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CHANGE OF ALGAL ASSOCIATIONS IN RELATION TO WATER POLLUTION[1,2]

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Abstract

The distribution pattern of algae in response to the increase of water pollution in the Hsin-Dien river in Taipei was investigated. Phytoplanktons from six stations along the river were collected in all seasons of a year. The differences in the algal species composition and the diversity of communities were related to the saprobity of waters. The change of the relative abundance of diatoms, green algae and flagellates was revealed to be good indication to water pollution. The seasonal succession of algal community was also investigated. The relation of water saprobity to the diversity of community was elucidated. The change of the components of algal associations, that are composed of five algal genera and their species, may be used as indication of the state of water pollution.

Key words: Phytoplankton; algal association; bioindicator; water pollution; seasonal succession.

Introduction

It is well known that the biological populations and water quality are interdependent. Hence the degree of water pollution can be evaluated by characterising the aquatic communities in the habitat (Sládeček, 1973; Verneaux, 1976; Persoone and De Pauw, 1979). According to the concept of biological indicator for various saprobic zones submitted by Kolkwitz and Marrson (1908 and 1909) and Liebmann (1962), several methods have been proposed to quantify the indicating organisms (Knöpp, 1954; Pantle and Buck, 1955; Zelinka and Marvan, 1961). For monitoring the river water quality various methods were developed. However, each method could be successfully used in some areas, but failure in others. The main problems

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are considered to be due to the existence of the differences in biogeographical regions and habitats. Hence each indicator system is usually valid only in a restricted area.

In Taiwan, although bioindicator methods for monitoring the pollution of surface waters has been used (Lee *et al.*, 1967; Hau *et al.*, 1976; Hong, 1979), the application of the methods still faces with difficulties, which is primarily due to the insufficient data base such as the basic knowledges on characteristics of local species and communities. In addition, the identification of an organism to species level is sometimes difficult because of the inadequate information of algal taxonomy. To overcome these difficulties the method using algal associations as the denotion of algal community type has been mentioned in previous paper (Wu, 1984). The attempt of using this method to study the change of algal communities in response to the increase of water pollution in the river was thus done. The influence of seasons on this change was also investigated.

Materials and Methods

Phytoplanktons from six stations along the Hsin-Dien river were collected with a plankton net throughout the year of 1984. The sampling stations are given in Fig. 1. The samples collected were identified by microscopy. The saprobic index (SI) of waters and the diversity index (DI) of algal community were calculated as mentioned previously (Wu, 1984). The state of water environment was characterized by measuring the contents of nitrate, nitrite, ammonium and phosphate after reacting with the reagents prepared by Macherey-Nagel GmbH & Co. In addition, the pH-value, dissolved oxygen, color, turbidity and conductivity of water in each sampling station were also measured immediately after sampling.

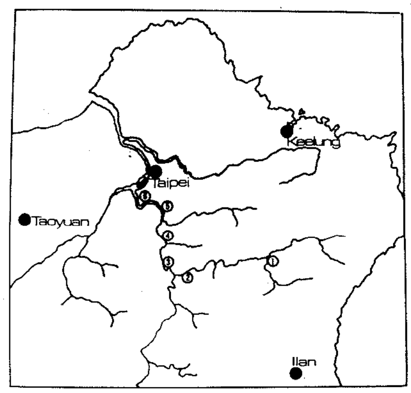

Fig. 1. A map of noith Taiwan showing the sampling stations.

Results

The degree of water pollution varied with sampling stations. The increases in the contents of ammonium and phosphate or in the conductivity, turbidity of waters, in company with the decreases in dissolved oxygen and pH-value of waters from up- to down-river were revealed. The results illustrated in Fig. 2 showed that between stations 4 and 5 there was a significant change in the ammonium and phosphate contents in waters as well as in dissolved oxygen and conductivity of waters. Such a change was resulted from the marked increase of water pollution due to mass inflow of wastewater into the river at station 4.

The water quality estimated by the indicating phytoplankton ranked from 1.2 to 3.0. It covered the range between oligosaprobity and α-mesosaprobity and coincided well with the results of physio-chemical analyses of waters. In general, the lower species diversity of algal community was revealed in those waters with higher saprobic index values. The plot of diversity index versus saprobic index, illustrated in Fig. 3, showed the linear relationship between them.

