Nitzschia paleaeformis and Nitzschia amplectens occurring in strongly acid waters of pH range from 1.0 to 3.9 in Japan

Toshiharu Watanabe and Kazumi Asai

Abstract

We have performed a statistical analysis on the pH tolerance of 485 diatom taxa in epilithic algal assemblages, collected from 215 freshwater sites, representing a pH gradient ranging from 1.0 to 12.5. In this study, 45 Nitzschia taxa occurred. Among them 22 belong to alkaliphilous (16 taxa) or alkalibiontic (6 taxa) taxa, while 21 are circum-neutral taxa. Only two taxa were recognized as acidobiontic taxa. In this paper, we report on the ecological and morphological features of these two strange Nitzschia taxa occurring in the strong acid waters from pH 1.0 to 3.9 in Japan.

Key index words: acidobiontic species, environmental frontier species, epilithic diatom, Nitzschia amplectens, Nitzschia paleaeformis, pH

Introduction

Many arguments have been presented on the relationship between the pH value and the distribution of diatom taxa i.e. Cholnoky (1968), Watanabe & Yasuda (1982), Meriläinen & Hutunen (1984), Charles (1985), Anderson et al. (1986), Dixit & Dickman (1986), and Dixit et al. (1988). Van Dam et al. (1994) tabulated acronyms and ecological indicator values of freshwater diatom taxa from the Netherlands. In the latter paper, Nitzschia paleaeformis Hust. is regarded as an acidobiontic taxon with optimal occurrence at a pH below 5.5.

Recently, we have studied attached diatom assemblages in the strong acid waters from pH 1.0 to 3.9 in Japan (Watanabe & Asai 1999). In this study, Nitzschia amplectens was found at 19 sites among 47 investigated sites and Nitzschia paleaeformis at 4 sites; moreover, the relative abundance of each taxon was fairly high at some sites (Text-fig. 1 and Table 1). We describe the ecological and morphological features of the two strange Nitzschia species.

Sampling sites and methods

Strong acid waters due to active fumaroles or mineral springs are common in Japan. We have collected samples at sites with strong acid water shown in Text-figure 1. In Table 1, pH, conductivity and water temperature at the sampling time are given for 20 sites. Sampling sites in streams receive the inflow of acid water from active fumaroles. Almost all lakes from where samples were collected are located in old craters and active fumaroles near the shore or at the bottom.

Epilithic algal forms were collected from sites below 30°C in water temperature by using a brush with slender brass bristles under the following conditions (Watanabe et al. 1990).

1. In flowing sites: Samples were collected from riffles about 30 cm deep at about 40 cm sec⁻¹ current speed. Samples were collected only from the flat upper surface of a boulder or non-living substrate whose surface is parallel to the water surface.

2. In stagnant sites: Samples were collected only from a vertical surface below 30 cm deep on any non-living substrate to avoid the effect of sedimented matter.

3. Use of sample whose standing crop was large, to obtain an assemblage which had reached maturity in succession.

Values of pH and EC shown in Table 1 were measured by using the TOA pH meter HM-12P and TOA conductivity meter CM-11P at each sampling site.

Accepted on October 22, 2004
Results

Among the sampling sites where the two *Nitzschia* species occurred, 17 sites (except sites 6,13,15) have the chemical characteristics shown in Table 2. The major source of acidity is sulfuric acid from active fumaroles for all lakes and streams, except for Lake Usoriyama (sites 11,12,16,17) and its outflow, the River Shouzu (sites 7,14) which receive acid inflows with comparatively low content of SO₄ ion.

*Nitzschia paleaeformis* Hust. 1950

Fig. 1–4

Krammer & Lange-Bertalot 1988. p. 92. Fig. 65:3–8A.

This taxon occurred with low abundance at four sites with pH 2.6 to 3.9 (Table 1). At site 9 (Lake Dōnuma), the relative abundance of the taxon in the diatom assemblage was high (72%), however, at other sites it was very low (below 3%). The source of acidity of waters at the four sites is sulfuric acid as shown in Table 2. This taxon occurred together with *Pinnularia acorcola*, *P. acidojaponica*, *Eunotia exigua* and *Caloneis aerophila*; these four species and the present taxon are all acidobiontic taxa (Watanabe & Asai 1999). Hustedt (1950) recorded this taxon as a new species in an epiphytic sample from Lake Pinn in Northern Germany. Van Dam *et al.* (1994) also pointed out that the taxon was acidobiontic.
In our samples, the valve is linear lanceolate with protracted to bluntly rostrate ends, 38.5–49 μm long, 4–4.5 μm broad, the ratio of length to breadth 9.4–11, fibulae 12–14 in 10 μm, and with a distinct central nodule appear, striae over 35 in 10 μm.

