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# WATER QUALITY PARAMETERS OF THE NUN RIVER, BAYELSA STATE, NIGERIA

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**ABSTRACT**

The water houses the fish and so must be in good condition in order to enable a good production output both in capture and culture fisheries. The water quality analysis of the lower reach of the Nun River was conducted by determining the physical and chemical parameters of the river water for 12 months. The parameters analyzed were pH, temperature, dissolved oxygen, total dissolved solids (TDS), turbidity, conductivity, carbon (IV) oxide, acidity, total alkalinity (TA) and total hardness (TH). The results showed that most of the parameters fell within tolerable and legal ranges for physico-chemical parameters. Again, all parameters showed significant differences among the means except pH and carbon (IV) oxide at ($p>0.05$). A negative and strong correlation existed between pH and $CO_2$ (-0.770775496); as $CO_2$ decreased, pH increased, thus as $CO_2$ values were at good range, pH levels were also good. A mean range of 6.97 and 7.69 was recorded for pH. This may also be compared with the acidity levels of the river which fell within 5 and 35 mg/L and alkalinity of 37.5 and 72.0 mg/L. Dissolved oxygen was above 5 mg/L recommended for fresh water species. Temperature was reported at 27.00 and 31.85 $^{o}$C which fell within the recommended range of 25 – 32 $^{o}$ C for tropical species. On the contrary, turbidity fluctuated invariably showing high transparency values of 27 - 31 cm between January to June while low values of 5.75 and 5.25 cm was recorded in August and September respectively. Positive and strong correlation existed between TDS and conductivity (0.870021322). At the highest value of 67.0 mg/L for TDS, conductivity was at its highest value of 123.5 µ/s which was seen in the month of November. Despite the location of the Nun River at the Niger delta area which makes it prone to pollution from oil explorations, the water quality properties still fell within healthy ranges for a freshwater ecosystem. Thus, more measures should be taken to ensure environmental protection and healthy surface waters.

**Keywords: Water quality, Physco-chemical parameters, Freshwater ecosystem, Nun river, Ekowe**

## INTRODCUTION

Water quality means the level of purity and health standard of a water body. It influences the survival and growth condition of aquatic species in both marine/brackish and freshwater environments. External agents, which could be physical, chemical or biological may introduce stress or pollutants into the ecosystem which may alter the sanity of the river water. Water quality parameters such as pH explain the acidity or alkalinity of the water body which influences the health status of that ecosystem. An unstable pH or pH pulses can result in quality variability of the water body and this can be buffered by the total alkalinity and hardness concentration in the affected water body. An unstable pH condition can result in drift responses by some aquatic invertebrates (Hopkins *et al.*, 1989) causing change in population and diversity of inhabiting organisms. Changes caused by acidification can alter the chemistry of the river water especially when the buffering capacity of the incipient water body is low. pH pulses can be buffered by the total alkalinity (TA) and hardness (TH) concentration in the affected water body hence, the importance of TA. In other words, TA influences the buffering capacity of a water body which means it determines the acid neutralizing capacity of the water. pH levels also influences the solubility and character of elements and ions. The rate of electrical charges and the ability of the water to conduct could also be related to the pH. Acid-base balance has so much to do with ionization potentials of the water, when cations and anions cancel out, neutralization has taken place. Thus, conductivity increases as these ions increase which is a function of ion species diversity or richness. TDS on the other hand, increases with increase in effluent influx into a water body which is a function of dissolved organic substances. Thus, chemical richness has to do with the total amount of ions present in the medium while chemical density has to do with the support system for the abundance and composition of the biotic community (Ude, 2012). Hence, conductivity and total dissolved solids (TDS) are described as the measure of chemical richness and chemical density of the water body (or the environment) respectively.

