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VISCOUS SCUM FORMED WITH OTHER INDIAN SEWAGES AND SEWAGE EFFLUENTS

VISCOUS SCUM

In the previous chapter, results of the bionomic studies on the viscous scum formed at the surface when raw, settled, Baroda sewage was stored were discussed. In this chapter an attempt is made to describe the characteristics of the viscous scums formed with some other Indian sewages and sewage effluents.

Extensive studies carried out on the microbial flora and fauna of sewage purified by the activated sludge process have indicated the presence of Zoogloea remigera (Butterfield 1935; Heukelekian and Littman, 1939; Wattie, 1943; Dugan and Lundgren, 1960, Dias and Bhat, 1964, Unz and Dondero, 1964; and Crabtree, McCoy, Boyle and Rohlich, 1965) along with certain types of free swimming and/or stalked ciliates. The importance of the latter in determining the condition of activated sludge has also been reported by a number of workers (Ardern and Lockett, 1936; Barker, 1949; Hartman, 1963; Hawkes, 1960, Jenkins, 1942; Pillai 1941; Pillai and Subrahmanian, 1942, 1943, 1944 and 1945; Pillai, Wadhawani, Gurubaxani, and Subrahmanian 1947, Pillai, Rajagopalan, and Seshachar, 1947 (a), Pillai, Mohan Rao, Prabhakar Rao, Sastri and Subrahmanian, 1960; and Curds, 1963). The special importanće of Vorticella has been stressed by Pillai (1941, 1943), Reynoldson (1942), Hartman (1943) and Hawkes (1960) in deciding the degree of purification of sewage.

During the course of our studies on the oxidation pond, method of purification of Baroda sewage, these organisms were seen to develop in the viscous scum formed at the surface during bacterial phase I in the first stage of operation. An attempt was made to detect the presence of these organisms at different situations of the Baroda Sewage Disposal Works and a few other sewage disposal works in India. The data thus obtained are reported in this chapter.

<u>Baroda Sewage Disposal Works</u>

At Baroda a part of the 8 mgd of sewage receives only primary treatment in a continuous flow settling basin and the purified effluent is mixed with the remaining untreated sewage and then used for irrigation. The raw sludge obtained from the continuous flow settling basin is digested in primary and secondary digesters and the gas produced thereby is used for domestic heating. The digested sludge is dried and sold as manure.

Samples of raw sewage, the floating scum, the raw sludge and the effluent from the continuous flow settling basin, the final secondary digested sludge, and the supernatant liquor from the secondary digester were kept without disturbance in one litre pyrex glass beakers which were loosely covered with Petri dishes for preventing dust from falling on the surface. This experiment was repeated many times and the results of a typical experiment are given below.

A scum was formed within 48 hours. Successive samples of the top scum and liquid were taken from each beaker as soon as the top scum was noticeable. This was done atleast once a day and several times in the case of some samples.

A loopful (1/2 cm. dia.) of the surface scum and a drop of the liquid were examined qualitatively first for identification of the organisms and then counts made.

The results of microscopic examination are shown in table 6-1 and those of the physico-chemical analysis in table 6-2.

Fingered, zoogloea colonies resembling the figures recorded for the pure culture of Z.ramigera by Butterfield (1935) and by Crabtree, McCoy, Boyle and Rohlich (1965) were formed in the case of samples drawn from the raw sewage, the top scum, the raw sludge and the final effluent from the continuous flow settling basin; and they disappeared in 2 to 8 days when the top scum formation on the surface also ceased.

However, they did not form in the case of the final secondary digested sludge liquor and the supernatant liquor from the secondary digester. The last two samples were characterised by the presence of a high amount of ammoniacal nitrogen (Table 6-2). It is, perhaps, possible that the high content of ammonical nitrogen prevented the growth of zoogloea as suggested by Rich (1955).

