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# Influence of Physicochemical Parameters on the Seasonal Variation of Phytoplankton Abundance and Diversity in River Donga, Taraba State, Nigeria

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## Abstract

*A study on the influence of physicochemical parameters on the seasonal variation of phytoplankton abundance and diversity was carried out in river Donga, Taraba state, Nigeria for a period of one. Three sampling sites designated as station 1 (S1), station 2 (S2), station 3 (S3) were chosen. Water samples were taken from the three sampling site every month for the period of twelve (12) months. The samples were analyzed for physicochemical parameters and phytoplankton diversity using standard methods. Analyses of variance (ANOVA), Descriptive statistics were used to analyze the data. The study revealed that pH, electrical conductivity (EC), total alkalinity, turbidity, dissolved oxygen (DO), total hardness, nitrate and phosphate varied significantly ($P<0.05$) between the season, while temperature, total dissolved solid (TDS) and nitrite were not significant between season. A total of 69 species belonging to 28 genera representing four phytoplankton groups were identified. The bacillariophyta was represented by 36 species (52.2%), charophyta 17 species (24.6%), cyanophyta 10 species (14.5%), chlorophyta 6 species (8.6%). A total of 602cell/L phytoplankton organisms were recorded in dry season and 119cell/L was observed in wet season.The phytoplankton in terms of species number showed the following order of abundance: Bacillariophyta > Charophyta > Cyanophyta > Chlorophyta. The phytoplankton abundance and diversity was higher in dry season than wet season. The Shannon, Simpson and Evenness indices for phytoplankton composition in dry season are 0.82, 0.46 and 0.56, in wet season are 0.77, 0.40 and 0.54 respectively. The diversity index showed that the River is unstable or polluted. The phytoplankton distribution and abundance was influence by physicochemical parameters of river Donga and seasonal variation. Constant monitoring, public awareness on the importance of phytoplankton and danger of polluting the river is highly recommended.*

**Key words: Phytoplankton, Physicochemical parameter, River Donga,**

**Introduction:** Plankton are mixed group of microscopic, living plants and animals that float, drift freely or feebly swim in water (marine or fresh) column independent of the shore and bottom (Ihejirika, C.E., Orji, U.A., Okeke, P.N., Imo, E.O. and Nwachukwu, J. I., 2023). Phytoplanktons are photosynthetic microscopic organisms which inhabit and float in open surface waters of lakes, rivers, and seas (Dauda, D.M., Emere, M.C., Umar, Y. and Umar, A. M., 2021; Zakariya, A.M., Muhammad, S.A., and Murtala, M.B., 2024). Phytoplanktons are the main food producers in a balanced aquatic ecosystem, serving as food for various higher organisms in addition to their crucial role in the carbon cycle (Dauda *et al*., 2021; Zakariya *et al*., 2024). Since phytoplankton responds quickly and sensitively to environmental changes (Ayoade and Aderogba, 2020), they are regarded as bioindicators of variations in water quality (Dauda *et al*., 2021; Zakariya *et al*., 2024; Vandi, P., Garba, B., Habu, U., Bello, H. A., Kunihya, I.Z. and Gambu, J.W., 2025). Rivers provides most of earths' freshwater resources and also provides humans with many benefits for both domestic and agricultural purposes, therefore, there is need for diversity and abundance of phytoplankton, as well as the physical and chemical properties of water, which are key indicators of water quality and the effects of environmental change (Barau, B.W., Bature, A.A., Bingari, S.M., David, D.L., Danba, E.P., Hammanjoda, S.A., Azuchukwuene, C.G. and Fauziya, K.M. 2020; Bonjoru, R., Shehu, J., Kyani, Z.A., Henry, G.B., Bagauda, D.A. and Emmanuel, I.H., 2023). These parameters influence phytoplankton growth and diversity, which in turn can affect the health and productivity of the ecosystem as a whole (Bonjoru *et al*., 2023).

The phytoplankton population of freshwater response to parameters like temperature, dissolved oxygen, pH and nutrient concentration of the medium and these parameters are influence by the inflow of effluents, sewage and decomposition of waste materials (Dauda *et al*., 2021). In a study by Vandi *et al*. (2025) at Lake Geriyo, Yola, they reported that some classes of phytoplankton correlate positively with temperature, TDS, TSS, pH, DO, BOD, conductivity and negatively with ammonia. Ugbeyide and Ugwumba (2021) and Zakariya *et al*. (2024) reported that higher numbers of phytoplankton were observed during the dry season

when compared with the wet season. In Lake Geriyo wet season recorded the higher number of phytoplankton than the dry season as confirmed by Vandi *et al*. (2025). Phytoplankton is also very useful in studying the biodiversity of the aquatic system. The study of phytoplankton is important in assessing the biotic component and adds significantly to the total estimation of the nature and overall economic potential of the aquatic environment (Ekanem, A.P., Job, B.E., Essien, A.E., 2018). River Donga plays a significant role in the livelihood of the people living within the catchment area and the entire Taraba State as it serves as source of water for fishing, transportation, domestic purpose, farming, revenue generation, etc. Few studies of such have been carried out on river Donga despite its enormous contributions. Therefore this study will assess the influence of physicochemical parameters on the seasonal variation of phytoplankton abundance and diversity of river Donga.

River Donga has long been used for irrigation, fishing, recreation and for domestic activities. While this water body is used for these purposes, many microorganisms have also found it a good habitat for quick proliferation. The river receives effluent discharges from rice mill, fertilizer runoff, pesticides, herbicides, diesel and petrol from engine boats, and domestic waste from people living close to the river. These are discharged into the river through drains, surface runoff and water ways during rainy season and through seepage. Furthermore, as population increases, the degree of pollutants seems to become worse. Increases in physicochemical concentrations become a matter of concern because of their toxicity and tendency to affect phytotplanktons diversity which may disrupt the food chain. However, following literature search of studies conducted in the study area, there is paucity of data regarding the dynamics of phytoplankton and other aquatic organisms. Therefore, the study analysed the levels of physicochemical in river Donga and their correlation with phytoplankton diversity, serving as an indicator of water quality and pollution.