The presence of carbon (IV) oxide in the water influences the acidity of a medium as well. It can induce acidification when it is converted to carbonic acid after it has been absorbed into the water and also from decomposing algae and organic wastes. Water with high buffering capacity regulates carbon dioxide saturation as it neutralizes the carbonic acid (Witman, 2017). The presence of carbon (IV) oxide in the water determines the acidity level also since it dissolves in water to form carbonic acid which lowers the pH of the incipient water. All these put together impact the inhabiting organisms. Poor water pH can induce poor response to feeding, reproductive stress in fishes, suppressed growth, increased vulnerability to pollutants, poor resilience to diseases and environmental stressors. For instance, Ferric hydroxide ($Fe(OH)_3$ or ($Fe_2O_3$-$3H_2O$, rust) as the most common species of ferric iron in natural waters is mostly solid at pH range of 5 to 8 because the solubility is very low (Nolan, 1962). Thus exists as relatively stable colloidal suspensions in the water. If pH of the medium increases, ferrous oxide, also known as iron (II), FeO is formed. In alkaline media (at pH 10 and above), Fe (OH) $^{2}$ (aq) is also formed (Nolan, 1962). Also, most chemical agents such as disinfectants, medications depend on pH for their effectiveness or potency (Ansell, 2005; Maillard, 2016). This simply explains the impact of pH or acid-base variability on other compounds in an aquatic media. Thus, the need for correlation analyses of data.

Influx of compounds such as phosphates and nitrates from wastes and fertilized soil from adjoining farmlands introduce eutrophication which is an indicator of nutrient pollution (Okogbue, *et al.*, 2017)[1]. As rain falls, run-offs find their ways into surface waters carrying along diverse compounds and nutrients. Nutrient pollution gives rise to low dissolved oxygen as the high organic load in the river place demand on oxygen level. One indication of nutrient pollution is algal bloom which is seen as greenish films on the water surface. If it is not controlled, the water body gets polluted. This is majorly the impact of phosphates and nitrates which act as fertilizers to the river water. This can come from detergents used during laundry, fertilizers, also from decaying kitchen refuse dumped in the river and feacal matters (common practice of the riverine communities). In addition, the fish and shellfish species can become infested with high microbial components from the organic materials making them unhealthy for consumption. Again, the competition for dissolved oxygen leaves the river water low in oxygen content which poses as risk for the fish stock. Nevertheless, the primary productivity of surface aquifers is determined by the components of the plankton diversity present in the water body.

The algal bloom may be beneficial as well as harmful. It is beneficial when the micro-floral community which is the main base of aquatic food web produce oxygen during their photosynthetic activities in the day (Okogbue *et al*., 2017)[2]. The photosynthesis by these phytoplankton are the primary source of dissolved oxygen in the ecosystem which is used up during respiration by both the fin and non-fin fish species, the microbial community, the macrophytes as well as the phytoplankton and the zooplankton. The photosynthetic activities of this group of organisms can also be affected by the incidence of high turbidity. The reduction in the river transparency which is as a result of high turbid waters reduces the rate of dissolved oxygen production in the water. The resultant condition is known as anoxia or hypoxia. This happens in some lakes especially, eutrophic lakes where the sediment level is too high with shallow water column and high turbidity which may be algae-induced or silt-induced hampers the penetration of light rays used by the floral community of the water body. High turbid water influences the productivity of fish and other aquatic organisms negatively. This induced anoxia may cause submerged macrophytes and planktons not to get enough ultra violet rays for photosynthetic activities that liberate oxygen. This also implies that carbon dioxide ($CO_2$) will be accumulating in the water since photosynthesis is hampered, little $CO_2$ is taken away rather respiration is taking place by all inhabiting organisms releasing $CO_2$ into the water. This can lead to $CO_2$ induced acidification. This can lower the water pH and induce other environmental stressors and discomfort for the organisms.

High anoxic conditions can result to massive fish kill and deterioration of the quality of the river water. High dissolved oxygen present in the water is equivalent to high oxidation-reduction potential (ORP) value and thus translates to a healthier lake or river (Horne and Goldman, 1994; Wetzel, 1983). Bottom sediments has less oxygen, in order words, high turbidity translates to reduced ORP. ORP measures the ability of a water body to cleanse itself or degrade waste products, such as contaminants, dead plants and animals. Therefore, low ORP translates to high biochemical oxygen demand (BOD) which means increased organic matter, siltation and dead zones which will not be good for aquatic organisms and biodiversity due to anoxia.

In addition, conductivity, total alkalinity and hardness of surface waters are also influenced by components of the medium. EC electrical conductivity and redox potentials influences the growth and survival of some plants, pH affects the solubility and availability of nutrients such as Fe, Zn, Mn, phosphates etc. For instance, most metals do not characteristically change either by chemical or microbial degradation (Wuana and Okieimen, 2011) but from one form to another making it bioavailable or biotoxic. Also phosphorous is less available at pH above 7.2 (Zhang *et al*. 2015), solubility of calcite (CaCO3) was greatly influenced by the $CO_2$ content of the water medium (James and Edworthy, 1985).

