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RELATION OF CHANGE IN RIVER DIATOM ASSEMBLAGES TO WATER POLLUTION[1]

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Abstract

The two years change of diatom assemblages in relation to water pollution in Hsin-Dien River, Taipei was studied. At six sampling stations along the river, water quality indicated by diatom species ranked from oligosaprobity to α-mesosaprobity. It agreed well with the results of physico-chemical analysis as well as that indicated by other algae. As response to increasing water pollution, the species richness and diversity of diatom assemblages decreased, whereas the redundancy increased. Also the ratio of araphid diatoms to centric diatoms within a community decreased, as the degree of pollution increased, independently on the seasons. The changes of all these properties were revealed to be well correlated with the saprobity of waters and therefore could be used as estimators of water quality in the river. The dominant and subdominant species found at sampling stations were gradated into three groups according to the extent of tolerance to water pollution. The associations of gradated species were considered to be of the more reliable parameter indicating the water quality.

Key words: Diatom assemblage; river; pollution; water quality; bioindicator.

Introduction

In recent years algae have been profusely used as ecological indicator (Whitton, 1979; Symoens *et al.*, 1981; Hosmani and Bharati, 1984; Austin and Deniseger, 1985). Diatoms are cosmopolitically distributed and are considered to be of the opportunistic algal group in the sense that they are quite sensitive to minor change in environment. It is not surprising that the distribution pattern of diatoms in waters may usually indicate the type of environment they inhabited. In fact, diatoms have been used in many area to estimate the trophic state and quality of waters (Watanabe, 1962; Fjerdingstad, 1964; Williams, 1964; Besch *et al.*, 1972; Schmidt and Christensen, 1975; Lange-Bertalot and Bonik, 1976; Carney, 1982; Martinez *et al.*, 1985; Tomás and Sabater, 1985).

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In Taiwan, most rivers have been polluted to various extent. The monitoring of water pollution in the rivers has been approached by different methods (Lee *et al.*, 1967; Hau *et al.*, 1976; Hong, 1979; Wu and Suen, 1985). In the previous paper, the change of phytoplankton associations in relation to water pollution in a river had been described. In this article, the distribution pattern of diatom assemblages in the same river was studied. An attempt to find out a simple applicable method using only diatom assemblages as indicator of water quality was made.

Materials and Methods

Diatom samples were gathered from April 1984 to November 1985 from six stations along the Hsin-Dien River, Taipei. The location of sampling stations had been demonstrated in previous paper (Wu and Suen, 1985). The samples were fixed with Lugol's solution and cleaned with acid mixture of acetic acid and sulfuric acid (9:1) and then mounted on slide for microscopic observation.

The number of taxa encountered in 500 cell counts was used as the measure of species richness in a community. The diversity index of community was calculated according to Shannon and Weaver (1949). The redundancy index of community was computed as mentioned by Cairns and Dickson (1971). The interstational similarity of diatom assemblages was tested using the C_λ index of overlap (Horn, 1966). The saprobity of waters at sampling stations was numerically expressed based on the indicator value of each species according to Liebmann's list of indicator organisms and the frequency of each species found (Pantle and Buck, 1955). A ratio of Araphidineae to Centrales was calculated based on the proportion of their presence, as used by Carney (1982).

Results

In the river studies, the water quality pronouncedly changed from station to station. According to the physico-chemical analysis of water samples, as demonstrated in previous paper (Wu and Suen, 1985), the water quality changed from oligosaprobity at station (st.) 2 to α-mesosaprobity at st. 6. As response to increasing water pollution, diatom assemblages also altered in their structure such as species composition and the relative abundance of species found. As shown in Table 1, the species richness and diversity of communities decreased from st. 2 to st. 6. The highest species number and diversity were revealed at st. 2 rather than st. 1, indicating that st. 1 was more polluted than st. 2. Similar result was also obtained by testing the redundancy of communities.