**Nitzschia amplectens** Hust. 1957

In this study, this taxon occurred at 19 sites, the waters of which receive an inflow of sulfuric or hydrochloric acid waters with pH range from 1.0 to 3.9 (Table 1,2). At such strong acid water sites, this taxon occurred together with the four same taxa as mentioned above for *Nitzschia paleaeformis*. We have also found that this taxon

<table>
<thead>
<tr>
<th>No.</th>
<th>Sampling site</th>
<th>Date</th>
<th>pH</th>
<th>EC (μS cm⁻¹)</th>
<th>WT (°C)</th>
<th>Relative abundance (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>River Susawa in Hakone(1)</td>
<td>Dec 12 1993</td>
<td>1.03</td>
<td>&gt;20000</td>
<td>6.4</td>
<td>11.6</td>
</tr>
<tr>
<td>2</td>
<td>R.Susawa(2)</td>
<td>Dec 12 1993</td>
<td>1.16</td>
<td>&gt;20000</td>
<td>7.9</td>
<td>37.4</td>
</tr>
<tr>
<td>3</td>
<td>R.Susawa(3)</td>
<td>Dec 12 1993</td>
<td>1.60</td>
<td>&gt;20000</td>
<td>9.1</td>
<td>17.3</td>
</tr>
<tr>
<td>4</td>
<td>R.Susawa(4)</td>
<td>Dec 12 1993</td>
<td>2.00</td>
<td>&gt;20000</td>
<td>6.2</td>
<td>14.4</td>
</tr>
<tr>
<td>5</td>
<td>Outflow from Myoban Spa</td>
<td>Dec 22 1993</td>
<td>2.24</td>
<td>2800</td>
<td>22.2</td>
<td>0.4</td>
</tr>
<tr>
<td>6</td>
<td>Pond received Umijigoku spa water</td>
<td>July 20 1974</td>
<td>2.60</td>
<td>–</td>
<td>29.0</td>
<td>28.2</td>
</tr>
<tr>
<td>7</td>
<td>R.Shouzu(Outflow from Lake Usoriyama)(1)</td>
<td>Aug 24 1972</td>
<td>2.70</td>
<td>–</td>
<td>24.2</td>
<td>1.9</td>
</tr>
<tr>
<td>8</td>
<td>R.Hirat received Myoban spa water</td>
<td>Dec 23 1993</td>
<td>2.80</td>
<td>947</td>
<td>23.8</td>
<td>2.6</td>
</tr>
<tr>
<td>9</td>
<td>L.Dōnuma</td>
<td>June 19 1977</td>
<td>3.00</td>
<td>–</td>
<td>15.9</td>
<td>71.8</td>
</tr>
<tr>
<td>10</td>
<td>R.Owakusawa in Hakone(1)</td>
<td>Dec 12 1993</td>
<td>3.03</td>
<td>2960</td>
<td>10.3</td>
<td>8.6</td>
</tr>
<tr>
<td>11</td>
<td>L.Usoriyama(1)</td>
<td>Aug 24 1972</td>
<td>3.20</td>
<td>–</td>
<td>23.0</td>
<td>1.5</td>
</tr>
<tr>
<td>12</td>
<td>L.Usoriyama(2)</td>
<td>Aug 24 1972</td>
<td>3.20</td>
<td>–</td>
<td>23.0</td>
<td>2.6</td>
</tr>
<tr>
<td>13</td>
<td>L.Bessho-numa</td>
<td>Nov 22 1975</td>
<td>3.40</td>
<td>–</td>
<td>11.5</td>
<td>7.0</td>
</tr>
<tr>
<td>14</td>
<td>R.Shouzu(2)</td>
<td>Aug 24 1972</td>
<td>3.40</td>
<td>–</td>
<td>24.2</td>
<td>1.5</td>
</tr>
<tr>
<td>15</td>
<td>Stream in Bandai High-land</td>
<td>June 19 1977</td>
<td>3.60</td>
<td>–</td>
<td>15.1</td>
<td>5.2</td>
</tr>
<tr>
<td>16</td>
<td>L.Usoriyama(3)</td>
<td>Aug 24 1972</td>
<td>3.70</td>
<td>–</td>
<td>23.1</td>
<td>1.1</td>
</tr>
<tr>
<td>17</td>
<td>L.Usoriyama(4)</td>
<td>Aug 24 1974</td>
<td>3.70</td>
<td>–</td>
<td>23.2</td>
<td>0.3</td>
</tr>
<tr>
<td>18</td>
<td>L.Akanuma(1)</td>
<td>Oct 26 1986</td>
<td>3.90</td>
<td>–</td>
<td>16.0</td>
<td>0.6</td>
</tr>
<tr>
<td>19</td>
<td>L.Akanuma(2)</td>
<td>Oct 26 1986</td>
<td>3.90</td>
<td>–</td>
<td>16.2</td>
<td>0.5</td>
</tr>
<tr>
<td>20</td>
<td>R.Owakusawa(2)</td>
<td>Dec 12 1993</td>
<td>3.92</td>
<td>2900</td>
<td>14.6</td>
<td>19.0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Site</th>
<th>5, 8</th>
<th>1, 2, 3, 4 (10, 20)</th>
<th>11, 12, 16, 17 (7, 14)</th>
<th>9</th>
<th>18, 19</th>
</tr>
</thead>
</table>

