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The Biology of a Sewage Treatment Plant
A Preliminary Survey
Decatur, Illinois

BY

H. P. K. Agersborg and W. D. Hatfield

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DEPARTMENT OF REGISTRATION AND EDUCATION
STATE WATER SURVEY DIVISION
A. M. BUSWELL, Chief
Urbana, Illinois

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The Biology of a Sewage Treatment Plant—A Preliminary Survey—Decatur, Illinois

BY H. P. K. AGERSBORG[1] AND W. D. HATFIELD[2]

Sewage purification is recognized as a combination of physical and biological phenomena, which effect sedimentation, coagulation, reduction and oxidation. The latter three processes are largely the result of the metabolism of many types of micro-organisms. In all probability bacteria play the most important part in sewage treatment, but any form of plant or animal that derives its food supply directly or indirectly from the organic matter in the sewage undoubtedly participates in the total purification.

Although a large amount of work has been done on the bacteriology of sewage treatment, very little fundamental data have been produced because of the lack of proper media and technique, particularly in anaerobic culture studies. Numerous investigators[2,3,4,5,6] have studied the protozoan life in Imhoff tanks, sludge digestion tanks and sprinkling filters. A few[1,7,8,13] have reported on the biology of the activated sludge process. Whether the protozoa aid in digestion and purification or whether their presence is an indication of the condition of the digestion processes is not fully established. However, as indicator organisms they may prove a great aid in operation of a treatment plant, supplementing if not supplanting some of the chemical analyses.

Due to the large quantity of industrial sewage at Decatur[9] and to the fact that the sewage plant comprises Imhoff tanks and partial aeration (pre-aeration)[9] followed by sprinkling filters, a biological study of the plant promised to be most interesting. Such a survey[7] was made during June, July and August, 1928.* In so short a time the work can be only of a preliminary nature, and therefore the data are presented with that restriction in mind.

The Sewage Treatment Plant

The sewage of the city of Decatur consists of about 6 million gallons per day of domestic sewage, including the normal industrial wastes in a city of 58,000 inhabitants, and 4 million gallons per day of waste from a corn-starch and glucose plant. The total industrial and human population equivalent (based on the factor 0.17 lb. 5-day B. O. D. per capita) in 1926 was about 350,000, but was reduced to a total of 125,000 early in 1928 by recoveries of the waste as by-products within the industrial plant.

[1] *Special Biologist, Sanitary District of Decatur.*

[2] *Supt., Sanitary District of Decatur.*

* The Illinois State Water Survey furnished the salary of the biologist for this work.

The sewage treatment plant is designed for an estimated population equivalent of 150,000 of mixed sewage and industrial waste. The capacities with a dry weather flow of 10 M. G. D. are as follows:

Imhoff Tanks—detention period	1.0 hour
sludge capacity-	3.03 cu. ft./cap.
Aeration—without re-aeration of sludge	2.5 hours
Aeration—with re-aeration of sludge	1.67 hour
sludge re-aeration	9 to 18 hours
Sprinkling Filters	3.0 acres, 6 ft. deep
Rate	3.3 M. G. A. D.
Secondary Settling Tank, detention period	30 minutes

Imhoff tanks, pre-aeration plant, dosing tanks and sprinkling filters, and experimental plant. Secondary tank in background—under water because of high river.

The efficiencies of the plant during June, July and August, 1928, are indicated in Table I.

The crude sewage received at the plant (except during times of storms) contained from 180 to 280 p. p. m. suspended matter and from 3 to 4 cc. per liter of settleable matter in one hour's settling. The average 5-day B. 0. D. was 236 p. p. m.; the total nitrogen about 25 p. p. m., of which 10 to 15 p. p. m. was free ammonia nitrogen; sulfur dioxide from the starch waste, 48 p. p. m.; pH, 6.2; dextrose about 8 p. p. m.

TABLE I

OPERATION RESULTS, DECATUR TREATMENT PLANT, JUNE, JULY AND AUGUST, 1928

	Suspended Matter			B. O. D. (5-day)		
	June	July	Aug.	June	July	Aug.
Crude Sewage, p. p. m.	270.0	183.0	180.0	281.0	210.0	218.0
Per Cent Removal by*						
Imhoff Tanks	68.8	55.1	60.0	22.6	34.0	31.3
Pre-aeration	61.0	45.1	50.0	53.8	54.7	54.1
Sprinkling Filters	66.6	70.5	62.8	86.5	90.9	89.5
Secondary Tanks	..	..	72.3	..	..	90.8

	Final Effluent		
	June	July	Aug.
Per Cent Stability	84.0	98.0	97.0
Nitrate Nitrogen	11.0	11.0	12.8
Total Sewage Flow, M. G. D.	9.12	10.30	9.88

* The per cent removals are the total removal of all the processes to and including the effluent under consideration.