**Materials and Methods: Study Area:** The study was carried out in part of Donga River which is located in Donga Local Government Area, of southern Taraba state in the North-Eastern Nigeria. The river is located on latitude $7^0$ 43'00"N and longitude $10^0$ 03'00"E of the equator. The river had its origin from the Mambilla Plateau in the Northeastern Nigeria, where it forms part of international border between Nigeria and Cameroon. The river flows northwest and it is one of the major tributaries of River Benue in Nigeria. The river is often turbid during wet season and clear during the dry season.

**Sample collection:** Water samples for physicochemical and biological analysis were collected on monthly basis for period of one year from October 2016 to September 2017 in the morning hour 8am -11am from three sampling stations. The sampling stations were located lengthwise along the River namely; station 1 (upstream near the bridge at Gyatta Aure ward), station 2 (old ferry terminal) and station 3 (Turu village, Fada ward). Water samples were collected in plastic bottles rinsed with distilled water, and stored at 4°C in ice caps and then transported to the laboratory prior to analysis.

**Determination of physicochemical parameters:** Physico-chemical parameters were determined in accordance with the standard procedures. The temperature was measured using mercury-in-glass thermometer calibrated in degree centigrade ($^0$C). The pH value was measured using Hanna pH meter model HI 8014. The water turbidity was measured using Hanna instrument microprocessor turbidity meter HI 93703. The turbidity value appeared after approximately 25 seconds and the value was recorded in NTU. Alkalinity and hardness were determined using standard method of APHA (2017). The water conductivity was measured using a combined conductivity/pH/T meter Hanna instrument model HI 8014. The meter probe was rinse before measuring another sample. The Dissolved Oxygen (DO) was measured using benchtop multiparameter photometer Hanna instrument with model number HI 83200. The TDS was measured using TDS meter Hanna instruments. Nitrate, nitrite, phosphate were measured using Hanna instruments HI 83200 benchtop multiparameter photometer.

**Phytoplankton Sampling:** Phytoplanktons were collected with plankton net of mesh size 55µm attached to a specimen bottles at the bottom with a ring opening 10cm diameter. This was done using a motorized boat or canoe towing at a very low speed for about 5-10 minutes. The net was shaken gently and sprayed from outside with clean water to concentrate the organisms at the bottom of the river in the test tube. The plankton net was hauled in and sample in the bottle were then transferred into 250ml well labeled specimen bottle with screw cap. The samples collected were preserved in 4% unbuffered formalin (Ogbuagu and Ayoade, 2012; Sharma, J., Parashar, A., Bagre, P. and Qayoom, I 2015).

**Laboratory Analysis:** Planktons samples brought from the field were transferred into test tubes for sedimentation. The test tubes were covered with cover slip and arranged on a rack, all having been labeled accordingly. The rack was placed on a vibration free surface in the dark cupboard and allowed to stay over a period of 24-48hrs. After then, the supernatant of each plankton sample in the test tube were decanted leaving the phytoplanktons which were transferred into a 10ml specimen bottle. Distilled water was added to the phytoplankton samples to make each up to 10ml suspension (Onyema, 2007).

**Identification of Phytoplanktons:** The fixed and preserved plankton samples were allowed to settle in the laboratory for 24hrs-48hrs. After settling, the supernatant were decanted to leave the sediment. The plankton sample were collected with the aid of 1ml dropping pipette and placed on a glass slide and covered with cover slip. The prepared slides were separately mounted on a motic compound microscope stage and viewed using 10X, 40X, 100X magnifications. When the organism of interest is focused on the microscope fitted with a digital camera, the picture was snapped in order to obtained sharp and clear picture using Amscope 3.7 digital camera. Standard keys and monograph; Pennak,

1978; Prescott, 1961; Prescott, 1978; Janse, S.V., Taylor, J., Ginkel, C., Gerber, A., 2006; Opute and Kadiri, 2014 were used for identification of the planktons. Guiry and Guiry, 2018 was used for taxonomy.

**Enumeration of Phytoplanktons:** The numerical abundance of each of the phytoplankton groups was determined by counting the number of each species (n) in each of the groups to know the total number (N) of the species in the groups. This was used for the calculation of the relative abundance, based on the formula:

% Ra = n(100)/N (Job and Ekpo, 2017; Ekanem *et al*., 2018)
Where: % Ra = relative abundance
n = number of individual species
N = total number of all individuals

**Statistical Analysis:** Data obtained from counting phytoplankton and physicochemical parameters (environmental variables) were analyzed for Analysis of variance (ANOVA) and Descriptive statistics using Statistical Packages for Social Sciences (SPSS) version 20. PAST version 3 was used to determine the diversity, dominance and evenness of phytoplankton taxa and Microsoft Excel 2010 was used for charts.

**Result And Discussion: Physicochemical Parameters:** Table 1 showed the seasonal mean values of physicochemical parameters in river Donga. The physicochemical properties have qualitative and quantitative effect on phytoplankton biomass (Ahmed, S., Roy, D., Uddin, H., Shil, S., Ahmed, S., 2016). In river Donga physicochemical properties such as water temperature, pH, total dissolved solids (TDS), total alkalinity, Dissolved oxygen (DO), etc were measured throughout the study period. The mean seasonal values of temperature showed no significance difference ($p<0.05$), with mean value of 27.31$^{o}$C in dry season and 27.47$^{o}$C in the wet season. The temperature was observed to be within the optimal range during the study period with slight variation due to change in weather conditions. Ahmed *et al.* (2016) reported an optimal range of water temperature which they ascribe the variation to weather conditions. The mean values were not significance between seasons, with lowest value recorded during the harmattan season. This finding is similar to that Inyang, A.I., Sunday, K.E. and Dan, M.U. (2016) reported lowest temperature during the harmattan season. High temperature was observed in March which was as a result of increase in photo period. Similar observation was made by Onyema (2018). Ugbeyide and Ugwumba (2021) reported a slight variation in mean water temperature between the seasons with higher value recorded in dry season than wet season. The result is similar to the current study. In Nasarawa reservoir low water temperature were recorded in the dry season months of November, February and March. According to Yusuf (2020) the lower water temperature in the reservoir could be due to seasonal changes in air temperatures involving the cool dry North-East winds. This observation is contrary to the current study.