From a study of Table 6-2, it will be seen that the 5-day BOD at 20°C of all the samples excepting the final secondary

6-5

Table :6-1: Microorganisms accompanying the zoogloeas

Sample	Zoogloeas seen for No. of days	Protozoa: Ciliates: Stalked		Protozoa: Ciliates: Free-swimming					Flagellates		Bacteria		
		Vorticella microstoma	Epistylis plicatilis	Chilodon sp	Lionotus sp	Paramecium caudatum	Spathidium spathula	Rotifer	Phacus pyrum	Monas sp.	Filamentous	Long rods	Spirillum
I. From the continuous flow settling basin:													
(a) Raw Sewage	4	CCC	-	-	-	C	C	-	CC	CCC	CCC	CC	-
(b) Top scum	3	CC	-	C	r	-	-	-	-	-	-	CC	-
(c) Raw Bottom Sludge	2	r	-	-	-	-	-	-	-	C	-	CC	CCC
(d) Effluent	8	CCC	-	C	--	-	-	-	CCC	CC	C	CCC	-
II. From the Secondary digester													
(e) Digested Sludge	0	rr	-	-	-	rr	-	-	-	-	-	-	-
(f) Supernatant liquor	0	rr	-	-	-	-	-	-	-	-	-	-	-
III. From the Laboratory model activated sludge													
(g) Effluent and sludge	0	-	C	-	-	-	-	r	-	-	-	-	-

* Values of the various symbols are for counts of individuals found in 25 fields; rrr=1, rr=1-50, r = 50-100, C = 100-200, CC = 200-500 and CCC = > 500

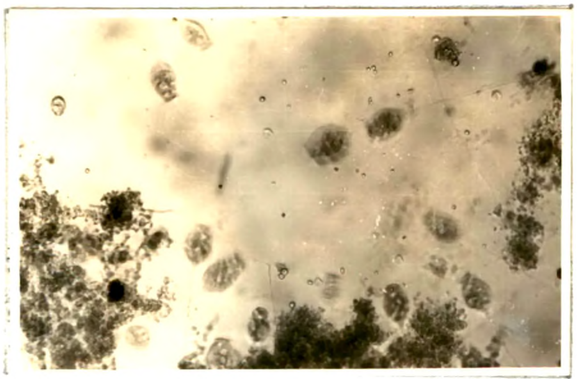
digested sludge are very high and their relative stability very low. The chemical conditions of these samples in which colonies of Zoogloea are found, in short, show varying degrees of purification and do not represent those of a well conditioned activated sludge and effluent. The spherical or fingered, lobed, zoogloeal colonies have been discovered in raw sewage and the other samples receiving no treatment at all. Thus it would be seen that the presence of Zoogloea organism is not associated with the chemical conditions involved in purification of sewage. Of course, a question may be asked whether this organism is the same as the one reported to occur in the sludge of an activated sludge plant. For this, a laboratory model activated sludge plant was set up and it was possible to detect similar organisms in the well purified sludge. Thus Zoogloea organisms seem to be present in all the sewage samples where ammoniacal nitrogen content is not very high.

Regarding the protozoans (Table 6-2 and Fig. 6-1) Vorticella microstoma was found in all the samples but in varying numbers. Podophrya fixa was also seen in a few cases. Paramecium caudatum was found in fairly large numbers in raw sewage along with fingered Zoogloea colonies. In other cases its number was comparatively less. Epistylis plicatilis was the other stalked celiate which was found only in the sludge from the laboratory

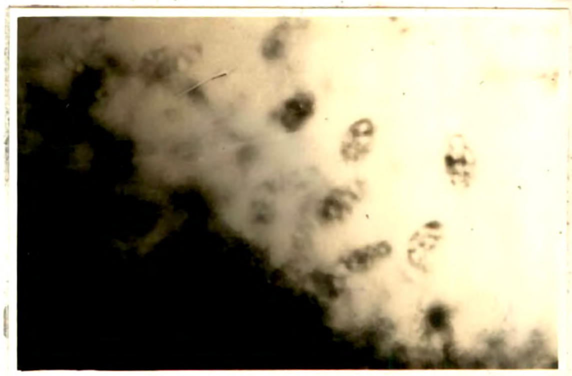
Table :6-2: Physico-chemical analysis of Sewage Samples drawn on 7-4-1966