A numerical expression of saprobien system (Fig. 1) based on the saprobic indices of indicating species and the relative abundance of species indicated that the water quality at the sampling stations ranked from oligosaprobity at st. 2 to

Table 1. *Variation of taxa number (S), diversity (D), redundancy (R) and saprobic index (SI) of diatom assemblages revealed at each sampling station from April 1984 to November 1985*

Date	Station 1				Station 2				Station 3				Station 4				Station 5				Station 6			
	S	D	R	SI	S	D	R	SI	S	D	R	SI	S	D	R	SI	S	D	R	SI	S	D	R	SI
1984 Apr.	49	3.68	0.27	1.58	54	5.08	0.08	1.48	49	4.49	0.15	2.10	27	2.58	0.34	2.34	24	2.67	0.36	2.33	21	2.46	0.38	2.58
Jul.	39	4.32	0.14	1.73	42	4.56	0.11	1.48	34	3.53	0.25	2.03	26	2.95	0.30	2.22	23	2.73	0.36	2.39	16	2.55	0.33	2.47
Sep.	38	4.01	0.19	1.71	42	4.29	0.15	1.53	37	3.86	0.20	1.96	31	3.34	0.27	2.09	27	3.02	0.31	2.27	26	2.94	0.32	2.52
Dec.	45	4.19	0.18	1.66	47	4.25	0.17	1.52	42	3.79	0.23	1.99	31	3.36	0.27	2.28	29	3.05	0.30	2.44	27	3.07	0.30	2.52
1985 Mar.	41	4.15	0.17	1.70	44	4.40	0.13	1.56	38	3.88	0.22	2.01	32	2.86	0.36	2.05	24	2.69	0.35	2.46	22	2.71	0.34	2.67
Nov.	39	4.15	0.14	1.61	41	4.17	0.13	1.45	38	4.03	0.18	1.98	33	3.66	0.34	2.37	33	3.41	0.35	2.47	27	3.02	0.38	2.49

α-mesosaprobity at st. 6. These results met well with that calculated according to total phytoplankton as well as that of physico-chemical analysis (see Wu and Suen, 1985). The tendencies of increase in saprobity from st. 2 to st. 6 and a higher saprobity at st. 1 than at st. 2 remained unchanged, in spite that there was somewhat fluctuation in saprobity during the study time (Fig. 1).

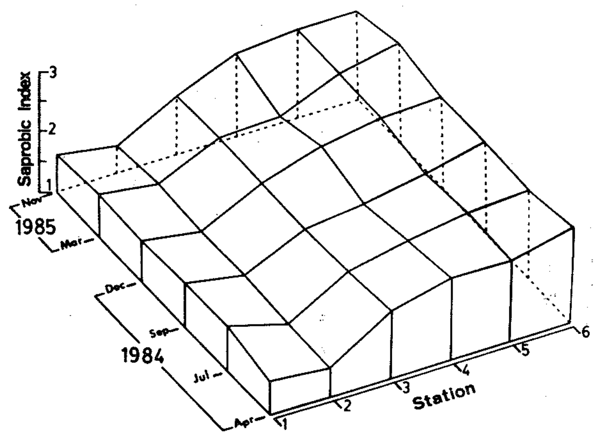

Fig. 1. Seasonal variation of saprobity of waters at each sampling station from April 1984 to November 1985.

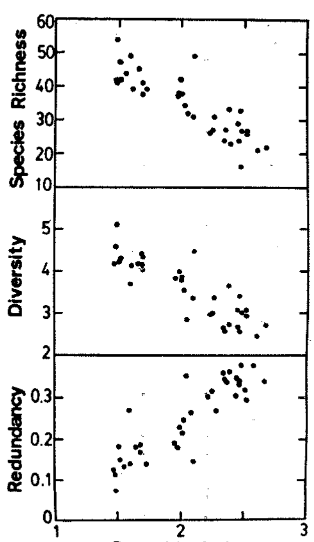

Fig. 2. Plot of species richness, diversity and redundancy of diatom assemblages versus saprobic index of waters, showing the relationship between them.

