石油精製工場の廃水中に形成されるスライムに関する研究－Ⅲ*

廃水中に浸漬したスライドグラスおよびガラス管に着生したスライムならびにスライム中の微小生物について

藤沢浩明・村上正忠

Studies on Slime- like Substance Formed in Drainage System of Refinery Plant-Ⅲ. Slime- like Substance on Slide Glass or Glass Pipe Submerged in Waste Water and Inhabiting Microorganisms

By
Hiroaki FUJISAWA and Masatada MURAKAMI

In the previous papers of this series[1,2], the slime-like substance (hereinafter called slime) formed in the drainage system of a refinery plant was investigated chemically and biologically.

The purpose of this paper is to investigate the situation of the formation of slime in more detail by the following method; (1) Submerging slide glass or glass pipe in the waste water for a definite period of time in all the seasons in order to obtain the slime artificially, (2) Quantitative determination of the slime, (3) Microscopic examination of microorganisms such as Bacillariophyceae, Cyanophyceae, Flagellata etc. in it.

The results are summarized as follows:

1. The slime accumulated on the slide glass submerged in the waste water (at Station 5, the catchment basin) much more in winter and autumn than in spring, and only a little in summer.

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Microorganisms such as Bacillariophyceae, Cyanophyceae, Flagellata etc. were found in all the slime examined, and the occurrence of these varied from season to season. For instance, in summer there was a remarkable decrease in the number of genera and in the detection frequency of each genus except *Skeletonema* and *Oscillatoria*, while in winter both the number and the frequency showed an increase.

2. The slime on the glass pipe submerged in the waste water (at Station 2, the drainage gallery by the distilling apparatus of crude oil), was considerably more in winter than in other seasons.

In the slime, microorganisms such as Bacillariophyceae, Cyanophyceae and Flagellata were found in winter, and Bacillariophyceae was found in autumn, but hardly any were detected in spring and summer.

3. Judging from the above-mentioned results of both experiments, it is revealed that the slime will grow abundantly in the drainage system of the refinery plant in seasons, and pointed out that the occurrence of microorganisms relates closely to the amount of slime.

Therefore, it can be considered that microorganisms such as Bacillariophyceae and Cyanophyceae play an important role in the formation of slime in the drainage system of the refinery plant.

緒　　言

前報[1, 2]に続いて，石油精製工場の廃水中に形成されるスライムの実態および生成の要因を明らかにする目的で，四季にわたって現場の廃水中にスライドグラスおよびガラス管を一定期間浸漬し，それぞれ付着生成したスライムの量を経時的に測定すると共に，スライム中に存在する珪藻類，藍藻類，鞭毛藻類などの微小生物の種類および出現頻度を調べた。これらの結果について報告する。

実 験 方 法

1．スライドグラスおよびガラス管の浸漬法

第1図に示した定点5（処理工程の終わりの集水池内の廃水）にスライドグラス（26×76㎜）14枚を，第2図に示すように固定して浸漬した。また，定点2（暗渠内の未処理の廃水）にガラス管（9×900㎜，内径7㎜）14本を，第3図に示すように固定して浸漬した。定点2にも定点5と同じように，スライドグラスを浸漬するつもりであったが，暗渠内が狭く，スライドグラスの固定装置を入れることができなかったので，適当な寸法のガラス管固定装置を作製し，これにガラス管を固定して浸漬することにした。

スライドグラス浸漬試験では，1971年8月，11月，1972年2月および5月，ガラス管浸漬試験では1971年11月，1972年2月，5月および8月の四季にわたって，それぞれ14日間浸漬し，その間0，1，3，5，7，10および14日ごとに2試料ずつを引き上げて供試した。なお，スライドグラスおよびガラス管を廃水中に浸漬してから30分後に引き上げたものをそれぞれ0日の試料とし，スライムの着生量の測定におけるブランクテストに用いた。

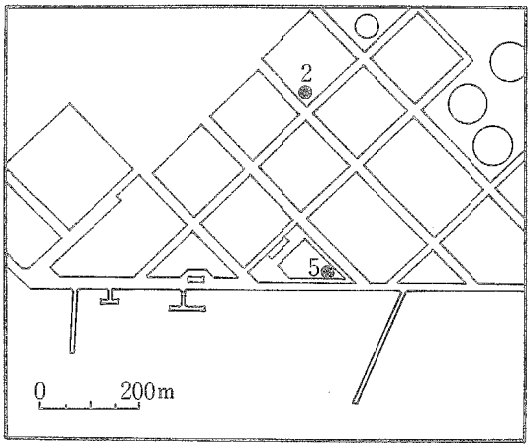


Fig. 1. Experimental stations set up in the drainage system of a refinery plant.
Station 5: Slide glass was submerged at this station in the catchment basin.
Station 2: Glass pipe was submerged at this station in the drainage gallery by the distilling apparatus of crude oil.

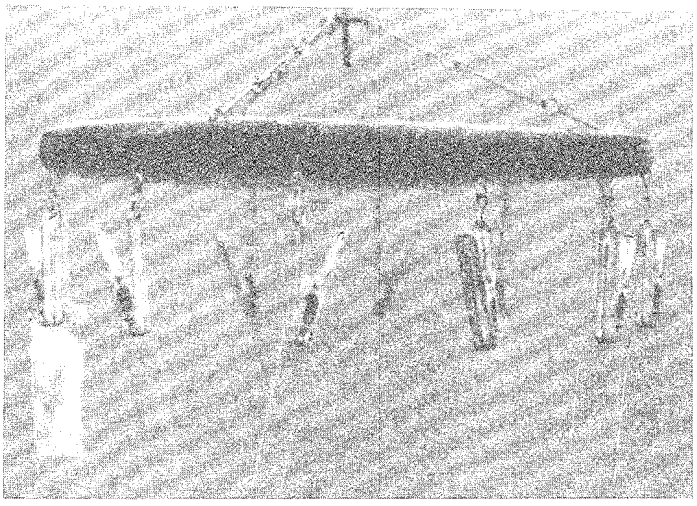


Fig. 2. An apparatus for the experiment in which slide glass was submerged in the waste water.

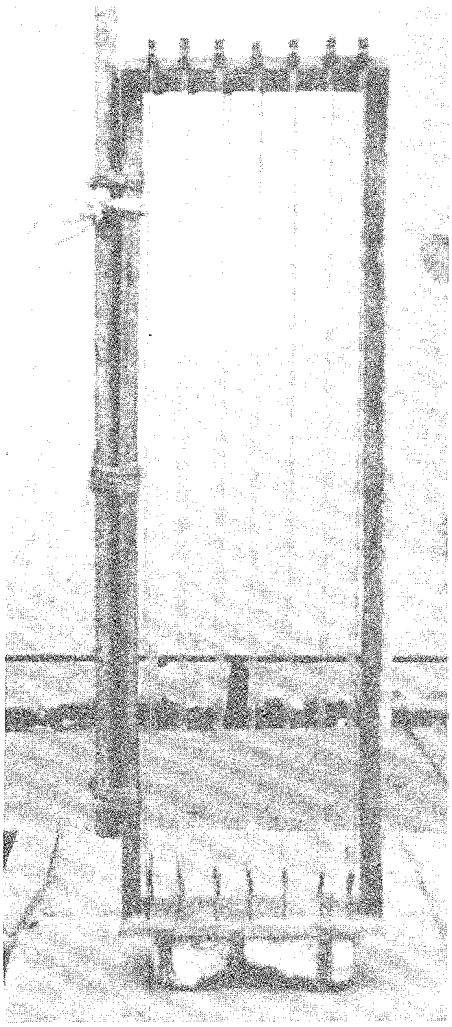


Fig. 3. An apparatus for the experiment in which glass pipe was submerged in the waste water.

2．スライムの着生量の測定法

廃水中から引き上げた各試料を，定法により恒量になるまで乾燥した後秤量した。ついで，着生したスライムを十分洗い落して，同じように乾燥した後秤量し，前後の差を求め，さらにブランク値を差し引いてスライム量とし，各2試料の平均値（乾物量，mg）で表した。

3．微小生物の分類および出現頻度

スライム中に存在する珪藻類，藍藻類，鞭毛藻類などの微小生物について，乾燥試料を直接400倍で検鏡すると共に，写真撮影によって形態を観察し，種属を同定した。なお，これらの微小生物は属レベルに整理し，各試料中の出現頻度をそれぞれ5段階で表した。

結　　果

1．スライドグラス浸漬試験

四季におけるスライムの着生量の経時的変化を第4図に，また，秋季および冬季におけるスライムの着生状態を第5図に示した。

第4図から，スライドグラス1枚あたりのスライムの着生量は，浸漬日数14日間の最大量でみれば，夏季に約90mg，秋季に約250mg，冬季に約300mg，春季に約160mgであって，冬季および秋季に多く，夏季および春季に少ない傾向がみられた。とくに，夏季では他の季節に比べて着生量が少なく，浸漬日数10日で最大となり，その後スライムがスライドグラスから剥離して，着生量が著しく減少した。その他の季節では，いずれも浸漬日数と共に着生量が増加し，浸漬日数最大の14日で最高を示した。

ついで，四季における浸漬日数ごとのスライム中の微小生物の種類および出現頻度を，それぞれ第1表～第4表に示した。

Table 1. Microorganisms in the slime on slide glass submerged in the waste water at Station 5 for a definite period of time in summer.

Organisms	Submergence time in days					
	1	3	5	7	10	14
Bacillariophyceae:						
Skeletonema costatum	+++++	+++++	+++++	+++++	+++++	+++++
Thalassiosira sp.			+		+	
Coscinodiscus sp.	+				+	
Chaetoceros spp.	++	+++	+++	+++	+++	+++
Thalassiothrix sp.		+	+	+		+
Navicula spp.		+	+		+	+
Amphora sp.		+				
Nitzschia spp.	+	+		+		+
Cyanophyceae:						
Oscillatoria sp.	+	+	++	++	+++	+++++
Phormidium sp.		+	+	+	+	+
Flagellata:						
Dictyocha fibula				+		
Ceratium fusus		+	+	+		+
Ciliata:						
Paramecium sp.	+	+	+	+		

Note: The frequency in occurrence of organism was graded as follows;
+++++, very abundant.
++++, abundant.
+++, common.
++, rare.
+, very rare.