Sample	Physical Analysis			Chemical Analysis expressed in mg per litre									
	Temp. (0_C)	pH	Relative stability ½days	5 day BOD at 20^oC	Acid $KMnO_4$ 3 mts	Acid $KMnO_4$ 4 hrs.	PO_4	Alkalinity Phenolph	Alkalinity Total	D.O	Nitrogen Am	Nitrogen NO_2	Nitrogen NO_3
I. From the continuous flow settling basin													
(a) Raw sewage	27.5	7.0	0	325	3.6	7.9	27.0	Nil	650	0	50	Nil	Nil
(b) Top scum	27.7	6.7	0	630	14.9	38.6	67.5	Nil	1000	0	9.5	Nil	Nil
(c) Raw Bottom sludge	27.4	6.9	0	-	-	-	134	Nil	1470	0	140	Nil	Nil
(d) Effluent	27.6	7.4	0	316	4.9	20.0	28.0	Nil	800	0	56	Nil	Nil
II. From the Secondary Digester													
(e) Digested sludge	28.0	6.9	0	33	8.3	38.6	61.0	Nil	2230	0	310	Nil	Nil
(f) Supernatant liquor	27.9	7.0	0	215	23.3	9.1	72.0	Nil	1280	0	230	Nil	Nil
III. From the Laboratory model activated sludge plant													
(g) Effluent	28.0	8.6	6	7.0	1.4	2.6	3.6	30.6	450	19.2	7.8	31.8	2.3

PO_4 = Orthophosphate ; D.O. = Dissolved Oxygen ; Am = Ammonia, No_2 = Nitrite ; No_s = Nitrate



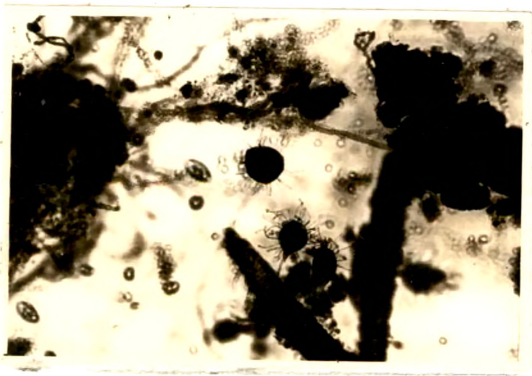
A: Vorticella microstoma x 100



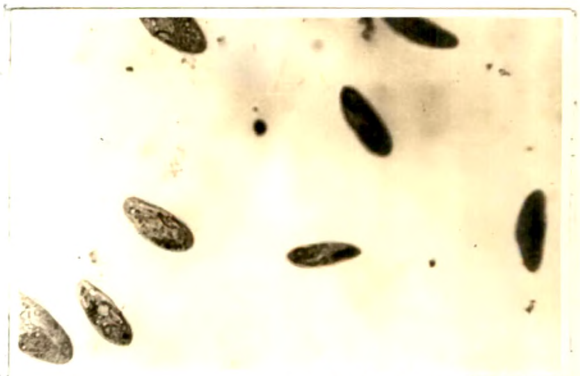
B: Vorticella microstoma x 100

C: Vorticella microstoma x 450

D: Vorticella sp. x 100



E: Podophrya fixa x 100



F: Paramecium caudatum x 100

Fig.6-1: Photomicrographs of the Dominant Protozoans found in the Viscous Scum model activated sludge plant. All other protozoans except Epistylis plicatilis and Zoogloea were found in samples of raw sewage as well as in samples drawn from different situations in the continuous flow primary settling basin and activated sludge plant. These observations raise an important question regarding the role of these organisms in sewage purification.

Raw Sewage Samples taken from Baroda and Bangalore

A sample of raw sewage brought to Baroda by air from the Indian Institute of Science, Bangalore was examined at room temperature and at 37°C for the formation of the viscous scum, zoogloeas and protozoans after storage in 500 ml pyrex beakers on October 10, 1966. Another sample of sewage obtained on February, 13, 1967 was also similarly treated along with Baroda Sewage for comparison. The results of this study are shown in Table 6-3.

