The Thailand Natural History Museum Journal 14(2), 39-50, 30 June 2021

http:doi.org.10.14456/thnhmj.2021.4

# Diversity of Diatoms in Selected Rivers of Indang, Cavite, Philippines and their Correlation to Water Properties

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## ABSTRACT

Diatoms have been used as indicator of water quality degradation in freshwater systems. Hence, this study was conducted to assess the diversity level of diatoms in selected rivers of Indang, Cavite and correlate the presence of diatoms to the physico-chemical parameters of river water. Water samples were collected in the rivers of Brgy. Bancod, Calumpang Lejos, Tambo Kulit, Banaba Cerca and Brgy 2, Indang, Cavite. These rivers are partly exposed to sunlight and are covered with wide vegetation of ferns, grasses, shrubs and trees. The river water is clear, and the riverbed is composed of rock, mud and laid with mixed course of sand with a continuous river water flow. The physico-chemical parameters such as temperature, velocity, depth, width, pH, salinity, TSS, TDS and DO were determined. Diatoms were examined using direct microscopy and were identified based on morphological characteristics. The physico-chemical properties of the rivers conform to the standard limits set by the DENR-EMB for Class B freshwater ecosystem. Ten identified genera of diatoms namely: *Synedra*, *Gyrosigma*, *Hantzschia*, *Cymbella*, *Achnanthes*, *Navicula*, *Neidium*, *Surirella*, *Bacillaria*, and *Pinnularia* were found in the rivers. One diatom was unidentified due to limitations of morphological characteristics observed during microscopy. Statistical analysis revealed that physico-chemical properties of the rivers were neither neglectable, moderately or highly correlated to the presence of most diatoms. The only chemical parameter that had significant correlation to the presence of *Cymbella* spp. was total suspended solid (TSS) while width and depth are significantly correlated to the presence of *Achnanthes* spp. For diversity indices, *Hantzschia* spp. were the most dominant and it showed the greatest similarity among the 10 identified diatoms. Meanwhile, *Synedra*, *Hantzschia*, *Cymbella*, *Navicula*, and *Neidium* had the highest species richness as compared to others. Shannon index of biodiversity indicate very low diversity of diatom even though they occur in high frequency.

**Keywords:** diatoms, rivers, diversity, physicochemical properties, diversity index.

## INTRODUCTION

Phytoplankton is one of the main sources of carbohydrates in many aquatic systems. They play a central role in the structure and functioning of freshwater ecosystems. They are a significant component of water ecosystems as primary producers (Ligeza and Wilk-Woźniak, 2011). Phytoplankton populations are well known to be influenced by space-time variations in hydro-chemical and physical parameters (UNESCO, 1981; Cloern *et al*., 1989). Meanwhile, the presence of phytoplankton in freshwater are also harmful as they produce biomass which generate bad smell, causing deoxidation and damage to aquatic life (Bellinger and Siege, 2010). Among the different groups of phytoplankton, diatoms are the most common type.

Diatoms are major group of algae and key components of the benthic microalgal communities (Armitage and Fong, 2004b). They act as a primary producer and form a large part of the benthos (Acs *et al*., 2004). Diatoms are good bioindicators of water quality in streams and rivers since the early 1900's (Stevenson and Pan, 1999, Chintapenta *et al*., 2018) because of their life cycles and their ability to respond quickly to a variety of environmental conditions such as organic pollution (Lange-Bertalot, 1979), siltation (Bahls, 1993), pH (Pan *et al*., 1996) and eutrophication (Kelly and Whitton, 1995; Potapova and Charles, 2005). Furthermore, diatoms can be found throughout the year and can be a source of many nuisance algal problems such as taste and odor impairment of drinking water and reduced water clarity. In Laguna de Bay, 83 diatom taxa belonging to

37 genera were identified in its slightly brackish and heavily polluted water (Ohtsuka *et al*., 2009).

Indang, Cavite is a first class municipality in the Province of Cavite. Rivers in this municipality are used as source of drinking water, for sanitation purposes, for recreation, as sources of fish and crustaceans, such as shrimps and crabs (Dimero, 2009; Reyes, 2015). The diversity of diatoms in Indang, Cavite, Philippines had not been previously studied. Hence, this study was conducted to determine the different diatoms found in the selected rivers and correlate the identified diatoms to physicochemical properties of river water. The results of this study will facilitate rapid assessment of the existing conditions of specific river ecosystems. Once the indicators are identified, a simplified process of assessment can be established.