The N/P ratio is an important parameter indicating the state of nutrient supply in waters. The N/P ratio obtained from dividing the soluble nitrogen, namely the sum of nitrate, nitrite and ammonium, by phosphate content did not vary to a great extent in the river. As shown in Table 1, the values ranged from 1.1 to 7.6. The greatest difference between stations, however, was no more than 5.3, which was revealed in September. In other seasons, the difference between stations was much smaller.

The composition of algal communities changed, as the degree of water pollution increased. The relative abundances of Chlorophyceae, Bacillariophyceae and Euglenaceae were revealed to successively change from up- to dow-nriver. In less polluted waters, such as stations 1, 2 and 3, Bacillariophyceae is the predominant algal group in all seasons. In polluted waters, such as stations 5 and 6, the relative

Table 1. *N/P ratio of water at each sampling station measured at different date*

Station	N/P Ratio			
	Feb. 3	Jul. 2	Sep. 25	Dec. 12
1	3.5	1.2	6.1	4.2
2	2.8	1.1	6.7	3.4
3	3.0	1.3	7.6	3.6
4	3.4	2.1	3.0	2.8
5	2.4	1.8	2.4	2.1
6	2.5	2.0	2.3	2.4

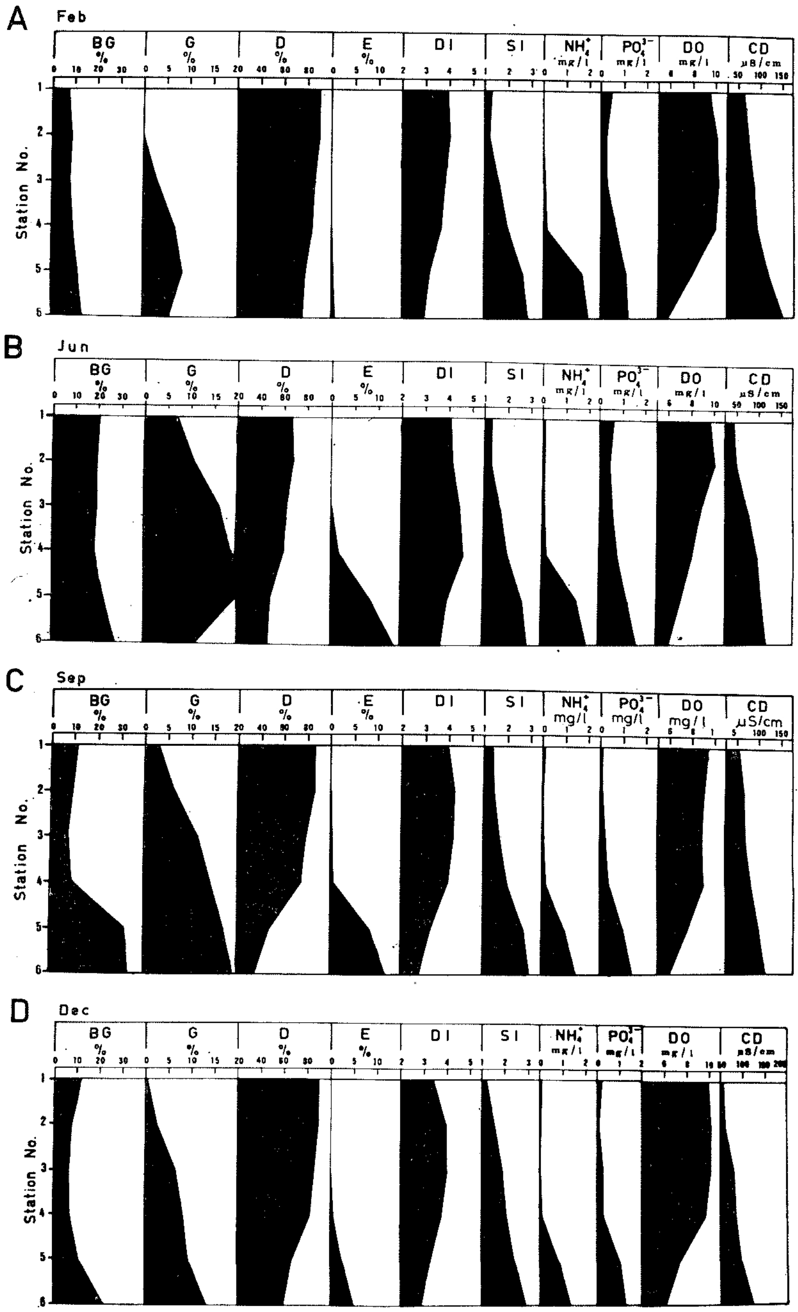

Fig. 2. Variation patterns of algal communities in relation to the increase of water pollution in 1984. (A): February; (B): June; (C): September; (D): December. Abbreviations: BG, blue-green algae; G, green algae; D, diatoms; E, euglenaceae; DI, diversity index of algal community; SI, saprobic index of water; DO, dissolved oxygen in water; CD, conductivity of water.

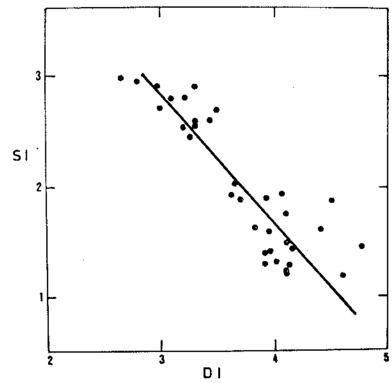

Fig. 3. Plot of saprobic index (SI) of waters versus diversity index (DI) of algal communities in the river studied showing the relationship between them.