The pH values were significance ($p<0.05$) between the two seasons, the mean value for dry season is 7.68 and 7.02 for the wet season. The mean pH values were significance ($p>0.05$) between the seasons and the values remain near neutral and in alkaline state. Dauda and Abba (2018); Babu and Mohan (2018); Manohar (2018); Adedeji, H.A., Idowu, T.A., Usman, M.A., and Sogbesan, O.A. (2019); Ghali, H., Osimen, E.C., Ogidiaka, E., Akamagwuna, F.C., Keke, U.N. and Edegbene, A.O. (2020) and Ugbeyide and Ugwumba (2021) reported similar observation to the current. Yusuf (2020) and Zakariya *et al*. (2024) observed higher pH values during the dry season and lower values during the rainy season in Nasarawa reservoir. His observation was similar to that of the present studies. The result was contrary to that of Davies, O.A., Teere, M.B., and Nwose, F.A. (2018) who reported slightly acidic pH in Orashi River. The TDS have higher mean value (35.33 mg/l) in the dry season which triple the value recorded in the wet season (12.61mg/l) and were statistically not significance between the seasons. TDS was higher in dry season as a result of decrease in water volume which increases the concentration of dissolved solids and lower in wet season, was due to increase volume of water which decreases the concentration of the solutes. Similar observation made by Usman *et al*. (2017) in Ajiwa reservoir and Ugbeyide and Ugwumba (2021) in Ibuya River. According to Hameed, I.O., Adeniyi, I.F., Adesakin, T.A. and Aduwo, A.I. (2019) higher mean TDS values were recorded in the dry season than in the rainy season which they believed is due to the fact that during the rainy season, more run-offs and allochthonous materials are washed into the Ifewara rreservoir. The results of the present study were contrary to the findings of Ibrahim and Nafiu (2017) in Thomas Dam, Kano state. Electrical conductivity mean seasonal values has shown significance different ($p<0.05$) between the seasons. The E/C recorded higher value (57.56 µS/cm) during the dry season, which almost doubled the value (31.72 µS/cm), obtained in the wet season. The conductivity was observed to be higher during the dry season than the wet season. The higher conductivity was attributed to increase TDS in dry season, which is as a result of reduced water volume and high temperature. Effiong, K.S., Inyang, A.I. and Robert, U.U. (2018); Abragam and Mathiarasi (2018) reported high values of conductivity during the dry season, which is attributed to as result of reduction in water volume, increase TDS, increase temperature and rich nutrient content. Also high conductivity was reported at Nasarawa reservoir during dry periods, which was as a result of evaporation due to high temperature (Yusuf, 2020). However, the result disagrees with the findings of Ibrahim and Nafiu (2017) and Omoboye, H.Y., Aduwo, A.I, Adewole, H. and Adeniyi, I.F. (2022). The total alkalinity recorded 109.36mg/l in dry season and 86.27mg/l in wet season. In the present study the seasonal total alkalinity mean values showed significant difference ($p<0.05$) between season and recorded higher in dry season than in wet season. The higher values in dry season can be attributed to reduction in water volume and increase in domestic activities and lower in wet season was due to increase