## MATERIALS AND METHODS

### Sampling Sites

The presence of diatoms were assessed in five selected rivers of Indang, Cavite - Barangay 2, Bancod, Calumpang Lejos, Banaba Cerca and Tambo M. Kulit, Indang, Cavite (Figure 1). Indang, Cavite, has several rivers that are interconnected to one another. From this, five rivers were selected and characterized to determine if the rivers were within the standard limits set by DENR for freshwater ecosystem. The banks of the five selected rivers of Indang are highly vegetated with tall trees, grasses and ferns. Residents visit the river to wash their clothes, to catch small fish and some crabs, and for swimming purposes. Some of the rivers have floating garbage and non-degradable wastes.

In every river stations, transect was marked parallel across the full width of the river. This was placed at 10 m, 40 m, and 100 m distance on both sides. Three 5 m radius sub plots were placed along each transect. Transect method was used to differentiate the areas of the river to determine the depth, width and physicochemical properties of the water (temperature, pH, dissolved oxygen, salinity and turbidity). The depth, width of the river and the water temperature were determined *in situ*. The depth of the river was determined using calibrated meter stick. The velocity or the river water was measured by allowing a floater move along the water current within the transect line. The speed was recorded using a stopwatch (Field Studies Council, 2016).

### Water Sample Collection

Two liters of water samples coming from the rivers were collected for chemical analysis. The containers were rinsed with distilled water and drained before use. Sampling was done every morning from 06:00 to 09:00. Each container had an amount of 50 ml of river water sample in each trial. Bottles were pre-labelled with the sampling sites (name of the river), the date and time of water sample collection and the depth of the sampling site. On the other hand, a sieve tube with 20µm size pore was used in collecting water samples for microscopic examination of diatoms. Lugol's solution was used to preserve 50 ml of water samples collected from selected rivers of Indang, Cavite. Sampling was done from September to December 2019 (wet season) at 06:00 to 10:00.

### Physicochemical Properties of Selected Indang Rivers

The water temperature, depth of the river, velocity of the water, water pH, salinity of water, total dissolved solids (TDS) of water, dissolved oxygen (DO) in water, and total suspended solids (TSS) of water from the selected rivers were determined using laboratory thermometer, Calibrated string with, stopwatch, pH meter, and Cyberscan and Chem Analyzer respectively (guided by a user manual).

### Microscopic Enumeration of Diatom

Ten milliliters of sample was placed in screw-capped test tubes and centrifuged at 3000 rpm for five minutes. Once the cells had been centrifuged, supernatant was carefully removed and the pellets were suspended in a small known volume. Concentrated samples were placed in a haemocytometer and the number of diatoms was determined. Distinct morphological features were also recorded and photomicrographs of each diatom were taken.

### Identification of Diatoms

Diatom was identified based on the morphological features using identification keys (Wetland Plants and Algae, 1999). For further identification, some literatures were used to identify its morphological characteristics (Bacillariophyceae, n.d.). Photographs were also compared using the Illustrated Guide to Some Common Diatom Species (Taylor *et al*., 2007) and Illustrated Key to Common Diatom Genera (Gell *et al*., 1999).

### Diversity Index

The diversity level of diatoms in terms of the number of genera, abundance, richness index, evenness index and Shannon's diversity index were determined using the formula:

$$H = -SUM[(p_i) \times \ln(p_i)]$$

Shannon's index was accounted for both abundance and evenness of the species present. The proportion of

