Epilithic diatoms of urban River Dilimi, Jos, Nigeria

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Abstract: For a long time now, diatoms have been used to determine the ecological integrity of freshwater bodies. Despite the ecological significance of diatoms in freshwater bodies, the taxonomic composition and autecology of diatoms in many freshwater bodies of Nigeria are yet to be investigated. The present work was carried out to ascertain the taxonomic composition of epilithic diatoms of River Dilimi in Jos, Nigeria. The physical and chemical properties of the river at two urban stations (were diatoms were sampled) were also determined. Mean NO_3 (mg l^{-l}) was 0.9 ($\pm$ 0.14) at the upstream station and 1.06 ($\pm$ 0.08) at the downstream station. Mean PO_4 (mg l^{-l}) was 0.03 ($\pm$ 0.14) at the upstream station and 1.3 ($\pm$ 0.7) at the downstream station. A total of 28 diatom genera and 83 species were documented from the study sites. Out of the 83 species, 59 occurred at the upstream site and 45 at the downstream site. The percent community similarity between the two sites was 24.71 %. At the upstream site the most common species were *Meridion circulare* (3.5 %), *Navicula mutica* (3.6 %), *Nitzschia amphibia* (3.0 %) and *Synedra ulna* (3.4 %). At the downstream site the most common species were *Cyclothella meneghiniana* (4.4 %), *Nitzschia amphibia* (8.8 %), *Nitzschia palea* (5.0 %), *Synedra ulna* (12.8 %), *Tabellaria fenestrate* (3.8 %) and *Tabellaria flocculosa* (3.1 %). Since both NO_3 and PO_4 concentrations in the river indicate that the river is polluted, the diatoms recorded in this study may be grouped as pollution tolerant diatoms, bearing in mind, too, that the river water is discoloured throughout the year.

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1. Introduction

Awareness of the deleterious effects of human pressures on aquatic environments has resulted in a long history of monitoring of freshwater bodies using biological indicators (Hellawell, 1986; De Pauw and Hawkes, 1993; Rosenberg and Resh, 1993; Knoben et al., 1995). Monitoring of the quality of running waters involve the use of several diatom-based indices (see Prygiel and Coste, 1993; Kelly and Whitton, 1995; Whitton and Kelly, 1995). Consequently, several studies have addressed the tolerances and preferences of diatoms along a number of environmental gradients (e.g. salinity, pH, trophy, saprobity and current preference; e.g. Denys, 1991a, b; van Dam et al., 1994; Rott et al., 1997).

Diatoms are a large and diverse group of single-celled microalgae. They are distributed throughout the world in nearly all types of aquatic systems and are one of the most important food resources in marine and freshwater ecosystems. Because there are many thousands of taxa with diverse ecological requirements, their siliceous remains are used extensively as environmental indicators in studies of climate change, acidic precipitation and water quality (see Stoermer and Smol, 1999; Potapova and Charles, 2002).

Despite the ecological significance of diatoms in freshwater bodies, the taxonomic composition and autecology of diatoms in many freshwater bodies in Nigeria are yet to be investigated. This is in agreement with the observations of Alfinito and Lange-Bertalot (2013) who noted that the freshwater diatom flora of Tropical West Africa is still poorly investigated. The present paper presents a report on the community composition of epilithic diatoms of an urban section of River Dilimi, to contribute to knowledge of freshwater diatoms in Nigeria. forests.

2. Material and Methods

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 pedestrian bridge, which links the University of Jos Students' Village (located on the left bank of the river) with the university's permanent site at the other bank. The areas adjacent to the river banks at the British-American axis of the river (because of the massive granite rocks that dot the area) have comparatively sparse human populations than those adjacent to the river banks at the downstream axis (i.e. from ca. 400m after the British-American bridge to the pedestrian bridge at the permanent site of the

University). By the time the river reaches the permanent site of University of Jos, it has passed through many densely populated poor neighbourhoods of Jos town, where houses and yards have direct links 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) washed away many houses and farm lands that were situated along the banks (Ezema, 2013). The locals defecate on the banks and in the river channel. House-hold organic wastes and wastes from business houses are ceaselessly emptied into the river by inhabitants of these poor neighbourhoods. The poor farming practices on the floodplains cause the river to be enrich with nutrients and silt. The water is discoloured throughout the year.