water volume and reduction in human activities. The result of the current study agrees with the observations Karthika, M., Shabana, S. and Ramasubramanian. V. (2017) and Goswami, K., Das, M.T., Kumar, S. and Mishra, A. (2018) in Lake Nainital. In a study by Musa, S.O., Waziri, M., Charles, A.H. and Adadu, M.O. (2021) at lower Benue River low total alkalinity was recorded. The observation was contrary to the present study. They attributed the low values recorded due to low photosynthetic activity. The finding of the current research was also contrary to the findings of Sharma *et al*. (2015). The dissolved oxygen (DO) mean values were significance ($p<0.05$) between the dry season (9.66mg/l) and wet season (8.31mg/l). Higher DO values in dry season are attributed to increase photosynthesis of phytoplankton, lower water turbidity. Similar observations were made by Ibrahim and Nafiu (2017); Effiong *et al.* (2018) and Yusuf (2020), but contrary to the findings in Ajiwa reservoir by Usman, L.U., Namadi, S. and Nafiu, S.A. (2017) recorded lowest concentration during dry season, which they attributed to the peak time of biochemical oxygen demand due to bacteria and other decomposers uptake. The mean seasonal values were significance for turbidity, with 274.78mg/l recorded in wet season and 43.69mg/l recorded in dry season. The higher value in wet season is confirmed to be as a result of increased amount of silt, clay and organic materials wash into the river when raining and lower in dry season as a result of reduced amount of silt into the river. This supports the observation of Usman *et al*. (2017); Dauda and Abba (2018) that high turbidity in Ajiwa reservoir during the rainy season was due to increase in surface run-off, which causes re-suspension of dissolved materials, flood and photosynthetic activites. Also Ibrahim and Nafiu (2017); Abragam and Mathiarasi (2018); Effiong *et al*. (2018) reported high turbidity during raining season. Ugbeyide and ugwumba (2021) reported turbidity higher than the stipulated standard at Ibuya River, which is similar to the present study. Numerous inorganic (mineral) substances are dissolved in water, such as calcium and magnesium along with their counter ion carbonate ($CO_3^{-2}$) comprise the basis for the measurement of hardness (Abdul-Halim, S.S., Hafizur Rahman, H.M., Md. Haque, M., Md. Rahman, S. and Md. Islam, S. 2018). The total hardness recorded a slightly higher value of 6.13mg/L in wet season than the dry season with mean of 5.04mg/l, and showed significance different ($p<0.05$) between the seasons. The values recorded in the present studies fluctuate between the months and stations. The hardness was higher in wet season which was due to runoffs, waste discharge into the river and it may also be due to buildups of chemicals as a result of human activities during dry season. This result is contrary to the finding of Usman *et al*. (2017) in Ajiwa reservoir and also that of Kathika *et al*. (2017) in Perur Lake. The nitrate seasonal mean values were significance ($p<0.05$) with lower value of 0.35mg/l in dry season and recorded 8.59mg/l in wet season. The highest values were observed during the wet season, which may be as a result of agricultural runoff from surrounding farms and washing of organic material in to the water body in wet season and lowest values were recorded in dry season. This was due to less agricultural activities. The result is similar to the observations of Ibrahim and Nafiu (2017) and Zakriya *et al*. (2024). In contrast to that of Effiong *et al*. (2018) who observed low nitrate value during the wet season and higher value during the dry season. In kalgwai Dam Ghali *et al*. (2020) observed low nitrate level which they attributed to insufficient inorganic nutrients accumulation, nutrients uptake by phytoplankton, microbial activities might have cause the low nutrients concentration in the dam. Nitrite is another form of the nitrogenous compound and an intermediate product of the transformation of ammonia into nitrate by bacterial activity (Abdul-Halim *et al*., 2018). The mean seasonal nitrite values were significance, with mean values of 0.34mg/l recorded in dry season and 0.28mg/l in wet season. Mama, A.C., Ghepdeu, G.F.Y., Ndam, J.R.N., Bonga, M.D., Onana, F.M. and Onguene, R. (2018) observed higher nitrite during the small raining season in Nyong estuary in Cameroon, these finding is not similar to that of the present study. The observation of this study is similar to that of Karthika *et al*. (2017). The phosphate showed significance differences between the seasons. The phosphate recorded a mean value of 2.15mg/l in dry season and slightly higher (3.33mg/l) in wet season. The higher value recorded in wet season was as a result of agricultural fertilizer, runoffs, sewage and organic wastes disposal, standing water from the surrounding increase the phosphate concentration. This agrees with the findings of Usman *et al*. (2017) and Zakariya *et al*. (2024).

**Biological Parameters:** A total of 69 species of phytoplankton belonging to 28 genera representing four phytoplankton groups were recorded. The Bacillariophyta was represented by 36 species contributing 52.2% of the total number of species recorded. The charophyta had 17 species representing 24.6% of the relative abundance. Cyanophyta were represented by 10 species contributing 14.5% of the total species. Chlorophyta have the least number of species with 6 species representing 8.6% of the total species as shown in figure 2. The distribution and relative abundance of phytoplankton from October 2016 to September 2017 is shown in Table 2. In the present study a total of four groups were identified which are bacillariophyta, cyanophyta, charophyta, and chlorophyta. A total of 602cell/L phytoplankton organisms were recorded in dry season. Charophyta recorded the highest count with a total of 421cell/L in dry season, with *Spirogyra spp*, *Closterium lanceolatum*, *Closterium aerosum*, *Cosmarium spp*, were dominant during the study period. The chlorophyta has the lowest phytoplankton count in dry season with a total of 10cell/L count in all the stations. *Ulothrix sp*, *U. variabilis*, *Pediastrum sp*., were the common species observed. The phytoplankton abundance decreases massively during the wet season, which may be attributed to high water turbidity and reduction in photoperiod, a total of 119cell/L was recorded. The diatom has the highest count recorded with 90cell/L, common species observed include *Pinnularia viridis*,

*Fragelaria rumpems, Synedra ulna var. danica, S. ulna var. bicep*. Chlorophyta recorded the lowest with only 2cell/L organisms and represent by *Chlamydomonas sp, Cylindrocapsa conterta*. Figure 3 and 4 summarized the distribution of phytoplankton in dry and wet seasons. The peak biomass observed during the dry season (March) in river Donga was as a result of favourable environmental conditions which lead to high temperature, longer photoperiod; decrease in water volume, less turbidity which encourages the development of phytoplankton.

Ekanem *et al.* (2018) reported that low phytoplankton observed in the Great Kwa river was as a result of reduce solar radiation due to run offs during wet season, which coincided with the study period. A research in Eastern Obolo River Estuary by Effiong *et al.* (2018) revealed that abundance of phytoplankton biomass during dry season may be due to stability of estuarine water, higher photosynthetic depth and lower turbidity and lower TSS. A study in Nasarawa reservoir revealed that high temperature, bright sunlight, high transparency and increase in tropholytic zone activities could decrease water level and bring the deep rich nutrients to the surface, which increase phytoplankton biomass during summer dry season (Yusuf, 2020). In Owalla reservoir and Hadejia River phytoplankton relative abundance were higher during the dry season than during the wet season as reported by Omoboye *et al*. (2022) and Zakariya *et al*. (2024) respectiviely. Hameed *et al.* (2019) observed a contrary result to that of present studies. They observed higher phytoplankton mean abundance during the rainy season than in the dry season, which they belief to be as a result of increase in ionic dilution during as well as an increase in nutrient inflow and introduction of organic matter from the surrounding vegetation.