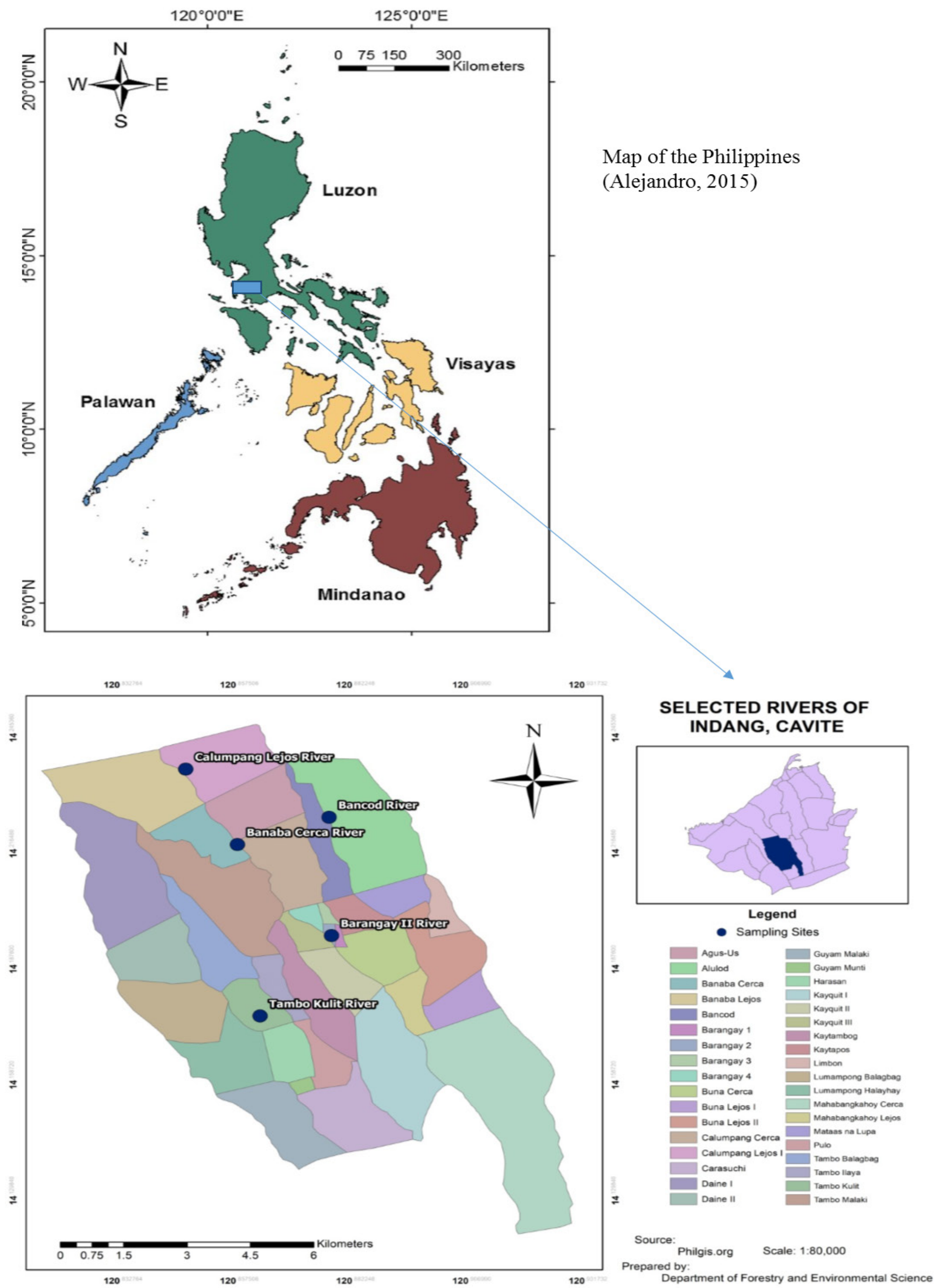


**Figure 1.** Location map showing the five selected rivers of Indang, Cavite.

species i relative to the total number of species (pi) was calculated, and then multiplied by the natural logarithm of this proportion (lnpi). The resulting product was summed across species, and multiplied by -1:

For the evenness computation, it was calculated by dividing $H$ by $H_{max}$ (here $H_{max} = \ln N$). The equitability of the evenness assumed a value between 0 and 1 with 1 being complete evenness.

$H_{max} = \ln(N)$ Maximum diversity possible

$E_H$ = Evenness = $H/H_{max}$

Variables: **SUM** = summation

**H** = Shannon's diversity index

**N** = number of species, = species richness

$p_i$ = proportion of total sample represented by species *i*
Divide no. of individuals of species *i* by total number of samples
$E_H$=equitability (evenness)

**Distribution of Diatoms**
The total number of each diatom species was compared to the 6-score scale developed by Korde 1956, (cited by Barinova *et al*., 2011) to assess the distribution of diatom in each river.

| SCORE | VISUAL ESTIMATE | CELL NUMBERS PER SLIDE |
|---|---|---|
| 1 | Occasional | 1-5 |
| 2 | Rare | 10-15 |
| 3 | Common | 25-30 |
| 4 | Frequent | 1 cell over a slide transect |
| 5 | Very frequent | Several cells over a slide transect |
| 6 | Abundant | One or more cells in each field of view |

**Data Analysis**
The analysis of data was done using the analysis of variance (ANOVA) to express the differences among mean chemical properties and was compared using Duncan's Multiple Range Test (DMRT). P value of $< 0.05$ was considered as significant. Pearson correlation was used to correlate the physico-chemical parameters of water and the occurrence of diatoms in the rivers.

**RESULTS AND DISCUSSION**

**Diatoms Identified in the Rivers**
Ten genera of diatoms and one unidentified diatom were found in five rivers of Indang, Cavite (Table 1 and Figure 2). Classification and identification of these diatoms were based on their morphological structure specially their shape and the presence of raphe and its location.