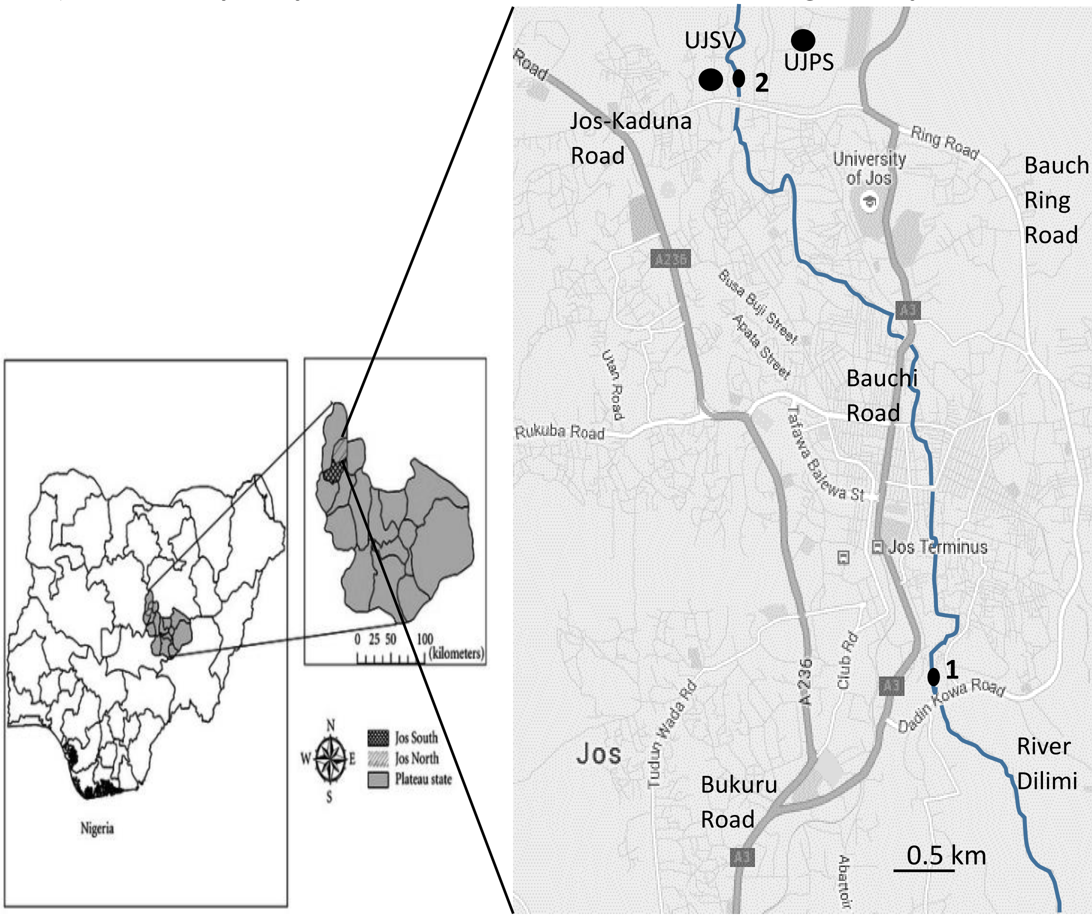

Figure 1: Study area with sampling sites 1 & 2 (N/B: UJSV = University of Jos Students' Village; UJPS = University of Permanent Site). Modified from Adebajo et al. 2012

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 (USGS, 2015).

Collection of epilithic diatoms

According to Stevenson (1990), periphyton samples should be collected during periods of stable flow, since high flows can scour the stream bed and result in flushing off the periphyton. Recovery after high discharge can be as rapid as seven days if severe scouring of substrata did not occur (Stevenson, 1990). Bearing this in mind, the two sites were sampled twice in May 2013. The first was before the first heavy rain of the year and the second was 10 days after the rain. 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. Diatoms 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 (Biggs and Kilroy, 2000). Diatoms were sampled within the circle. The samples were preserved with 4 % formalin. This study was planned with emphasis on the spatial composition of the diatoms, with reference to the study sites. Thus, even though diatoms were sampled at two different times, samples from stones at each sampling station were pooled to form a composite sample for that location (see Kelly et al., 1998; Fetscher et al., 2014). In the laboratory, the pooled samples were transferred to 250 ml sample bottles and distilled water added to bring the sample volume to 200 ml.