また，出現した微小生物の顕微鏡写真を，それぞれ付図Ⅰ～付図Ⅹに掲げた。

第1表～第4表から明らかなように，各季節ともスライム中に，かなりの種類あるいは量の珪藻類，藍藻類，鞭毛藻類などの微小生物が検出された。

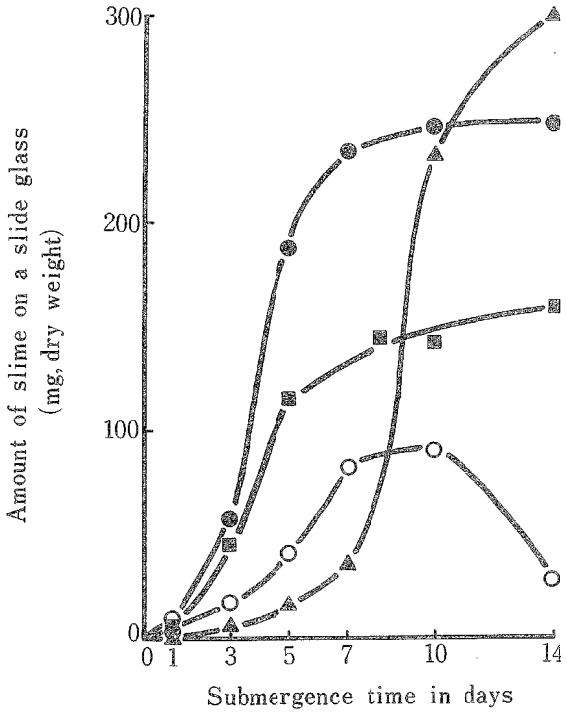
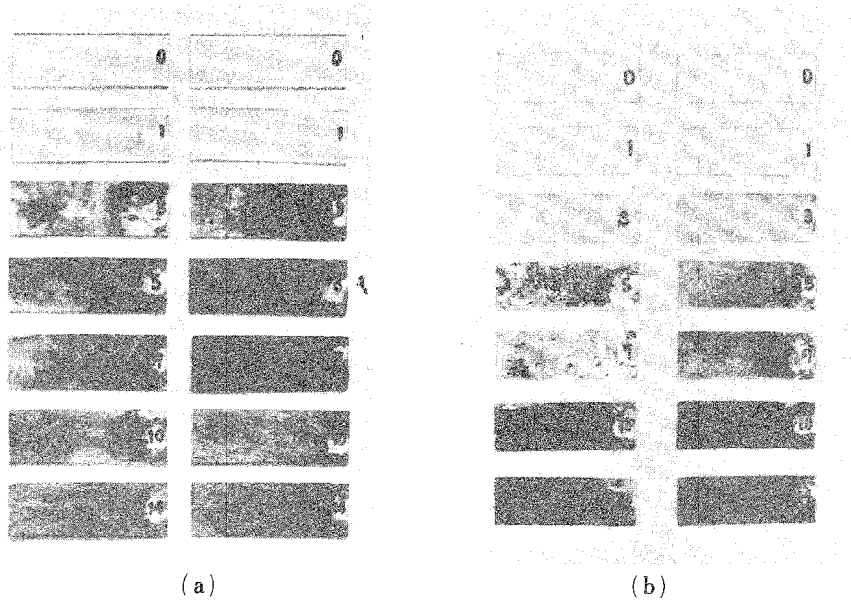


Fig. 4. Time courses of the amount of slime on slide glass submerged in the waste water at Station 5 in all the seasons.
○: Amount of slime on a slide glass in summer.
●: Amount of slime on a slide glass in autumn.
▲: Amount of slime on a slide glass in winter.
■: Amount of slime on a slide glass in spring.



(a) (b)

Fig. 5. The slime on slide glass submerged in the waste water at Station 5 for a definite period of time in autumn and winter.
(a): The slime formed on slide glass in autumn.
(b): The slime formed on slide glass in winter.
Figure recorded on slide glass represents the elapsed days of submergence.

夏季には *Skeletonema* が，秋季には *Skeletonema, Coscinodiscus, Thalassiothrix, Nitzschia, Oscillatoria* および *Achroonema* が，冬季には *Skeletonema, Coscinodiscus, Rhizosolenia, Chaetoceros, Thalassionema, Asterionella, Nitzschia* および *Oscillatoria* が，春季には *Skeletonema, Coscinodiscus, Thalassiothrix, Amphora, Oscillatoria* および *Ceratium* が，いずれも優勢に出現した。とくに，*Skeletonema* は周年にわたって優勢に出現した。また，これらの優勢出現種属は，一般に浸漬初期の1～5日の間にすでに著しく出現することがわかった。

夏季には他の季節に比べて，出現した微小生物の種類数が少なく，また，*Skeletonema* を除くと一般に出現頻度が低かった。

Table 2. Microorganisms in the slime on slide glass submerged in the waste water at Station 5 for a definite period of time in autumn.

Organisms	Submergence time in days					
	1	3	5	7	10	14
Bacillariophyceae:						
Skeletonema costatum	+++++	+++++	+++++	+++++	+++++	+++++
Thalassiosira spp.	+	+		+	+	++
Coscinodiscus spp.	+	++	++	+++	++++	+++++
Asteromphalus sp.				+	+	+
Lauderia sp.		+			+	
Rhizosolenia spp.	+	+	++	++	++	++
Chaetoceros spp.	+++	+++	+++	+++	+++	+++
Biddulphia sp.			+			
Synedra sp.	++	++	++	++	++	++
Thalassionema nitzschioides	++	++	++	+++	++++	++++
Thalassiothrix sp.	++	+++	+++	+++++	+++++	+++++
Asterionella japonica	+++	+++	+++	+++	+++	+++
Diploneis sp.		+		+		
Pleurosigma sp.	+	+	++	++	++	++
Navicula spp.	++	++	++	++	++	+++
Amphora sp.	+	+	+	+	+	+
Nitzschia spp.	++	+++	+++	+++	+++	+++++
Bacillaria sp.		+				
Cyanophyceae:						
Oscillatoria sp.	+	+++	++++	+++++	+++++	+++++
Achroonema sp.		+	++	++++	+++++	+++++
Flagellata:						
Dictyocha fibula	+	+		+		
Ceratium fusus		+		+	+	

Note: The frequency in occurrence of organism was graded as follows;
+++++, very abundant.
++++, abundant.
+++, common.
++, rare.
+, very rare.

Table 3. Microorganisms in the slime on slide glass submerged in the waste water at Station 5 for a definite period of time in winter.

Organisms	Submergence time in days					
	1	3	5	7	10	14
Bacillariophyceae:						
Melosira sp.		+	+		+	+
Skeletonema costatum	+++	+++++	+++++	+++++	+++++	+++++
Thalassiosira spp.		++	++	+++	+++	+++
Coscinodiscus spp.	+++	+++	++++	++++	++++	+++++
Asteromphalus sp.		+	+	+		+
Lauderia sp.				+		
Guinardia sp.				+		+
Rhizosolenia spp.	+	+++++	++++	+++++	++++	+++++
Chaetoceros spp.	+++++	+++++	+++++	+++++	++++	+++++
Eucampia sp.		+		+		
Biddulphia sp.		+				+
Hemiaulus sp.		+	++		+	+
Synedra sp.	+	+++	++++	++++	+++	+++
Thalassionema nitzschioides	+++	+++++	+++++	+++++	+++++	+++++
Thalassiothrix sp.	+++	+++	++++	++++	++++	++++
Asterionella japonica	+++++	+++++	+++++	+++++	+++++	+++++
Diploneis sp.		+	+		+	+
Pleurosigma spp.	+	++	+	+	+	+
Navicula spp.		+++	++++	++++	+++	++++
Amphora sp.		+	++	+++	++++	++++
Cymbella sp.			+			
Nitzschia spp.	++	+++++	+++++	+++++	+++++	+++++
Cyanophyceae:						
Oscillatoria sp.	+++	+++++	+++++	+++++	+++++	+++++
Phormidium sp.	+				+	
Flagellata:						
Dictyocha fibula	+	++	+	+	+	+
Ceratium spp.		+	+	++	+	++
Ciliata:						
Tintinnopsis sp.				+	+	+

Note: The frequency in occurrence of organism was graded as follows;
++++, very abundant.
+++, abundant.
++, common.
+, rare.
+, very rare.

Table 4. Microorganisms in the slime on slide glass submerged in the waste water at Station 5 for a definite period of time in spring.

Organisms	Submergence time in days					
	1	3	5	8	10	14
Bacillariophyceae:						
Melosira sp.		+				+
Skeletonema costatum	+++	++++	+++++	+++++	+++++	+++++
Thalassiosira spp.				+	+	+
Coscinodiscus spp.		+++	+++++	++++	++++	+++++
Asteromphalus sp.			+			
Lauderia sp.		+	+			
Guinardia sp.				+		
Rhizosolenia spp.	+		+	+	+	
Chaetoceros spp.	++	++	+	++	++	++
Thalassionema nitzschioides	+++	++++	+++	++++	++++	++++
Thalassiothrix sp.	+++	+++++	+++++	+++++	+++++	+++++
Asterionella japonica		+	+			
Cocconeis sp.		+				
Achnanthes sp.			+			+
Diploneis sp.					+	
Pleurosigma spp.	+	+	+	+		+
Navicula spp.		+++	+++	+++	+++	+++
Amphora sp.		++++	++++	+++++	+++++	+++++
Cymbella sp.					+	+
Nitzschia spp.	+++	++	+++	+++	++++	++++
Cyanophyceae:						
Oscillatoria sp.	+++	+++++	+++++	+++++	+++++	+++++
Phormidium sp.		++	++	+++	+++	+++
Flagellata:						
Dictyocha fibula	+	+++	++++	+++	+++	+++
Dinophysis sp.		++	+	+	+	+
Pyrophacus horologicum				+		
Ceratium spp.	+++	+++++	+++++	+++++	+++++	+++++

Note: The frequency in occurrence of organism was graded as follows;
+++++, very abundant.
++++, abundant.
+++, common.
++, rare.
+, very rare.

