CHANGES OF TROPHITY CONDITIONS IN THE RIVER DANUBE AT GÖD
Danubialia Hungarica XCIV.

by

K. T. KISS

Danube Research Station of the Hungarian Academy of Sciences, Göd

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The phenomenon of eutrophication has been observed and investigated in many surface waters including rivers. The River Danube is not an exception to that either, since the increasingly higher individual numbers of plankton algae in the river point to advanced trophity. Dobler – Schmidt (1980) report on the eutrophication of the southern part of the Hungarian section of the Danube. Authors compare their data from 1976 – 1977 with those obtained by Uherkovich (1969) in 1966 – 1967. Vörös (1974) also described the trophity conditions of this section of river. We can form a notion of the trophity of the Danube between Rajka and Esztergom on the basis of the paper by T. Bartalis (1978).

In this paper a picture will be given of the eutrophication of the Göd section of the Danube on the basis of comparison between the quantitative data obtained by Szemes (1964, 1967, 1968, 1969, 1971, Szemes et al. 1963) and our own experimental results.

Samples for algological studies were drawn weekly from under the water surface in the main current of the Danube at Göd (1669 riv km). After fixation with Lugol solution, the samples were allowed to settle in counting chambers and then examined in Utermöhl's inverted plankton microscope (OPTON) (Utermöhl 1958). Trophity conditions and the process of eutrophication in the river will be characterized on the basis of algal counts (Felföldy 1980). In the evaluation of results, species number of phytoplankton samples will be also presented. Species number will be given as species per a thousand algal individuals according to Lund et al. (1958) and Hajdu (1977).

RESULTS AND CONCLUSIONS

On the basis of studies carried out in the period between 1979 and 1981, the phytoplankton of the Danube at Göd can be characterized in the following:

Individual numbers of plankton algae started increasing in the post winter period, generally in the second half of February. Algal growth rate increased, and in the still cold water of 3 – 5 °C phytoplankton density became very high in early and middle March (Fig. 1, 2). This spring bloom was characterized by the dominance of species belonging to *Stephanodiscus*, making up more than 90% of the phytoplankton. In 1979 and 1981, this early spring mass growth of algae had two peaks. In 1980 the total individual number of algae in plankton had only one maximum. This was found to be due to the changes of discharge. In periods of flood waves, individual numbers always diminished, and following the subsiding of flood waves, the total algal count increased in the receding water.

Algal count was generally higher in spring (April and May), than in early spring, though concerning species composition there was great similarity between the two periods. Marked differences could be observed only in the second half of May. It was then that the temperature of water increased by 5 – 8 °C within 2 – 3 weeks. Species number of phytoplankton increased by 50 – 100%, and the phytoplankton of the Danube with more or less constant species composition from early summer to late October developed. While there were scarcely any changes in species composition, individual numbers exhibited essential changes in this period too. In the case of long lasting flood waves, e.g. in July – August 1980, individual numbers in river phytoplankton were low for several weeks. Smaller flood waves of shorter duration, however, diminished algal count only for 1 – 2 weeks. During balanced water flow between the flood waves, the phytoplankton of the Danube was both rich and numerous.

Also during periods of high algal count in summer and early autumn, *Stephanodiscus species* formed 70 – 80% of total algal individual number. Beside this species, *Cyclotella meneghiniana*, *Skeletonema potamos*, *Nitzschia acicularis* can be mentioned from among the diatoms as species of greatest frequency and attaining individual numbers *Chlorococcales* also exhibited highest individual numbers. Most frequent and most numerous members of this order were *Actinastrum hantzschii*, *Ankistrodesmus acicularis*, *A. angustus*, *Dictyosphaerium ehrenbergianum*, *Oocystis borgei*, *Scenedesmus acuminatus*, *S. quadricauda*, *Tetrastrum staurogeniaeforme*. In addition to the aforementioned species, *Chroomonas acuta* and a few species of the genus *Cryptomonas* distinguished themselves by their great frequency and great individual numbers.