Table 1. Physical and chemical parameters measured at the sampling sites (means and standard deviations)

Parameter	Upstream	Downstream
Air Temperature (°C)	26.3 ± 3.9	30.8 ± 2.6
Water Temperature (°C)	23.8 ± 3.4	27.8 ± 1.5
Dissolved Oxygen (mg l^{-1})	7.1 ± 0.07	$4.3^{ns1} \pm 0.28$
BOD_5	$0.75^{*1} \pm 0.07$	3.7 ± 0.14
Fe (mg l^{-1})	$0.05^{ns2} \pm 0$	0.65 ± 0.07
NO_3 (mg l^{-1})	$0.9^{ns3} \pm 0.14$	1.06 ± 0.08
PO_4 (mg l^{-1})	$0.03^{ns4} \pm 0.14$	1.3 ± 0.7
NO_3:$P0_4$ ratio	30	0.8
pH	7.8 ± 0.3	7.9 ± 0.4
Conductivity (µs cm^{-1})	$213^{*2} \pm 1.41$	512 ± 51.62
Total Dissolved Solids (ppm)	$112^{ns5} \pm 7.07$	257 ± 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 $t(1) = 19.67$, $p = 0.03$)

Identification and enumeration of the diatoms

Each sample bottle was moderately shaken in order to get a homogenous solution before a subsample of 50 µl was taken for microscopic analysis, which involved identification and counting of the diatom species. 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 analyses. Stancheva et al. (2012) suggested the use of plane microscope slide instead of a counting chamber for proper identification and counting of mixed microalgae species. Three hundred (300) diatom cells were identified to species level and enumerated at 400x magnification. Although larger counts reduce uncertainty associated with organism counts (Birks, 2010), it has been shown that the benefit of increasing counts above 300 is not high (Stancheva et al., 2012). The diatoms were viewed under randomly-selected six viewing fields. Shear stress may be very high on stone surfaces in lotic freshwater bodies, resulting in patchy distribution of algae on substrates. This has permitted some workers to restrict the number of viewing fields to six (e.g. Baffico et al., 2004). Several diatom identification keys for freshwater ecosystems (including Durand and Leveque, 1980; Pentecost, 1984; Biggs and Kilroy, 2000) and the web were used in the identification of the species.

3. **Statistics**

Species Density

Species density was calculated thus: C/A = (TN x SV x ACS)/(AVF 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 number of stones sampled for that site (see Biggs and Kilroy, 2000).

Percent (%) composition of diatom species at the two sites

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 in the site sampled, and the result multiplied by 100; e.g. % Composition of a species "A" was given as: A = (a/b) x 100 %, where: *a* is the calculated C/A for species A, and *b* is $\sum$ C/A for a sampled location (e.g. Stevenson, 1990).

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: n_i = 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.

Percent (%) community similarity

After calculating H', the percent similarity index of sot algae in the two sites was calculated. This 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.

A 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 set were statistically significant ($\alpha = 0.05$).

4. Results

Physico-chemical parameters studies

The river water was discoloured throughout the sampling period (and is indeed discoloured throughout any given year). Mean water temperature was 23.8°C (upstream) and 27.8°C (downstream). These temperatures were, however, lower than air temperatures at the respective sites. Water temperature depended on the time of the day records were taken, with water temperature increasing as the sun rises. Though dissolved oxygen concentration was relatively higher at the upstream sampling site than at the downstream station, the difference was not statistical significant. Biochemical oxygen demand, on the other hand, was significantly higher downstream. There was no statistically significant difference in Fe, NO_3 and PO_4 concentrations at the two sites. However, NO_3 and PO4 concentrations were relatively higher downstream. N:P ratio approached unity (0.8) downstream, while upstream the ratio was 30:1. Both sites had similar pH readings, and which indicated that the river is weakly alkaline. Whereas conductivity was significantly higher at the downstream site than at the upstream station, the difference in TDS concentrations was not statistically significant (Table 1).

The diatoms

A total of 28 diatom genera and 83 species were documented from the study sites. Out of the 83 species, 60 occurred at the upstream site and 46 at the downstream site (Table 2). Thus, the upstream site was richer in species than the downstream site. The percent community similarity between the two sites was 24.71 %. Shannon diversity index was higher (4.06) at the upstream site than at the downstream site (3.27). These results are shown in Table 3. At the upstream site the genera *Gomphonema* and *Navicula* were the most common, and at the downstream site it was *Nitzschia* that was the most common genus (Table 4). The percent occurrence of the most common species at each of the two sites is presented in Table 5. At the upstream site the most common species were *Meridion circulare* (3.5 %), *Navicula mutica* (3.6 %), *Nitzschia amphibia* (3.0 %) and *Synedra ulna* (3.4 %). At the downstream site the most common species were *Cyclothella meneghiniana* (4.4 %), *Nitzschia amphibia* (8.8 %), *Nitzschia palea* (5.0 %), *Synedra ulna* (12.8 %), *Tabellaria fenestrate* (3.8 %) and *Tabellaria flocculosa* (3.1 %).