**Diversity Indices:** The phytoplankton diversity indices for different seasons are shown in table 2. The dry season is the most diverse with 53 species and 602cell/L. The Shannon and Simpson index for phytoplankton assemblages for the dry season are 0.82 and 0.46 respectively. The species evenness was moderately distributed, with an evenness value of 0.56. The wet season was represented by 35 species and a total of 119 cell/L count was made. The Shannon, Simpson and Evenness indices for phytoplankton composition in wet season are 0.77, 0.40 and 0.54 respectively. Ganai and Parveen (2013) reported that for Indian lakes, the Shannon-Weiner diversity index proposed as diversity index greater than ( > 4) is clean water; between 3-4 is moderately polluted water and less than 2 (< 2) is heavily polluted water. In the current study the Shannon diversity of 0.82 in the dry season and 0.77 for wet season. The study showed diversity indexes between seasons have values less than 1, which can be considered unstable for both season. The result support the findings of Esenowo, I.K., Ugwumba, A.A.A. and Akpan, A.U. (2019) pointed out that Shannon index of less than 2 indicating heavy pollution of Nwaniba River. Seasonal variation of phytoplankton taxa revealed more species diversity and abundance during dry season than during wet season. Yusuf (2020) reported higher diversity in dry than wet season. The result is contrary to that of Ibrahim and Nafiu (2017) who observed high biotic indices in wet season than dry season.

**Conclusion:** The study revealed that abundance of phytoplankton was higher during dry season and lower during wet season. This variation might be due to sensitivity, as their structure and metabolism changes quickly in response to environmental changes. It is also concluded that physicochemical parameters and seasonal variation to a large extent influences the distribution and abundance of phytoplankton in river Donga.

**Recommendation:** It is recommended that government and non- governmental institutions, organizations should encourage constant research and awareness on the physical, chemical and biological parameters of river water bodies with the view monitoring any harmful environmental changes in the aquatic ecosystems.

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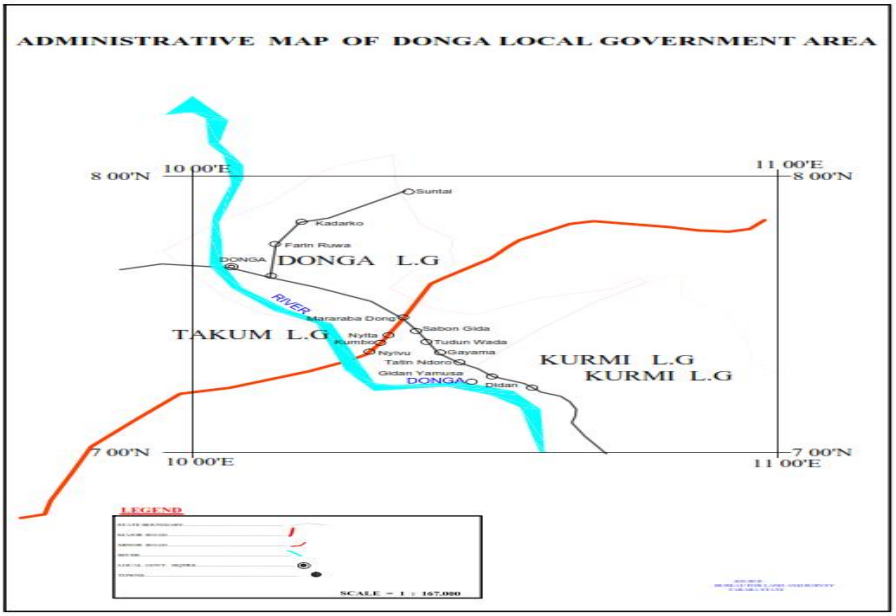


**Figure 1. Map of Donga Local Government Area Showing Section of River Donga**

**Table 1. Mean Seasonal Values for Physicochemical Parameters in Donga River**

| | SEASON | STANDARD | ANOVA |
|---|---|---|---|

| PARAMETER | DRY | WET | WHO(2011) | NIS(2007) | F-value | p-value |
|---|---|---|---|---|---|---|
| **TEMP (ºC)** | 27.31±2.67 | 27.47±1.43 | 30 | NS | 0.034 | 0.857 |
| **pH** | 7.68±0.84 | 7.02±0.22 | 6.5-8.5 | 6.5-8.5 | 7.720 | 0.012* |
| **TDS (mg/L)** | 35.33±58.15 | 12.61±3.20 | 250 | 500 | 2.652 | 0.121 |
| **E/C (µS/cm)** | 57.56±9.35 | 31.72±10.53 | 250 | 1000 | 52.764 | 0.000** |
| **TOTA (mg/L)** | 109.36±13.29 | 86.27±2.78 | NS | NS | 6.769 | 0.018* |
| **TURB (NTU)** | 43.69±10.74 | 274.78±103.33 | 5 | 5 | 72.296 | 0.000** |
| **DO (mg/L)** | 9.66±0.96 | 8.31±1.90 | 10 | NS | 10.120 | 0.005* |
| **TOTH (mg/L)** | 5.04±0.80 | 6.13±1.68 | 100 | 150 | 7.211 | 0.015* |
| **$NO_3$ (mg/L)** | 0.35±0.28 | 8.59±4.00 | 50 | 50 | 84.132 | 0.000** |
| **$NO_2$ (mg/L)** | 0.34±0.15 | 0.28±0.58 | 3 | 0.2 | 0.159 | 0.695 |
| **PHOS (mg/L)** | 2.15±0.92 | 3.33±0.81 | 0.2 | NS | 9.850 | 0.006* |

TEMP= Temperature, TDS= Total Dissolved Solid, E/C= Electrical Conductivity, TOTA= Total Alkalinity, TURB= Turbidity, DO= Dissolved Oxygen, TOTH= Total Hardness, $NO_3$= Nitrate, $NO_2$= Nitrite PHO= Phosphate.