It will be seen that the Bangalore sewage examined on October 10, 1966 was found to contain hundreds of Zoogloea colonies and very minute, circular protozoans only, while the sample brought on February 13, 1967 did not contain any zoogloeas at all but only very minute, circular protozoans. The Baroda sewage in contrast, as usual showed the presence of numerous zoogloea colonies and the minute protozoans etc.

Industrial and Sanitary Wastes from Alembic Chemical Works, Baroda

Next, table 6-4 shows the results of examination of samples brought from the treatment unit of the industrial and sanitary wastes at the Alembic Chemical Works, Baroda. The treatment unit is an oxidation ditch.

Table :6-3:A Comparative Study of the Viscous Scums formed in Raw Sewage S
Indian Institute of Science, Bangalore on 7-10-66 and 13-2-67
Disposal Works on 13-2-67

Description	Source	Bangalore Sci. Institute						Bangalore Sci.Insti				
	Temp.( )	Room Temp.			37°			Room Temp.			37°	
	After hours	24	48	72	24	48	72	24	48	72	24	48
Viscous scum		Yes	yes	yes	yes	yes	yes	Nil	Nil	Nil	Nil	Nil
Bacteria:Zoogloea colonies		ccc	ccc	ccc	ccc	ccc	ccc	"	"	"	"	[illegible]
Very long thread bacteria		Nil	Nil	Nil	Nil	Nil	Nil	r	r	r	r	r
Yellowish filamentous " (Iron)		"	"	"	"	"	"	rr	rr	rr	rr	r
Long wavy rods		"	"	"	"	"	"	r	r	r	r	c
Long spirilla(s)or short-rods(R)		"	"	"	"	"	"	s-c	s-cc	s-cc	s-cc	s-
Beggiatoa alba		"	"	"	"	"	"	Nil	Nil	Nil	Nil	Nil
Protozoa												
Monas sp.		"	"	"	"	"	"	"	r	c	c	c
Very small circular forms		ccc	ccc	ccc	ccc	ccc	ccc	"	rr	r	c	c
Paramecium caudatum		Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil
Synura sp.		"	"	"	"	"	"	"	"	"	"	"
Spathidium spathula		"	"	"	"	"	"	"	"	"	"	"
Lionotus fasciola		"	"	"	"	"	"	"	"	"	"	"
Aspidisca sp.		"	"	"	"	"	"	"	"	"	"	"
Chilodon or Plagiopyla		"	"	"	"	"	"	"	"	"	"	"
Vorticella microstoma		"	"	"	"	"	"	"	"	"	"	"
Telotroch forms(T) or Intranstylum sp.		"	"	"	"	"	"	"	"	"	"	"
Vorticella sp.		"	"	"	"	"	"	"	"	"	"	"
Epistylis sp.or Opercularia		"	"	"	"	"	"	Nil	Nil	Nil	Nil	Nil
Rotifer		"	"	"	"	"	"	"	"	"	"	"

Tab;e :6-4: Studies on the Formation of Zoogloea colonies and Protozoans on Storage of Industrial Wastes from Alembic Chemical Works Ltd., Baroda on August 23, 1966.