5. Discussion

Physical and Chemical Parameters

Water temperature was dependent on air temperature, which increased as the sampling time approached noon. Sample collections were carried out at the two sites on the same day between 09:00 and 12:00, beginning at the upstream site. The foregoing explains why water temperature was relatively higher at the downstream site. Although there was no statistically significant difference in dissolved oxygen concentrations between the two sampling sites, the higher BOD value at the downstream site could imply that the downstream site was subjected to more nutrient loads than the upstream site. This view is supported by the relatively high concentrations of NO_3 and PO_4 at the downstream site. The increase in nutrients, especially those of organic origin, will cause an increase in bacteria that degrade them. The increase in bacterial activity will, in turn, provoke a high BOD level (see Pearson and Rosenberg, 1978).

Table 2: Diatom species at the upstream and downstream sampling sites of River Dilimi, Jos

Diatom species	Presence (+) or Absence (-) Upstream site	Downstream site
Achnanthes exigua **Grun.**	-	+
Achnanthes exiguoides **Compère**	+	-
Achnanthes lanceolata (**Bréb.**) **Grun.**	-	+
Achnanthes linearis forma *curta* **H.L. Smith**	+	-
Achnanthidium cf. *latecephalum* **Kobayasi**	-	+
Achnanthidium minutissimum **(Kütz.) Czarn.**	+	+
Amphora ovalis (**Bréb.**) **Kütz.**	+	-
Amphora veneta var. *capitata* **Haw.**	-	+
Anomoeoneis sphaerophora (**Ehr.**) **Pfitzer**	+	-
Asterionella formosa **Hass.**	+	-
Brachysira sp.	+	-
Cyclotella meneghiniana **Kütz.**	-	+
Cyclotella stelligera (**Cl. & Grun.**) **Van Heurck**	-	+
Cymbella microcephala **Grun.**	-	+
Cymbella minuta **Hilse**	+	-
Cymbella ventricosa **Kütz.**	+	-
Diatoma hiemale var. *mesodon* **(Ehrenb.) Grun.**	+	-
Diatoma mesodon (**Ehr.**) **Kütz.**	+	-
Diatoma vulgare **Bory**	+	-
Diploneis gruendleri (**A.S.**) **Cl.**	-	+
Diploneis puella (**Schum.**) **Cl.**	+	-
Eolimna minima (**Grun.**) **Lange-Bert.**	+	+
Fragilaria construens (**Ehr.**) **Grun.**	-	+
Fragilaria vaucheriae **(Kütz.) Peters.**	+	-
Frustulia rhomboides (**Ehr.**) **De Toni**	+	-
Frustulia vulgaris (**Thwaites**) **De Toni**	+	-
Gomphonema affine **Kütz.**	+	-
Gomphonema angustatum **Kütz.**	+	-
Gomphonema augur **Ehr.**	+	+
Gomphonema gracile **Ehr.**	+	-
Gomphonema lanceolatum var. *insignis* (**Greg.**) **Cl.**	-	+
Gomphonema minutum (**Ag.**) **Ag.**	+	-
Gomphonema olivaceum **Lyng.**	+	+
Gomphonema parvulum (**Kütz.**) **Kütz.**	+	+
Gomphonema pumilum (**Grun.**) **Reich & Lange-Bert.**	+	-
Luticola mutica (**Kütz.**) **Mann** in **Round & al.**	+	+
Mastogloia smithii **Thwaites**	+	+
Melosira granulata (**Ehr.**) **Ralfs**	+	+
Melosira sulcata (**Ehr.**) **Kütz.**	+	-
Melosira varians **Ag.**	+	+
Meridion circulare **(Grev.) Ag.**	+	-
Navicula amphiceropsis **Lange-Bert.** & **Rumrich**	-	+
Navicula atomus **Nægeli**	+	+
Navicula capitoradiata **Germ.**	+	+
Navicula cincta (**Ehr.**) **Ralfs**	-	+
Navicula cryptocephala **Kütz.**	+	+
Navicula elegans **W. Sm.**	+	-
Navicula elkab **Müll.**	+	-

