# Epilithic Soft Algae of Dilimi River in Jos, Nigeria

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**Abstract:** River Dilimi flows through urban areas in Jos, Nigeria. As a result of this, a lot of human-generated pollutants find their way into the river. The locals attach a lot of socio-economic importance to the river. But the scientific community has shown minimal interest in the ecology of the river. Hence, there is a dearth of information in the literature about the biotas (especially soft algae) that inhabit the river. Epilithic soft algae were sampled from the river at two sites (an upstream site close to British-America bridge, and a downstream site at the pedestrian bridge, Unijos permanent site). Nutrients (N and P), biochemical oxygen demand (BOD), conductivity, and total dissolved solids (TDS) levels were relatively higher at the downstream site, which suffers more from anthropogenic pollution. Seven Divisions of soft algae were registered during this study. Cyanobacteria, Charophyta, Chlorophyta and Dinophyta were recorded at the upstream site. The fore-mentioned Divisions (excluding Dinophyta) plus Euglenophyta, Ochrophyta and Cryptophyta were observed in samples collected at the downstream site. Cyanobacteria was the most common group of soft algae at the upstream site with 82 % occurrence. At the downstream site, Chlorophyta was the most common group with 35 % occurrence, followed by Cyanobacteria (29 % occurrence) and Euglenophyta with 16 % occurrence. A total of 78 species of soft algae were recorded in this study. The downstream site was richer in species (57 species vs. 30 species at the upstream site), and had a higher diversity index value (3.89 vs. 2.67 Shannon index at the upstream site). The community similarity index between the two sites was low (11.5 %). This study is the first to describe the community of soft algae in River Dilimi, a grossly polluted river. Hence, the documented soft algae could be described as pollution tolerant organisms.
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**Keywords:** Dilimi River; epilithic soft algae; Nigeria; pollution tolerant organisms

## 1. Introduction

In lotic ecosystems, due to the main unidirectional flow of water, the first signs of eutrophication may be detected by changes in the periphytic community [1, 2]. And because the first signs of change often occur in attached communities [3, 4, 5], the biological monitoring of periphyton has been deemed a useful tool in the detection of anthropogenic impacts on rivers and streams. Occurrence and changes in the composition of periphytic species [6, **7**, 8] are closely associated with environmental pollution [9]. Periphyton is, also, sensitive to the amount and type of pollutants. For example, species composition and abundance of periphyton have been reported to be highly dependent on the nitrogen/phosphorus (N:P) ratio [10].

Soft algae communities, as a constituent of periphyton, contribute immensely to the biodiversity associated with lotic ecosystems. They grow on pebbles, stones, boulders and bedrocks in rivers and other aquatic ecosystems. They form the basis of the aquatic food, and act as natural purification agents of freshwater bodies, since they absorb nutrients and other pollutants. They are very responsive to degradation of water quality (often changing in both taxonomic composition and biomass where even slight contamination occurs). They can proliferate when high concentrations of nutrients occur in the water and velocities are low. They can provide habitat for many other organisms, especially rotifers [see 11, 12, 13]. They, thus, serve as micro environmental indicators of physical, chemical, and biological disturbances that occur in lotic ecosystems [see 12], and, hence, serve as indicators of biological integrity of freshwater bodies [e.g. 14, 15, 16, 17].

River Dilimi originates from the Jos Plateau and passes through five other Nigerian states (Jigawa, Kano, Yobe, Borno and Bauchi, where it is has acquired different names such as Hadejia, Jama'are, Kamadugu and Yobe River) before finally emptying into Lake Chad. The river supports several socio-economic activities of the locals [see 18, 19]. The people fish, wash clothes and bath in the river. They also harvest water from the river for domestic use, agriculture and block moulding. Farmers and vegetable-mongers wash harvested vegetables in the river before taking them to the market. However, irrespective of the diverse uses of the Dilimi River by the locals, the scientific community has paid little attention to the river [20]. Hence, the ecology, biology and taxonomy of biotas inhabiting the river are not well studied. Soft algae of the river have, hitherto, not been studied and reported in the literature.

This work was designed primarily to take an inventory of epilithic soft algae in the River Dilimi, using two sampling sites that served only as reference sites. Hence, samples collected for each site was pooled to form a composite sample. For this kind of study, many researchers [e.g. 21-23] suggest the collection of a single composite sample for each study location.

