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Preliminary algological study on biofouling in industrial water systems

by
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Abstract: This paper deals with the algological investigation and the elimination of biofouling in industrial cooling water systems. Samples were taken from cooling water systems of different Hungarian Works in 1982. The algal fouling of different sampling sites was compared by cluster analysis. We give an outline about the possibilities of protective measures.

INTRODUCTION

A frequent problem of industrial water management is the forming of biofouling on the heat exchange surface of open cooling water systems and the elimination of these deposits (BIRCHALL, 1979; MANSFIELD, 1978; THACKERY, 1980; etc.).

The formation of biofouling involves the danger of increasing the corrosion, decreasing the cooling efficiency and excessing the energy demand. Biofouling developing on the heat exchange surface of cooling water systems can be divided into inorganic and organic fraction. The former one is mainly resulted due to the precipitation of ferric compounds and scale. The latter one consists of living and dead algae, fungi and slime-forming bacteria. The quickly and massively proliferating micro-organisms stop up the water distribution and aeration troughs and disrupt the flow of cooling water and a fouling crust of several centimeters on the cooling exchange surfaces. The higher temperature favours the proliferation which may cause difficulties in the system during the vegetation period when an intensive cooling would be necessary. The algae can continue their propagation in the winter months due to higher temperature of cooling water.

Unfortunately, the fouling problems of water systems in Hungary is discussed by some papers only (LAKATOS et al., 1979; LAKATOS and PAPP, 1982; RÉCSEY, 1974). Among the papers published abroad it is worth mentioning those which focus on the biofouling composition of cooling water systems (BIRCHALL, 1979; MANSFIELD, 1978; SLADECKOVA, 1961), and THACKERY's paper (1980) which deals with this question from an economic point of view. Moreover, CHARACKLIS et al. (1982) and PEDERSEN (1982) present results on the dynamics of biofouling formation and the applicable methods for its study. KIRKPATRICK et al. (1980) present results of their investigations on the fouling formed on the surface of the cast- iron pipes.

MATERIAL AND METHODS

Our 17 qualitative samples were taken in the Tisza Chemical Works (TVK), the Lenin Metallurgical Works (LKM), Hungarian Bearing Works (MGM) and Oil Refinery Works (TIFO) from their vertical plates of David-type cooling towers and cooling basins.

Chemical, bacteriological, algological and zoological investigations of biofouling were carried out to reveal the circumstances of the fouling formation and its structural composition. This paper presents the results of the algological analysis.

For the identification of algae, Amplival-type microscope was used. The diatoms were determined after H_2O_2 treatment from the constant-preparatum bedding in Pleurax.

RESULTS

71 taxa were identified from samples of 17 sites (Table 1). It can be stated that some samples are very poor in species compared to the biofouling of natural water-bodies. The cooling towers provide special conditions for the algae. The species composition of the algal community is often influenced by a treatment of algicide or algistatic compounds. Only certain species of algae are able to endure these extreme circumstances, following significant disturbance from time to time. This may result in the fact that teratological algae are often present in the samples, as opposed to natural water-bodies, making the identification of species more difficult (Fig. 1).