Table 2 contd.:

Navicula humilis **Donk.**	+	-
Navicula cf. *margalithii* **Lange-Bert.**	+	-
Navicula minima **Grun.**	+	-
Navicula mutica **Kütz.**	+	-
Navicula pygmaea **Kütz.**	+	-
Navicula radiosa **Kütz.**	+	-
Navicula ramosissima (**Ag.**) **Cl.**	+	-
Navicula seminulum **Grun.**	+	-
Navicula subrhynchocephala **Hust.**	+	-
Navicula tripunctata (**Müll.**) **Bory**	-	+
Navicula tripuctata var. *schizonemoides* **Van Heurck**	+	-
Navicula vaucheriae **Peters.**	+	-
Navicula veneta **Kütz.**	-	+
Neidium affine var. *genuina* **Cl.**	-	+
Neidium affine var. *genuine* forma *minor* **Cl.**	+	-
Nitzschia amphibia **Grun.**	+	+
Nitzschia capitellata **Hust.**	-	+
Nitzchia communis **Rabenh.**	+	-
Nitzschia compressa (**Bailey**) **Boyer**	-	+
Nitzschia dissipata **(Kütz.) Grun.**	+	+
Nitzschia epithemioides **Grun.**	-	+
Nitzschia kuetzingioides **Hust**.	-	+
Nitzschia palea (**Kütz.**) **W. Sm.**	+	+
Nitzschia perminuta (**Grun.**) **Perag.**	-	+
Nitzschia sublinearis **Hust**.	-	+
Pinnularia biceps **Greg.**	-	+
Pinnularia microstauron (**Ehr.**) **Cl.**	+	-
Pinnularia subcapitata **Greg.**	+	+
Pinularia viridis **Nitzsch.**	+	+
Pleurosira laevis (**Ehr.**) **Compère**	-	+
Rhoicosphenia curvata (**Kütz.**) **Grun.**	+	+
Sellaphora pupula (**Kütz.**) **Mereschk.**	+	+
Sellaphora sp.	-	+
Stauroneis crucicula (**W. Sm.**) **Donkin**	+	-
Synedra ulna (**Nitzsch) Ehr.**	+	+
Tabellaria flocculosa (**Roth**) **Kütz.**	+	+
Tabellaria fenestrata (**Lyng.**) **Kütz.**	-	+

The major source of N and P loadings in the downstream section of the study sites is untreated sewage from homes and business centres, as well as direct defecation into the river banks and 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. McCormick et al., 1998). Jarvie et al. (2002) 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. To my knowledge, there is no such treatment plant linked with the Dilimi River. Soil tillage and fertilizer applications are also common habits in the downstream axis of the river. This, without doubt, contributed soil materials and nutrients to the river via runoffs.

Inorganic nutrients and organic enrichments are major water quality concerns in streams and rivers (Porter et al., 2008). Nitrogen and phosphorus are nutrient sources that may cause increased growth of aquatic plants and algae. Hence, N and P from farmland runoff or industrial and municipal discharges have been associated with widespread and expanding eutrophication of freshwaters (Millennium Ecosystem Assessment, 2005; Carpenter, 2008). Carpenter (*op. cit.*) suggested that control measures for runoff of both

N and P would include decreased use of fertilizers, containment and treatment of manure, and tillage practices that conserve soil. Though many researchers are of the opinion that P appears to be the major pollutant that constrains algae production in freshwater ecosystems (Schindler, 1977; Carpenter, 2008), comparison of algal biotest results and chemical nutrient concentrations in lakes suggest that a mass 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 Ulén, 1978; Forsberg and Ryding, 1980; Fu and Winchester, 1994; Hellström, 1996; McCormick et al., 1998; Ekholm, 2008). From the foregoing it could be stated that in Dilimi River, P is the limiting nutrient at the upstream site, and N at the downstream station. This may have resulted from high organic pollution load downstream (see Kelly and Whitton, 1995).