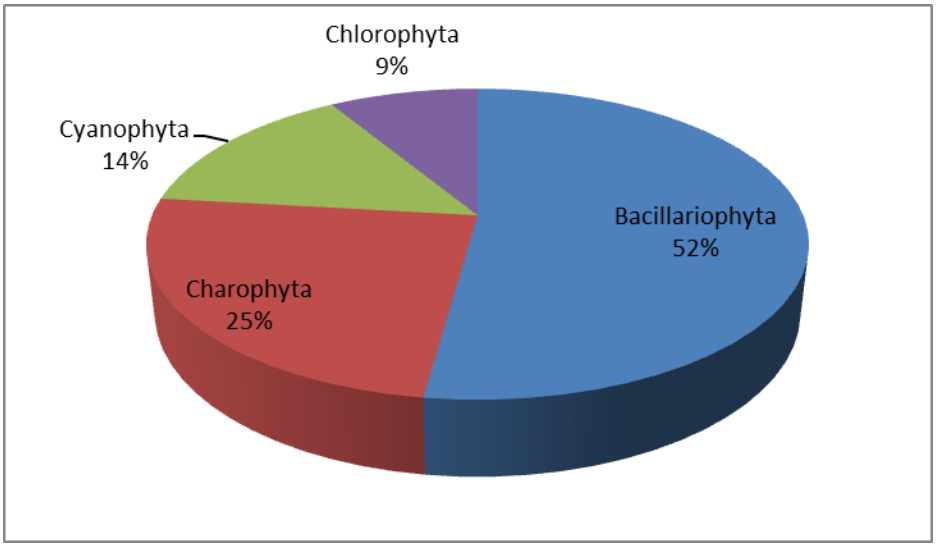


**Figure 2: Percentage composition of the different phyla observed during the study**

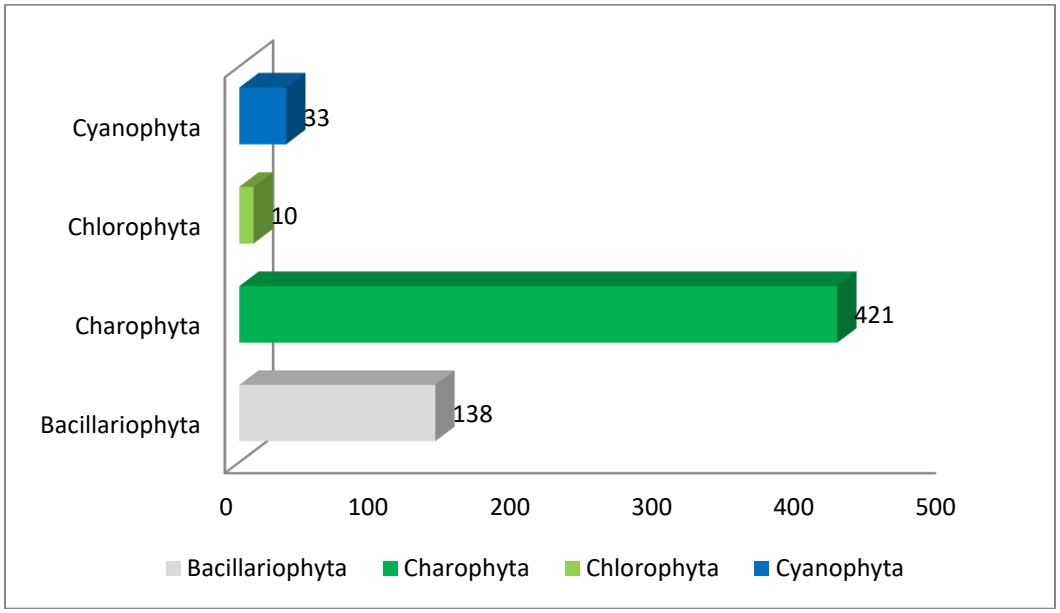


**Figure 3: Distribution and Abundance of Phytoplankton during Dry season in River Donga**

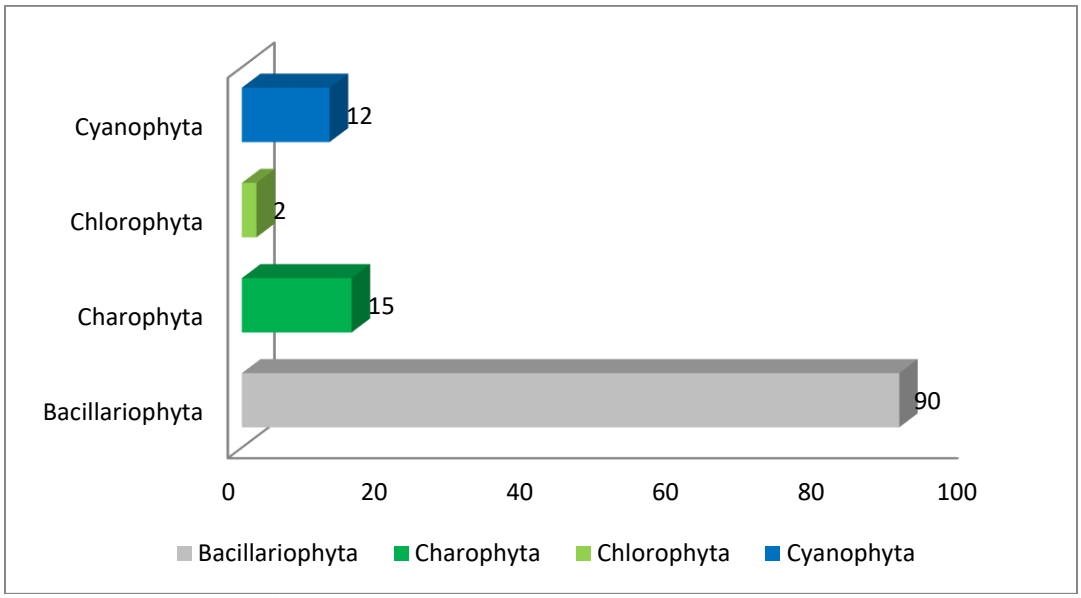


**Figure 4: Distribution and Abundance of Phytoplankton during Wet season in River Donga**

**Table 2. Taxonomy, abundance and distribution of phytoplankton in river Donga from October 2016 – September 2017**

| Phytoplankton Taxa | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Total | Relative Abundance% |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **PHYLUM: BACILLARIOPHYTA** | | | | | | | | | | | | | | |
| **CLASS: BACILLARIOPHYCEAE** | | | | | | | | | | | | | | |
| **Order: Bacilariales** | | | | | | | | | | | | | | |
| *Nitzschia* sp. | - | - | - | - | 1 | - | - | - | - | - | - | - | 1 | 0.14 |
| *N. acicularis* (Kutz) W. Smith | - | - | 1 | - | - | - | - | - | - | - | - | - | 1 | 0.14 |