During late autumn and winter, the phytoplankton of the Danube was not rich in species. Its total individual number varied from a few hundred thousand to 2 million in one liter.

Table I shows the species composition of some characteristic phytoplankton samples from the Danube, i.e. two samples for two (spring and summer) periods of high phytoplankton density each. The first pair of samples is characterized by high algal counts, the second by lower ones. Concerning the species composition of samples of nearly identical density (species number per one thousand individuals) we can state the following:

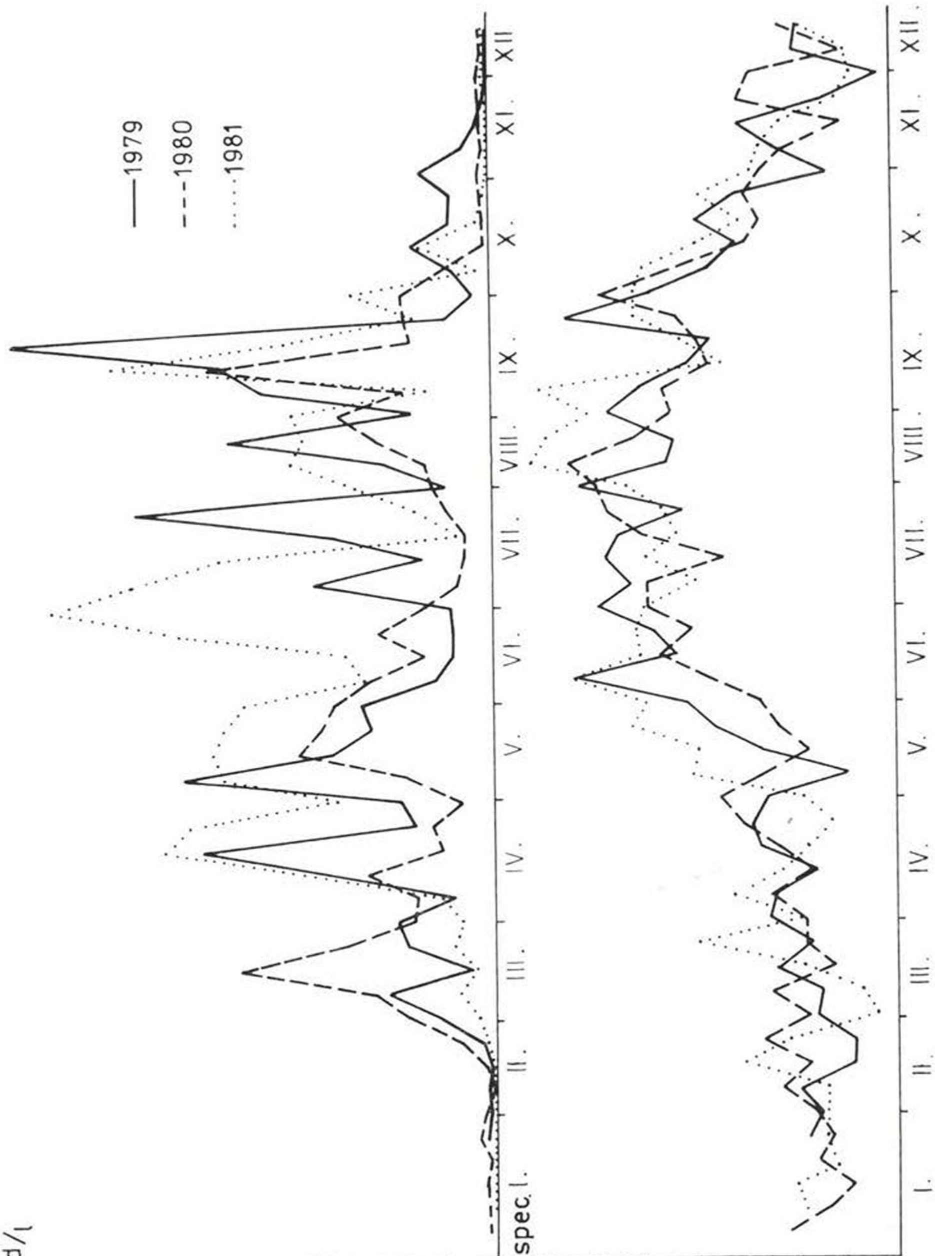

Fig. 1. Changes in species and individual number of the phytoplankton in the Danube between 1979 and 1981 (number of species per one thousand individuals)

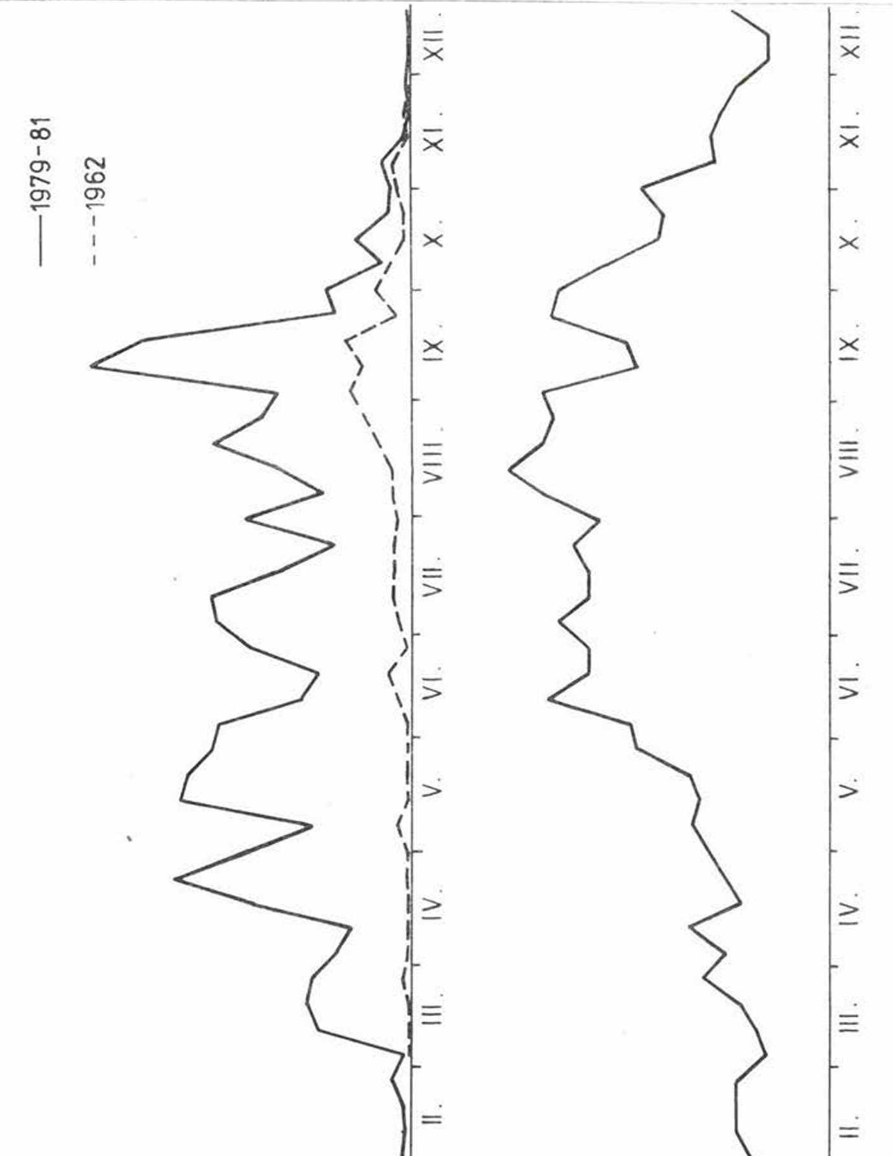

Fig. 2. Changes in the individual and species number of the phytoplankton in the Danube on the basis of the weekly averages between 1979–1981, and in 1962 (species number per one thousand individuals)