2．ガラス管浸漬試験

四季におけるスライムの着生量の経時的変化を第6図に，また，秋季および冬季におけるスライムの着生状態を第7図に示した。

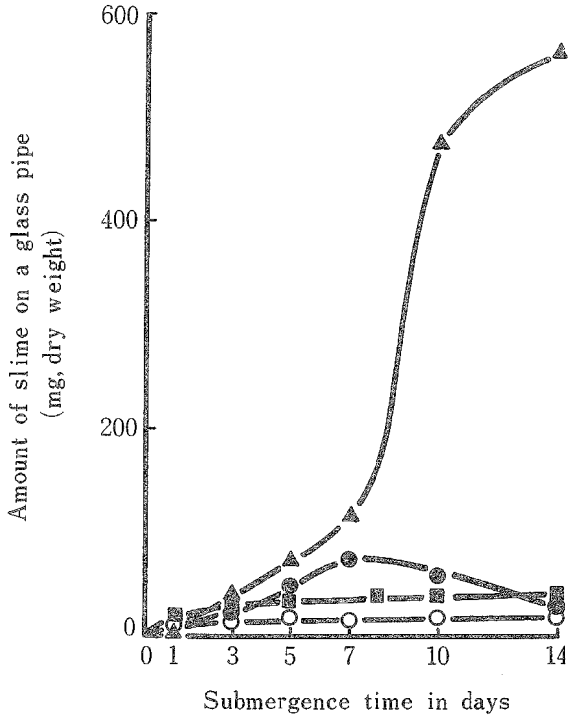
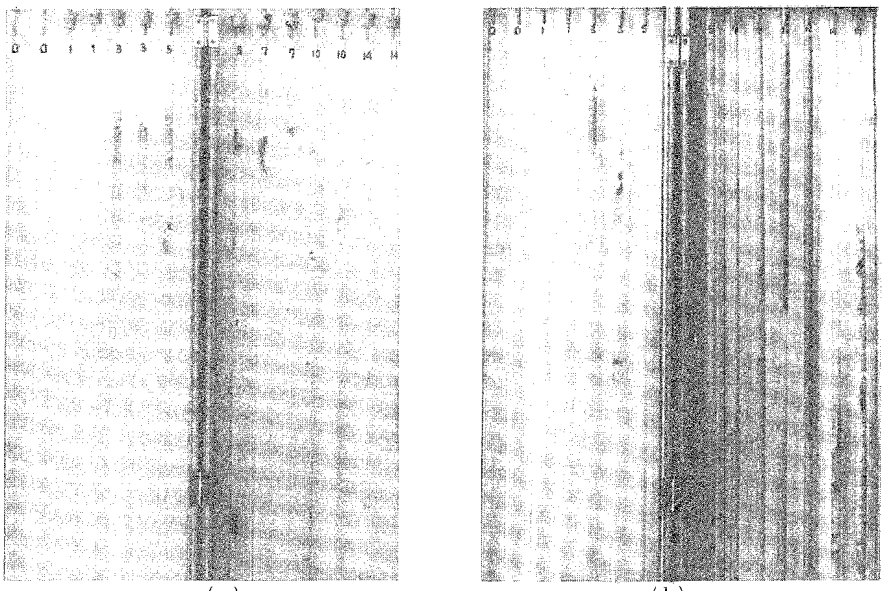


Fig. 6. Time courses of the amount of slime on glass pipe submerged in the waste water at Station 2 in all the seasons.
○: Amount of slime on a glass pipe in summer.
●: Amount of slime on a glass pipe in autumn.
▲: Amount of slime on a glass pipe in winter.
■: Amount of slime on a glass pipe in spring.



(a) (b)

Fig. 7. The slime on glass pipe submerged in the waste water at Station 2 for a definite period of time in autumn and winter.
(a): The slime formed on glass pipe in autumn.
(b): The slime formed on glass pipe in winter.
Figure recorded on glass pipe represents the elapsed days of submergence.

第6図から，ガラス管1本あたりのスライムの着生量は，浸漬日数14日間の最大量でみれば，秋季に約75㎎，冬季に約560㎎，春季に約50㎎，夏季に約20㎎であって，冬季には着生量が多く，その他の季節には

Table 5. Microorganisms in the slime on glass pipe submerged in the waste water at Station 2 for a definite period of time in autumn.

Organisms	Submergence time in days					
	1	3	5	7	10	14
Bacillariophyceae:						
Skeletonema costatum	+	++	++	+++	+++	+++
Thalassionema nitzschioides		++	++	++	++	++
Thalassiothrix sp.		+	++	++	++	++
Asterionella japonica		+		+	+	
Nitzschia sp.		+		+		+

Note: The frequency in occurence of organism was graded as follows;
+++++, very abundant.
++++, abundant.
+++, common.
++, rare.
+, very rare.

Table 6. Microorganisms in the slime on glass pipe submerged in the waste water at Station 2 for a definite period of time in winter.

Organisms	Submergence time in days					
	1	3	5	7	10	14
Bacillariophyceae:						
Skeletonema costatum	+	++	+++	++++	+++++	+++++
Coscinodiscus spp.		+		+	+	+
Rhizosolenia spp.			+		++	++
Chaetoceros spp.		+		+	++	++
Thalassionema nitzschioides		+		+	+	
Thalassiothrix sp.			+++	+++	++++	++++
Asterionella japonica		++	+++	+++	+++	+++
Diploneis sp.			+			
Navicula sp.		+				+
Nitzschia spp.		+	+++	++++	+++++	+++++
Cyanophyceae:						
Oscillatoria sp.			+	++	+++	+++
Flagellata:						
Dinophysis sp.			+			

Note: The frequency in occurrence of organism was graded as follows;
+++++, very abundant.
++++, abundant.
+++, common.
++, rare.
+, very rare.

いずれも少なかった。

ついで，秋季および冬季における浸漬日数ごとのスライム中の微小生物の種類および出現頻度を，第5表および第6表に示した。

第5表および第6表から明らかなように，スライム中の微小生物として，秋季には *Skeletonema, Thalassionema, Thalassiothrix* などが，冬季には *Skeletonema, Nitzschia, Thalassiothrix, Asterionella, Oscillatoria* などが検出された。そして，秋季には冬季に比べて，出現した微小生物の種類数が少なく，一般に出現頻度も低かった。また，かなり多く検出された種類でも，浸漬初期の1～5日の間では，おおむねそれらの出現頻度が低い傾向がみられた。

なお，春季および夏季には，浸漬したガラス管に微小生物がほとんど検出されなかった。

考　　察

定点5におけるスライドグラス浸漬試験の結果から，スライムの着生量が最も多い冬季では，スライム中に検出された微小生物の種類数が最も多く，また出現頻度も最も高く，逆にスライム量が最も少ない夏季では，微小生物の出現も最も少ない傾向がみられた。そして，一般にスライムの着生量と微小生物の存在量との間には，密接な相関関係が認められた。

また，スライドグラスに着生したスライム中の微小生物の出現状況（種類および頻度）と，前報[2)]の自然に形成されたスライム中の微小生物についての調査結果を比べると，多少の差異はあるが，四季にわたっておおむね一致していることがわかった。

これらのことから，スライドグラス浸漬法は，石油工場の廃水中におけるスライムの生成状況およびスライム中の微小生物の出現状況を調べるのに，きわめて有効適切な方法であると思われる。

次に，定点2におけるガラス管浸漬試験の結果から，スライムの着生量が最も多い冬季では，スライム中に微小生物がかなりの種類検出され，またスライムの着生量が少ない秋季でも，少ないながら微小生物の存在が認められたのに比べ，スライム量がきわめて少ない春季および夏季では，微小生物はほとんど存在しないことがわかった。

なお，ガラス管を浸漬した春季および夏季における定点2の廃水は，いずれも浸漬期間中のpH価が11.1～12.5であり，その中には細菌を除くと（細菌の存在数は200 cells/ml 以下であった。）生物の存在がほとんど認められなかったので，ガラス管に着生したスライム中に微小生物が検出されなかったものも当然であろう。

スライドグラスに着生したスライム中には，自然に形成されたスライム中と同じように多くの量の微小生物が検出され，これに比べ，ガラス管に着生したスライム中の微小生物の存在量は，自然に形成されたスライム中の微小生物の存在量よりもはるかに少なかった。このことから，ガラス管浸漬法はスライドグラス浸漬法よりも劣っており，廃水中のスライムの生物を調べるには適切な方法とは考えられない。

スライドグラスおよびガラス管浸漬試験では，浸漬日数14日間においてスライドグラス1枚あたり90～300 mg，またガラス管1本あたり75～560 mg のスライムが着生した。したがって，実際の集水池（定点5）および廃水暗渠（定点2）では，かなりの量（季節によって増減するが）のスライムが形成されるものと推定される。

さらに，スライムの着生量が多い場合にはスライム中の微小生物の存在量も多いことから考えると，スライムの形成には微小生物，とくに珪藻類および藍藻類が重要な役割を果していることが明らかである。なお，珪藻類および藍藻類のほか，細菌もスライムの形成の主役であると考えられるが，本実験ではとくに検討しなかった。

要　約

石油精製工場の廃水中に形成されるスライムの実態および生成の要因を明らかにする目的で，四季にわたって現場の廃水中にスライドグラスおよびガラス管を一定期間浸漬し，それぞれ付着生成したスライムの量を経時的に測定すると共に，スライム中に存在する珪藻類，藍藻類，鞭毛藻類などの微小生物の種類および出現頻度を調べ，次に示す結果を得た。

1．スライドグラス浸漬試験におけるスライムの着生量は冬季および秋季に多く，ついで春季となり，夏季に最も少なかった。

スライドグラスに着生したスライム中の微小生物の出現状況は季節によって異なるが，いずれにも珪藻類，藍藻類，鞭毛藻類などが検出された。

とくに，*Skeletonema* および *Oscillatoria* は周年にわたって優勢に出現し，*Coscinodiscus*, *Thalassiothrix*, *Thalassionema* および *Nitzschia* が，夏季を除くいずれの季節にもおおむね優勢に出現した。夏季には他の季節に比べて微小生物の出現種類数が少なく，また *Skeletonema* および *Oscillatoria* を除くと，一般に出現頻度も低かった。そして，冬季には微小生物の出現種類数が最も多く，またそれらの出現頻度もおおむね高かった。

2．ガラス管浸漬試験におけるスライムの着生量は冬季に多く，他の季節ではいずれも少なかった。

ガラス管に着生したスライム中には，冬季に *Skeletonema*, *Nitzschia*, *Thalassiothrix*, *Asterionella*, *Oscillatoria* などが，秋季に *Skeletonema* などが出現したが，春季および夏季には微小生物がほとんど検出されなかった。

3．上述の1および2から，現場の廃水中では，季節によって増減はあるが，かなりの量のスライムが形成されるものと推定される。また，スライムの着生量と微小生物の存在量との間には密接な相関関係がみられ，スライムの形成には微小生物，とくに珪藻類および藍藻類が重要な役割を果していることが認められる。

4．本実験で採用したスライドグラス浸漬法は，石油工場の廃水中におけるスライムの生成の実態を調べる方法として，きわめて有効適切であると考えられる。

終わりに，微小生物の分類および取りまとめについて懇切なご指導を戴いた本校鶴田新生教授に心から感謝の意を表する。また，微小生物の同定について有益なご教示を戴いた京都大学梅崎　勇助教授，東海区水産研究所高野秀昭博士，東京理科大学鈴木静夫助教授，本校故尾形英二教授の諸氏に深謝する。なお，本実験に協力された本校水産微生物学研究室卒論学生吉井正幸および清水克実の両君に謝意を述べる。

文　献

1) 藤沢浩明・村上正忠，1973：本報告，22，29～38.
2) 藤沢浩明・村上正忠，1973：本報告，22，39～48.