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Denticula* spp. | - | - | - | - | - | - | - | - | - | - | 2 | - | 2 | 0.28 |
| **Order: Coscinodiscales** | | | | | | | | | | | | | | |
| *Coscinodiscus radiates* Her. | - | - | - | - | - | - | - | - | 1 | - | - | - | 1 | 0.14 |
| **Order: Cymbellales** | | | | | | | | | | | | | | |
| *Cymbella* sp. | - | - | - | - | - | - | 1 | - | - | - | - | - | 1 | 0.14 |
| *C. tumidula* (krammer) W.Smith | - | - | - | - | 2 | 2 | 2 | - | - | - | - | - | 6 | 0.83 |
| *C. tumida* (Breb) V. Heurek | - | - | - | - | - | - | - | - | - | 1 | - | - | 1 | 0.14 |
| *Gomphonema* spp. | - | - | - | - | - | - | 1 | - | - | - | - | - | 1 | 0.14 |
| *G. lanceolatum* Maguin. | - | - | - | - | - | - | 1 | - | - | - | - | - | 1 | 0.14 |
| **Order: Fragilariales** | | | | | | | | | | | | | | |
| *Synedra* spp | 2 | 8 | 3 | - | 10 | 3 | - | 1 | 1 | 1 | - | - | 29 | 4.02 |
| *S. ulna* (Nitzch) Ehr. | 5 | 6 | 6 | 2 | 10 | 4 | 7 | 4 | 5 | 5 | 1 | 5 | 60 | 8.32 |
| *S. ulna* var. *subaequalis* | - | - | - | 1 | - | - | - | - | - | - | - | - | 1 | 0.14 |
| *S. ulna* var. *bicep* | - | - | - | 1 | - | - | - | 1 | - | 3 | - | 3 | 8 | 1.10 |
| *S. ulna* var. *danica* | 2 | - | - | - | 7 | - | 2 | - | 2 | 3 | 1 | 1 | 18 | 2.49 |
| *S. fasiculata* | - | - | - | - | 2 | - | - | - | - | - | - | 2 | 4 | 0.55 |
| *S. fasiculata* var. *truncate* | - | - | - | - | - | - | - | - | 2 | - | - | - | 2 | 0.28 |
| *S. fasiculata* Ag. Herb | - | - | - | - | - | - | - | - | - | 3 | - | - | 3 | 0.42 |
| *Fragilaria* sp. | 1 | 1 | 3 | - | 3 | - | - | - | 1 | 1 | - | - | 10 | 1.39 |
| *F. rumpems* Her. | - | - | 4 | 1 | 2 | 1 | 1 | - | - | - | 1 | 2 | 12 | 1.66 |
| *F. vaucheriae* (Kutz) | - | - | 1 | - | - | - | - | - | - | - | - | - | 1 | 0.14 |
| *F. capucina* (Kutz) | - | - | - | - | - | - | - | - | - | - | - | 1 | 1 | 0.14 |
| **Order: Naviculales** | | | | | | | | | | | | | | |
| *Navicula* spp. | 2 | - | 1 | 1 | 3 | 4 | - | 1 | - | - | - | - | 12 | 1.66 |
| *N. gregaria* | - | - | 1 | 1 | - | 1 | - | - | - | - | - | - | 3 | 0.42 |
| *N. transitan* var. *derasa* | - | - | - | - | - | 2 | - | - | - | - | - | - | 2 | 0.28 |
| *N. cryptocephala* (Kutz) | 1 | - | - | - | - | 2 | 1 | - | - | - | - | - | 4 | 0.55 |
| *N. tripunctata* | - | - | - | - | - | - | - | - | - | - | - | 1 | 1 | 0.14 |
| *Pinnularia* sp. | - | - | - | - | - | 1 | - | - | - | - | - | - | 1 | 0.14 |
| *P. viridis* (Nitzch). Her. | - | - | - | 1 | 2 | - | - | 1 | 1 | - | - | 2 | 7 | 0.97 |