Generally, diatom common in freshwater are classified into centric diatom species which are circular in shape and are adapted to live in the water column and pennate diatoms that live in benthic habitats but are often temporarily re-suspended in the water column. Based on the results, all identified diatoms were pennates. They were subdivided into: araphid with one genus *Synedra*; monoraphid with *Achnanthes*; and biraphid which comprised of *Gyrosigma*, *Hantzschia*, *Cymbella*, *Navicula*, *Neidium*, *Surirella*, *Bacillaria* and *Pinnularia*. This finding was in agreement with previous reports that pennate diatoms were dominant in freshwater bodies,

**Table 1.** Total count, distribution, evenness, and richness of identified diatoms in selected rivers of Indang

| GENUS | TOTAL COUNT | PERCENTAGE (%) | DOMINANCE RANK | EVENNESS | RICHNESS | DIVERSIY INDEX | DISTRIBUTION |
|---|---|---|---|---|---|---|---|
| *Synedra* spp. | 24 | 8.57 | 6 | 0.93 | 5 | 1.50 | Occasional |
| *Gyrosigma* spp. | 3 | 1.07 | 9 | 0.98 | 3 | 1.08 | Occasional |
| *Hantzschia* spp. | 78 | 27.86 | 1 | 1.03 | 5 | 1.66 | Common |
| *Cymbella* spp. | 29 | 10.36 | 5 | 0.65 | 5 | 1.04 | Rare |
| *Achnanthes* spp. | 41 | 14.64 | 3 | 0.74 | 4 | 1.03 | Rare |
| *Navicula* spp. | 49 | 17.5 | 2 | 0.72 | 5 | 1.16 | Rare |
| *Neidium spp.* | 11 | 3.93 | 7 | 0.87 | 5 | 1.40 | Rare |
| *Surirella* spp. | 38 | 13.57 | 4 | 0.91 | 3 | 1.00 | Rare |
| *Bacillaria* spp. | 1 | 0.36 | 10a | 0 | 1 | 0 | Occasional |
| *Pinnularia* spp. | 1 | 0.36 | 10b | 0 | 1 | 0 | Occasional |
| Unidentified | 5 | 1.79 | 8 | 0.01 | 3 | 0.95 | Occasional |

*Diversity Index: 5 (high diversity) good; 4 (diversity slightly reduced) fair; 3 (diversity significantly reduced) doubtful; 2 (diversity low) poor; 1 (diversity very low) bad.