Although the differences in both NO_3 and PO_4 concentrations at the upstream and downstream sites were not statistically significant, the values recorded for these compounds during this study suggest that the river is rich in N and P loads, and, hence, polluted. It has been argued that nitrate-nitrogen concentrations above 3 mg/L and any detectable amounts of total phosphorus (above 0.025 mg/L) may be indicative of pollution from fertilizers, manures or other nutrient-rich wastes (see Pond Facts #2 of Penn State Extension). The downstream site is located immediately the river course has passed through a heavily populated and largely poor neighbourhoods in Jos North Local Government. Some inhabitants of these neighbourhoods farm on the floodplains, tilling and applying fertilizers to the soil. Added to this, the amount of municipal wastes and raw sewage from these settlements that find their way into Dilimi River, particularly between the upstream sampling site and the downstream site (though yet to quantified and reported in the literature) is disturbing. Runoffs from these neighbourhoods empty tons of pollutants into this river every year.

The river is weakly alkaline at both sites. This might imply that the river is rich in biodiversity. The high number of diatom species documented during this study corroborates this statement. In contrast, acidic freshwater bodies are characterized by benthic algal communities with low diversity (Whitton and Diaz, 1981); and Baffico et al. (2004) reported that the epilithon of an acidic stream in Argentina was dominated (99% of total biomass) by one genus: *Gloeochrysis* (Chrysophyceae). 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. Electrical conductivity and the amount of TDS in a water body are controlled by many factors, including human activities within the immediate surroundings of the ecosystem. As earlier noted, the downstream section of the river is heavily impacted by the activities of the dense human populations along its course. The mineralisation of pollutants by bacteria will cause the river to have more solutes and, hence, elevated EC and TDS levels.

Table 3: Species richness, Shannon diversity and % community similarity of diatoms at the sampling sites of River Dilimi, Jos, Nigeria

Index	Upstream	Downstream
Species Richness	60 species	46 species
Shannon Index (H')	4.06	3.27
Community Similarity (%)	24.71	

Table 4: Percent composition of the most common diatom genera at the sampling sites

Diatom genus	% composition upstream	% composition downstream
Gomphonema	15.0	7.5
Navicula	28.0	12.0
Nitzschia	10.0	25.0

Table 5: Percent composition of the most common diatom species at the sampling sites

Species	% at upstream site	% at downstream site
Cyclothella meneghiniana	0	4.4
Gomphonema minutum	2.8	0
Gomphonema parvulum	2.8	2.8
Gomphonema pumilum	2.8	0
Meridion circulare	3.5	1.4
Navicula atomus	2.5	2.3
Navicula capitoradiata	2.7	2.0
Navicula mutica	3.6	0
Nitzschia amphibia	3.0	8.8
Nitzschia palea	2.6	5.0
Synedra ulna	3.4	12.8
Tabellaria fenestrata	0	3.8
Tabellaria flocculosa	1.5	3.1

The diatoms

The diatoms recorded in this study could well be described as pollution tolerant organisms. As already noted, the concentration levels of both N and P nutrient elements at the study sites suggest that the river is polluted. Kelly and Whitton (1995) observed that the genus *Achnanthes* is common across a wide range of conditions, and that *A. minutissima* is often the dominant diatom in oligo/mesotrophic rivers and streams, whereas *A. lanceolata* tends to be most common in more nutrient-rich conditions. In the present study, whereas *A. minutissima* appeared in both the upstream and downstream sites, suggesting a wide tolerance to concentrations of nutrients, *A. lanceolota* was only observed in the comparatively more nutrient-loaded downstream site; thus, corroborating the findings of Kelly and Whitton (1995). Similarly, *Achnanthes exigua* was present only in the downstream site, suggesting high tolerance to nutrient pollution. Wan Maznah and Mansor (2000) had described *A. exigua* as a pollution tolerant diatom.

Kelly and Whitton (1995) also reported that many forms of *Navicula* (and *Sellaphora)* are usually abundant in eutrophic waters, and that *Gomphonema parvulum* is a pollution tolerant species. These reports strengthen the conclusions drawn from the present study. Blinn and Herbst (2003) observed, too, that *Cyclotella meneghiana* is associated with conditions that define freshwater habitats with lower ecological integrity. Many species of *Nitzschia* (Kelly and Whitton, 1995; Blinn and Herbst, 2003), including *Nitzschia amphibia* and *Nitzschia palea* (Wan Maznah and Mansor, 2000) have been described as pollution tolerant species. *Synedra ulna* is also a pollution tolerant species (Lange-Bertalot, 1979).

6. Conclusion

The urban section of River Dilimi is polluted. Thus, the diatoms recorded in this study could be described as pollution-tolerant organisms.

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