Description	Source	S_1		S_2		S_3		S_4		S_5		S_6		S_7	
	After hours	24	72	24	72	24	72	24	72	24	72	24	72	24	72
Viscous scum		Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Nil	Nil	Nil	Nil
Bacteria : Zoogloea colonies		Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	"	"	"	"
Very long thread bacteria		"	"	"	"	"	"	"	"	"	"	"	"	"	"
Yellowish filamentous " (Iron)		"	"	"	"	"	"	"	"	"	"	"	"	"	"
Long wavy rods		"	"	"	cc	ccc	c	ccc	"	ccc	ccc	"	"	"	"
Long spirilla(S) or Short Rods(R)		(R)-ccc	(R)-ccc	(R)-	Nil	Nil	Nil	Nil	"	Nil	Nil	(R)-c	(R)-ccc	"	"
Beggiatoa alba		Nil	Nil	Nil	"	"	"	"	"	"	"	Nil	Nil	"	"
Protozoa															
Monas sp.		"	"	Nil	"	Nil	Nil	Nil	"	"	"	"	"	"	"
Very small circular forms		"	ccc	r	ccc	"	ccc	"	"	r	c	"	"	"	"
Paramecium caudatum		Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	"
Synura sp.		"	"	"	"	"	"	"	"	"	"	"	"	"	"
Spathidium spathula		"	"	"	"	"	"	"	"	"	"	"	"	"	"
Lionotus fasciola		"	"	"	"	"	"	"	"	"	"	"	"	"	"
Aspidisca sp.		"	"	"	"	"	"	"	"	"	"	"	"	"	"
Chilodon or Plagiopyla		"	"	"	"	"	"	"	"	"	"	"	"	"	"
Vorticella microstoma		"	"	"	"	"	"	"	"	"	"	"	"	"	"
Telotroch forms or Intranstylum sp.		"	"	"	"	"	"	"	"	"	"	"	"	"	"
Vorticella spp.		"	"	"	cc	"	cc	"	ccc	"	r	"	"	"	"
Epistylis or Opercularia sp.		"	"	"	Nil	Nil	Nil	"	Nil	"	Nil	"	"	"	"
Rotifer		"	"	"	"	"	"	"	"	"	"	"	"	"	"

(S_1= Sanitary wastes & washings from Sanitary and Fermentation Sections excepting antibiotic and distillery wastes;
S_2= From oxidation ditch near influent point ;
S_3= Down stream of rotor No.2; S_4= Effluent from the ditch; S_5=Final effluent from the clarifier;
S_6=Antibiotic Plant. S_7= Distillery Waste.

The results show that there was the development of a viscous scum without the zoogloea colonies contained in it. All the samples showed the presence of a Vorticella sp., (Fig.6-1) and of minute circular protozoans, long wavy rods and short rods.

Atladra Sewage Disposal Works, Baroda

The results of examination of samples drawn from the Atladra Sewage Disposal Works treating mostly industrial wastes from the Alembic Chemical Works and Sarabhai Chemical Works, Baroda with a small proportion of sanitary sewage of the workers and from the few residential colonies on the west of the railway line are shown in table 6-5. The method of treatment consists of grit removal, primary sedimentation basin, secondary treatment by trickling filters followed by final sedimentation basin.

A viscous scum was found to develop after 48 hours at 37°C in the three samples. Zoogloea colonies were seen in all the samples. A maximum number of colonies was found in raw sewage and the minimum in the final effluent after sedimentation.

Vorticella microstoma in different stages of formation :- telotroch forms, stalkless forms and with long contractile stalks were seen in raw sewage. Vorticella sp a comparatively smaller form than V.microstoma was seen in fairly large numbers in the effluent from the trickling filter and in the final effluent after sedimentation. Epistylis sp. or Opercularia sp was not seen.

Delhi Sewage Disposal Works at Okhla

Table 6-6 shows the results of examination of seven samples

Table:6-5: Studies on the Formation of Zoogloea colonies and Protozoans on Storage of Samples taken from Atladra Sewage Disposal Works, Baroda, on January 1, 1968. (Mostly Industrial Wastes).