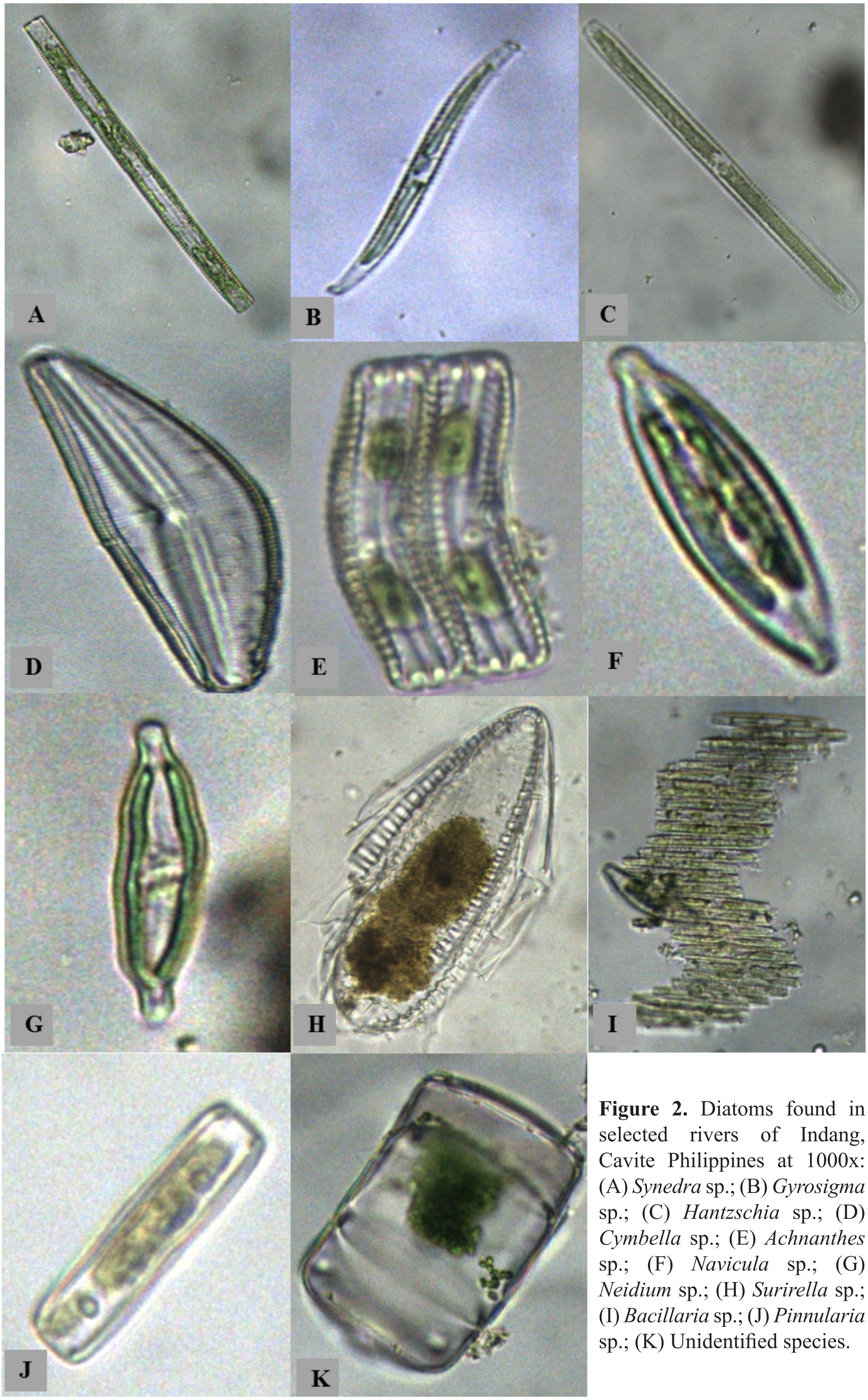


**Figure 2.** Diatoms found in selected rivers of Indang, Cavite Philippines at 1000x: (A) *Synedra* sp.; (B) *Gyrosigma* sp.; (C) *Hantzschia* sp.; (D) *Cymbella* sp.; (E) *Achnanthes* sp.; (F) *Navicula* sp.; (G) *Neidium* sp.; (H) *Surirella* sp.; (I) *Bacillaria* sp.; (J) *Pinnularia* sp.; (K) Unidentified species.

whereas centric diatoms were more abundant in marine ecosystem (Round *et al*., 1990; Peerapornpisal, 2006).

Regarding the frequency of diatoms, the most abundant diatoms found in the rivers of Indang, Cavite were *Hantzschia* spp. (78), *Navicula* spp. (49), *Achnanthes* spp. (41), *Surirella* spp. (38), *Cymbella* spp. (29), *Synedra* spp. (24). The least common among the diatom species were *Neidium* spp. (11), Unidentified (5), *Gyrosigma* spp. (3), *Bacillaria* sp. (1) and *Pinnularia* sp. (1).

**Diatom Diveristy**

Based on the results, *Hantzschia* spp. was the most dominant among the 10 identified diatoms with a total count of 78 (27.86%) (Table 1). It was followed by *Navicula* spp. with a total of 49 individual cells (17.5%). On the other hand, *Bacillaria* spp. and *Pinnularia* spp. rank 10 which were considered as the least dominant among the identified diatoms. Meanwhile, in the study of Leelahakriengkrai and Peerapornpisal (2011), *Navicula*, *Nitzschia* and *Gomphonema* were the dominant genera. In addition, *Navicula* spp., *Nitzschia* spp., *Gomphonema* spp., *Pinnularia* spp., *Cymbella* spp., *Achnanthes* spp., *Luticola* spp. and *Surirella* spp. were the diatoms identified in the studies conducted in Europe and Asia by Tien (2004), Atazadeh *et al*. (2007), Chatháin and Harrington (2008), and Kupe *et al*. (2008). Among these, *Navicula* spp. had the highest number of species. Majority of these diatoms were also found in this study.

Species evenness (E) relates to the evenness of the number of individuals within each species. It ranges from zero to one and provides information on the community structure, where, the closer the value to one, the greater the similarity among species abundances. Result showed that majority of the diatoms showed greater similarity as indicated by the value obtained in species evenness. Among these, *Hantzschia* spp. showed the greatest similarity with a value of 1.03, followed by *Gyrosigma* spp. (0.98), and *Synedra* spp. (0.91). Evenness usually is low when there is an abundant growth of filamentous algae and high when filamentous algae are absent (Prakash and Verma, 2009). This conforms to the results of the study where most of the diatoms found were exist as solitary.

Richness assessed the overall number of taxa recorded from a particular sampling site. Among the diatoms, *Synedra* spp., *Hantzschia* spp., *Cymbella* spp., *Navicula* spp. and *Neidium* spp. had the highest species richness as compared to others. High species richness indicates a complex community in which a high degree of species interaction is possible. In terms of distribution of diatoms (Table 1), *Hantzschia* was the most common genus while others occur occasionally or rarely. On the other hand, Shannon index of diversity indicate very low diversity of diatoms even though they occur in high frequency. This may be associated to the nutrient levels of the rivers. Since most of the rivers were used for households and recreational purposes, organic materials did not usually accumulate in the area. Jüttner *et al*., (1996) concluded that taxa richness and diversity index were significantly higher in agricultural streams than in organically polluted streams. Meanwhile, Synder *et al*. (2002) inferred that high nutrient levels were consistent with greatest diatom taxa diversity.