Table 2. pH and major ion content in water at each sampling site (By Dr. K. Satake, National Institute for Environmental Studies).

<table>
<thead>
<tr>
<th></th>
<th>Myoban Spa</th>
<th>R.Susawa</th>
<th>L.Usoriyama</th>
<th>L.Dōnuma</th>
<th>L.Akanuma</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
<td>2.2</td>
<td>2.3</td>
<td>3.0</td>
<td>3.2</td>
<td>3.9</td>
</tr>
<tr>
<td>Na⁺(mg l⁻¹)</td>
<td>–</td>
<td>58.6</td>
<td>24.9</td>
<td>40.0</td>
<td>78.6</td>
</tr>
<tr>
<td>K⁺(mg l⁻¹)</td>
<td>–</td>
<td>5.2</td>
<td>–</td>
<td>5.0</td>
<td>10.4</td>
</tr>
<tr>
<td>Ca²⁺(mg l⁻¹)</td>
<td>45.1</td>
<td>168.1</td>
<td>0.7</td>
<td>473.4</td>
<td>177.5</td>
</tr>
<tr>
<td>Mg²⁺(mg l⁻¹)</td>
<td>8.4</td>
<td>4.0</td>
<td>–</td>
<td>135.9</td>
<td>42.6</td>
</tr>
<tr>
<td>Fe³⁺-Fe²⁺(mg l⁻¹)</td>
<td>18.0</td>
<td>387.4</td>
<td>–</td>
<td>4.9</td>
<td>1.96</td>
</tr>
<tr>
<td>Mn²⁺(mg l⁻¹)</td>
<td>0.45</td>
<td>3.5</td>
<td>–</td>
<td>12.3</td>
<td>3.85</td>
</tr>
<tr>
<td>Al³⁺(mg l⁻¹)</td>
<td>23.2</td>
<td>792.6</td>
<td>–</td>
<td>37.1</td>
<td>–</td>
</tr>
<tr>
<td>SO₄²⁻(mg l⁻¹)</td>
<td>670</td>
<td>5484</td>
<td>12.7</td>
<td>3488</td>
<td>652</td>
</tr>
<tr>
<td>Cl⁻(mg l⁻¹)</td>
<td>2.1</td>
<td>29.6</td>
<td>26.0</td>
<td>9.2</td>
<td>133.8</td>
</tr>
</tbody>
</table>

In our samples, the valve is linear lanceolate with protracted to bluntly rostrate ends, 38.5–49 μm long, 4–4.5 μm broad, the ratio of length to breadth 9.4–11, fibulae 12–14 in 10 μm, and with a distinct central nodule appear, striae over 35 in 10 μm.

**Nitzschia amplectens** Hust. 1957


In this study, this taxon occurred at 19 sites, the waters of which receive an inflow of sulfuric or hydrochloric acid waters with pH range from 1.0 to 3.9 (Table 1,2). At such strong acid water sites, this taxon occurred together with the four same taxa as mentioned above for *Nitzschia paleaeformis*. We have also found that this taxon
occurred in polluted (DAIpo value: 26, 37, 42. α-
mesosaprobic, β-mesosaprobic; Watanabe et al.
1990) and brackish streams in Sumatra. In this
case, the taxon occurred together with Pinna-
laria subcapitata and Surirella robusta.