Table I

Phytoplankton composition in some characteristic water samples from the Danube

	20.03.1980.	29.08.1979.	9.04.1981.	2.09.1981
Asterionella formosa Hass.	245		10	11
Ceratoneis arcus Kütz.			10	
Cyclotella meneghiniana Kütz.	49	98	10	
Cymbella ventricosa Kütz.	98			
Diatoma hiemale var. *mesodon* (Ehr.) Grun.	49			
D. vulgare Bory			10	
Melosira distans var. *alpigena* Grun.		196	10	
M. granulata (Ehr.) Ralfs		98		22
M. italica (Ehr.) Kütz.		49		
Navicula cryptocephala Kütz.	47			
Nitzschia acicularis W. Smith	98	343	69	110
Rhizosolenia longiseta Zachar.				22
Skeletonema potamos (Weber) Hasle		3 675		2 058
Stephanodiscus spp.	48 855	14 015	9115	5330
Surirella ovata Kütz.	98			
Synedra acus Kütz.		49	29	22
S. ulna (Nitzsch.) Ehr.				22
other *Pennales* spp.	147	49	10	77
Bacillariophyceae total	49 686	45 572	9273	7674
Actinastrum hantzschii Lagerh.		196		44
Ankistrodesmus acicularis (A. Br.) Kors.		196	20	132
A. angustus Bern.		686	98	814
A. arcuatus Kors.		49		66
A. longissimus var. *acicularis* (Chod.) Brunnt.	49	49		22
A. minutissimus Kors.		245	10	88
Ankyra ocellata (Kors.) Fott				22
Chlorella vulgaris Beijer	98		78	396
Chloromyrus paulii Hortob				66
Chodatella balatonica Scherf.				44
Ch. citriformis Snow		49		
Coelastrum microporum Naeg.		490		11
C. spaericum Naeg.				22
Crucigenia tetrapedia (Kirchn.) W et. G. S. West				11
Dictyosphaerium ehrenbergianum Naeg.		196	10	110
D. pulchellum Wood		294	10	198
Didymocystis inconspicua Kors.				11
D. planctonica Kors.		196		88
D. tuberculata Kors.		49		22
Didymogenes palatina Schmidle				22
Kirchneriella irregularis (G. M. Smith) Kors.				110
K. lunaris (Kirchn.) Moeb.		49		11
K. obesa (W. West) Schmidle				22
Lagerheimia genevensis Chod.			10	11
Micractinium pusillum Fres.				22
Nephrochlamys rotunda Kors.				44
N. subsolitaria (G. S. West) Kors.		49		110
Nephrocytium agardhianum Naeg.				44
Oocystis borgei Snow		343	10	66
Pediastrum boryanum (Turp.) Menegh.		49		22
P. tetras (Ehr.) Ralfs				22
Scenedesmus acuminatus Lagerh.		147	10	66