abundance of Bacillariophyceae was lower. The occurrence of green algae, usually of the genera *Pediastrum*, *Scenedesmus*, *Pandorina*, *Eudorinr* and *Closterium*, is the indication of β-mesosaprobity. At station 3 and 4, these algae appeared in considerable amount. The abundance of Euglenaceae, predominantly of *Euglena* and *Phacus*, indicated the state of α-mesosaprobity at stations 5 and 6.

In contrast to the above three algal groups, the relative abundance of blue-green algae did not change in great extent in the river. Among blue-green algae, *Oscillatoria* was the dominant genus at all stations studied. In response to the increasing water pollution, the species of this genus changed. For example, *O. nigra* and *O. limnetica*, the indicating species for oligosaprobity, dominated at stations 1 and 2. At stations 4, *O. limosa* and *O. tenuis* were the predominant species. The indicating species for α-mesosaprobity, *O. formosa* and *O. chalybea*, dominated at stations 5 and 6.

Similarily to the successive change of genus *Oscillatoria*, there was also a clear change in diatom species along the river. The most significant change was revealed in those genera of *Fragilaria*, *Gomphonema*, *Cymbella*, *Synedra*, *Surirella*, *Melosira*, *Navicula* and *Nitzschia* (see Table 2). The diatom assemblages are good indicator for estimation of water quality in this river.

To simply denote the change of algal communities in the river the method of association was used. The species co-occurring in a station were clustered according to their abundance revealed there. An association comprising of five algal species is given in Table 2 to denote the type of a community. The constituent of association is the characteristics of each community and hence can be used as the indication to water pollution.