Lange-Bertalot & Simonsen (1978) stated that
the typical biotope of this taxon is expected in
brackish water, taking into consideration the re-
sults of their investigations in which they found
this taxon together with other halophilous dia-
toms in polluted rivers in Spain.

In our samples, the valve is lanceolate with
more or less convex margins in the middle and
bluntly rostrate ends; 16–34 μm long, 4–5 μm
broad, the ratio of length to breadth 4.5–6.6,
fibulae 11–13 in 10 μm, the central nodule is
distinct. Striae approximately over 40 in 10 μm.

Discussion

In our statistical analysis on the pH tolerance
of 485 diatom taxa in epilithic algal assemblages,
45 Nitzschia taxa occurred. Among them, 22 taxa
prefer alkaline waters; however, the taxa prefer-
ing acid waters were very few, i.e. only the two
taxa mentioned above were recognized as acido-
biontic taxa (Watanabe & Asai 1999).

In the table compiled on the ecological indica-
tor values of freshwater diatom taxa by Van
Dam et al. (1994), 103 Nitzschia taxa were re-
corded. Among them 51 taxa were recorded as
alkaliphilous or alkalibiontic taxa, while only 4
taxa were acidophilous or acidobiontic. This pH
classification is derived from Hustedt (1937–
1939). In the list of diatoms found in sediment
cores from eight south Swedish lakes with five
pH preference groups based on the numerical
methods for the inference of pH variations pro-
posed by Håkansson (1993), 29 Nitzschia taxa
were listed. Among them, 22 taxa were regarded
as alkaliphilous taxon, however, there were no
acidophilous or acidobiontic taxa.

The above mentioned investigators have used
the acidobiontic taxon as the name of a pH pref-
ference group, however, their ecological meaning
of the word is essentially different from ours.
Statistical analysis on the tolerance index value
for pH was undertaken on 485 diatom taxa
(Watanabe & Asai 1999). As a result, 39 taxa be-
low 4.77 weighted pH average of all sites where
it appeared (Watanabe & Asai 1999). Among
these 39 taxa, Nitzschia paleaformis had a toler-
ance index value of 20.45, weighted pH average
3.05 and N. amplectens had an index value of
10.42, pH average 2.50. The values of these two
Nitzschia taxa are lower than those of other aci-
dobiontic taxa. We also considered that these
two acidobiontic Nitzschia taxa which occurred
near the ends of the environmental gradient
were noteworthy environmental frontier species
having a tolerance for a severe environment
which can be considered as a ruins of primitive
water environment (Watanabe & Asai 1995).

Acknowledgements

We wish to thank Dr. Kenichi Satake, National
Institute for Environmental Studies for providing
data of water analysis by using the atomic ab-
sorption analysis.

References

Relationships between diatom assemblages in
lake surface-sediment and limnological charac-
teristics in southern Norway. 97–109. In : Smol,
J.P., Battarbee, R.W., Davis, R.B. & Merlijn,
J. (eds) Diatom and lake acidity. Dr. W. Junk
sediment diatom assemblages and lake water
characteristics in Adirondack lakes. Ecology
66 : 994 – 1011.
Cholnoky, B.J. 1968. Die Ökologie der Dia-
tomeen in Binnengewässern. 699 pp. Verlag J.
Cramer, Lehre, Berlin.
Dixit, S.S. & Dickman, D. 1986. Correlation of
surface sediment diatoms with the present lake
water pH in 28 Algoma lakes, Ontario, Canada.
Hydrobiologia 131 : 133–143.
Dixit, A.S., Dixit, S.S. & Evans, D. 1988. The re-
lationship between sedimentary diatom assem-
blages and lake water pH in 35 Quebec lakes,
Håkansson, S. 1993. Numerical methods for the
inference of pH variations in mesotrophic and
eutrophic lakes in southern Sweden. A pro-
Hustedt, F. 1937–1939. Systematische und ökolo-
gische Untersuchungen über die Diatomeen-
Nitzschia paleaeformis and N. amplectens occurring in strongly acid waters

Figs 1–4. Nitzschia paleaeformis Hust.

Figs 5–21. Nitzschia amplectens Hust.

Scale bar = 10 µm


Toshiharu Watanabe : Institute of Periphyton, Higashigawa-cho 518, Shinkyogoku St., Nakagyo-ku, Kyoto 604—8046, Japan
Kazumi Asai : Osaka Medical College, Daigaku-cho 2—7, Takatsuki, Osaka 569—0801, Japan