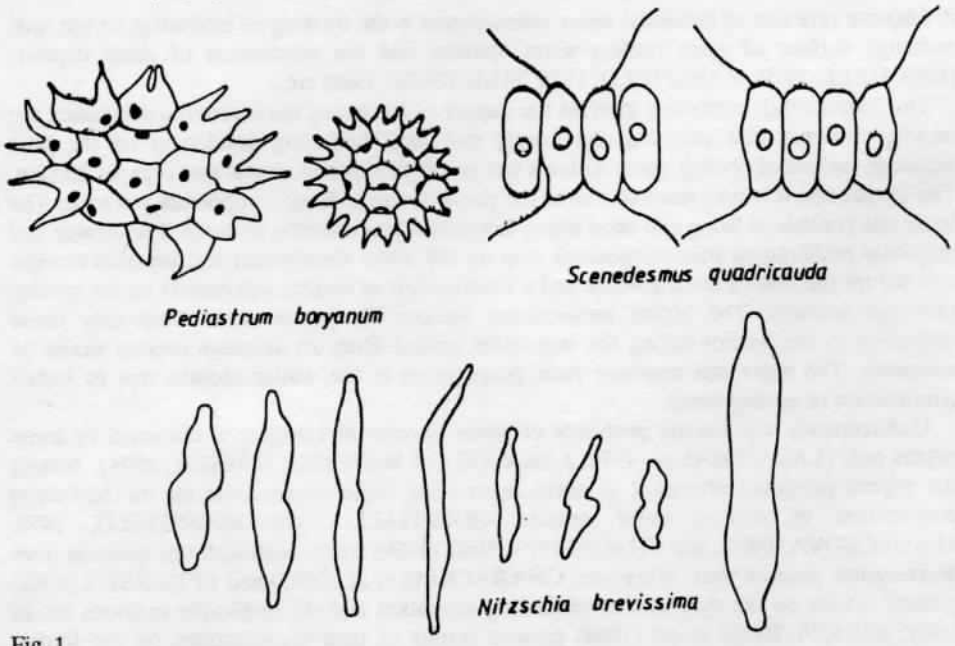

Fig. 1
Teratological algae in the biofouling of water cooling systems. (The basic form of species are also illustrated)

It is characteristic in general that the algal flora consists of particular species occurring in a mosaic-like pattern which is visible to the naked eye on the basis of different colours of the biofouling. The fouling is mainly composed of filamentous blue algae with the exception of samples collected at TIFO. Although the species number of diatoms was higher, their estimated biomass was only a small part of the biomass of filamentous Cyanophyta algae.

Diatoms occurring in the biofouling belonged to the Pennales but some Centrales species were also found, e.g. *Melosira varians,* observed in unexpectedly high numbers at the sampling sites TVK 5 and MGM 3. Among the Pennales, the species *Nitzschia palea* can be mentioned as a constant species, which was especially abundant in the samples collected from TIFO, MGM 2. and TVK 3. The *Gomphonema parvulum* in samples MGM and a *Gyrosigma* species in samples TVK 1–5 were also of high degree. The green algae belonging to the Chlorococcales were characteristic of the samples taken from TIFO and a lot of *Scenedesmus* species were present in the samples collected at TVK 3. In the sample LKM 1, a species of *Lyngbya* was very frequent among the blue algae, while in other samples they were absent. Beside the typical phytotectonic species (e.g. *Achnanthes* sp., *Gomphonema* sp., etc.), euplanctonic species also occurred many times (*Crucigenia* sp., *Scenedesmus* sp., etc.) which might have suspended into the biofouling from the supplemental water.

The distribution of taxa by phylum in different samples is illustrated on Fig. 2. Based on the results of algological investigations, cluster analysis was applied using the Jaccard's similarity index (Fig. 3). The LKM and MGM were found to be the most similar sampling sites, while the other two sites (TVK and TIFO), which use the same supplemental water differed considerably from each other, in respect of their algal-fouling. This provides evidence on the observation that the population of the surface depends only partly on the supplemental water, while it can be attributed more significantly to the spreading of spores by air. Because of the very low level of similarity, there is a need for analysing the composition of biofouling in the different cooling water systems which may provide a good basis for successful protection.

POSSIBILITIES OF BIOFOULING ELIMINATION

The raw water supplemented to the Works is treated first mechanically and later with alum. Subsequently, it moves on through the cooling systems in two ways:

- flows through the cooling system and returns to the river,
- after cooling off in a recycling system, the water returns again to the cooling system.

In the former flow-through system, however, only some kinds of substrate treatment can be considered because the water returns to the river immediately and this puts a limit on the application of chemicals due to their toxic effect on the living environment. In the latter, recirculating cooling water systems biocide and biostatic compounds can be applied as well.

Considering the possibilities of protection it is advisable to pay attention to the ratio of living and dead fraction of biofouling. The mud in the dead fraction provides, partly, an appropriate nutrient reservoir and a good adhesive surface for the algae. The circulating water constantly transports the nutrients which are needed for living algae, and this is an open cooling system thus natural light is abundant, available, while temperature have is also favourable for the algae.

The possible of the solutions biofouling formation for the prevention on the heat exchange surfaces are as follows:

– Decreasing the concentration of suspended matter (mud) in the supplemental water and thereby reduction of the nutrient supply in the cooling water systems.

– Applying selective algistatic and algicide chemicals into the feed water to prevent the proliferation of algae in recycling systems.

– Selection and treatment of substrates that impede the settlement and proliferation of algae and the application of such base and covering materials which, even if they do not stop the forming biofouling, significantly retard its formation.

– Making the conditions unfavourable for the algae (e.g. selective discolouring, nutrient supply, etc.) and preventing the formation of scale and the corrosion processes (e.g. adding organic polyphosphate, etc.).