Description	Room Temperature						37°C					
Source	R.Sewage		T.F.Effl.		After Sedi.		Raw Sewag.		T.F.Effl.		After Sedi.	
After Hours	24	48	24	48	24	48	24	48	24	48	24	48
Viscous scum	Nil	Yes	Nil	Yes	Nil	Nil	Yes	Yes	Yes	Yes	Yes	Yes
Bacteria: Zoogloea colonies	r	c	r	Nil	"	"	cc	ccc	rr	Nil	r	Nil
Very long thread bacteria	Nil	Nil	Nil	Nil	"	"	Nil	Nil	Nil	Nil	Nil	Nil
Yellowish filamentous bacteria	"	"	"	"	"	"	"	"	"	"	"	"
Long wavy rods	"	ccc	r	"	"	"	"	"	"	"	"	"
Long Spirilla(S) or Short Rods (R)	ccc	(s)-c	Nil	"	"	"	"	"	"	"	"	"
Beggiatoa alba	Nil	Nil	"	"	"	"	"	"	"	"	"	"
Protozoa												
Monas sp.	"	"	"	"	"	"	"	"	"	"	"	"
Very small circular forms	r	ccc	"	"	cc	ccc	ccc	c	c	"	ccc	"
Paramecium caudatum	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil
Synura sp.	"	"	"	"	"	"	"	"	"	"	"	"
Spathidium spathula	"	"	"	"	"	"	"	"	"	"	"	"
Lionotus fasciola	"	"	"	rr	"	"	"	"	"	"	"	"
Chilodon (C) or Plagiopyla	"	"	c	Nil	"	"	"	"	"	"	"	"
Vorticella microstoma	"	cc	rr	"	rr	r	r	c	"	"	"	r
Telotroch forms	rrr	r	rrr	"	rrr	r	rr	r	r	"	r	Nil
Vorticella microstoma (Stalkess)	Nil	cc	r	"	Nil	c	r	Nil	Nil	cc	r	cc
Vorticella sp.	"	"	c	cc	r	cc	Nil	"	cc	Nil	cc	Nil
Epistyles sp(E) or Opercularia (O)	"	Nil	Nil	Nil	"	Nil	"	"	Nil	"	Nil	"
Rotifer	"	"	"	"	"	"	"	"	"	"	"	"

Table :6-6: Delhi Sewage Disposal Works: Samples collected on January 14, 1968 between 12 noon and 1 p.m. from different situations and the samples incubated at 10 a.m. at 37^{o} on 16-1-68 at Baroda.

Description / Source	S_1		S_2		S_3		S_4		S_5		S_6		S_7		S_8	
After hrs.	24	48	24	48	24	48	24	48	24	48	24	48	24	48	24	48
Viscous scum	Yes	Yes	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil
Bacteria: Zoogloea colonies	c	r	"	"	"	"	"	"	"	"	"	"	"	"	"	"
Very long thread bacteria	Nil	c	"	"	"	"	"	"	"	"	"	"	"	"	"	"
Yellowish filamentous "	r	c	"	"	"	"	"	"	"	"	"	"	"	"	"	"
Long wavy rods in motion	Nil	Nil	"	"	"	"	"	"	"	"	"	"	"	"	"	"
Long Spirilla(S) or Short rods (R)	(R)-cc	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"
Beggiatoa alba	Nil	rr	"	"	"	"	"	"	"	"	"	"	"	"	"	"
<u>Protozoa</u>																
Monos sp.	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"
Very small, circular forms	"	cc	"	"	"	"	"	"	"	"	"	"	"	"	"	"
Paramecium caudatum	rr	rr	"	"	"	"	"	"	"	"	"	"	"	"	"	"
Synura sp.	r	r	r	"	"	"	"	"	"	"	"	"	"	"	"	r
Spathidium spathula	Nil	Nil	Nil	"	"	"	"	"	"	"	"	"	"	"	"	Nil
Lionotus faciola	"	"	"	"	r	"	"	"	"	"	"	"	"	"	"	"
Aspidisca sp.	"	"	"	"	Nil	"	"	"	"	"	"	"	"	"	"	"
Chilodon sp.	"	"	"	r	"	"	rr	"	rr	"	rr	"	"	"	r	"
Vorticella microstoma	"	"	"	Nil	"	"	Nil	"	Nil	"	Nil	"	"	"	Nil	"
Telotroch forms or intran-stylum sp.	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"
Vorticella sp.	"	rr	"	"	"	"	"	"	"	c	"	"	"	"	"	"
Epistylis or Opercularia	"	Nil	"	"	"	"	"	"	"	Nil	"	"	"	"	"	"
Rotifer sp.	"	"	"	"	"	"	"	"	"	"	rrr	"	"	"	"	"

Table :6-6:(Contd.) Delhi Sewage Disposal Works: Samples collected on January 14, 1968 between 12 noon and 1 p.m.; and Incubated at 10 a.m. at 37°C on January 16,1968 at Baroda, stained Smears of the Surface scum for Sudanophilic Granules after Burdon