**Physical Properties of the River**

The physical properties of the selected rivers of Indang, Cavite (water temperature, depth, velocity) were determined and recorded (Table 2).

**Temperature.** Only slight differences on the temperature of the river were noted during the sampling period. This may be attributed to the sampling months, December and January which were both cold months. The highest water temperature was observed in Banaba Cerca river (25.25º C) while Barangay Dos river had the lowest temperature of 23.5º C.

The temperatures of the five rivers were within the DENR-EMB (Philippines) standard which was 3º C over the ambient temperature. These temperatures would not cause stress to aquatic ecosystem. At this range, the water still maintains its ability to hold essential dissolved gases like oxygen (Buthcher and Covington, 1995; Lawson, 2011).

**Depth.** The average depth of different stations of Indang rivers ranged from 0.16 meters to 0.80 meters. The deepest among the five rivers is the Banaba Cerca river with an average depth of 0.80 meters and the shallowest is the Tambo Kulit river which had an average depth of 0.16 meters because of the submerged rocks in the water.

**Velocity.** The water flow in the selected rivers of Indang was quite slow to fast ranging from 7.93 cm/s to 23.18 cm/s.

**Chemical Properties of River Water**

The chemical properties of water (pH, salinity, total dissolved solids (TDS), dissolved oxygen (DO) and total soluble solids (TSS)) from the five selected rivers of Indang were determined and recorded (Table 3). It provides necessary information to evaluate the condition of the rivers as well as the diatoms.

**pH.** In general, the pH values of the river water were

**Table 2.** Mean of the physical properties of selected rivers of Indang, Cavite

| RIVERS | WATER TEMPERATURE (ºC) | DEPTH (meter) | VELOCITY (cm/s) |
|---|---|---|---|
| **Bancod** | 25 | 0.53 | 13.02 |
| **Banaba Cerca** | 25.25 | 0.80 | 13.85 |
| **Brgy Dos** | 23.5 | 0.47 | 7.93 |
| **Calumpang Lejos** | 24.75 | 0.45 | 16.94 |
| **Tambo Kulit** | 24.25 | 0.16 | 23.2 |

**Table 3.** Mean chemical properties of selected rivers of Indang, Cavite

| | RIVER/CHEMICAL PROPERTIES | | | | | |
|---|---|---|---|---|---|---|
| | STANDARD | BANABA RIVER | BANCOD RIVER | BARANGAY 2 RIVER | CALUMPANG LEJOS RIVER | TAMBO KULIT RIVER |
| **pH** | 6.5 – 8.5 | 7.65a | 7.55a | 7.16a | 7.43a | 7.2a |
| **Salinity (PPT)** | 0.05 ppt | .159b | .168c | .153a | .155ab | .157ab |
| **TDS (mg/L)** | 1000 mg/L | 197.4a | 210.61b | 196.27a | 192.79a | 196.97a |
| **DO (mg/L)** | 5 mg/L | 8.48c | 9.8b | 7.91ab | 7.96ab | 5.28a |
| **TSS(mg/L)** | Not more than 30 mg/L increase | 13.07a | 7.95a | 8.28a | 9.92a | 10.83a |

*Source: standard criteria for the physic-chemical properties of water was cited by Maglangit *et al*., 2014.
*Means followed by the same letters are not significantly different at 0.05 level of difference (DMRT).
*Note: Indang River is classified as Class B (recreational water class). http://calabarzon.denr.gov.ph

at the neutral level and slightly alkaline and within the DENR-EMB (Philippines) standard for Class B freshwater ecosystem. Statistical analysis revealed that there was no significant difference on the pH of the five rivers. The pH of the water depends on many factors such as air, temperature and wastewater discharges.

**Salinity.** The highest salinity value was recorded on Bancod river with a value of 0.168 ppt, followed by Banaba Cerca river with a value of 0.159 ppt. Barangay Dos river registered the lowest salinity of 0.153 ppt. Statistical analysis revealed that the salinity of Calumpang Lejos river and Tambo Kulit river were not significantly different with each other.

**Total Dissolved Solids (TDS).** Result revealed that the highest total dissolved solid was noted on Bancod river with a value of 210.61 mg/l. Meanwhile, slight differences on the values of total dissolved solids were noted on the remaining rivers which ranges from 192.79 – 197.4 mg/l. These were below to the standard set by the DENR-EMB. Statistical analysis revealed that the total dissolved solids of Bancod river was significantly different to the values of the other four rivers.

**Dissolved Oxygen.** The dissolved oxygen of the five rivers exceeded the standard set by the DENR-EMB for Class B freshwater which was 5mg/L but the values were not enough to cause algal bloom. The highest dissolved oxygen value was recorded on Bancod river with a value of 9.8mg/L, followed by Banaba Cerca river with 8.48mg/L. Tambo Kulit river registered the lowest dissolved oxygen of 5.28 mg/L.