Alternatively, the characteristics of algal communities can sometimes be simply

Table 2. *Succession of phytoplankton elements in 1984 at sampling stations*

Station	February		June		September		December	
	Dom. Genera	Association	Dom. Genera	Association	Dom. Genera	Association	Dom. Genera	Association
1	*Fragilaria* *Synedra* *Lyngbya*	*Frag. capucina* *Synedra ulna* *Lyngbya limnetica* *Cymbella tumida* *Cocconeis placentula*	*Fragilaria* *Synedra* *Gomphonema*	*Frag. capucina* *Synedra ulna* *Gom. ventricosum* *Cymbella* div. sp. *Gyrosigma spencerii*	*Fragilaria* *Synedra* *Gomphonema*	*Frag. capucina* *Synedra ulna* *Gomphonema* div. sp. *Micrasterias foliacea* *Achnanthes lanceolata*	*Fragilaria* *Navicula* *Oscillatoria*	*Frag. capucina* *Navicula* div. sp. *Osc. limnetica* *Euastrum horikawae* *Nitzschia luzonensis*
2	*Fragilaria* *Synedra* *Melosira*	*Frag. capucina* *Synedra ulna* *Melosira varians* *Cymbella tumida* *Oscillatoria nigra*	*Fragilaria* *Gomphonema* *Bacillaria*	*Frag. capucina* *Gom. ventricosum* *Bac. paxillifer* *Cymbella* div. sp. *Hydrosera triquetra*	*Fragilaria* *Synedra* *Melosira*	*Frag. capucina* *Synedra ulna* *Melosira varians* *Gomphonema* div. sp. *Achnanthes laceolata*	*Fragilaria* *Cymbella* *Melosira*	*Frag. capucina* *Cymbella cistula* *Melosira varians* *Nitzschia* div. sp. *Oscillatoria agardhii*
3	*Fragilaria* *Melosira* *Bacillaria*	*Frag. capucina* *Melosira varians* *Bac. paxillifer* *Cymbella* div. sp. *Oscillatoria nigra*	*Fragilaria* *Pediastrum* *Sphaerocystis*	*Frag. capucina* *Ped. duplex* *Sph. schroeteri* *Scenedesmus* div. sp. *Navicula* div. sp.	*Fragilaria* *Pediastrum* *Melosira*	*Frag. capucina* *Ped. duplex* *Melosira varians* *Synedra ulna* *Bacillaria paxillifer*	*Fragilaria* *Pediastrum* *Melosira*	*Frag. capucina* *Ped. duplex* *Melosira varians* *Nitzschia* div. sp. *Navicula cryptocephala*
4	*Melosira* *Surirella* *Bacillaria*	*Melosira varians* *Surirella* div. sp. *Bac. paxillifer* *Fragilaria capucina* *Osc. limosa*	*Melosira* *Surirella* *Closterium*	*Melosira varians* *Surirella* div. sp. *Closterium acerosum* *Pediastrum* div. sp. *Fragilaria capucina*	*Melosira* *Surirella* *Pediastrum*	*Melosira varians* *Surirella* div. sp. *Ped.* div. sp. *Fragilaria capucina* *Oscillatoria tenuis*	*Melosira* *Surirella* *Closterium*	*Melosira varians* *Surirella* div. sp. *Closterium acerosum* *Navicula cryptocephala* *Oscillatoria tenuis*
5	*Nitzschia* *Oscillatoria* *Navicula*	*Nitzschia palea* *Osc.* div. sp. *Navicula cryptocephala* *Euglena* div. sp. *Melosira varians*	*Euglena* *Oscillatoria* *Pandorina*	*Euglena* div. sp. *Osc. formosa* *Pandorina morum* *Phacus* div. sp. *Scenedesmus oblique*	*Oscillatoria* *Euglena* *Pandorina*	*Osc. formosa* *Euglena* div. sp. *Pandorina morum* *Nitzschia palea* *Navicula cryptocephala*	*Oscillatoria* *Nitzschia* *Pediastrum*	*Osc. chalybea* *Nitzschia palea* *Pediastrum* div. sp. *Naviclua cryptocephala* *Melosira varians*
6	*Nitzschia* *Navicula* *Euglena*	*Nitzschia* div. sp. *Nav. pygmaea* *Euglena* div. sp. *Oscillatoria* div. sp. *Chlamydomonas* sp.	*Euglena* *Oscillatoria* *Nitzschia*	*Euglena* div. sp. *Osc. formosa* *Nitzschia* div. sp. *Phacus* div. sp. *Chlamydomonas* sp.	*Oscillatoria* *Euglena* *Nitzschia*	*Osc. formosa* *Euglena* div. sp. *Nitzschia palea* *Navicula rhychocephala* *Pandorina morum*	*Oscillatoria* *Nitzschia* *Navicula*	*Osc. chalybea* *Nitzschia palea* *Navicula cryptocephala* *Pleurosigma* sp. *Pediastrum duplex*

denoted by algal formation in place of algal association. A formation comprising of three algal genera that are most abundant at the stations studied, in most cases, already may indicate the type of algal communities. It is worth to note that each formation indicates only a saprobic level of water. A saprobic level, however, may be denoted by several types of algal formations, dependently on the seasonal and geographical differences.