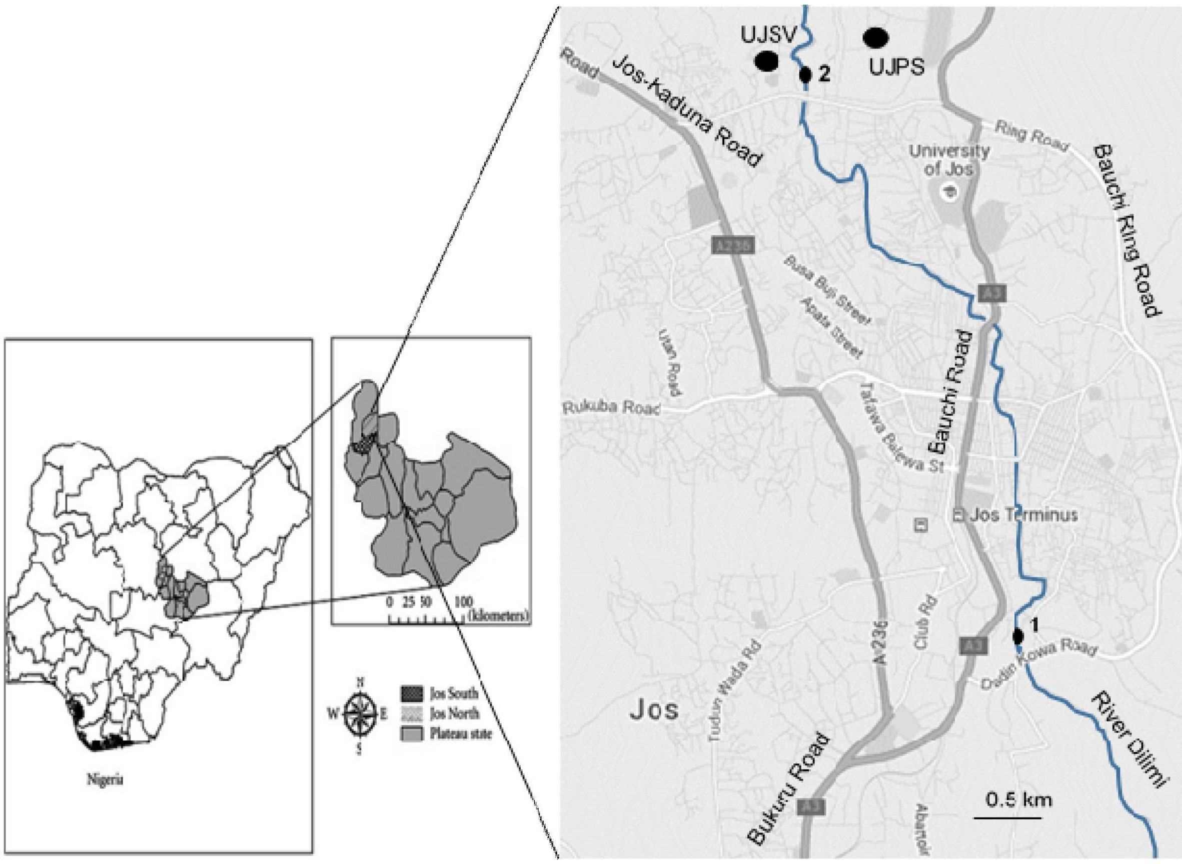


Figure 1. A section of Jos town showing River Dilimi and the study sites [1: upstream; 2: downstream; UJSV: University of Jos (Unijos) Students' Village; UJPS: Unijos Permanent Site]. Modified from Adebajo et al [68]