Conductivity is the measure of the ease at which electric charges or heat pass through a medium e.g. aqueous solution while total hardness is the total calcium and magnesium ion concentration in water expressed as the concentration of calcium carbonate. There is still the presence of other divalent ions such as magnesium and iron hence, water hardness is also defined as the measure of divalent metal cations. Thus, any water body with low hardness is prone to acidification or impact of pH pulses. Total alkalinity on the other hand is the concentration of bases which determines the neutralization capacity of the waterbody.

This simply explains the importance of pH analysis of the water since it influences the overall characteristics in a given water body. Also, there is the need for general water quality routine checks from time to time to ensure water quality standard is maintained in our aquifers and also to enhance biodiversity since diverse groups of aquatic organisms inhabiting the ecosystems are influenced by their environments. This study therefore sorts to establish the water quality status of the lower reach of the Nun River and to assess them in the light of the set standards for water quality by governing bodies (WHO, USEPA, etc.)

## MATERIALS AND METHODS

### Study area: Ayama and Ekowe Communities in the Southern Ijaw LGA of Bayelsa State, Nigeria.

The Nun river analysis was conducted by sampling the river water from two (2) points serving as the upstream and the downstream. Distance from Ayama to Ekowe = 34.0 km

Upstream: Ayama: Coordinates – N $04^0$ 52.321’
E $006^0$ 12.543’
Elevation: 4m above sea level
Downstream: Ekowe: Coordinates – N $04^0$ 42.464’
E $006^0$ 05.590’
Elevation: 4m above sea level



### Data collection

The river was sampled during the wet and dry seasons for twelve months recording November to March for dry season samples and April to October for the wet season samples. Hanna water quality test kit was used for the analyses. Sampling bottles of one litre capacity were used to take water samples from the respective sampling points to form the duplication.

Samples were analyzed according to methods described by EIFAC (1983) and APHA (1975) for physical and chemical parameters. pH, temperature, total dissolved solids (TDS), and conductivity were analyzed using a conductivity meter in-situ. Dissolved oxygen, carbon (IV) oxide, acidity, total alkalinity (TA) and total hardness (TH) were determined using titrimetric method while turbidity was measured from the secchi disc reading method.

**Data analysis**

The water quality data was analyzed using SPSS. All values with the same superscript on the same row are not significantly different while those with different superscripts are significantly different. The data were further analyzed using the Duncan Test (DMRT) for the separation of the means and correlation analysis for the relationships that existed amongst the physco-chemical parameters.