Description	Source	S_1		S_2		S_3		S_4		S_5		S_6		S_7		S_8	
	After Hrs.	24	48	24	48	24	48	24	48	24	48	24	48	24	48	24	48
Very long thread Bacterium		Nil	Nil	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL
Long wavy rods		Few	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"
Short rods		Full	"	"	"	Full	"	"	"	"	Full*	Full	Full*	Full	Full	"	"
Cocci		Nil	"	"	Full	Nil	Full	Full	Few	"	Nil	Few	Nil	Full	Nil	Full	"
Spirilla		Nil	"	"	Nil	"	Nil	Nil	Nil	"	"	Nil	"	Nil	"	Nil	"
Zoogloea colonies		Full	Full	"	"	"	"	"	"	"	"	"	"	"	"	"	"
Clusters of Bacteria		Nil	Nil	"	"	"	"	"	"	"	"	"	"	"	"	Full	Full

* Clusters of Bacteria (rods) all fully black.

S_1 = Raw Sewage from flowing channel

S_2 = Effluent from the Dorr-Oliver Primary Settling tank

S_3 = Effluent from a trickling filter fed with 2 parts of raw sewage and 3 parts of effluent

S_4 = Effluent after sedimentation of the filtrate from the Dorr-Oliver Trickling Filter.

S_5 = Effluent from the Simplex aerators (mixed liquor)

S_6 = Effluent after Sedimentation of the mixed liquor.

S_7 = Supernatant from one of the digestors.

S_8 = River Channel containing mixed effluent.

drawn from the New Delhi Sewage Disposal Works at Okhla where there are primary and secondary treatment units. There are Dorr-Oliver primary clariflocculators followed by secondary trickling filters, Simplex high-speed aerating cones, and final sedimentation and basins. Samples were drawn from all the different situations in the disposal works, on January 16, 1968. The raw sewage alone showed the presence of a viscous scum after 24 to 48 hours of incubation at 37°C. All the other samples did not develop a viscous scum even after 48 hours.

The raw sewage alone showed a large number of Zoogloea colonies, long spririlla and Paramecium caudatum. The effluent from the Simplex aerating cones showed the presence of the smaller sized Vorticella sp only

Long wavy rods, clusters of bacteria, short rods, and the zoogloea colonies showed the presence of sudanophilic granules on staining the dried and fixed smears of the top scum.

DISCUSSION

The presence of fingered, branch-bearing Zoogloea has been noted on a number of occasions in the Baroda Sewage Disposal Works. It is not known whether the Zoogloea colonies discovered in the different situations are the same as or different from the typical Zoogloea ramigera of activated sludge, and whether they are slime-forming or flocculent types of bacteria. In any case, they seem to be different in their ecological status and in the nature of the accompanying protozoans from the classical Zoogloea ramigera. The reasons for the absence of Zoogloeas in the two of the samples are unknown.

On one of the two occasions when sewage samples were brought from Banglore, the sewage showed the presence of Zoogloea colonies alone. Why they were not found on the second occasion, is not known.

The mixture of industrial and sanitary wastes from the treatment plant at the Alembic Chemical works, Baroda did not show the presence of Zoogloea colonies at all.

In the case of the samples drawn from the Delhi Sewage Disposal Works at Okhla, the Raw Sewage alone showed the presence of Zoogloea colonies, while in the case of the Atladra Sewage Disposal Works at Baroda, all the samples showed the presence of Zoogloea colonies. Vorticella microstoma in different stages of formation were seen in the raw sewage. The effluent from the trickling filter and the final effluent showed less numbers of the Vorticella sp which were comparatively smaller in size than the Vorticella microstoma. Further work is necessary in order to find out why zoogloea colonies were not found on some occasions in sewages.