– Using other biological protection measures (e.g. cyanophags, saprophytic fungi, etc.).

SUMMARY

This paper discusses the composition and possibilities of elimination of algal-fouling forming in the cooling water systems. In our opinion there is a need for chemical, bacteriological, algological and zoological analysis to reveal the condition of the biofouling formation and economic possibilities of its elimination.

The samples were taken from cooling water systems of four Works (TVK, TIFO, MGM, LKM). Cluster analysis was used to compare the composition of the algal-fouling of different sampling sites. It was observed that the biofouling mainly consists of filamentous blue algae (Cyanophyta), but most species belong to the Pennales. In the biofouling, teratological form of algae can be found more frequently than in natural water bodies, because of the disturbance. In this paper we survey possibilities of protecting measures and problems.

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Table 1

taxon	TVK 1.	TVK 2.	TVK 3.	TVK 4.	TVK 5.	LKM 1.	LKM 2.	LKM 3.	LKM 4.	LKM 5.	MGM 1.	MGM 2.	MGM 3.	TIFO 1.	TIFO 2.	TIFO 3.	TIFO 4.
CYANOPHYTA																	
Lyngbya limnetica Lemm.						+							+				
Oscillatoria chalybea (Mert.) Gom.	+		+	+	+	+	+		+			+	+				
O. limosa Agh.	+		+	+	+		+										
O. princeps Vauch.						+											
O. tenuis Agh.						+	+				+						
O. sp.	+	+		+	+					+	+		+				
Phormidium foveolarum (Mont.) Gom.				+		+	+			+			+				
Ph. retzii (Agh.) Gom.	+																
Ph. sp.				+		+											
CHROMOPHYTA																	
Melosira granulata (Ehr.) Ralfs				+	+								+				
M. varians Agh.	+		+	+	+			+					+				
Stephanodiscus sp.	+							+		+							
A. lanceolata (Breb.)Grun.		+				+	+						+				+
Achnanthes minutissima Kütz.		+				+	+		+	+					+	+	
A. sp.		+															
Amphora veneta Kütz.						+	+	+		+							
Bacillaria paradoxa Gmelin					+			+			+		+				+
Ceratoneis arcus Kütz.	+																
Cocconeis hustedtii Krasske		+					+	+	+	+			+	+		+	+
C. sp.				+		+					+						+
Cymbella minuta Hilse		+		+		+	+	+		+			+				
C. sp.											+	+					
Diatoma hiemale (Lyngb.) Heiberg								+									
D. vulgare Bery		+															
D. vulgare var. capitulata Grun.							+										
Fragilaria contruens (Ehr.) Grun.									+	+							+
Frustulia rhomboides (Ehr.) de Toni					+	+											
F. vulgaris Thwaites								+	+	+							
Gomphonema longiceps var. subclavata Grun.				+													
G. elivaceum (Lyngb.) Kütz.		+		+		+	+			+	+						
G. parvulum Kütz.											+	+					
G. parvulum var. subelliptica Cleve												+	+				
Gyrosigma sp.	+	+	+		+												

Mastogloia smithii var. amphicephala Grun.														+									
M. sp.	+										+		+				+		+			+	
Navicula cuspidata var. Heribaudi Peragallo								+															
N. radiosa Kütz.													+										
N. saprophila Lange-Bert.			+	+	+	+		+			+		+	+	+		+					+	
N. subminuscula Manguin	+		+		+	+	+	+		+	+		+	+									
N. tuscula (Ehr.) Grun.								+															
N. sp. I.					+																		
N. sp. II.							+																
N. sp. III.							+										+			+		+	
Nitzschia brevissima Grun.															+								
N. commutata Grun.									+						+		+						
N. linearis (Agh.) W. Seith			+		+				+														
N. palea (Kütz.) W. Smith	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+			
N. palea var. tenuirostris Grun.			+			+	+	+		+	+						+	+	+				
N. paleacea Grun.				+	+					+												+	
N. sigmoidea (Nitzsch.) W. Smith				+																			
N. sp.			+		+																		
Pinnularia viridis (Nitzsch.) Ehr.	+			+																			
P. sp.																							
Surirella ovata Kütz.	+			+																			
S. sp.	+																						
Synedra affinis Kütz.				+	+		+	+	+						+		+			+		+	
S. ulna Ehr.				+	+																		
S. sp.	+			+																			
Tabellaria flocculosa (Reth) Kütz.				+																			
CHLOROPHYTA																							
Chlorococcales sp. I.					+	+	+															+	+
C. sp. II.						+	+	+					+				+		+			+	+
Crucigenia tetrapedia (Kirchn.) W. & G.S. West	+	+	+									+					+		+				
Hyaloraphidium contortum Pasch. & Korn.		+			+	+		+														+	+
Pediastrum boryanum (Turp.) Menengh.		+	+	+		+		+	+	+							+		+			+	+
Scenedesmus abundans (Kirchn.) Chod.									+														
S. acuminatus (Lagerh.) Chod.			+																			+	
S. acutus Meyen		+	+	+							+		+									+	+
S. bicaudatus (Hansg.) Chod.										+													
S. quadricauda (Turp.) Bréb.								+															
S. sp.			+	+																			