## 2. Material and Methods

### 2.1. Study Area

The urban section of Dilimi River runs through Jos North Local Government Area of Plateau State, Nigeria (Figure 1). Two sampling sites that included an upstream sampling station at about 200 m away from (and downstream of) the British-American bridge, and a downstream sampling location at the University of Jos students' pedestrian bridge, which links the University of Jos Students' Village (located on the left bank of the river) with the university's permanent site on the right bank. The area adjacent to the river banks at the British-American axis (because of the massive granite rocks that dot the area) have comparatively sparse human populations than the area adjacent to the river banks at the downstream axis (i.e. from ca. 400m after the British-American bridge to the students' pedestrian bridge at the permanent site of the University of Jos). By the time the river reaches the permanent site of the University of Jos, it has passed through many densely populated poor neighbourhoods of Jos town, where houses and yards have direct link with the river, and the flood plains intensively farmed. A consequence of encroaching into the river banks was that in July 2012 the overflow of the river (after heavy rains) swept off many houses and farm lands that were situated along the banks [24]. Apart from these encroachments, the locals also defecate on the banks and in the river channel. Household organic and inorganic wastes, as well as wastes from business houses are ceaselessly emptied into the river by inhabitants of these poor neighbourhoods. The poor farming practices also enrich the river with nutrients and silt. The river water is, hence, discoloured throughout the year. In fact, the water has an odour.

### 2.2. Physico-chemical Parameters Studies

Temperature was measured on the spot using a mercury thermometer. Water conductivity, total dissolved solids (TDS) and pH were also measured on the spot with a multi-parameter water tester (HANNA® instruments). Nitrate nitrogen and phosphate phosphorus were equally measured on the spot with the JBL TESTSET™ reagents for iron, nitrate, and phosphates. Dissolved oxygen and biochemical oxygen demand ($BOD_5$) were determined by iodometric (Winkler) method [25]. Although I have already published the results elsewhere [see 20], they will still be shown in the present paper, because sampling for the two studies were carried out on the same day.

**2.3. Collection of Epilithic Soft Algae**

According to Stevenson [21], periphyton samples should be collected during periods of stable flow, since high flows can scour the substratum and result in flushing off the periphyton. Recovery after high discharge can be as rapid as seven days if severe scouring of the substrata did not occur [21]. Bearing this in mind, the two sites were sampled twice in May 2013. The first was before the first major rainfall of the year and the second was 10 days after the rainfall. Four submerged stones (one each from the riffles, runs, shallow pools and nearshore areas of the river) were sampled randomly at each sampling location, by wading into the river. Each stone was placed in a white laboratory tray. Soft algae were brushed off each of the stones, using a tooth brush and rinsed with limited quantity of river water. The cap of the sample holder (16.6 $cm^2$) was used to define a sampling circle on each stone, by placing it on the stone. A circular mark was scratched on the stone around the outside of the cap with the tip of a scalpel blade [26]. Soft algae were sampled within the circle. The samples were preserved with 4 % formalin. This study was planned with emphasis on the spatial composition of the algae, with reference to the study sites. Thus, even though epilithic algae were sampled at two different times, samples from stones at each sampling station were pooled to form a composite sample for that location. The pooled samples were transferred to 250 ml sample bottles and distilled water added to bring the sample volume to 200 ml.

**2.4. Identification and Enumeration of the Soft Algae**

Each sample bottle was moderately shaken in order to get a homogenous solution before taking 50 µl subsample for microscopic analysis – i.e. identification and counting of the soft algae. The 50 µl subsample was dropped on a plane microscope slide and carefully covered with a cover slip to exclude bubbles. The slide was then transferred to the microscope stage for the analysis. Stancheva *et al.* [27] suggested the use of plane microscope slide instead of a counting chamber for proper identification and counting of mixed microalgae species. Three hundred (300) soft algae units (cells or filaments) were identified to species level and enumerated at 400x magnification. Although larger counts may reduce uncertainties associated with organism counts [28], the benefit of increasing counts above 300 is not high [27]. The algae were viewed under randomly-selected six viewing fields, as suggested by Baffico *et al.* [29]. Several soft algae identification guides for freshwater ecosystems [including 26, 30-32] and the web were used in the identification of the species.

**2.5. Species Density**

Species density was calculated as follows: C/A = (TN x SV x ACS)/(AVS x NVF x VSS x SA), where C/A is the number of cells or filaments, as the case may be, per surface area of stone sampled; TN, total number of individuals; SV, sample volume; ACS, area of cover slip; AVF, area of viewing field at 400x magnification; NVF, number of viewing fields scanned; VSS, volume of subsample; and SA, surface area of stone sampled. The area of stone surface sampled was calculated as the surface area of an individual stone ($mm^2$) multiplied by the total number of stones sampled for that site [see 26].

**2.6. Percent (%) Composition of Soft Algae Species**

This was calculated for each species by dividing species density (C/A) of each species by the total density summed from values recorded for each of the species each site, and the result multiplied by 100. For example, % Composition of a species “A” was given as: A = (a/b) x 100 %, where: *a* is the calculated C/A for the species A, and *b* is ∑ C/A for a sampled location [e.g. 21].