An adequate supply of dissolved oxygen gas is essential for the survival of aquatic organisms. Oxygen is produced by rooted aquatic plants and algae as a product of photosynthesis (Cuyahoga River Water Quality Monitoring Program, Cleveland State University, n.d.).

**Total Suspended Solid (TSS).** Lower values of the total suspended solids (TSS) were observed on the five rivers of Indang which ranges from 7.95 mg/l to 13.90 mg/l. Among the five rivers, Bancod had the lowest TSS with 7.95 mg/l, followed by Barangay II river with 8.28 mg/l. On the other hand, the highest TSS among the five rivers was noted on Banaba Cerca river with 13.90 mg/l. In general, the total suspended solid of the rivers were within the standard limit set by the DENR-EMB.

**Correlation of Diatoms to Physiochemical Properties of River Water**

Based on the results (Tables 4 and 5), the presence

**Table 4.** Correlation between diatom species and physical characteristics of water in selected rivers of Indang, Cavite

| IDENTITY | PEARSON R. | SIG. (2-TAILED | REMARKS |
|---|---|---|---|
| *Synedra* spp. | | | |
| Velocity | -.346 | .327 | Moderate Correlation |
| *Hantzchia* spp. | | | |
| Temperature | .370 | .293 | Moderate Correlation |
| Width | -.387 | .270 | Moderate Correlation |
| Depth | -.574 | .083 | High Correlation |
| *Cymbella* spp. | | | |
| Velocity | -.356 | .313 | Moderate Correlation |
| *Achananthes* spp. | | | |
| **Width** | **-.768**** | **.009** | **Very High Correlation** |
| **Depth** | **-.713*** | **.021** | **Very High Correlation** |
| *Navicula* spp. | | | |
| Temperature | .394 | .260 | Moderate Correlation |
| Width | -.300 | .400 | Moderate Correlation |
| Depth | -.491 | .149 | Moderate Correlation |
| *Neidium* spp. | | | |
| Temperature | .492 | .149 | Moderate Correlation |
| *Surirella* spp. | | | |
| Width | -.611 | .061 | High Correlation |
| Depth | -.562 | .091 | High Correlation |
| *Bacillaria* spp. | | | |
| Width | .509 | .133 | Moderate Correlation |
| Depth | .403 | .249 | Moderate Correlation |
| *Pinnularia* spp. | | | |
| Temperature | .319 | .368 | Moderate Correlation |
| Unidentified | | | |
| Velocity | .376 | .284 | Moderate Correlation |
| Width | -.321 | .366 | Moderate Correlation |
| Depth | -.418 | .229 | Moderate Correlation |

**Correlation significant at the 0.01 level (2-Tailed)
*Correlation significant at the 0.05 level (2-Tailed)
*0.0–0.1no correlation
*0.11 –0.25 neglible correlation
*0.26 –0.5 moderate correlation
*0.51 –0.75 high correlation
*0.76 –1 very high correlation

**Table 5.** Correlation between diatom species and chemical characteristics of water in selected rivers of Indang, Cavite

| GENUS/ CHEMICAL CHARACTERISTICS | PEARSON R. | SIG. (2-TAILED) | REMARKS |
|---|---|---|---|
| *Synedra* spp. | | | |
| pH | -.535 | .111 | High Correlation |
| Salinity | -.488 | .153 | Moderate Correlation |
| TDS | -.433 | .211 | Moderate Correlation |
| TSS | .289 | .418 | Moderate Correlation |
| *Gyrosigma* spp. | | | |
| pH | -.552 | .098 | High Correlation |
| Salinity | -.317 | .372 | Moderate Correlation |
| TDS | -.319 | .369 | Moderate Correlation |
| TSS | -.389 | .267 | Moderate Correlation |
| *Hantzchia* spp. | | | |
| pH | -.433 | .212 | Moderate Correlation |
| DO | -.428 | .217 | Moderate Correlation |
| TSS | -.305 | .392 | Moderate Correlation |
| *Cymbella* spp. | | | |
| pH | -.332 | .348 | Moderate Correlation |
| DO | .330 | .352 | Moderate Correlation |
| **TSS** | **-.829**** | **.003** | **High Correlation** |
| *Achananthes* spp. | | | |
| pH | -.371 | .291 | Moderate Correlation |
| DO | -.336 | .343 | Moderate Correlation |
| TSS | -.540 | .107 | High Correlation |
| *Navicula* spp. | | | |
| pH | -.472 | .169 | Moderate Correlation |
| Salinity | -.335 | .345 | Moderate Correlation |
| TDS | -.320 | .368 | Moderate Correlation |
| TSS | -.387 | .269 | Moderate Correlation |
| *Neidium* spp. | | | |
| pH | -.371 | .291 | Moderate Correlation |
| *Surirella* spp. | | | |
| pH | -.408 | .241 | Moderate Correlation |
| Salinity | -.266 | .457 | Moderate Correlation |
| TSS | -.418 | .229 | Moderate Correlation |
| *Bacillaria* spp. | | | |
| pH | -.277 | .438 | Moderate Correlation |
| TDS | -.261 | .467 | Moderate Correlation |
| TSS | .263 | .463 | Moderate Correlation |
| Unidentified | | | |
| Salinity | -.369 | .294 | Moderate Correlation |
| TDS | -.393 | .261 | Moderate Correlation |
| DO | -.394 | .260 | Moderate Correlation |
| TSS | .625 | .053 | High Correlation |