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *P. subcapitata* A. Boyer. | - | - | - | - | - | - | - | 1 | - | 1 | - | - | 2 | 0.28 |
| *P. appendiculata* Maguin. | - | - | - | - | - | - | - | - | - | - | - | 1 | 1 | 0.14 |
| *Gyrosigma* sp. | - | - | - | - | - | 1 | - | - | - | - | - | - | 1 | 0.14 |
| *G. accummatum* (Kutz) | - | - | - | - | 2 | - | - | - | - | - | - | - | 2 | 0.28 |
| **Order. Surirellales** | | | | | | | | | | | | | | |
| *Surirella* spp. | - | - | - | - | - | 1 | - | - | - | - | - | - | 1 | 0.14 |
| *S. tenera* | - | - | - | 1 | - | 5 | 4 | - | - | - | - | - | 10 | 1.39 |
| *S. ovate* W. Smith | - | - | - | - | 1 | 2 | 2 | - | 1 | - | - | - | 6 | 0.83 |
| *S. robusta* Her. | - | - | - | - | - | 5 | 3 | - | - | 1 | - | - | 9 | 1.25 |
| *S. tenussima* Hustedt. | - | - | - | - | - | 2 | - | - | - | - | - | - | 2 | 0.28 |
| **Sub total** | | | | | | | | | | | | | **228** | **31.63** |
| **PHYLUM: CYANOPHYTA** | | | | | | | | | | | | | | |
| *Anabaena* spp. | - | - | - | - | 13 | - | - | - | - | - | - | - | 13 | 1.80 |
| *Aulosira laxa* (Kirchner) | - | - | - | - | - | - | - | - | - | 1 | - | - | 1 | 0.14 |
| *Nostoc* spp. | - | - | - | - | 1 | - | - | - | - | - | - | - | 1 | 0.14 |
| **Order: Oscillatoriales** | | | | | | | | | | | | | | |
| *Lyngbya* spp. | - | - | - | - | 3 | - | - | - | - | - | - | - | 3 | 0.42 |
| *Oscillatoria* sp. | - | - | - | - | - | 1 | 4 | 1 | - | - | - | - | 6 | 0.83 |
| *O. sancta* (Keutz) (Gomont) | - | - | 1 | - | 2 | 3 | - | - | - | - | - | - | 6 | 0.83 |
| *O. chalybea* Mertens (Gomont) | - | - | - | - | - | 5 | - | - | - | - | - | - | 5 | 0.69 |
| **Order: Spirulinales** | | | | | | | | | | | | | | |
| *Spirulina subsalsa* Gomont | - | - | - | 3 | - | 1 | - | - | - | 1 | 2 | 1 | 8 | 1.10 |
| *S. nordstedt* Gomont | - | - | - | - | - | - | - | - | - | - | - | 1 | 1 | 0.14 |
| *S. major* (Kuetzing) Gomont | - | - | - | - | - | - | - | - | - | 1 | - | - | 1 | 0.14 |
| **Sub total** | | | | | | | | | | | | | **45** | **6.23** |
| **PHYLUM: CHAROPHYTA** | | | | | | | | | | | | | | |
| *Closterium* spp. | - | - | - | - | - | 1 | - | - | - | - | - | - | 1 | 0.14 |
| *C. aerosum* Her. | 2 | - | 7 | - | 1 | - | - | - | - | - | - | - | 10 | 1.39 |
| *C. ehrenbergii* Meneghini (Ralf) | - | - | 1 | - | - | 3 | - | - | - | - | - | - | 4 | 0.55 |
| *C. lanceolatum* Kutzing (Ralf) | 2 | 4 | 8 | - | 3 | - | - | - | - | - | - | - | 17 | 2.36 |
| *C. leibellula* | - | - | 1 | - | - | - | - | - | - | - | - | - | 1 | 0.14 |
| *C. monoliferum* Her. | 1 | 1 | - | - | - | - | - | - | - | - | - | - | 2 | 0.28 |

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *C. pseudolunula* Borge. | - | - | - | 2 | - | - | - | - | - | - | - | - | 2 | 0.28 |
| *C. rostratum* Her. | - | - | - | - | 1 | - | - | - | - | - | - | - | 1 | 0.14 |
| *C. spetsbergense* var. *laticeps* | - | - | - | 1 | 1 | - | - | - | - | - | - | - | 2 | 0.28 |
| *Cosmarium* spp. | - | - | - | - | 4 | 1 | - | - | - | - | - | - | 5 | 0.69 |
| *C. decoratum* West & G.S West | - | - | - | - | 1 | - | - | - | - | - | - | - | 1 | 0.14 |
| *C. pachydermum* | - | - | - | - | 2 | - | - | - | - | - | - | - | 2 | 0.28 |
| *Desmidium swartzii* C. Agardh | - | - | - | - | 1 | - | - | - | - | - | - | - | 1 | 0.14 |
| *Micrasterias americana* Her. Ralf | - | - | - | - | 1 | 1 | - | - | - | - | - | - | 2 | 0.28 |
| *Straurastrum* spp. | - | - | - | - | - | 1 | - | - | - | - | - | - | 1 | 0.14 |
| **Order: Zygnematales** | | | | | | | | | | | | | | |
| *Spirogyra* spp. | 6 | 1 | 18 | 24 | 30 | 290 | 2 | - | 1 | 1 | 2 | 5 | 380 | 52.70 |
| *Zygnema* sp. | - | - | - | - | - | - | - | - | - | - | 2 | 2 | 4 | 0.55 |
| **Sub total** | | | | | | | | | | | | | **436** | **60.48** |
| **CLASS: CHLOROPHYCEAE** | | | | | | | | | | | | | | |
| **Order: Chlamydomonadales** | | | | | | | | | | | | | | |
| *Chlamydomonas* spp. | - | - | - | - | - | - | - | - | - | - | - | 1 | 1 | 0.14 |
| **Order: Sphaeropleales** | | | | | | | | | | | | | | |
| *Cylindrocapsa conterta* (West) | - | - | - | - | - | - | - | - | 1 | - | - | - | 1 | 0.14 |
| *Pediastrum* spp. | - | - | - | - | 1 | 1 | - | - | - | - | - | - | 2 | 0.28 |
| **CLASS: TREBOUXIOPHYCEAE** | | | | | | | | | | | | | | |
| **Order: Chlorellales** | | | | | | | | | | | | | | |
| *Geminella interupta* (Turpin) | - | - | 1 | - | - | - | - | - | - | - | - | - | 1 | 0.14 |
| **Order: Ulotrichales** | | | | | | | | | | | | | | |
| *Ulothrix* spp. | - | - | - | - | 1 | 1 | - | - | - | - | - | - | 2 | 0.28 |
| *U. variabilis* (Kutzing) | - | - | - | - | - | 5 | - | - | - | - | - | - | 5 | 0.69 |
| **Sub total** | | | | | | | | | | | | | **12** | **1.67** |
| **Overall Total** | **24** | **21** | **57** | **39** | **113** | **348** | **31** | **10** | **16** | **23** | **11** | **28** | **721** | **100** |

**Table 3. Seasonal Diversity Index of phytoplankton.**

| SEASON | DIVERSITY INDEX IINDEX | | |
|---|---|---|---|
| | Shannon _H | Simpson_ 1-D | Evenness _ e^H/S |

| | | | |
|---|---|---|---|
| **DRY** | 0.82 | 0.46 | 0.56 |
| **WET** | 0.77 | 0.40 | 0.54 |