**2.7. Species diversity**

Shannon Index (H’) was used to calculate the species diversity index at each study site. This was calculated thus: H’ = − ∑ [(ni/N) x ln (ni/N)], where: ni = number of individuals of each species (the $i^{th}$ species), N = total number of individuals for the site, and ln = the natural log of the number.

**2.8. Community Similarity index (%)**

The similarity index (%) of soft algae between the two sites was obtained by multiplying a calculated Jaccard index by 100. Jaccard Index (J) was calculated thus: J = sc/(sa + sb + sc), where: sa and sb are the numbers of species unique to samples a and b, respectively, and sc is the number of species common to the two samples.

**2.9. Student’s t-Test**

Paired Two Sample for Means t-Test [P(T<=t) two-tail] was performed to further test if differences observed in some of the data sets were statistically significant (α = 0.05).

## 3. Results

### 3.1. Physico-chemical Parameters Studies

Water temperature was lower than air temperature, but both depended on both cloud cover and time of the day (increasing as the sun rises on a cloudless sky). Temperatures were lower at the upstream site (23.8 $\pm$ 3.9 °C) than at the downstream site (27.8 $\pm$ 2.6 °C). Dissolved oxygen concentration was higher upstream (7.1 $\pm$ 0.07 mg $l^{-1}$) than downstream (4.3 $\pm$ 0.28 mg $l^{-1}$), but the difference was not statistically significant. Also, there was no statistically significant difference in TDS, Fe, NO3 and PO4 concentrations between the two sites. N:P ratio was lower downstream (0.8), and higher upstream (30). The river is weakly alkaline as observed from the pH readings. The difference in biochemical oxygen demand between the two sites was statistically significant. So, too, was the difference in conductivity levels (Table 1).

### 3.2. The soft algae

Four Divisions of soft algae (Cyanobacteria, Dinophyta, Charophyta and Chlorophyta) were recorded at the upstream site, and six (Cyanobacteria, Charophyta, Chlorophyta, Euglenophyta, Ochrophyta and Cryptophyta) at the downstream site (Tables 2 and 3). Cyanobacteria was the most common group among the soft algae community at the upstream site (Figure 2). At the downstream site Chlorophyta was the most common Division (Figure 3). Dinoflagellates, cryptophytes and ochrophytes were rare. Among the Cyanobacteria the genus *Gloeocapsa* was the most common of all the genera recorded with 45.23 % occurrence at the upstream site. Within the Division Euglenophyta, *Euglena* (11.16 %) was the most common genus with *E. viridis* (9.88 %) the most common species (Table 3). There was a total of 174,582 units of soft algae per square mm of stone surface at the upstream site, and 210,290 units $mm^{-2}$ at the downstream site. Species richness was higher at the downstream site than at the upstream site. A similar observation was made for species diversity (Shannon index). Community similarity index between the two sites was 11.5 % (Table 4).

**Table 1.** Physical and chemical properties of the sampling sites

| Parameter | Upstream | Downstream |
|---|---|---|
| Air Temperature (°C) | 26.3 $\pm$ 3.9 | 30.8 $\pm$ 2.6 |
| Water Temperature (°C) | 23.8 $\pm$ 3.4 | 27.8 $\pm$ 1.5 |
| Dissolved Oxygen (mg $l^{-1}$) | 7.1 $\pm$ 0.07 | $4.3^{ns1}$ $\pm$ 0.28 |
| $BOD_5$ | $0.75^{*1}$ $\pm$ 0.07 | 3.7 $\pm$ 0.14 |
| Fe (mg $l^{-1}$) | $0.05^{ns2}$ $\pm$ 0 | 0.65 $\pm$ 0.07 |
| $NO_3$ (mg $l^{-1}$) | $0.9^{ns3}$ $\pm$ 0.14 | 1.06 $\pm$ 0.08 |
| $PO_4$ (mg $l^{-1}$) | $0.03^{ns4}$ $\pm$ 0.14 | 1.3 $\pm$ 0.7 |
| $NO_3$:$P0_4$ ratio | 30 | 0.8 |
| pH | 7.8 $\pm$ 0.3 | 7.9 $\pm$ 0.4 |
| Conductivity (µs $cm^{-1}$) | $213^{*2}$ $\pm$ 1.41 | 512 $\pm$ 51.62 |
| Total Dissolved Solids (ppm) | $112^{ns5}$ $\pm$ 7.07 | 257 $\pm$ 26.16 |