** Correlation significant at the 0.01 level (2-Tailed)
*Correlation significant at the 0.05 level (2-Tailed)
*0.0 - 0.1 no correlation
*0.11- 0.25 Negligable correlation
*0.26 - 0.5 moderate correlation
*0.51- 0.75 high correlation
*0.76 – 1 very high correlation

of *Synedra* spp. and *Gyrosigma* spp., in the rivers of Indang, Cavite was highly correlated to the pH of the water and moderately correlated to salinity, TDS and TSS. In terms of the physical characteristics of the river, only velocity was moderately related to *Synedra* spp. However, there was no significant correlation between the presence of these diatoms to the physico-chemical properties of the rivers which means that their growth did not necessarily depend on the physico-chemical properties of the water.

In case of *Hantzschia* spp., their presence is moderately related to pH, DO, TSS, temperature and width and highly related to the depth of the river. However, no significant correlations were noted to these parameters. Meanwhile, *Cymbella* spp. was moderately related to pH, DO and velocity but significantly correlated to the TSS. TSS was the chemical parameter that was significantly correlated to the presence of diatom. This means that the TSS in the river water supported or favored the growth of *Cymbella* spp.

On the other hand, the pH, DO and TSS were moderately and highly related to the presence of *Achnanthes* spp. respectively. It was also noted that width and depth were very highly related to the presence of *Achnanthes* spp. and were found to be significantly correlated at 0.01 and 0.05 level, respectively. This means that the width and the depth of the rivers greatly affected the presence and growth of *Achnanthes* spp. Meanwhile, Navicula spp. was moderately related to pH, salinity, TDS, TSS, temperature, width and depth. *Neidium* spp. is only moderately correlated to pH and temperature but insignificant to the other parameters. *Surirella* spp. was moderately correlated to pH, salinity and TSS, highly related to width and depth but had no relations to TDS and DO of the water.

Likewise, *Bacillaria* spp. was moderately related to pH, TDS, TSS, width and depth of the river while the unidentified diatom was moderate correlated to salinity, TDS, DO, velocity, width and depth. Surprisingly, the presence of *Pinnularia* spp. had no relation to any chemical parameters of the river water and was found moderate correlated only to temperature. This means that this diatom may grow in any freshwater with different chemical properties and could tolerate a wide range of water quality.

Comparison of the chemical properties of the river water to the standard limits set by the DENR-EMB revealed that the river water is within the criteria for the CLASS B freshwater ecosystems. This implies that the water of the five rivers of Indang, Cavite is not polluted.

The dominant species such as *Achnanthidium minutissimum*, *Cymbella turgidula*,*Gomphonema lagenula*, and *Navicula symmetrica* were found in clean to moderate water quality, thus could be used to indicate said water qualities (Leelahakriengkrai and Peerapornpisal 2010). Krammer and Lange-Bertalot (1986) reported that *Cymbella turgidula* was found in rather clean to moderate water quality. In the case of *Gomphonema lagenula* and *Navicula symmetrica*, they indicated clean to moderate water quality, which was similar to the report of Reichardt (1999) who found Gomphonema lagenula occurred in moderate water quality and reported that Navicula symmetric was found in moderate water quality.

## CONCLUSION

Diatoms found in Indang rivers were all pennates belonging to genera *Synedra*, *Gyrosigma*, *Hantzschia*, *Cymbella*, *Achnanthes*, *Navicula*, *Neidium*, *Surirella*, *Bacillaria*, and *Pinnularia*. Among these, *Hantzschia*, *Cymbella*, *Navicula*, and *Neidium* showed the highest species richness. Despite the high frequency of the different genera of diatom, very low diversity was recorded using the Shannon index of biodiversity. The physico-chemical properties of the rivers were within the standard limits set by the DENR-EMB, Philippines which indicates that the rivers are not yet polluted. Only the total suspended solid (TSS), and width and depth of the rivers showed significant correlation to the presence of *Cymbella* sp. and *Achnanthes* sp., respectively.

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Received: 24 November 2020
Accepted: 26 April 2021
Published Online: 14 June 2021
Published in Print: 30 June 2021