S. armatus Chod.		49		
S. ecornis (Ralfs) Chod.			10	66
S. granulatus W. et G. S. West			10	22
S. intermedius Chod.				33
S. opoliensis P. Richt.				22
S. quadricauda (Turp.) Breb.		147	10	110
S. spinosus Chod.		49		22
Schroederia setigera (Schroed.) Lemm.				88
Siderocelis ornata Fott		98	10	88
Siderocystopsis fusca (Kors.) Swale				22
Tetraëdron caudatum (Corda) Hangs.		49		88
T. incus (Teil.) G. M. Smith		49		
T. muticum (A. Br.) Hansg.		49		
Tetrastrum glabrum (Roll) Ahlstr. et. Tiff		49		22
T. staurogenieforme (Schroed.) Lemm.		196		77
Treubaria triappendiculata Bern.				11
T. varia Tiff. et Ahlstr.				11
other *Chlorococcales* spp.		980	98	143
Chlorococcales total	147	5047	394	3564
Lyngbya limnetica Lemm.	49		10	22
Romerica gracilis Koczw.		49		
Euglena sp.			10	
Lepocinclis sp.			10	
Trachelomonas volvocina Ehr.	294		59	44
Chroomonas acuta Utermöhl	147	539	294	264
Cryptomonas ovata Ehr.	49	294	69	22
C. platyuris Skuja			10	44
Dinobryon divergens Imhof			10	22
D. sertularia Ehr.	98			
Kephirion sp.			10	
Mallomonas caudata Iwanoff				33
Synura uvella Ehr.	49		39	
Dichotomococcus curvatus Kors.			10	66
Heterodesmus multicellularis Wawrik				44
Chlamydomonas spp.	681	881	143	281
Chlorogonium maximum Skuja			10	44
Pandorina morum (Müller) Bory				22
Pteromonas angulosa Lemm.			11	
Straurastrum paradoxum Meyen				12
egyéb algák		390	88	22
Algal count 1000 ind./l	51 200	52 770	10 450	12 180

- Species number is the lowest in the spring sample with high algal count.
- Species number of the summer sample of high algal count was more than two times that of the former.
- Species number of the spring sample of low algal count is higher.
- The species number of the summer sample of low algal count was the highest, nearly two times that of the former one.

	20.03.1980.	23.08.1979.	9.04.1981.	2.09.1981.
Individual number (1000 ind./l)	51 200	52 730	10 490	12 180
Species number (species/one thousand individual)	22	53	42	80

In phytoplankton samples of high algal count, the number of species falling to one thousand individuals is always essentially lower than in less dense samples. High species number is, however, always characteristic of the phytoplankton of the period from early summer to early autumn.

On the basis of his investigations in 1962, Szemes (1967) has given a general description of the phytoplankton of the Danube at Budapest (This year agreed in its basic characteristics with any of the years between 1957 and 1965).

He stated that in spring phytoplankton was relatively poor and less numerous. He observed extreme fluctuations in individual numbers. In the phytoplankton the diatoms dominated. During summer, *Chlorophyta* and *Cyanophyta* spp. appeared in considerable numbers beside the diatoms. Algal count varied from 150 thousand to 4 million per liter, the minimum being the consequence of a flood wave.

His results showed, that in samples of autumn phytoplankton high individual number of diatoms was characteristic. Algal count fluctuated between extreme limits (1,08 and 13,04 million ind./l) (Fig. 1, 2). During winter phytoplankton was rather poor both in individual and species number, and species of *Chlorophyta* and *Cyanophyta* were not significant.

According to Szemes, the diatoms made up the essential part of the phytoplankton of the Danube in the period between 1958 and 1965. Out of them *Stephanodiscus hantzschii* was the most frequent.

On the basis of algal counts, the trophity of the Danube at Göd can be characterized in the following:

- Between 1979 and 1981, the river was eutrophic in January–February, it was eu-polytrophic from March to the middle/end of October, then became again eutrophic. In the growth period, it approximated the polytrophic level for a short time, and reached the meso-eutrophic quality during winter. (Fig. 3).
- The data provided by Szemes show that from 1957 to 1965 the river was oligotrophic, oligo-mesotrophic (occasionally ultra-oligotrophic) between January and February. From late March to the end of October, it was mesotrophic, eutrophic, and later oligotrophic, oligo-mesotrophic. Ower the whole of the growth period, it reached the limit of eutrophy, or even exceeded it for a short time.

On comparing the two periods, not only the increase of algal counts is evident. Fig. 3 suggests that the interval between minimum and maximum values had also diminished recently.