PLATE

Explanation of Plates

Photomicrographs of microorganisms (Bacillariophyceae, Cyanophyceae, Flagellata and Ciliata) in the slime on slide glass submerged in the waste water at Station 5 (catchment basin) in a refinery plant for a definite period of time in all the seasons.

Scale bar in all the plates indicates 50μ and applies to all the figures.

PLATE I

Fig. 1. *Skeletonema costatum* in the slime on slide glass submerged in the waste water for a day in summer.

Fig. 2. *Coscinodiscus* sp. and *Skeletonema costatum* in the slime on slide glass submerged in the waste water for a day in summer.

Fig. 3. *Ceratium fusus* and *Skeletonema costatum* in the slime on slide glass submerged in the waste water for three days in summer.

Fig. 4. *Paramecium* sp. and *Skeletonema costatum* in the slime on slide glass submerged in the waste water for five days in summer.

Fig. 5. *Phormidium* sp. and *Skeletonema costatum* in the slime on slide glass submerged in the waste water for seven days in summer.

Fig. 6. *Thalassiosira* sp. and *Skeletonema costatum* in the slime on slide glass submerged in the waste water for ten days in summer.

Fig. 7. *Chaetoceros* sp. and *Skeletonema costatum* in the slime on slide glass submerged in the waste water for fourteen days in summer.

Fig. 8. *Nitzschia* sp. and *Skeletonema costatum* in the slime on slide glass submerged in the waste water for fourteen days in summer.

PLATE I

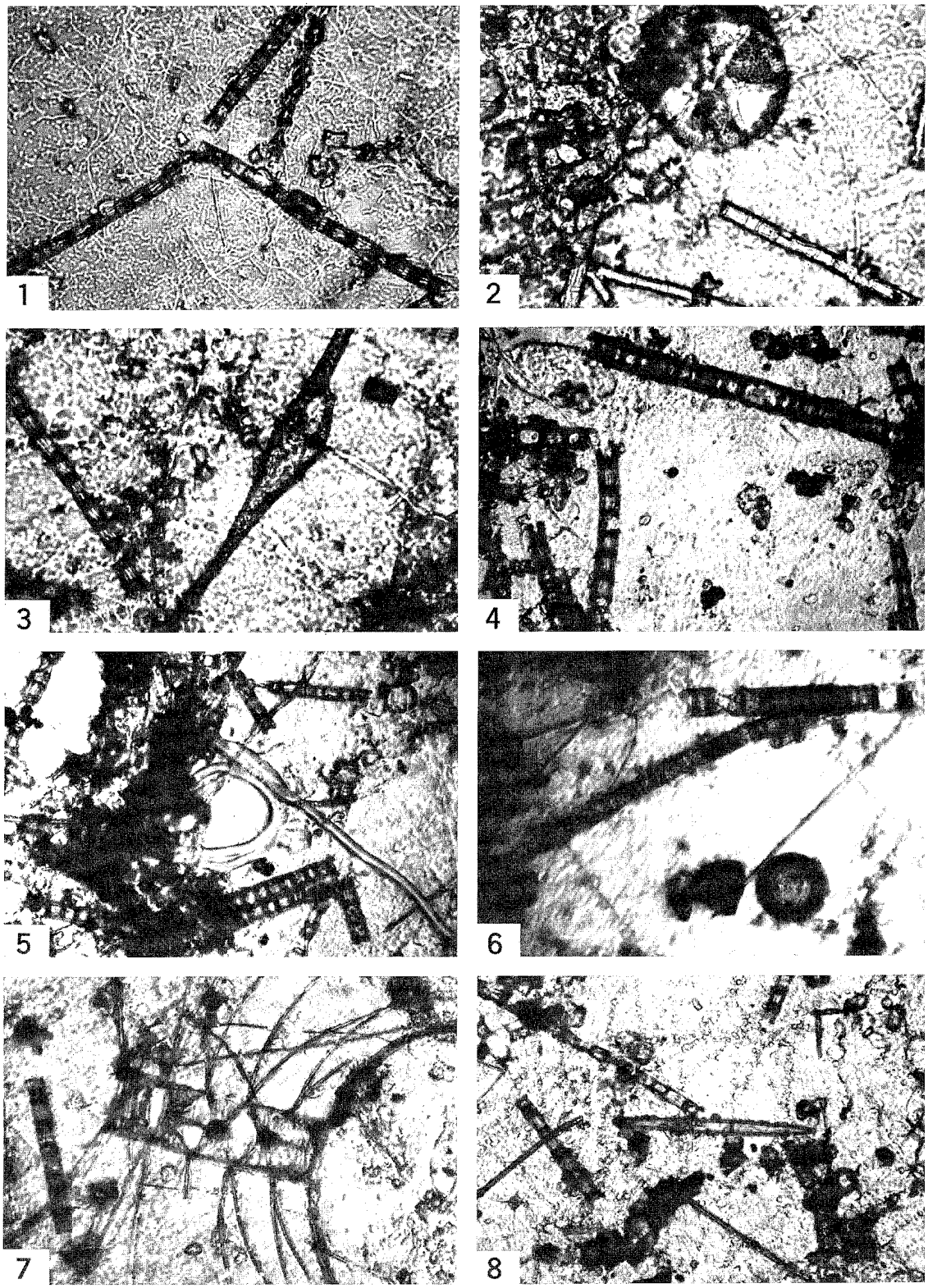


PLATE II

Fig. 9. *Skeletonema costatum* in the slime on slide glass submerged in the waste water for a day in autumn.

Fig. 10. *Asterionella japonica, Thalassiothrix* sp. and *Chaetoceros* sp. in the slime on slide glass submerged in the waste water for a day in autumn.

Fig. 11. *Asterionella japonica* in the slime on slide glass submerged in the waste water for three days in autumn.

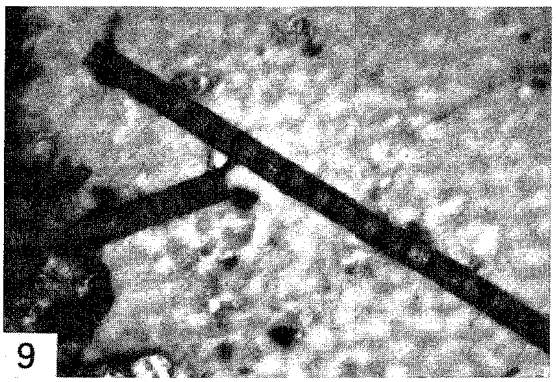
Fig. 12. *Coscinodiscus* sp. (side view) in the slime on slide glass submerged in the waste water for three days in autumn.

Fig. 13. *Rhizosolenia* sp. in the slime on slide glass submerged in the waste water for three days in autumn.

Fig. 14. *Asterionella japonica* and *Thalassionema nitzschioides* in the slime on slide glass submerged in the waste water for five days in autumn.

Fig. 15. *Oscillatoria* sp. in the slime on slide glass submerged in the waste water for five days in autumn.

Fig. 16. *Chaetoceros* sp. in the slime on slide glass submerged in the waste water for five days in autumn.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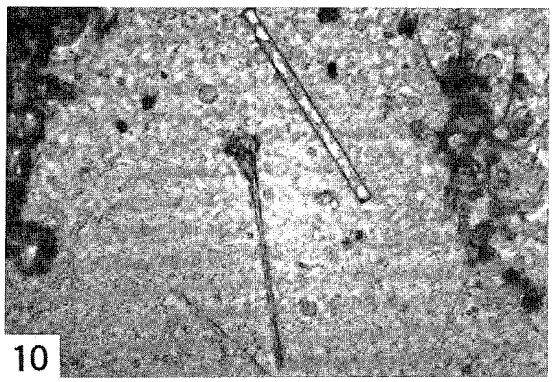
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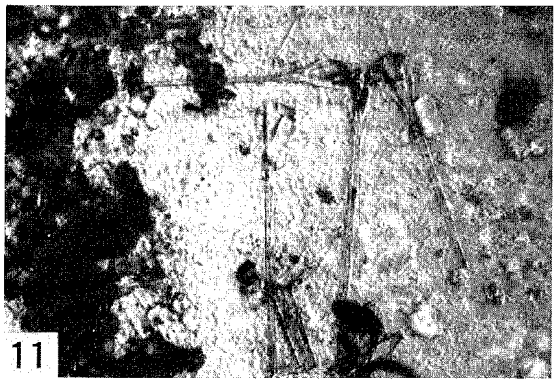
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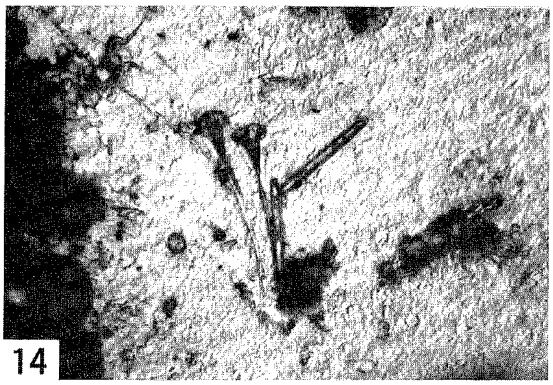
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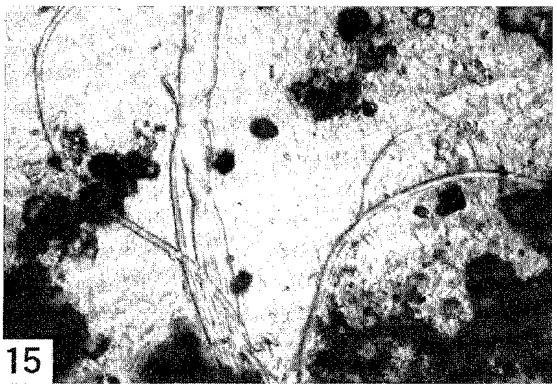
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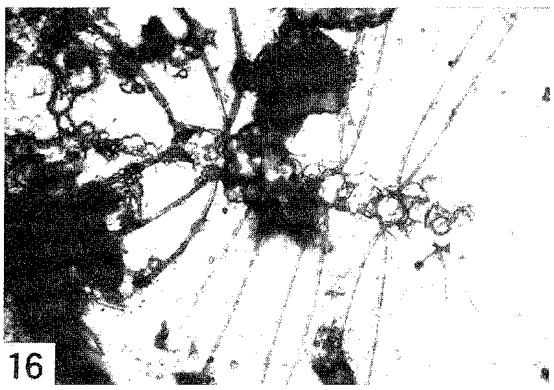
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PLATE III

Fig. 17. *Thalassionema nitzschioides* in the slime on slide glass submerged in the waste water for seven days in autumn.

Fig. 18. *Ceratium fusus* in the slime on slide glass submerged in the waste water for seven days in autumn.

Fig. 19. *Thalassiothrix* sp. in the slime on slide glass submerged in the waste water for seven days in autumn.