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## RESULTS

**Table 1: The water quality parameters of the Nun River**

| PARAMETER | MONTHS | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **JAN** | **FEB** | **MAR** | **APRI** | **MAY** | **JUN** | **JUL** | **AUG** | **SEPT** | **OCT** | **NOV** | **DEC** | **SEM** | **LOS** |
| pH | 7.28 | 7.69 | 7.96 | 7.53 | 7.52 | 7.43 | 7.45 | 7.13 | 6.96 | 6.97 | 7.67 | 7.41 | 2.15 | NS |
| Temp. (0c) | $30.30^{cd}$ | $31.55^{ab}$ | $29.35^{e}$ | $30.40^{c}$ | $30.30^{cd}$ | $27.25^{k}$ | $28.45^{f}$ | $27.00^{kl}$ | $28.15^{i}$ | $29.50^{cg}$ | $31.85^{a}$ | $30.10^{cf}$ | 0.32 | * |
| DO (Mg/L) | $6.75^{d}$ | $7.70^{a}$ | $7.45^{ac}$ | $6.50^{e}$ | $5.00^{ik}$ | $7.50^{ab}$ | $6.30^{ef}$ | $5.85^{h}$ | $5.50^{i}$ | $5.35^{ij}$ | $6.00^{g}$ | $7.00^{c}$ | 0.20 | * |
| TDS (Mg/L) | $47.00^{bc}$ | $40.50^{de}$ | $46.00^{be}$ | $37.50^{f}$ | $41.00^{d}$ | $41.00^{d}$ | $44.50^{bf}$ | $37.50^{f}$ | $36.50^{fg}$ | $46.50^{bd}$ | $67.00^{a}$ | $49.00^{b}$ | 2.35 | * |
| Turbidity (cm) | $28.75^{ad}$ | $28.75^{ad}$ | $27.50^{af}$ | $31.25^{a}$ | $30.50^{ab}$ | $29.50^{ac}$ | 7.40 | $5.75^{f}$ | $5.25^{fg}$ | $13.15^{e}$ | $16.50^{d}$ | $19.75^{c}$ | 2.07 | * |
| Cond (µ/s) | $78.00^{g}$ | $77.10^{gh}$ | $94.50^{cd}$ | 73.00 | $84.50^{ef}$ | $88.00^{e}$ | $70.00^{j}$ | $70.00^{j}$ | $75.50^{i}$ | $96.50^{c}$ | $123.50^{a}$ | $102.00^{b}$ | 4.42 | * |
| $CO_2$ (Mg/L) | - | 10.00 | 6.25 | 11.00 | 10.00 | 10.00 | 6.75 | 12.50 | 13.75 | 11.00 | 8.75 | 10.00 | 4.20 | NS |
| Acidity (Mg/L) | - | $35.00^{a}$ | $12.50^{f}$ | $25.00^{b}$ | $25.00^{b}$ | $20.00^{d}$ | 10.00 | $25.00^{b}$ | $25.00^{b}$ | $15.00^{e}$ | $25.00^{b}$ | $5.00^{g}$ | 2.03 | * |
| TA (Mg/L | - | $72.00^{a}$ | $40.00^{h}$ | $45.00^{fg}$ | 37.50 | $54.00^{bc}$ | $45.00^{fg}$ | 37.50 | $48.00^{f}$ | $52.50^{bd}$ | $52.50^{bd}$ | $57.00^{b}$ | 3.52 | * |
| TH (Mg/L) | - | $34.50^{g}$ | $52.50^{d}$ | $42.00^{f}$ | $52.50^{d}$ | $51.00^{de}$ | $52.50^{d}$ | $67.50^{a}$ | $60.00^{b}$ | $52.50^{d}$ | $60.00^{b}$ | $60.00^{b}$ | 3.86 | * |

($P<0.005$)

Table 1 shows the physicochemical characterization of aquatic media of the Nun River in Ayama and Ekowe communities as the up and down stream sampling points respectively. This was conducted for 12 months from January to December. No values were recorded for four parameters in January for reasons hinging on limitations. The pH of the river water occurred at safe limits not exceeding 6.5 and 9.0 as recommended for a good culture medium. The values did not vary significantly along the months and seasons. The pH presented at the lowest mean of 6.96 and there were no significant differences among the months assessed while the temperature occurred at ranges between 27 – 31.85 $^{o}$C with significant differences. During the rainy season

(March – September), the temperature across the sampled months statistically and significantly varied at $P<0.05$ showing lower values. However, during the dry season (October – February), the temperature values were relatively higher although within tolerable ranges for tropical freshwater aquatic species.

Dissolved oxygen (DO) at 5 mg/L as the lowest mean value recorded was a good report for the Nun River. Values as high as 7.70 mg/L was also recorded as the highest mean value in the month of February and 5.35 mg/L in October as the lowest mean value however, the values varied significantly. Also, the concentration of the total dissolved solids (TDS) also varied significantly within the months assessed with the highest values of 46.5, 67.0, 49.0 and 47.0 mg/L recorded during the dry season between October and January respectively.

Turbidity fluctuated with seasons showing lower values from January to June at mean values ranging between 27.5 and 31.25 cm while high values less than 20 cm was recorded from July to December. There were significant differences among the means. Conductivity occurred at values significantly different within the months. Range of 70.0 and 123.5 µ/s was recorded within the 12 months of survey. Carbon (IV) Oxide on the other hand did not vary significantly when analyzed. However, a mean range of 6.25 and 13.73 mg/L was recorded.