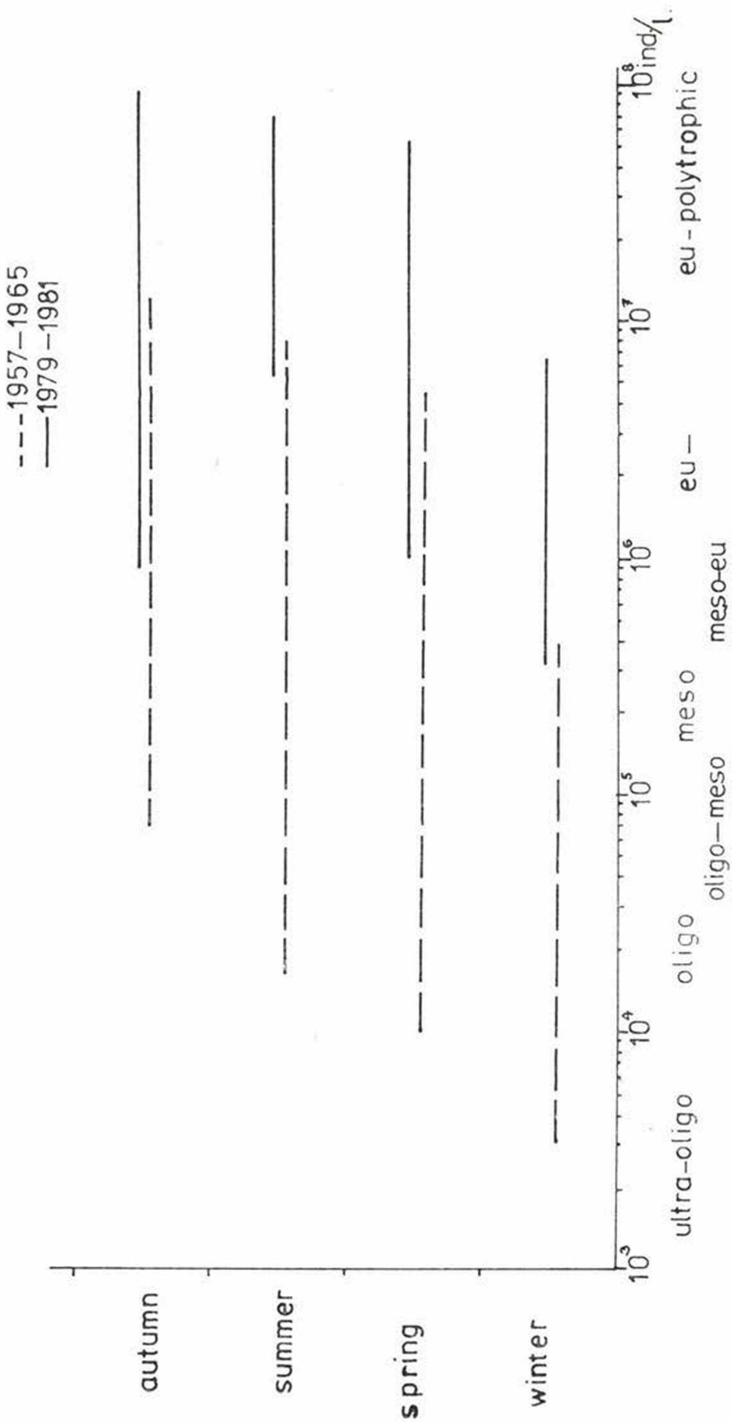

Fig. 3. Values for the individudal number of the phytoplankton in the Danube — and the intervals of trophity levels.

Only in the knowledge of data from several years is it possible to make suggestions concerning the eutrophication resp. increase of trophity of a particular stream. It is not sufficient to make comparison between maximal individual numbers only.