Fig. 20. *Asteromphalus* sp. and *Pleurosigma* sp. in the slime on slide glass submerged in the waste water for seven days in autumn.

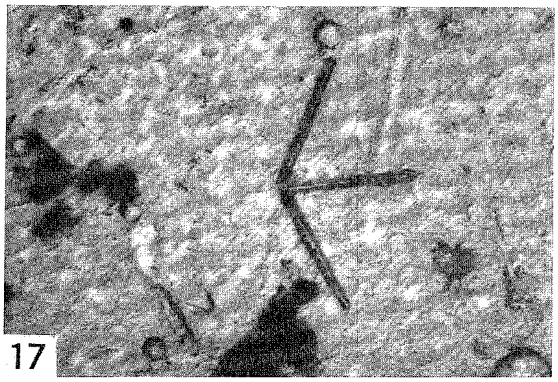
Fig. 21. *Nitzschia* sp. and *Thalassiothrix* sp. in the slime on slide glass submerged in the waste water for ten days in autumn.

Fig. 22. *Oscillatoria* sp. and *Achroonema* sp. in the slime on slide glass submerged in the waste water for ten days in autumn.

Fig. 23. *Oscillatoria* sp. and *Achroonema* sp. in the slime on slide glass submerged in the waste water for ten days in autumn.

Fig. 24. *Coscinodiscus* sp. in the slime on slide glass submerged in the waste water for fourteen days in autumn.

PLATE III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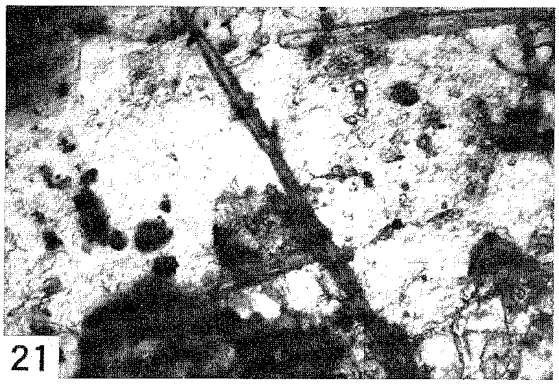
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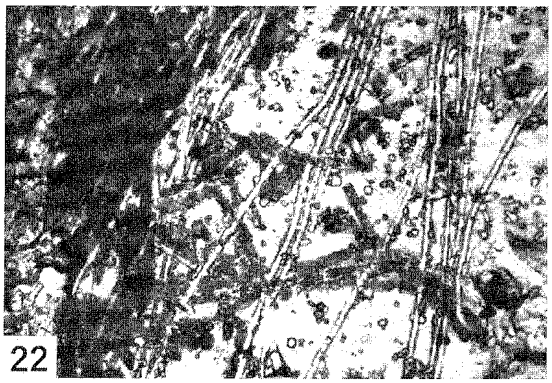
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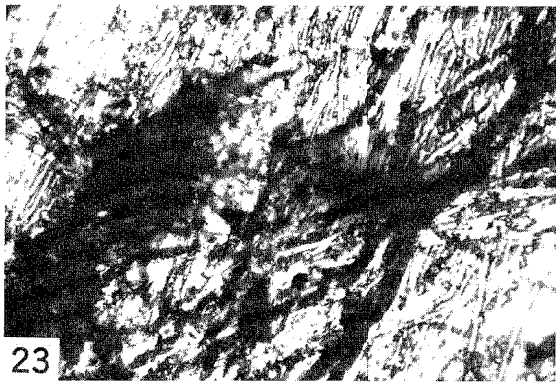
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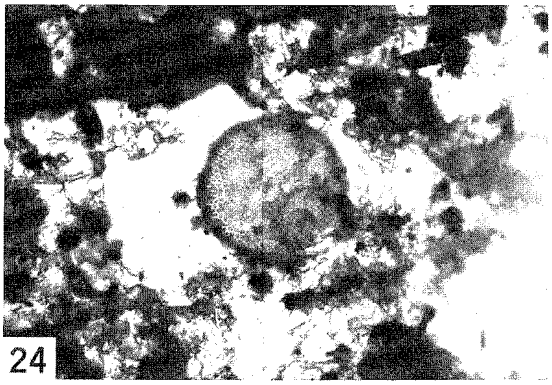
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PLATE Ⅳ

Fig. 25. *Asterionella japonica* in the slime on slide glass submerged in the waste water for a day in winter.

Fig. 26. *Coscinodiscus* sp. in the slime on slide glass submerged in the waste water for a day in winter.

Fig. 27. *Pleurosigma* sp. in the slime on slide glass submerged in the waste water for a day in winter.

Fig. 28. *Chaetoceros* sp. in the slime on slide glass submerged in the waste water for a day in winter.

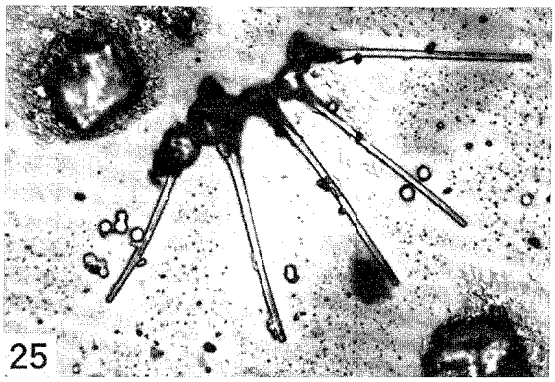
Fig. 29. *Chaetoceros* sp. in the slime on slide glass submerged in the waste water for three days in winter.

Fig. 30. *Thalassionema nitzschioides* in the slime on slide glass submerged in the waste water for three days in winter.

Fig. 31. *Rhizosolenia* sp. in the slime on slide glass submerged in the waste water for three days in winter.

Fig. 32. *Dictyocha fibula* in the slime on slide glass submerged in the waste water for three days in winter.

PLATE Ⅳ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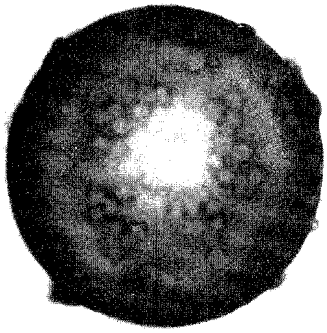
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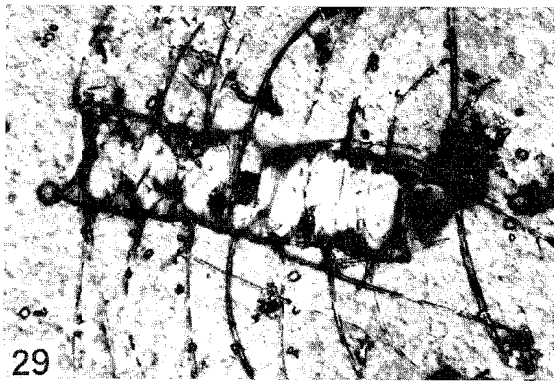
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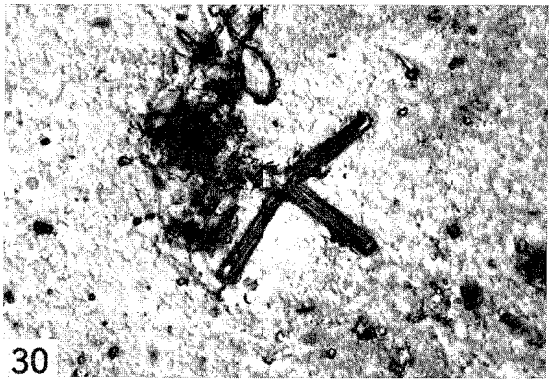
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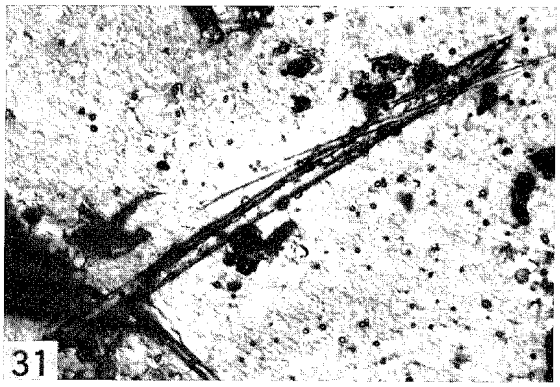
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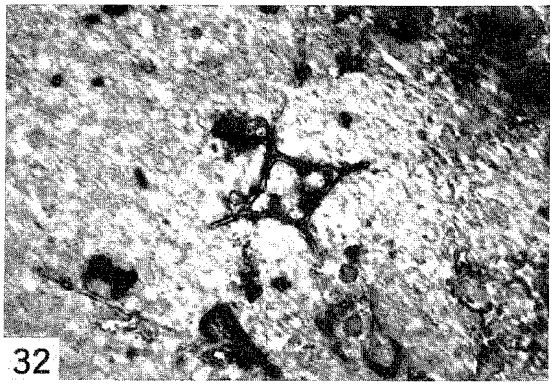
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PLATE V

Fig. 33. *Skeletonema costatum, Thalassiothrix* sp. and *Asterionella japonica* in the slime on slide glass submerged in the waste water for five days in winter.

Fig. 34. *Hemiaulus* sp. and *Asterionella japonica* in the slime on slide glass submerged in the waste water for five days in winter.

Fig. 35. *Eucampia* sp. and *Asterionella japonica* in the slime on slide glass submerged in the waste water for five days in winter.

Fig. 36. *Nitzschia* sp. in the slime on slide glass submerged in the waste water for five days in winter.

Fig. 37. *Oscillatoria* sp. in the slime on slide glass submerged in the waste water for five days in winter.

Fig. 38. *Amphora* sp. in the slime on slide glass submerged in the waste water for five days in winter.

Fig. 39. *Asterionella japonica* in the slime on slide glass submerged in the waste water for seven days in winter.

Fig. 40. *Rhizosolenia* sp. and *Oscillatoria* sp. in the slime on slide glass submerged in the waste water for seven days in winter.