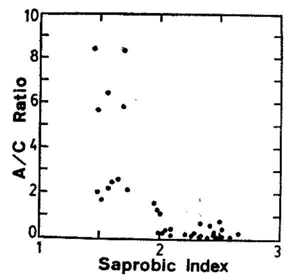

Fig. 3. Relationship between the ratios of araphid diatoms to centric diatoms (A/C ratio) within diatom assemblages at each sampling station and the saprobity of waters.

The plot of species richness, diversity and redundancy versus saprobic indicies (Fig. 2) showed that they were approximately linearly correlated.

The test of interstational community similarity showed that low similarity existed between clean-water (such as st. 1 and 2) and polluted stations (such as st. 5 and 6) (Table 2). In comparing with st. 2, diatom assemblages at st. 1 had higher similarity to st. 5 and 6. This also implicated that st. 1 was more polluted than st. 2.

Table 2. *Interstational similarities of diatom communities in different seasons of 1984*

April / July	Station						September / December	Station					
	1	2	3	4	5	6		1	2	3	4	5	6
Station							Station						
1	—	0.81	0.56	0.44	0.29	0.38	1	—	0.78	0.65	0.26	0.31	0.34
2	0.86	—	0.70	0.24	0.18	0.14	2	0.71	—	0.55	0.08	0.09	0.11
3	0.32	0.48	—	0.75	0.46	0.19	3	0.59	0.77	—	0.69	0.25	0.39
4	0.19	0.22	0.68	—	0.19	0.11	4	0.58	0.38	0.85	—	0.62	0.43
5	0.47	0.17	0.42	0.45	—	0.48	5	0.55	0.29	0.63	0.57	—	0.60
6	0.54	0.17	0.29	0.26	0.85	—	6	0.49	0.31	0.64	0.59	0.64	—

The computation of the ratio of araphid pennates to centrics diatoms (A/C ratio) showed that it decreased with increasing water pollution (Table 3). The species accounting for the A/C ratio were: *Fragilaria capucina, F. constreus, F. fonticola, F. ulna, Synedra acus, S. rumpens* var. *fragilarioides* f. *fonticola, S. ulna, S. ulna* var. *amphirhynchus, S. ulna* var. *spathulifera, Cyclotella meneghiniana, C. stelligera, Melosira granulata, M. italica* and *M. varians.* These species were quite different in tolerance to water pollution. The A/C ratio was usually higher than 2 at clean-water stations such as sts. 1 and 2, because *Fregilaria* presented there in high percentage. The A/C ratio decreased from st. 2 to 6 due to the marked decrease in parts of *Fragilaria* and *Synedra* and the increase in part of *Melosira.* A close correlation of A/C ratio with saprobity of waters was illustrated in Fig. 3.

In general, a diatom species usually can be revealed at more than one station. The distribution pattern of a species was determined by the species-specific tolerance to water pollution. The common diatom species found in the river were classified into three groups according to their tolerance to pollution (Table 4). The species belonging to the same group usually present in association with each other. Such an association can be used as indicator of water quality.

Table 3. *Change of the ratios of araphid diatoms to centric diatoms (A/C ratio) within diatom assemblages at each sampling station from April 1984 to November 1985*

Date		Station					
		1	2	3	4	5	6
1984	Apr.	2.20	5.67	0.43	0.17	0.02	0.02
	Jul.	2.07	1.96	0.27	0.18	0.04	0.03
	Sep.	5.79	27.50	1.55	0.19	0.18	0.16
	Dec.	2.59	2.66	0.31	0.21	0.20	0.41
1985	Mar.	8.33	6.40	1.15	0.40	0.30	0.27
	Nov.	2.43	8.40	1.31	1.29	0.62	0.46
Average		3.90	8.76	0.84	0.41	0.23	0.22

Table 4. *Common intolerant. moderate tolerant and tolerant diatom species found in Hsin-Dien River to water pollution*