**Table 2: Correlation analysis of the water quality parameters of the Nun River**

| | *pH* | *Temp. (oC)* | *D O (mg/L)* | *TDS (mg/L)* | *Turbidity (cm)* | *Cond. (EC (µ/s)* | *CO2 (mg/L)* | *Acidity (mg/L)* | *T A (mg/L* | *T H (mg/L)* |
|---|---|---|---|---|---|---|---|---|---|---|
| pH | 1 | | | | | | | | | |
| Temp. (oC) | 0.47720749 | 1 | | | | | | | | |
| D O (mg/L) | 0.577224514 | 0.091319943 | 1 | | | | | | | |
| TDS (mg/L) | 0.321582152 | 0.544477053 | 0.003088011 | 1 | | | | | | |
| Turbidity (cm) | 0.60327715 | 0.461513782 | 0.490586967 | -0.028352625 | 1 | | | | | |
| Cond. (EC (µ/s) | 0.293303669 | 0.462046013 | 0.006213736 | 0.870021322 | 0.082944709 | 1 | | | | |
| CO2 (mg/L) | -0.770775496 | -0.265221252 | -0.428720114 | -0.456918338 | -0.300673811 | -0.29936091 | 1 | | | |
| Acidity (mg/L) | 0.023442255 | 0.247343525 | -0.084031998 | -0.219004297 | 0.20468407 | -0.243807225 | 0.447260174 | 1 | | |
| T A (mg/L | 0.086400297 | 0.443307602 | 0.520126335 | 0.180099651 | 0.195820088 | 0.210858394 | 0.042137124 | 0.218674946 | 1 | |
| T H (mg/L) | -0.432682886 | -0.466847136 | -0.465055201 | 0.243970424 | -0.67197346 | 0.247439862 | 0.228695367 | -0.363079918 | -0.517180129 | 1 |

pH and DO (r = 0.577224514) correlated positively which is the opposite situation for pH and $CO_2$ (r = -0.770775496) which correlated negatively. TDS and temperature at (r = 0.544477053) was positive. Conductivity and TDS was positive and strong (r = 0.870021322). The correlation between DO and $CO_2$ was negative though not strong. Some other parameters were not strongly correlated (Table 2).

## DISCUSSION

Table 1 shows the physical and chemical characteristics of the Nun River. This showed that the pH of the Nun River was stable throughout the months analyzed and so occurred at healthy ranges for fresh water ecosystem. pH in water could be influenced by carbon (IV) oxide ($CO_2$) at low pH, hydrogen carbonate ($HCO_3$) or as carbonate ($CO_3$) at high pH. In other words, pH is determined by the presence and form this carbon compounds present in the medium. The concentrations of carbon (IV) oxide as well as other acidic substances greatly influence the pH of natural waters. When the acidity influences water quality variables, the pH will be low and may fall outside legal limits of 6.5. Thus, anything below 6.5 will affect the progressive development and survival of aquatic life as well as the productivity of the water body. At low pH, water is acidic and $CO_2$ is in free form. Carbonate and bicarbonate are safe between 20 mg/L and 5000 mg/L. These forms of carbon constitute the main buffers which accounts for the acid neutralizing capacity (ANC or alkalinity) of the water.

The result of the analysis in Table 1 showed that $CO_2$ values were not significantly different across the months analyzed at a range of 6.25 and 13.75 mg/L. $CO_2$ values of 6.5 mg/L has been reported for Dilimi river by Anadu and Akpan (1986) while Ude (2012) reported a range of 1.20 and 3.14 mg/L in all his four sample stations in his study. Cole and Prairie (2009) explained carbon as dissolved inorganic carbon (DIC) stating that it is present in all natural waters in the form of free $CO_2$. As a poisonous gas, carbon dioxide is harmful to most animals. Levels of 30 ppm (parts per million or mg/L) are harmful to most organisms. Values greater than 35 ppm is considered limiting to all aquatic organisms. This supports the inference from this study that the $CO_2$ values did not exceed the safe limit. $CO_2$ should not occur in high concentrations because it has been established that a high level of carbon (IV) oxide usually indicates the presence of dead natural materials undergoing decomposition which could result to water pollution or anoxic conditions (Kotoski, 2003). Also, rivers and lakes act as $CO_2$ sinks, as shown by Cai (2003); as the plants photosynthesize in the day, $CO_2$ is removed from the medium. Paquay et al., (2007) stated in two river analysis that water residence time, groundwater inputs and occasional flood events are the predominant drivers of the spatial and temporal patterns in the distribution of carbon (IV) oxide pressure in the environment ($pCO_2$) causing an oversaturation in rivers and an under saturation in the estuary. Hence, $CO_2$ enter the water by natural means.