The actual trophity of river water depends on various factors. Potential trophity level, which means the quantity of available plant nutrients is of greatest importance. That kind of actual trophity in which the potential trophity is realized depends (in the most wide sense) on meteorological factors, on the actual condition of the river. Thus, the actual trophity of a river can exhibit considerable fluctuations in the course of a year, even in that of several consecutive years. This fluctuation is closely reflected by the maximal algal counts.

The changes, increases of trophity level can be evaluated on the basis of the average individual number of algae in samples of eutrophic quality, resp. the average individual number for a larger period (e.g. season). Table 2 composed on this basis, contains data, longer series of data from papers by Szemes (1964, 1967, 1968, 1969, 1971, Szemes et al. 1963) as well as averages of our data series resp. those of their maxima.

Table II

Maximal and average individual numbers of algae in phytoplankton samples from the Danube

Place of sampling	Time	Spring March – May		Summer June – August		Autumn September – November		Winter December – February	
		max	avg	max	avg	max	avg	max	avg
1647 riv. km	1957					7.04	3.35	0.25	0.07
	1958	9.34	1.43	7.89	2.88				
	1960			3.03				0.07	
	1961	4.02							
1659 riv. km	1961					10.08	2.61		
1647 riv. km	1962	2.26	0.49	4.03	2.84	12.69	4.73		
1959 riv. km	1965	0.28	0.10	2.92	0.25	11.54	3.88		
1669 riv. km	1979	61.05	25.21	70.60	24.05	95.90	20.64	6.50	1.91
	1980	51.20	23.11	32.38	16.39	56.15	11.40	1.99	0.85
	1981	65.41	30.72	90.56	39.51	75.33	14.99	6.95	1.50
	1982								

Comparison of our data from 1979 – 81 with the results obtained by Szemes between 1957 and 1965 shows that average and maximal algal counts had risen 5 – 10 times higher (Fig. 4). This comparison is permissible, since the samples collected by Szemes originate from the profiles at

1647 resp. 1659 riv km, and our own ones from the profile at Göd at 1669 riv. km. Our examinations showed that in this section of about 20 km length there was no essential difference in individual number between phytoplankton samples.

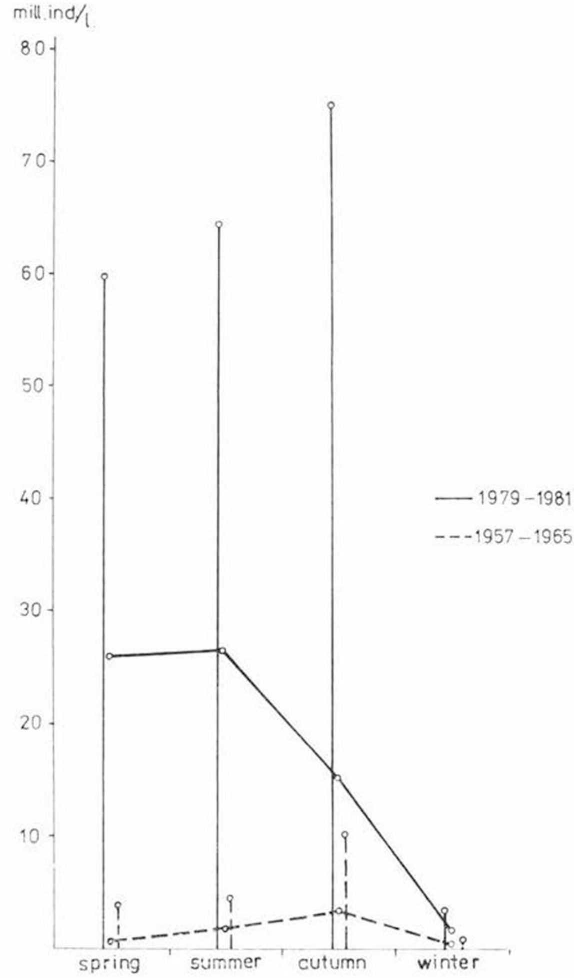

Fig. 4. Averages of algal counts of all the samples and that of the maximal values in the single seasons.