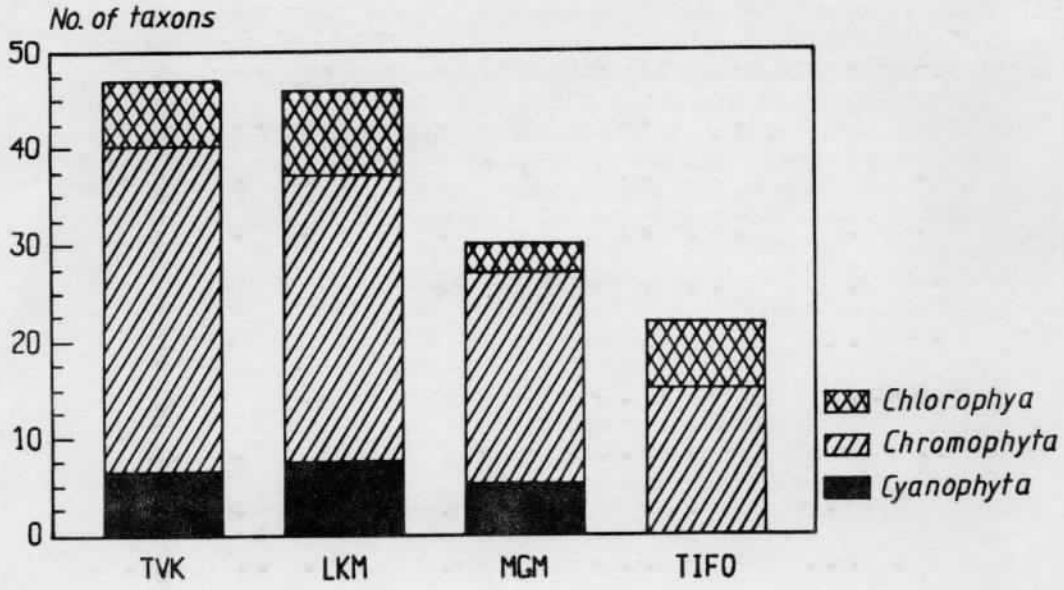

Fig. 2.
Distribution of taxa according to phylla

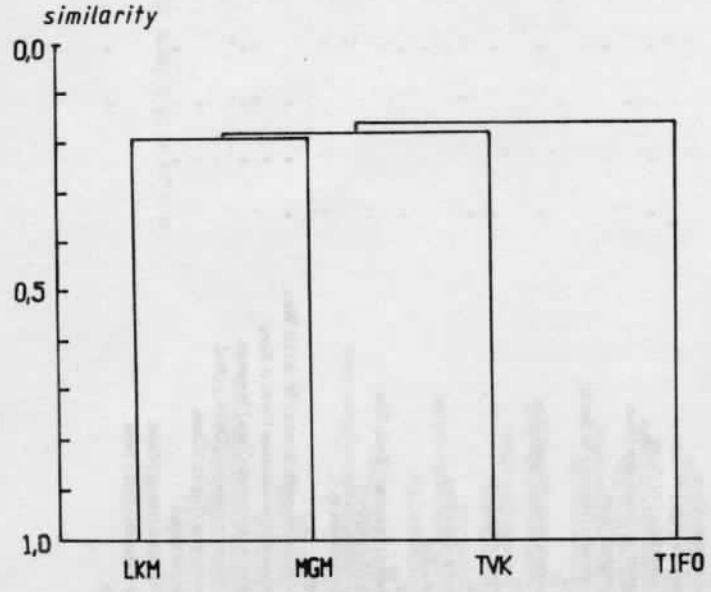

Fig. 3.
Dendrogram based on the Jaccard's similarity index