Viscous Scum Formation at the Surface of Stored Sewage

Raw sewage contains coarser particles, insoluble, colloidal and pseudo-colloidal material and soluble organic constituents. Coarser particles are precipitated by gravity in continuous flow settling basins, so that the effluent contains a gradation of particles varying in size from colloidal aggregates or finely suspended matter to true colloids and to material in molecular dispersion. The quantity of true colloidal matter in sewage is small according to Mills (1932) and Rudolf and Gehm (1939); and most of the non-settleable, non-soluble material in sewage is in a state of colloidal aggregation. "This might be taken to indicate that the colloidal matter in sewage has a natural tendency to form aggregates or that it is a transitory stage between larger particles and material in solution" (Heukelekian 1941).

So, when Jones and Travis (1926) placed settled sewage in a glass vessel for a day or so, they observed discrete particles to appear either floating in the liquid, attached to the sides of the vessel or settled at the bottom. (Heukelekian 1941). They attributed this phenomenon to increased internal surface. Blitz and Krohnke (1904, cited by Heukelekian 1941), on the other hand, were of the opinion that "the colloidal matter in sewage was adsorbed by the aerobic growth consisting of the colonized forms of plants and animals." They suggested the formation of an adsorption compound of the colloidal matter and the gelatinous coating. This was followed by oxidation or conversion of the adsorbed matter directly by the oxygen of the air essentially by chemical means. Thus the biological growth was admitted to be important only in furnishing adsorptive surface."

Renn (1956) has given an explanation for the mechanism of the viscous scum formation in biologically active systems. "When water containing low concentrations of organic matter stands undisturbed, the molecules of dissolved organic stuffs reorient themselves in the water mass so that energy is lost. This energy loss is effected by the translocation and concentration of organic materials at the air-water interface and at the containing solid-water interfaces. The process goes on in sterile systems quite as well as in biologically active waters. The conditions in unsterilized water is somewhat different. If a shallow tray of swamp water is allowed to stand overnight in a very quiet room the surface will become evenly coated with a continuous sheet of bacteria. Here the migration of organic matter goes on in the same manner as in sterile systems. In addition the growing bacterial population also concentrates at the air-water and water-solid interfaces." He adds that the mechanisms of bacterial concentration are doubtless mixed but must involve both interfacial trapping of moving cells and preferential growth on the surfaces themselves.

Gainey and Lord (1961) have stated that fats accumulate at the surface of stored sewage; and the viscous scums have been shown to contain about 8% fat.

So, the formation of the viscous scum at the surface of stored sewage may be explained on the basis of the above theories.

From the working of the activated sludge process, it is well known that a preformed bacterial slime accelerates the rate of flocculation and clarification of sewage. The acceleration may be brought about by mass inoculation with specific organisms or by the presence of organisms creating an adsorptive surface wherein the process of hydrolysis and oxidation may be carried out at a more accelerated rate. (Heukelekian 1941).

Studies on sewage purification especially with the activated sludge process made during the earlier half of this century show that (a) special types of bacteria which are incapable of growing on conventional media are involved in the process; (b) the true water and sewage bacteria have the peculiar characteristic of sticking to submerged surfaces forming zoogloeal growths; (c) the number of individual organisms in a zoogloeal colony runs into billions and constitute the major portion of solid matter; (d) each of the bacterial cells in a zoogloeal colony is covered with a capsuler slime which may act as an adsorptive surface; (e) that the soluble organic matter of sewage may be directly removed as a result of direct oxidation and assimilation; (f) the insoluble colloidal particles and their aggregates may be hydrolyzed in the liquid phase by the enzymes that are secreted, while with other particles a preliminary stage of adsorption prior to hydrolysis and oxidation may be necessary. (Heukelekian 1941).

Studies made in the latter half of this century go to show that (a) all types of bacteria are involved, and that they are capable of flocculation and precipitation under special circumstances; (b) several types of zoogloeal bacteria were isolated, each differing from the other in important taxonomical and physiological respects, thus leading to a confusion about the role and function of *Zoogloea ramigira* in sewage purification.

SUMMARY

1. The formation of the viscous scum in sewage samples drawn from Banglore, Baroda and Delhi; and from the different situations of the Sewage Disposal Works at Baroda and Delhi is discussed.
2. An explanation for the formation of the viscous scum is given.
3. The role of the dominant organisms in the viscous scum in sewage purification is discussed.