Not only the algal counts changed between the two periods, but their seasonal distribution as well. In the Budapest section of the Danube, as stated by Szemes, total individual number of phytoplankton was the greatest in fall (Fig. 4). During our studies from 1979 to 1981 total individual number of phytoplankton was often great as early as March. By comparing seasonal average values, we can state that in the last years algal counts in the spring and summer samples were generally higher than in the autumn ones.

Such an increase of trophity as is described in the foregoing is believed to be due to the following:

1. The potential trophity of the river which is characterised by plant nutrient supply did not increase in such a measure as might have been expected from the increases of algal counts. During 1958 and 1959, the mineral nitrogen content of Danube water was 1000 – 2000 mg/m^3 at Budapest (P á s z t ó 1963). This corresponded to the eu-polytrophic, polytrophic level according to the classification prepared on the basis of literature on deep lakes (F e l f ö l d y 1980). In 1979 – 80, the amount of mineral nitrogen was 1500 – 2500 mg/m^3 according to our measurements.

Concerning the quantity of phosphorus forms, we do not have at our disposal detailed series of data from the early 60s. Then, PO_4-P concentration was 10 – 30 mg/m^3. In 1979 – 80, total P content varied in the range between 50 and 100 mg/m^3, 30% of which was mostly PO_4-P. This suggests, that the phosphorus load of the river had not increased essentially, either. Thus, the potential trophity of the Danube at Budapest rose in a much smaller measure than its actual trophity.

2. Of the other factors affecting the level of actual trophity we can leave out of consideration in our reasoning the meteorological ones and a good many other effective factors too, since they did not change essentially either. As far as is known today, the changes must have occurred in the suspended matters transport of the river, since the light conditions depending on it showed considerable changes (D v i h a l l y 1978 – 79).

Investigations showed that in the mean- and low-water periods, the transparency of water had increased during the previous 10 years, and in 1979 – 80 it became 2 – 3 times that of the 60s, in the section at Göd. This is obviously due to the effect of the series of reservoirs constructed in Germany and Austria in the 70s. Owing to damming, namely, one part of the suspended matters of water settles out from water of decreased flow velocity and consequently the transparency of water increases. In rivers with high suspended matters content, often the absence of light is the limiting factor of phytoplankton production during the growth period. Thus, if the transparency of Danube water increased 2 – 3 times, algal growth must have also increased. This change is likely to be the decisive factor which caused such an increase in the actual trophity level.

Summary

The eutrophication in the section of the Danube at Göd was illustrated by comparing the algal counts from periods from 1957 to 1965 and from 1979 to 1981, resp.

The algal count of phytoplankton has increased 5 – 10 times during the last 20 years. This applies both to average and maximal values. The difference between minimal and maximal algal counts diminished (Fig. 3).

During the growth period between 1957 and 1965, the river was generally meso-eutrophic, eutrophic, except in flood times. In the last years, however, the river has become eu-polytrophic.

During late summer and fall in the early 60s, phytoplankton of great individual number characterized the Danube at Göd. From 1979 to 1981 algal counts corresponding to those in early fall 1959–1965 were not unfrequent as early as the beginning of March.

In both study periods, some *Stephanodiscus* species were the dominant members of phytoplankton, though lately several such species also occurred with 100.000–1.000.000 individual numbers which are generally characteristic of eutrophic waters.

It was stated that the increased nutrient supply causing increased potential trophity in the receiving water body, contributed to the increase of eutrophication. The rise of actual trophity indicated also by 5–10 times higher algal counts, is thought to be due firstly to the improved light conditions. It was the increased transparency of water that caused the intensive growth of algae as early as spring. It is supposed that the improved light conditions are the result of the effect of the series of reservoirs constructed at the German and Austrian section of the Danube causing the suspended matters content of the river water to settle out.

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