Intolerant species	Moderate tolerant species	Tolerant species
Achnanthes crenulata	*Bacillaria paxillifer*	*Navicula cincta*
Ach. inflata	*Cymbella lanceolata*	*Nitzschia clausii*
Ach. lanceolata	*Cym. turgidula*	*Nit. obtusa* var. *scalpelliformis*
Cocconeis placentula	*Gomphonema parvulum*	*Nit. palea*
Cymbella tumida	*Melosira granulata*	*Nit. parvula*
Fragilaria constreus	*Mel. varians*	*Nit. pygmea*
Fra. ulna	*Navicula crytocephala*	*Nit. pseudosigma*
Gomphonema gracile	*Nav. rhynchocephala*	
Gom. angustatum	*Surirella* div. sp.	
Gyrosigma kuetzingii	*Synedra ulna*	
Hydrosera triquetra		

Discussion

The assessment of water quality can be done by using several indices (Tolkamp, 1985). The approach for developing the biological indices is generally based either on the mathematical properties of populations of organisms within a community, such as diversity of species (Cairns and Dickson, 1971; Dennis and Patil, 1979; Smith and Gibson, 1979), or on the types and quantities of certain indicator organisms, such as saprobien system (Zelinka and Marvan, 1961). The diversity of species is a summary of the relationship between species and individuals in a community. In less polluted environment, the community is characterized by smaller numbers of individuals per taxon and large number of taxa. As a result, this will give rise to higher diversity index and lower redundancy. The diversity itself, however, is not a reliable estimator for water quality, because it may vary to great extent in some cases (Archibald, 1972; Smith and Gibson, 1979). For biological assessment of water quality, therefore, some other parameters such as species richness, redundancy and ecological conditions should be taken into account. The results demonstrated above indicate that species richness, redundancy and diversity and diversity of diatom assemblages are well correlated with the saprobity of waters. This implicates that all of these parameters can be used as estimator for water quality in the river studies.

The expression of water quality using saprobien system mentioned by Sládeček (1973) sometimes may be over-estimated for oligosaprobic waters or under-estimated for α-mesosaprobity. This is considered to be due to insufficient informations about indicating species. To overcome this problem Lange-Bertalot (1978 and 1979) proposed an alternative using gradated tolerance of diatom species as indicators for river water quality. The gradation of the tolerance of species is sometimes difficult, because it requires enough informations of the charcteristics of species and ecosystem. Another available parameter for biological assessment of water quality is the species association. This is based on the fact that certain associations of species are empirically far more probable than others (Hutchinson, 1967). The concept of phytoplankton associations can also be applied to diatom assemblages. In the river studies, the common diatom species that dominate or subdominate in the waters of each saprobic level are grouped together according to their tolerance to water pollution. The species belonging to the same group usually appear in association with each other. Such an association can therefore be use as indicator of water quality.

The A/C ratio in diatom assemblages, as shown above, is well correlated with water quality. Although the ratios may vary to some extent in different seasons, the tendency of decrease in the value with increase of water pollution remains unchanged. This tendency is consistent with the diatom index (i. e. ratio of centric diatoms to pennate diatoms) proposed by Nygaard (1949). In the lakes, Stockner and Benson (1967) had proposed that A/C ratio increased during eutrophic condition. Similar results have also been reported later by Stockner (1972) and Carney (1982). These are, however, just contradictory to the results obtained from the river studies. This is probably due to the difference in the type of aquatic environment. Consequently, the diatom assemblages found in either environments are quite different.

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河川矽藻族羣變化與水污染關係

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沿新店溪選六站作二年之取樣比對，發現矽藻羣落內種數、歧異度及族羣冗長度之變化與水質有密切相關。以矽藻作污染指標顯示取樣站水質由上游之一級水降爲下游之三級水，此結果與以物理化學方法所測得相似。藻羣中無殼縫矽藻對中心型矽藻之比值與水質也有密切相關，此值也可作爲水質指標。吾人將常見之矽藻種，依其對污染之耐度，區分爲三羣，由羣中品種出現之比例，更能精確指示水質狀況。