N/B: ns = not statistically significant; * = statistically significant; $ns^1$ paired t(1) = 11.4, p = 0.056; $ns^2$ paired t(1) = 12, p = 0.053 ; $ns^3$ paired t(1) = 1, p = 0.50; $ns^4$ paired t(1) = 2.49, p = 0.24; $ns^5$ paired t(1) = 10.7, p = 0.059 $*^1$ paired t(1) = 19.67, p = 0.032; $*^2$ paired t(1) = 19.67, p = 0.03

## 4. Discussion

### 4.1. Physical and Chemical Parameters

Water temperature was lower than that of air, and increased as the sampling time approached noon. Data and sample collections were carried out on the same day, beginning from the upstream site, between 09:00and 12:00 hours. The foregoing explains why temperature was relatively higher at the downstream site. Although the difference in dissolved oxygen concentration at the two sites was not statistically significant, the higher mean BOD value at the downstream site corroborates the findings associated with nutrient concentration at the two sites. The downstream site is subjected to more nutrient loads than the upstream site. The increased nutrient load downstream (especially of organic pollutants) has the potential to cause an increase in bacteria load. An increase in bacteria load would lead to an increase in bacterial activity, which will, in turn, quicken the consumption of dissolved oxygen [see 33]. The major source of N and P loadings in the downstream section of the study site is untreated sewage from homes, business centres, and direct defecation on the river banks and in river channel. Phosphorus enrichment, for example, is associated with increased microbial biomass and activity, resulting in faster rates of decomposition and nutrient cycling downstream of aquatic ecosystems [e.g. 34]. Jarvie *et al.* [35] observed that phosphorus treatment at selected major sewage treatment works in the upper Thames basin in the UK resulted in significant reductions in in-stream P concentrations. There is no such treatment plant associated with the Dilimi River. The findings in this study are in line with the observation that nutrient enrichments are major water quality concerns in lotic ecosystems [see 36-38]. Soil tillage and fertilizer applications are also common practices along the downstream axis of the study site. These habits indirectly load soil materials and nutrients into the river, via runoff. Control measures for runoff loading of both N and P would include containment and treatment of manure, decreased use of fertilizers, and a control of soil tillage practices [see 37].