PLATE V


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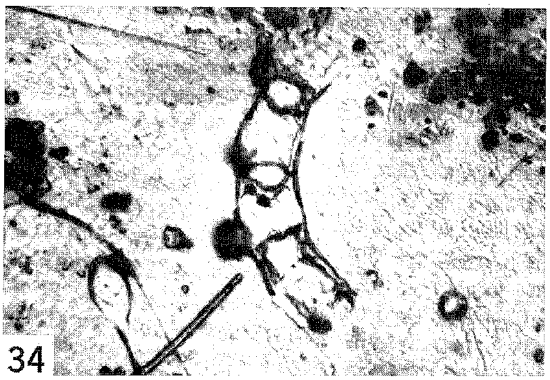
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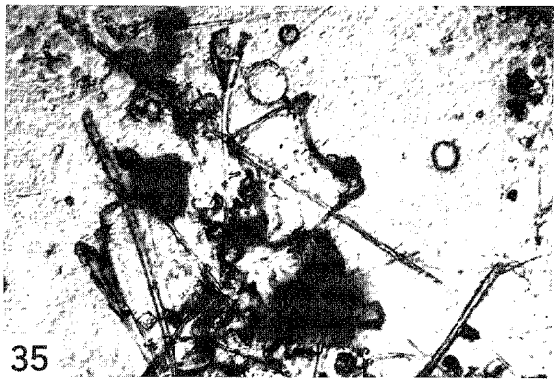
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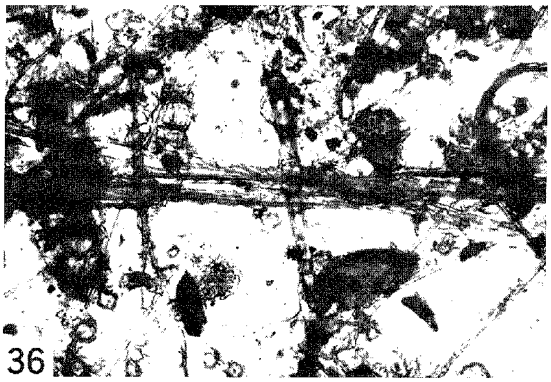
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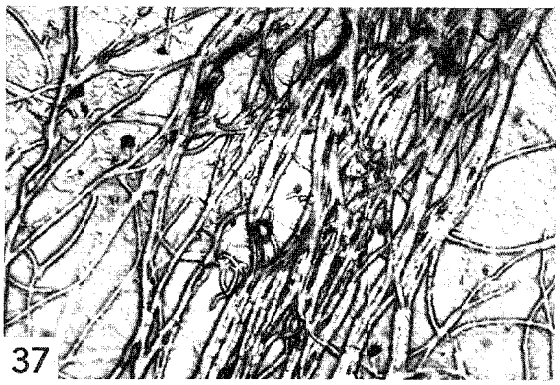
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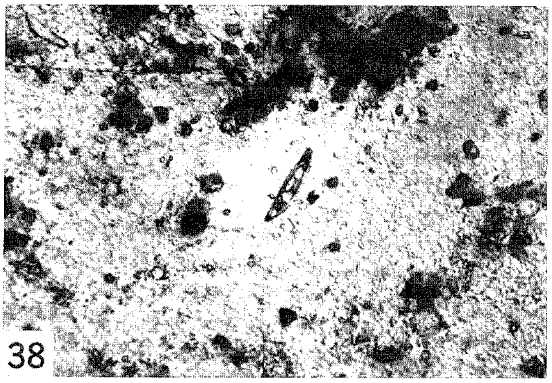
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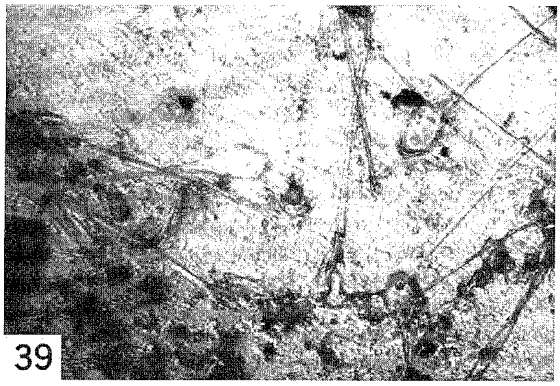
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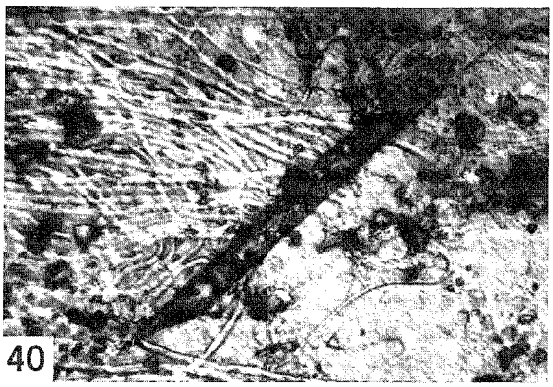
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PLATE VI

Fig. 41. *Nitzschia* sp. and *Oscillatoria* sp. in the slime on slide glass submerged in the waste water for seven days in winter.

Fig. 42. *Thalassiothrix* sp. in the slime on slide glass submerged in the waste water for seven days in winter.

Fig. 43. *Ceratium fusus* in the slime on slide glass submerged in the waste water for seven days in winter.

Fig. 44. *Ceratium furca* in the slime on slide glass submerged in the waste water for seven days in winter.

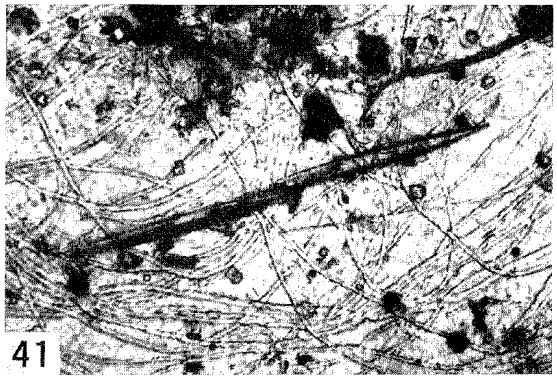
Fig. 45. *Rhizosolenia* sp. in the slime on slide glass submerged in the waste water for seven days in winter.

Fig. 46. *Nitzschia* sp. in the slime on slide glass submerged in the waste water for seven days in winter.

Fig. 47. *Thalassionema nitzschioides*, *Thalassiothrix* sp. and *Oscillatoria* sp. in the slime on slide glass submerged in the waste water for ten days in winter.

Fig. 48. *Oscillatoria* sp. in the slime on slide glass submerged in the waste water for ten days in winter.

PLATE VI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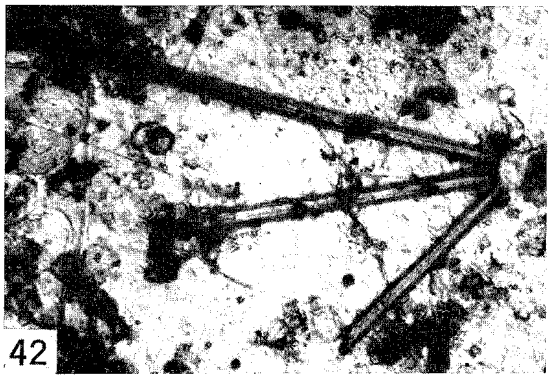
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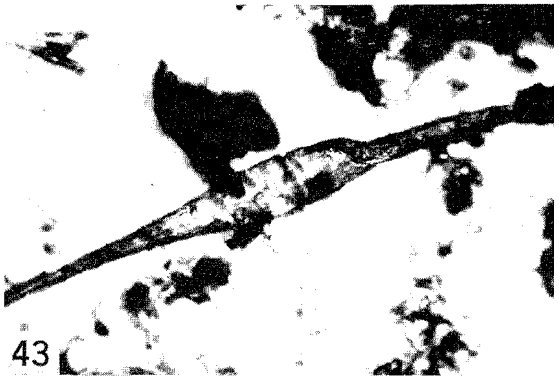
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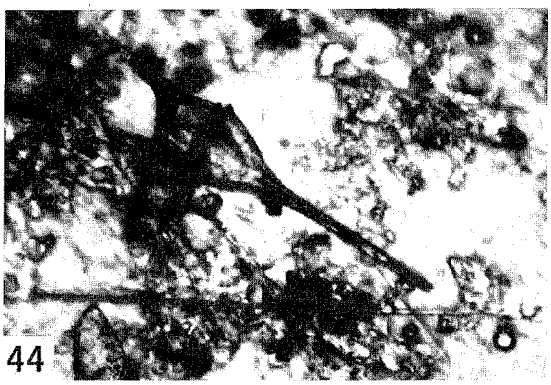
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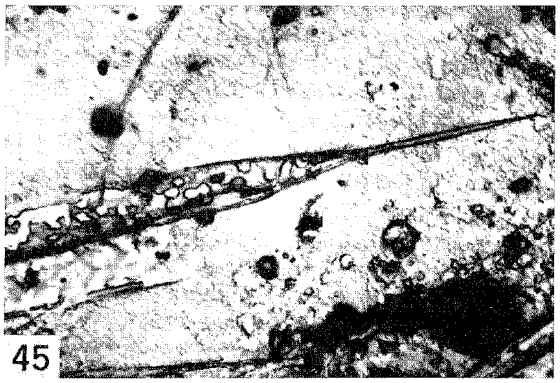
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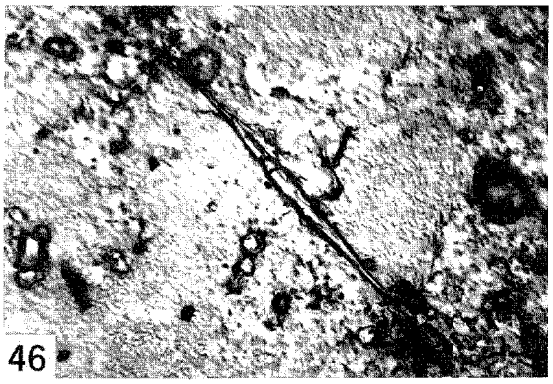
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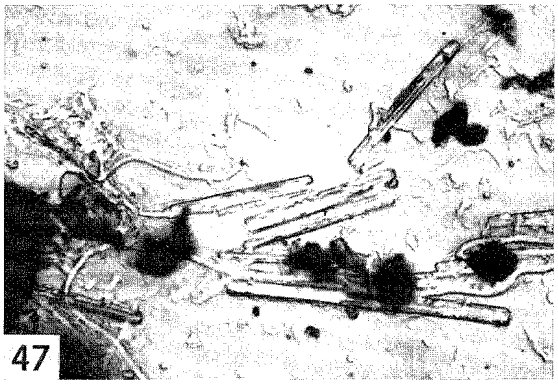
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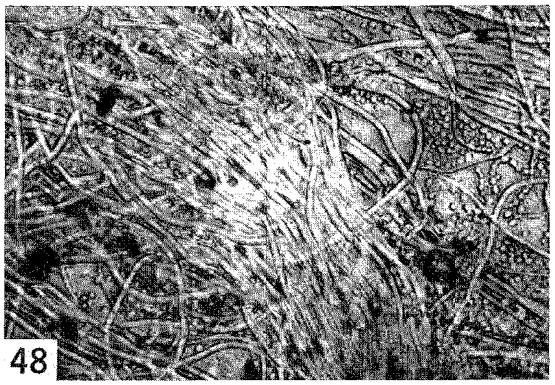
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PLATE Ⅶ

Fig. 49. *Oscillatoria* sp. in the slime on slide glass submerged in the waste water for fourteen days in winter.