Discussion

The results demonstrated above show that the increasing water pollution from up- to down-river can be revealed not only by the physico-chemical analyses but also by the indicating phytoplankton. In relating to increasing pollution the distribution pattern of algae changed in the species composition as well as the diversity of community. Potentially, a variety of categories of organisms may present in each aquatic ecosystem. However, the change of water environment due to pollution will bring about the rapid change of individual organisms in their population and communities. A special kind of species or group of organisms may hence become dominant in peculiar water environment. The characteristics of an algal community is therefore the indication of the state of water environment.

The change of algal community in the river might also be resulted from the change in nutrient supply in waters. Phosphorus, for instance, is recognized as the usual deficit nutrient in freshwater and accordingly is the limiting factor for algal growth. The inflow of wastewater usually gives rise to the problem of over supply of P and bring about the eutrophication in waters. Smith and Kalff (1983) indicated however that the variation of P supply was not a major selective influence on the size or species composition of algal community. Experimentally, it has been proved that it is not the P supply but the N/P ratio which is decisive for algal growth (Rhee, 1974, 1978). The optimum ratio of N/P for growth varies widely from species to species. The difference in optimum ratio may provide a basis for competitive elimination and co-existence of algal species in waters (Rhee, 1982). The results demonstrated above indicate that the inflow of pollutants into the river only results in little change of N/P ratio in waters. Such small change in N/P ratio therefore may not be the causal factor accounting for the marked change of algal communities in the river. The results shown above indicate that the change of algal communities is closely correlated with water pollution. The water pollution may give rise to the changes of physico-chemical properties of water environment and therefore provides a selective force for algal distribution in the river. Principally, only the species capable of adapting to the polluted environment may inhabit there. At the stations studied, however, some of the species not belonging to the indicated saprobic level were appeared. These algae were propably transported from upriver by stream. This may influence to some extent the value of saprobic index calculated in terms of indicating phytoplanktons. In fact, the saprobic level of water at stations studied should be somewhat higher than the given values shown above.

It is worth noting that the biological assessment of water quality is based on the assemblages of diverse algal species inhabiting in the river rather than on the individual or a few indicating species. To denote algal assemblages the association of dominant algal genera and their species have been used (Penzhorn, 1977; Wu, 1984). Associations are composed of species that have similar reactions to common biotope. The concept of association is hence a simplification of the response of algal species to the environment. In principle, the denotion of algal assemblages by association has the geographical specificity. This is due to the existing biogeographical difference in various communities. Besides, different seasons also strongly influence the distribution pattern and constituents of algal communities. To establish a useful bioindicator system for water quality such ecological characteristics of communities should be investigated.

Diatoms are the algal group commonly used as indicating organisms for trophic state and saprobity of waters (Fjerdingstad, 1964; Williams, 1964: Besch *et al.*, 1972; Schmidt and Christensen, 1975). In the river studied diatoms are the dominant group in all seasons. The constituents of their assemblages significantly changed from station to station. At the stations studied, the change of the relative abundances of the genera such as *Gomphonema, Cymbella, Fragilaria, Synedra, Surirella, Melosira, Nitzschia* and *Navicula* is well related to the degree of water pollution. A further investigation taking account of the relationship between the characteristics of diatom assemblages and water pollution will be published in separate article.

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藻類種羣變遷與水污染關係

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自新店溪上游至下游選取六處，作全年藻類採樣及水質測試，以研究溪中藻類種羣因應水污染所作之變遷。浮游藻族羣中，矽藻，綠藻及裸藻類之相對數量，會隨水污染程度之不同而作明顯的增減。矽藻類各屬間有顯著的沿河消長，藍綠藻類的顫藻屬其數量上雖無沿河作消長，但有明顯的種消長現象。以上兩類均可作爲此溪中水污染的生物指標。爲簡便表示藻類羣落因應水污染之變遷情形，吾人以五種藻類組成之種羣作爲各級水質下污類羣落之特性代表。由種羣組成份子變遷之情形，可反應水污染之情況。