**Table 2.** Density and % composition of epilithic cyanobacteria, euglenophytes, and charophytes at the study sites

| **Taxon** | **Density Upstream Units/mm$^2$ (%)** | **Density Downstream Units/mm$^2$ (%)** |
|---|---|---|
| **Cyanobacteria** | | |
| *Aphanizomenon flos-aquae* **Ralfs ex Bornet & Flahault** | 2934 (1.68) | 5624 (2.67) |
| *Chamaesiphon incrustans* **Grunow** | 3179 (1.82) | |
| *Coelosphaerium aponina* **Kützing** | 3179 (1.82) | |
| *Coelosphaerium naegelianum* **Unger** | | 2690 (1.28) |
| *Gloeocapsa punctata* **Nägeli** | | 4890 (2.33) |
| *Gloeocapsa rupestris* **Kützing** | 51345 (29.41) | |
| *Gloeocapsa sanguinea* **(C. Agardh) Kützing** | 3179 (1.82) | |
| *Gloeocapsa turgida* **(Kützing) Hollerbach** | 24450 (14.00) | 4646 (2.21) |
| *Hyella fontana* **Huber & Jadin** | | 3668 (1.74) |
| *Lyngbya major* **Meneghini ex Gomont** | | 6113 (2.91) |
| *Lyngbya martensiana* **Meneghini ex Gomont** | 4157 (2.38) | |
| *Microcoleus lacustris* **Farlow ex Gomont** | 2934 (1.68) | |
| *Microcystis aeruginosa* **(Kützing) Kützing** | 3179 (1.82) | |
| *Nodularia spumigena* **Mertens ex Bornet & Flahault** | 19560 (11.20) | |
| *Nostoc entophytum* **Bornet & Flahault** | | 2934 (1.40) |
| *Oscillatoria jasorvensis* **Vouk** | 4890 (2.80) | 4646 (2.21) |
| *Oscillatoria limnetica* **Lemmermann** | 2934 (1.70) | |
| *Oscillatoria platensis* **(Gomont) Bourrelly** | 3668 (2.10) | 2690 (1.28) |
| *Oscillatoria simplicissima* **Gomont** | | 3179 (1.51) |
| *Plectonema tomasianum* **Bornet ex Gomont** | | 3668 (1.74) |
| *Pseudanabaena minuta* **Skuja** | | 2690 (1.28) |
| *Rivularia biasolettiana* **Meneghini ex Bornet & Flahault** | 6113 (3.50) | 2445 (1.16) |
| *Stigonema mamillosum* **C. Agardh ex Bornet & Flahault** | | 7336 (3.49) |
| *Synechococcus leopoliensis* **(Raciborski) Komárek** | | 3912 (1.86) |
| *Synechocystis aquatilis* **Sauvageau** | 3668 (2.10) | |
| **Charophyta** | | |
| *Closterium aciculare* **T. West** | | 2934 (1.40) |
| *Closterium ehrenbergii* **Meneghini ex Ralfs** | | 3179 (1.51) |
| *Cosmarium candianum* **Delponte** | 734 (0.42) | |
| *Cosmarium circulare* **Reinsch** | 1956 (1.12) | 2934 (1.40) |
| *Cosmarium cucurbita* **Brébisson ex Ralfs** | | 1467 (0.70) |
| *Cosmarium margaritiferum* **Meneghini ex Ralfs** | 2690 (1.54) | |
| *Cosmarium praemorsum* **Brébisson** | | 2690 (1.54) |
| *Cylindrocystis brebissonii* **(Ralfs) De Bary** | | 2934 (1.36) |
| *Euastrum montanum* **West & G.S. West** | | 734 (0.42) |
| *Gonatozygon monotaenium* **De Bary** | | 2690 (1.28) |
| *Mougeotia floridana* **Transeau** | | 4157 (1.98) |
| *Netrium digitus* **(Brébisson ex Ralfs) Itzigsohn & Rothe** | | 2690 (1.28) |
| *Penium polymorphum* **(Perty) Perty** | | 3423 (1.63) |
| *Spirogyra gracilis* **Kützing** | 2690 (1.54) | 2690 (1.28) |
| *Staurastrum anatinum* **Cooke & Wills** | | 978 (0.47) |
| *Staurastrum cingulum* **(West & G.S.West) G.M.Smith** | | 1956 (0.93) |
| *Staurastrum paradoxum* **Meyen ex Ralfs** | 1223 (0.70) | |
| *Zygnema stellinum* **(O.F.Müller) C.Agardh** | 1712 (0.98) | |
| *Zygogonium ericetorum* **Kützing** | 8313 (4.76) | |

**Table 3.** Density and % composition of epilithic chlorophytes, dinophytes, cryptophytes and ochrophytes at the study sites