Fig. 50. *Oscillatoria* sp. in the slime on slide glass submerged in the waste water for fourteen days in winter.

Fig. 51. *Ceratium* sp. and *Oscillatoria* sp. in the slime on slide glass submerged in the waste water for fourteen days in winter.

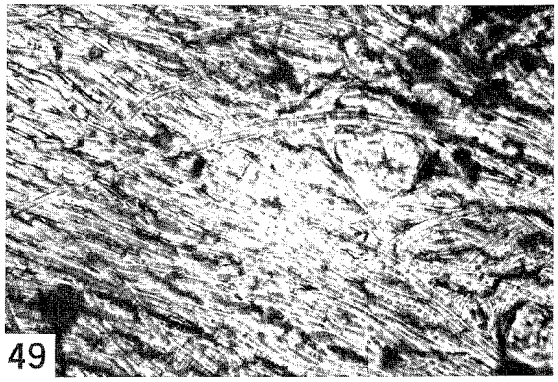
Fig. 52. *Skeletonema costatum* and *Oscillatoria* sp. in the slime on slide glass submerged in the waste water for fourteen days in winter.

Fig. 53. *Nitzschia* sp. and *Oscillatoria* sp. in the slime on slide glass submerged in the waste water for fourteen days in winter.

Fig. 54. *Thalassiosira* sp. in the slime on slide glass submerged in the waste water for fourteen days in winter.

Fig. 55. *Navicula* sp. in the slime on slide glass submerged in the waste water for fourteen days in winter.

Fig. 56. *Melosira* sp. in the slime on slide glass submerged in the waste water for fourteen days in winter.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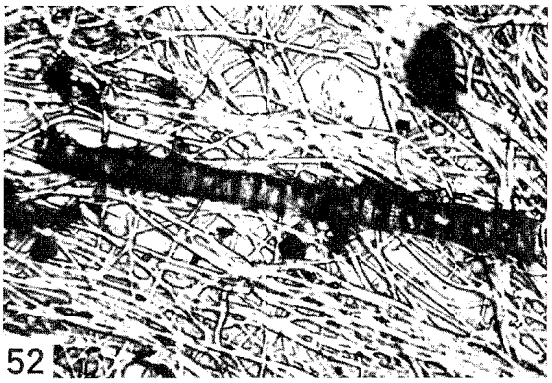
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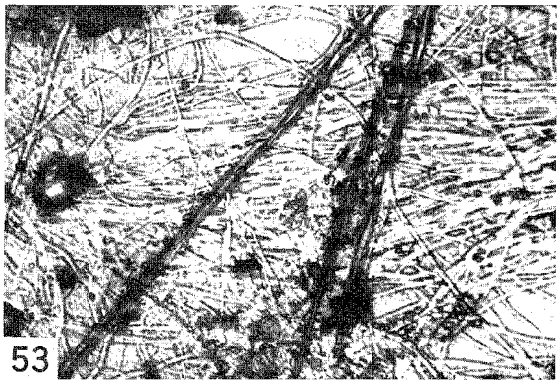
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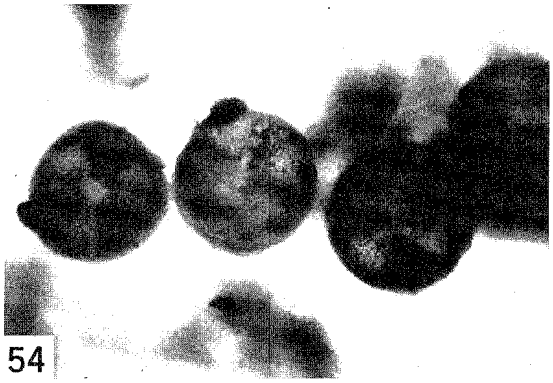
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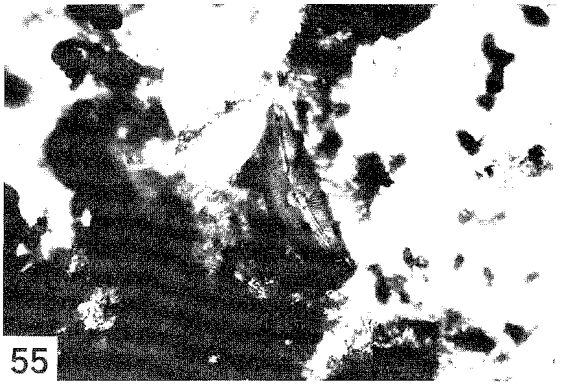
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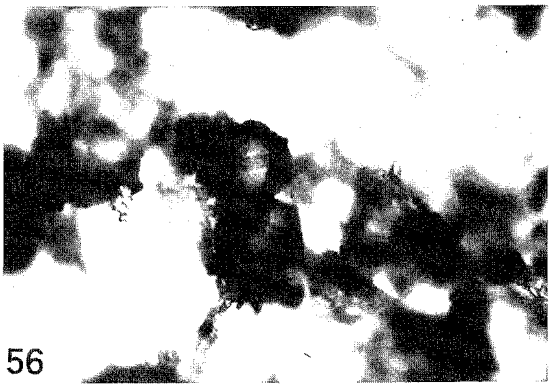
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PLATE Ⅷ

Fig. 57. *Pleurosigma* sp. in the slime on slide galss submerged in the waste water for a day in spring.

Fig. 58. *Pleurosigma* sp. in the slime on slide glass submerged in the waste water for a day in spring.

Fig. 59. *Ceratium furca* and *Skeletonema costatum* in the slime on slide glass submerged in the waste water for a day in spring.

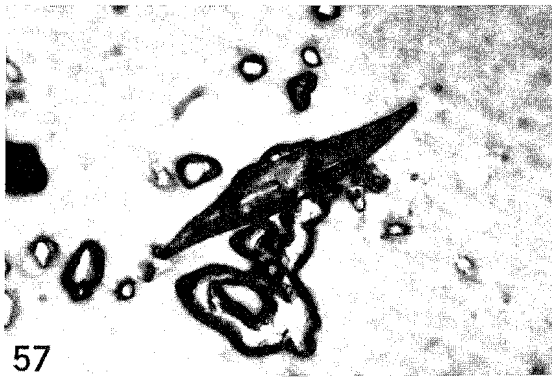
Fig. 60. *Ceratium fusus* in the slime on slide glass submerged in the waste water for a day in spring.

Fig. 61. *Thalassiothrix* sp. and *Amphora* sp. in the slime on slide glass submerged in the waste water for three days in spring.

Fig. 62. *Nitzschia* sp. in the slime on slide glass submerged in the waste water for three days in spring.

Fig. 63. *Navicula* sp. in the slime on slide glass submerged in the waste water for three days in spring.

Fig. 64. *Oscillatoria* sp. in the slime on slide glass submerged in the waste water for three days in spring.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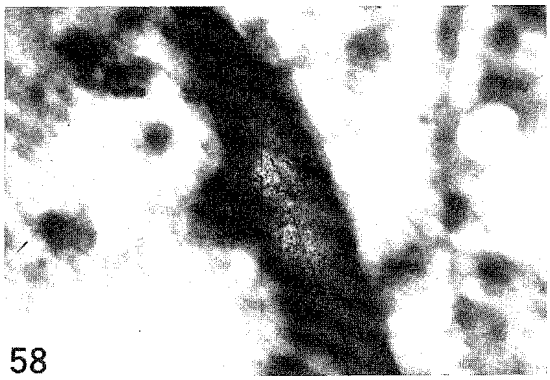
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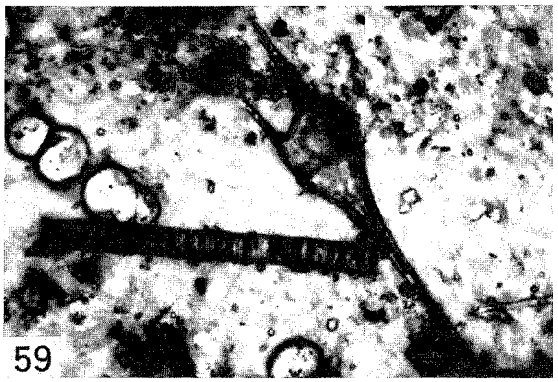
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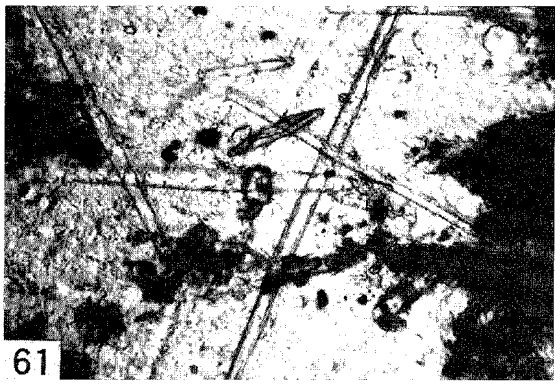
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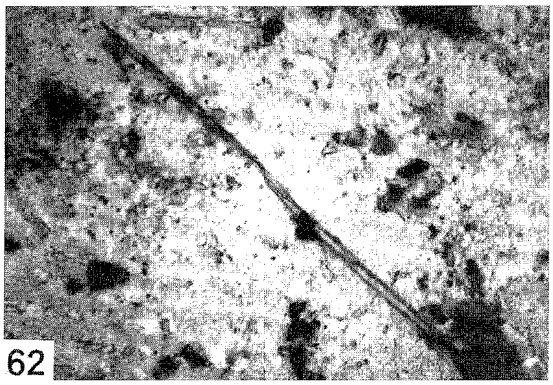
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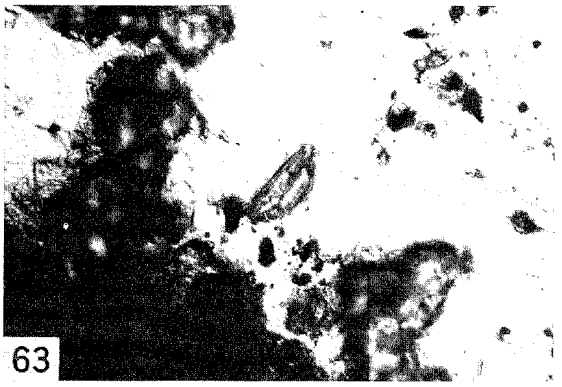
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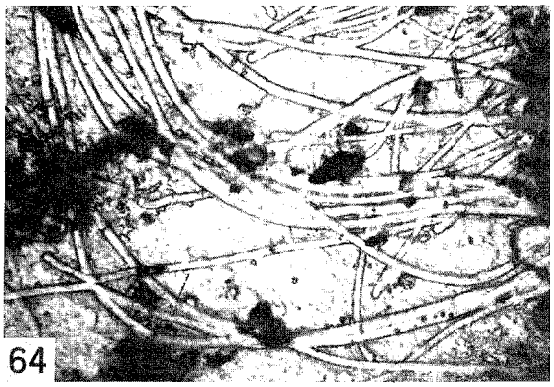
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PLATE IX

Fig. 65. *Amphora* sp. in the slime on slide glass submerged in the waste water for five days in spring.

