659175	0.45258415	0.4714378
E-A	0.5766667	-0.4325842	1.58591749	0.4362780
F-A	0.7566667	-0.2525842	1.76591749	0.1931143
C-B	-1.1833333	-2.1925842	-0.17408251	0.0188174*
D-B	-0.7400000	-1.7492508	0.26925082	0.2097534
E-B	0.3933333	-0.6159175	1.40258415	0.7752366
F-B	0.5733333	-0.4359175	1.58258415	0.4420465
D-C	0.4433333	-0.5659175	1.45258415	0.6846637
E-C	1.5766667	0.5674158	2.58591749	0.0021775*
F-C	1.7566667	0.7474158	2.76591749	0.0008591*
E-D	1.1333333	0.1240825	2.14258415	0.0249290*
F-D	1.3133333	0.3040825	2.32258415	0.0090947*
F-E	0.1800000	-0.8292508	1.18925082	0.9890907

Note: Pairs of means with * are significantly different at 0.05

Conclusion and Recommendation

Overall tributary river water quality analyses of Tugbo watershed and river were within the standards, however; the present findings are preliminary. A positive relationship among parameters was determined between different land uses. In addition, the quality of the water gradually reduced from upstream to downstream. The result will be utilized as the best measures to attain sustainability in the protection and conservation of the watershed. By developing and implementing watershed plans, stakeholders and communities will work together to protect the water resources and realize land use decisions, and eventually would help in improving the overall quality and health of the watershed. Continuous monitoring of physical-chemical parameters in the tributary is highly recommended to generate useful information. Water quality indicators should be included in the succeeding water quality research.

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