| **Taxon** | **Density Upstream** Units/mm$^2$ (%) | **Density Downstream** Units/mm$^2$ (%) |
|---|---|---|
| **Chlorophyta** | | |
| *Botryococcus braunii* **Kützing** | | 3423 (1.63) |
| *Bulbochaete* sp. | | 6113 (2.90) |
| *Chlamydomonas acidophila* **Negoro** | | 2690 (1.28) |
| *Chlamydomonas stellata* **O. Dill** | | 2690 (1.28) |
| *Chlamydomonas* sp | | 2690 (1.28) |
| *Chlorella vulgaris* **Beyerinck [Beijerinck]** | 2690 (1.54) | 2690 (1.28) |
| *Cladophora* sp. | | 3668 (1.74) |
| *Coelastrum cambricum* **W. Archer** | | 2934 (1.40) |
| *Coelastrum microporum* **Nägeli** | 978 (0.56) | |
| *Eremosphaera viridis* **De Bary** | | 3423 (1.63) |
| *Eudorina elegans* **Chodat** | | 2690 (1.28) |
| *Geminella minor* **(Nägeli) Heering** | | 3668 (1.74) |
| *Gongrosira incrustans* **(Reinsch) Schmidle** | | 1223 (0.58) |
| *Monoraphidium* sp. | | 2690 (1.28) |
| *Oedogonium acrosporum* **De Bary ex Hirn** | 2934 (1.68) | |
| *Oedogonium anomalum* **Hirn** | | 2690 (1.28) |
| *Oedogonium subellipsoideum* **Tiffany** | | 2690 (1.28) |
| *Oocystis lacustris* **Chodat** | 2690 (1.54) | 3179 (1.51) |
| *Pediastrum tetras* **(Ehrenberg) Ralfs** | | 3423 (1.63) |
| *Quadrigula pfitzeri* **(Schröder) G.M.Smith** | | 3668 (1.74) |
| *Scenedesmus arcuatus* **(Lemmermann) Lemmermann** | | 4401 (2.09) |
| *Schizomeris leibleinii* **Kützing** | | 2690 (1.28) |
| *Sphaerocystis schroeteri* **Chodat** | | 4890 (2.32) |
| *Stigeoclonium aestivale* **(Hazen) Collins** | | 7336 (3.49) |
| *Trentepohlia umbrina* **(Kützing) Bornet** | 734 (0.42) | |
| **Cryptophyta** | | |
| *Cryptomonas ovata* **Ehrenberg** | | 2690 (1.28) |
| **Dinophyta** | | |
| *Gymnodinium rotundatum* **Klebs** | 2445 (1.40) | |
| **Euglenophyta** | | |
| *Colacium cyclopicola* **(J.Gicklhorn) Woronichin & Popova** | | 2445 (1.16) |
| *Euglena viridis* **(O.F.Müller) Ehrenberg** | | 20783 (9.88) |
| *Euglena anabaena* **Mainx** | | 2690 (1.28) |
| *Phacus unguis* **Pochmann** | | 3668 (1.74) |
| *Trachelomonas* sp. | | 3912 (1.86) |
| **Ochrophyta** | | |
| *Ophiocytium cochleare* **(Eichwald) A.Braun** | | 2690 (1.28) |
| *Vacuolaria virescens* **Cienkowski** | | 2690 (1.28) |

Though many researchers are of the opinion that P is the major pollutant that constrains algae production in freshwater ecosystems [see 37, 39], a comparison of results of algal bioassays and nutrient concentrations in freshwater bodies suggests that an N:P ratio above 17 indicates P limitation, a ratio below 10 indicates N limitation and values between 10 and 17 indicate that either of the nutrients may be limiting [see 34, 40-44]. From the foregoing it could be stated that at the study sites, P is the limiting nutrient upstream, and N downstream.

While the differences in both $NO_3$ and $PO_4$ concentrations at the upstream and downstream sites were not statistically significant, the concentrations recorded for these compounds during this study (and the filthiness of the immediate surroundings of the river) suggest that the section of the river studied is actively polluted. It has been argued that nitrate-nitrogen concentrations above 3 mg $l^{-1}$ and any detectable amounts of total phosphorus (usually above 0.025 mg $l^{-1}$) may be indicative of pollution from fertilizers, manures or other nutrient-rich wastes [see 45]. The downstream site is affected by a heavily populated and largely poor neighbourhood with a very poor sanitary habit. The amount of municipal wastes and raw sewage from these settlements that find their way into Dilimi River (though yet to be quantified and reported in the literature) is disturbing [20].