Alkalinity also influences water pH. It is simply a measure of the acid binding capacity of the water also termed, the buffering capacity. The Nun River recorded rates at acceptable ranges making the river water productive at a range of 37.5 – 72.0 mg/L. Generally at high pH, alkalinity is at good rate thus, carbon will be present in a carbonate form which triggers a buffer action. Apparently, waters with low alkalinity are poorly buffered against pH changes and so fish for instance, are more susceptible to some chemicals in water condition with low alkalinity. Thus, the amount of acid required to cause a specified change in pH in a given volume of water increases as a function of the total alkalinity in the water. An alkalinity range of 50 – 300 mg/L is recommended by Boyd and Lichtkoppler (1979) as productive for fish production.

Water acidity on the other hand, represents the reduced acid binding capacity of the water or the inability of water to buffer acid (Hanna Test Kit Teacher's Guide, 2016). This means that the alkalinity of the water body should not be less than the acidity in any given time of water quality assessment to ensure good water quality criteria. In this analysis, the TA values exceeded the acidity values indicating good water quality criteria for Nun River (37.5 – 72.0 mg/L of TA and 5.0 – 35.0 mg/L of acidity – see Table 1).

On a general note, the acidity, total alkalinity (TA) and total hardness (TH) of the Nun river water recorded significant differences. There were no specific trends in the increase or reduction in the concentration of these parameters with respect to seasons (wet and dry). In other words, high and low values were recorded in the dry season as well as in the wet season for the three parameters showing that the acidity, alkalinity and total hardness of the river water were not season dependent. Seasonal variability of surface waters has also been observed after a study in Ebonyi river by Ude (2012). For Nun river, TA and TH fell within ranges of 20 – 100 mg/L recommended for freshwater ecosystems with the highest values of 72 mg/L and 67 mg/L respectively and lowest values of 37.5 and 34.5 mg/L respectively. In other words, the Nun River water is well buffered and has high neutralization capacity against pulsating effects of pH.

The dissolved oxygen values reported in this study has shown stable DO in the lower reach of the Nun River. In aquatic systems, the distribution of oxygen (DO) is one factor that influences fish distribution (Goldberg, 1975) and migration. Migration here can be lateral or vertical in search of dissolved oxygen. Low DO beyond tolerable rates (< 5mg/L) can induce retarded growth rate and this may be lethal at 1 – 3 mg/L if prolonged (Ugwu and Mgbenka, 2006). From the results on Nun River, DO records exceeded the safe limit of 5 mg/L. This will stabilize species diversity and richness.

Turbidity of the Nun river did not follow a particular pattern such as seasonality because the low values were recorded for the first six months (27.50 – 31-25 cm) while higher values occurred from July to December (5.25 – 19.75 cm). The highest mean value for secchi disc reading of 31.25 cm was reported during the onset of rainy season in April while low values of 7.40, 5.75 and 5.25 cm was recorded in July, August and September respectively which may be attributed to a period of drains from upstream run-offs. Turbidity could be caused by siltation or by algal bloom. When it is caused by heavy siltation as in the case of the Nun River during the rainy season, the gills of the fish could be clogged and may lead to mechanical injury to fish and possible asphyxiation. Nonetheless, out of the 12 months analyzed, about 3 months recorded very poor transparency of less than 10 cm secchi disc reading with 10 months out of the 12 months recording less than 30 cm secchi disc reading (Table 1) recommended for fish production (desirable range of 30 – 60 cm) (Bluwey et al., 2018). Therefore, turbidity (secchi disc reading) less than 30 cm means high particles and high aphotic zone (area of low light penetration) which hampers light penetration for photosynthesis since it represents the clarity or cloudiness of the water body.

Dissolved oxygen was not adversely affected by turbidity as can be seen in the result (Table 2). The high turbid water usually limits light penetration which reduces photosynthetic activities of the planktons and submerged aquatic plants which release oxygen in the process as they take in carbon dioxide. DO occurred at recommended rates of > 5 mg/L for healthy culture medium for aquatic life to reduce stress and to enhance bioprocesses. Ling *et al*, (2017) reported seasonal impact on the water quality of the Bakun Reservoir by an outflow from upstream which influenced decrease in temperature, pH, dissolved oxygen and increased the turbidity and total suspended solids (TSS) downstream. The Nun River is impacted by run-offs during the wet season as high turbidity (low transparency) are recorded during the rains which results from run-offs from upstream. High nutrient content and organic load from these run-offs may consume a lot of oxygen for decomposition processes which affects the dissolve oxygen level available for the living organisms in situ.