Fig. 66. *Coscinodiscus* sp. in the slime on slide glass submerged in the waste water for five days in spring.

Fig. 67. *Chaetoceros* sp. in the slime on slide glass submerged in the waste water for five days in spring.

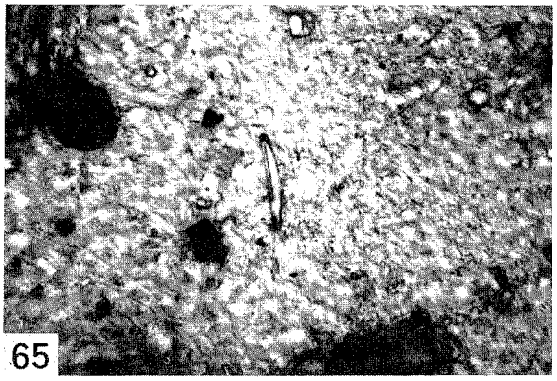
Fig. 68. *Nitzschia* sp. in the slime on slide glass submerged in the waste water for five days in spring.

Fig. 69. *Skeletonema costatum* and *Oscillatoria* sp. in the slime on slide glass submerged in the waste water for five days in spring.

Fig. 70. *Dictyocha fibula* in the slime on slide glass submerged in the waste water for five days in spring.

Fig. 71. *Ceratium* sp. and *Oscillatoria* sp. in the slime on slide glass submerged in the waste water for five days in spring.

Fig. 72. *Oscillatoria* sp. and *Thalassiothrix* sp. in the slime on slide glass submerged in the waste water for five days in spring.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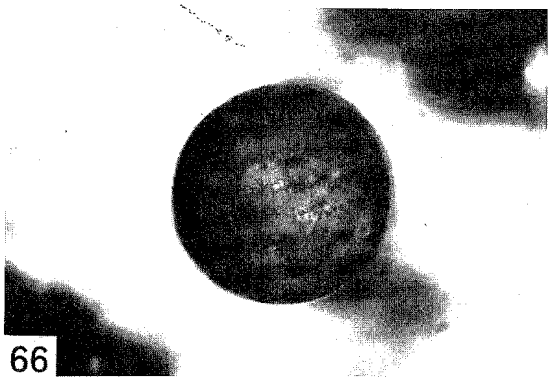
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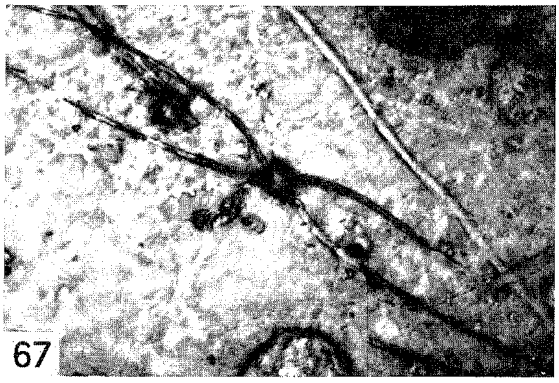
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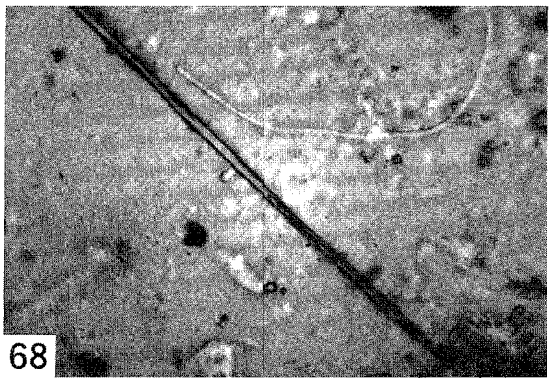
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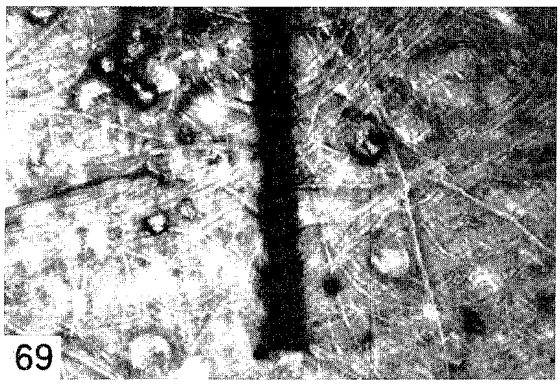
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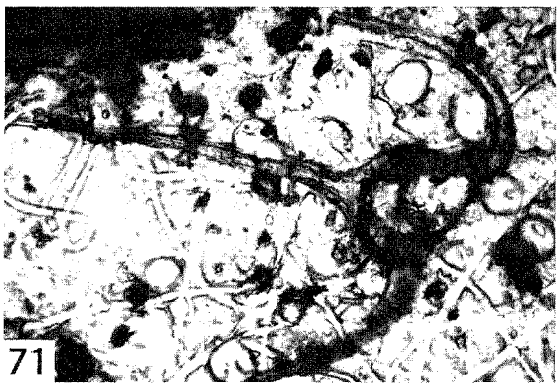
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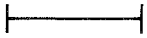

PLATE X

Fig. 73. *Coscinodiscus* sp. (side view) in the slime on slide glass submerged in the waste water for eight days in spring.

Fig. 74. *Oscillatoria* sp. in the slime on slide glass submerged in the waste water for eight days in spring.

Fig. 75. *Phormidium* sp. in the slime on slide glass submerged in the waste water for ten days in spring.

Fig. 76. *Thalassiothrix* sp. in the slime on slide glass submerged in the waste water for ten days in spring.

Fig. 77. *Thalassiothrix* sp. in the slime on slide glass submerged in the waste water for fourteen days in spring.

Fig. 78. *Coscinodiscus* sp. in the slime on slide glass submerged in the waste water for fourteen days in spring.

Fig. 79. *Oscillatoria* sp. and *Thalassiothrix* sp. in the slime on slide glass submerged in the waste water for fourteen days in spring.

Fig. 80. *Oscillatoria* sp. in the slime on slide glass submerged in the waste water for fourteen days in spring.


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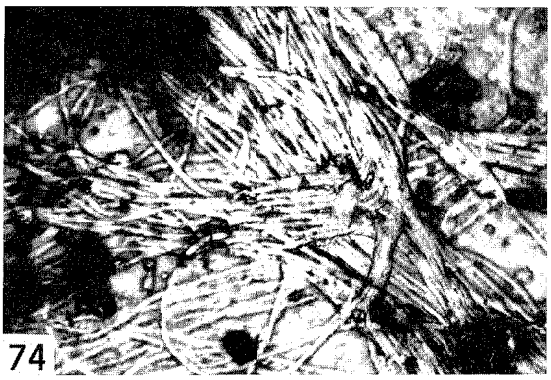
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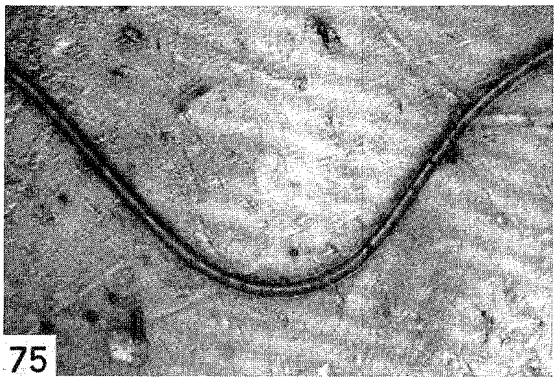
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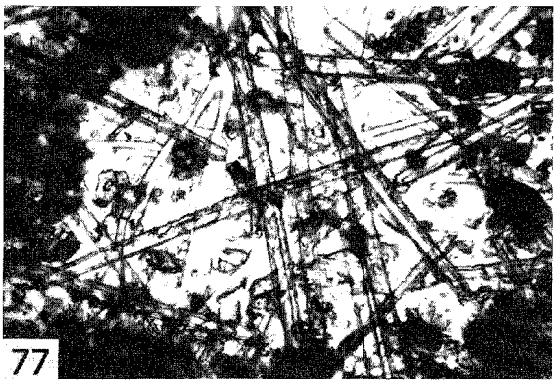
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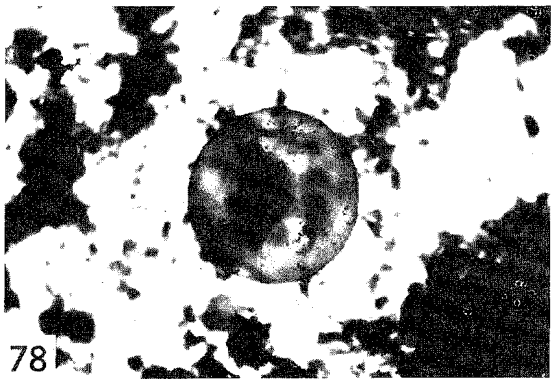
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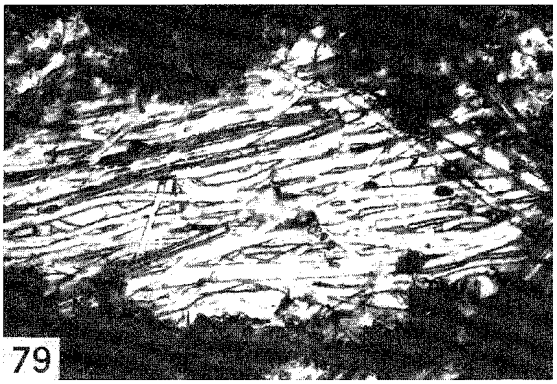
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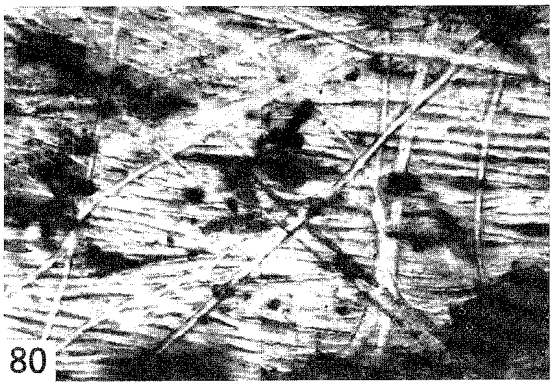
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