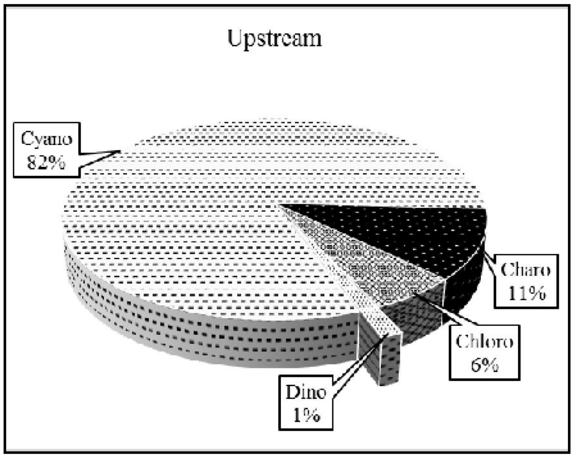


**Figure 2.** Composition (%) of soft algae upstream (Cyanobacteria 82, Charophyta 11, Chlorophyta 6, & Dinophyta 1)

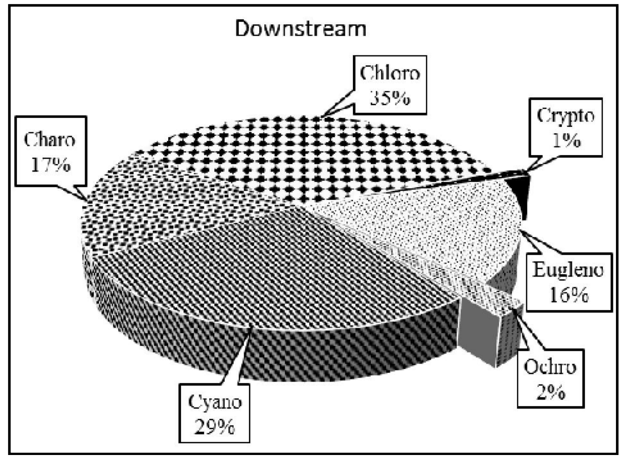


**Figure 3.** Composition (%) of soft algae downstream (Chlorophyta 35, Cyanobateria 29, Charophyta 17, Euglenophyta 16, Ochrophyta 2, & Cryptophyta 1)

**Table 4.** Species richness, diversity and % community similarity indices of epilithic soft algae at the sampling sites

| Index | Upstream | Downstream |
|---|---|---|
| Species Richness | 30 species | 57 species |
| Shannon (H') | 2.67 | 3.89 |
| Community Similarity (%) | 11.5 | |

The river is weakly alkaline and, thus, (in the absence of pollution) has the capacity to support many forms of aquatic life. The large number of species of soft algae witnessed during this study supports this assertion. This is in contrast to acidic freshwater bodies, which are characterized by benthic algal communities with low diversity [29, 46]. The high electrical conductivity and TDS values witnessed at the downstream site are indications that this section of the river had more solutes (including chemical ions) than the upstream site. Human activities greatly impact the conductivity and concentration of TDS in lotic ecosystems. As earlier noted, the downstream section of the river is heavily loaded with domestic and industrial wastewater, and untreated sewage, as well as suffers impact from poor farming practices on the floodplains. Most probably, a high bacterial activity (mineralisation of organic wastes) must have played a role in the elevation of EC and TDS at the downstream site.

**4.2. The Soft Algae**

Hitherto, there is no information in the literature on soft algae in Dilimi River, Jos, Nigeria. This observation is not unique to the river. For example, Potapova [47] reported that the taxonomy and ecology of many riverine algae in North America have yet to be studied, just as Porter [48] observed that the autecology of soft algae is poorly understood. Many researchers in Nigeria work on planktonic algae [e.g. 49, 50]. Only a few [e.g. 51] work on attached algae in lotic ecosystems. Although Tiseer et al. [51] sampled phytoplankton and attached algae in the Samaru Stream in Zaria, Nigeria, their report failed to show which algae where planktonic and which were periphytic. This made it difficult for any comparison to be made between periphytic soft algae species in Samaru Stream and those in Dilimi River.

The downstream site of the Dilimi River was richer in species and had a higher species diversity index than the upstream site. The comparatively higher nutrient loads (pollutants) at the downstream axis of the river must have contributed to these findings. Pearson and Rosenberg [33] and Krewer and Holm [52] are of the opinion that if pollutants are readily available as food for algae, they will easily bring about an increase in population via bio-stimulation. And results from several bioassay techniques have demonstrated benthic algal growth stimulation with additions of P [52, 53], N [54], and both P and N [55, 56].

The soft algae in the study sites could be referred to as pollution-tolerant algae (see 15, 33, 47, 57-59]. Although species of *Cladophora* do have contrasting ecological preferences [26], the genus is often associated with eutrophication [see 60]. Similarly, species of *Closterium* [57, 61], *Chlorella* [47, 57, 62, 63], *Cosmarium* [57], *Oedogonium* [47], *Oscillatoria*, [64], *Scenedesmus* [13, 62, 65, 66], *Stigeoclonium,* [13, 59], and *Euglena* [67] have been cited as indicators of polluted waters.

## 5. Conclusion

The present study succeeded in qualifying and quantifying epilithic soft algae in the Dilimi River. The study also presented some autecological information about the soft algae. In view of the fact that the section of the River Dilimi studied is nutrient-enriched, the soft algae recorded in this study could be described as pollution tolerant algae.

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