High TDS also may be harmful to aquatic life, clog gills and hamper light penetration for photosynthesis (Alabaster and Lloyd, 1980; Ude, 2012) just like in turbidity. However, weak and negative correlation occurred between these two parameters. This could be attributed to the fact that turbidity is linearly related to total suspended solids (Hannouche, A., Chebbo G., Gwenaël R., Bruno T., Bruno J. Lemaire, *et al*.., 2012) and not dissolved solids. Palmer and O'Keefe (1990) has published a recommended limit not more than 120 mg/L of TDS to be ideal to support aquatic life or it will be harmful for fisheries production. This report has shown that the

TDS for Nun river fell below the safe limit of 120 mg/L with the highest value at 67.0 mg/L recorded for the month of November (Table 1).

The correlation between TDS and temperature at (r = 0.544477053) was positive. The warmer the medium the more solute will dissolve. Conductivity and TDS was positive and strong (r = 0.870021322). The more solutes are dissolved the more ions are dissociated and free which are liable to conduct electrical charges which translates to their ionization potentials. According to Wheland (1975), electrical conductivity in charge transfer complexes require some electron transfer from donors to acceptors stating that the amounts of ion that theoretically could be present in solution for instance, also depend on redox potentials which is proportional to conductivity. According to Goncharuk *et al. (*2010), 'the relationship between the oxidized and reduced forms of a substance in water is characterized by the ORP value' thus, determining the chemical composition of water under equilibrium conditions is ideal. For example, the oxygen and chlorine are oxidizers and so accept electrons when present in water thus, making them possess high electric potentials. In other words, reducing agents such as ammonia and other organic compounds possess low electric potentials, hence, translates to low ORP values. Basically, the amount of an element (e.g. iron) in solution in natural water in a balanced ecosystem is related to the water pH and redox potentials (Eh) of the solution (which is influenced by the conductivity). According to Boyd (2015), total hardness (the amount of divalent ions) of a water sample can be calculated from the known ionic composition of the water. In order words, redox potentials of dissolved components and their ability to dissociate and unite to form other species which may have synergistic or antagonistic effect which impacts the environment accordingly thus determines the sanity of the water body.

The correlation results showed that pH and DO (r = 0.577224514) correlated positively which is the opposite situation for pH and $CO_2$ (r = -0.770775496) which correlated negatively. Therefore, high pH favours dissolution of oxygen while low pH is influenced by $CO_2$ dissolution. The correlation between DO and $CO_2$ was negative though not strong. The more DO in the medium shows the incidence of high water recharge which influence the conversion of carbonic acid to atmospheric carbon gas which is released into the atmosphere at the water-air interface (Schrope, 2012) and/or the removal of $CO_2$ by photosynthesis which releases oxygen into the medium causing the two parameters to be inversely proportional in the medium. High oxygen content in fish culture medium do not just only enhance the availability of DO for the organisms, it also translates to high ORP (Horne and Goldman, 1994; Wetzel, 1983) and low BOD which depicts cleaner and healthier environment for aquatic life. Finally, this shows the Nun River water quality condition is not outside tolerable ranges for a tropical aquatic environment thus presents a healthy freshwater ecosystem for sustainable management of the fisheries resources.

## CONCLUSION

The study on the Nun River revealed that the water quality parameters analyzed were at tolerable ranges for this freshwater environment except turbidity. The water pH occurred at safe levels making other parameters more stable since pH influences most physco-chemical parameters such as the solubility of gases, metals and ionization potentials of the medium. This is important for acidification effects of carbon dioxide, buffering effect of the acid neutralizing components such as the TA and TH and redox potentials. Although the values of turbidity varied greatly even below the legal limit for healthy surface water, care should be taken in river bank management and farming activities on the adjoining farmlands to reduce loose soils movements and river bank erosions during rainy season. Thus, the water quality status of these surface waters is recommended for routine check of these parameters to assess them in the light of the stipulated standards for better environmental and sustainable management of aquatic resources.



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