An estimate of some of the material introduced into the sewage by the starch waste may be obtained from the following average data:

STARCH WASTES

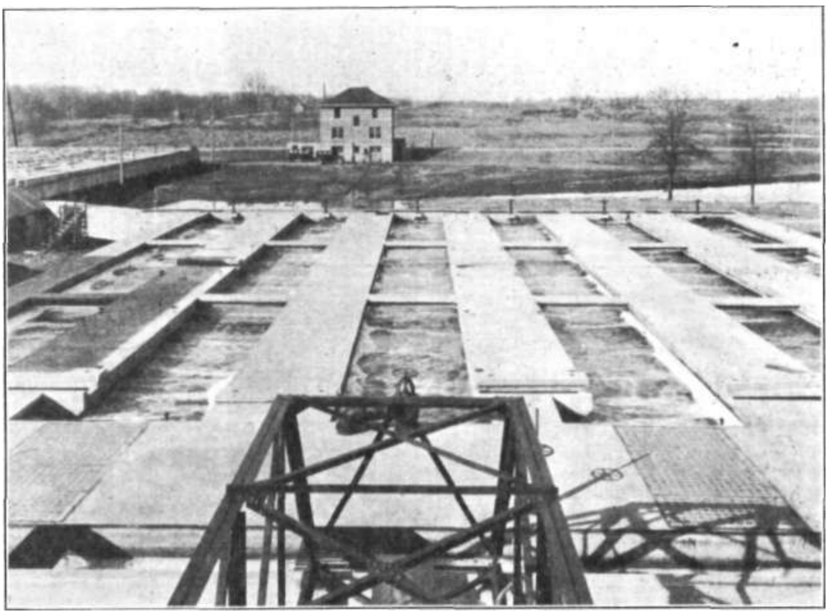
Total solids	30,000 lb. per day
Volatile solids	14,000 lb. per day-
Total nitrogen	1,000 lb. per day
Sugar (dextrose)	670 lb. per day
Sulphur dioxide	4,000 lb. per day
B. O. D. (5-day)	12,500 lb. per day

Biological Studies

Sewage.—Due to the presence of the strong industrial waste it is not surprising to find a scarcity of life in the raw sewage. Microscopical examinations of the raw sewage revealed the constant presence of bacilli, cocci and the filamentous bacteria *Sphaerotilus natans.* Fungi, algae, protozoa and metazoa were not usually present except as encysted cells. On July 5, after the holiday shutdown of industry, the following organisms were found: bacilli, cocci, *Sphaerotilus natans, Oscillaria, Monas, Colpidium* (?) and dead *Opercularia.*

Imhoff Tanks.—In the sludge digestion chamber of the Imhoff tanks some of the encysted organisms are freed and a healthy protozoan flora builds up, which may be seen under the microscope devouring bacteria and amorphous matter of the sludge. A microscopic survey of sludge from the sludge digestion compartments of the six Imhoff tanks revealed that the individual tanks did not differ materially and that there was **a** characteristic change of flora from the bottom to the top of the tank.

A summary of this survey is given in Table II. The samples were collected by pumping from various depths and immediately examined under the microscope with low power, high power and oil immersion where necessary. The samples were taken at about two-foot intervals of elevation.



Office building, Imhoff tanks, aeration tanks.

Bacilli, cocci and *Sphaerotilus natans* were present at all elevations, with *Zoogloea ramingera* found only occasionally at the surface of the sludge. Three species of Vahlkampfia (a rhizopod related to amoeba) were usually present at all elevations, but were most numerous in the sludge. Small flagellates were present at all depths, but were more abundant at the sludge line or in the liquor just above the sludge line. In this region, where fresh organic matter is continuously being deposited, the greatest number of flagellates were found. A few ciliates were present in the sludge, but they occurred more abundantly in the liquor above the sludge. *Metopus sigmoides*, *Oxytricha* and *Colpidium* were almost always present in the liquor.

The hydrogen-ion concentration of the sludge liquor at different depths was determined colorimetrically and with the quinhydrone electrode. The latter gave pH values about 0.2 higher than were obtained with brom-thymol-blue and recorded in Table II. This discrepancy was found to be due to the very rapid loss of CO_2 from the solution during the manipulation

TABLE II

MICROSCOPICAL SURVEY OF THE IMHOFF TANKS

Source of Samples	Bacteria				Algae				Protozoa																															Metazoa		pH
									Rhizopoda								Flagellata									Ciliata																
	Bacilli	Cocci	*Sphaerotilus natans*	*Zoogloea ramingera*	Blue-green algae	*Trochiscia*	*Chlorosphaera*	*Richteriella globosa*	*Vahlkampfia guttula*	*V. limax*	*V. minuta (sp. nov.)*	*Protamoeba primitiva*	*Hartmanella hyalina*	*Dimastigamoeba*	*Mastigella*	Encysted and free amoeba	*Bodo (sp.)*	*Bodo caudatus*	*Cercobodo*	*Oikomonas*	*Dinomonas vorax*	*Peranema*	*Petalomonas carcinata*	*Heteromita ovata*	*Heteronema acus*	*Holophrya*	*Prorodon*	*Chaenia*	*Lionotus*	*Amphileptus (sp.)*	*Colpidium*	*Paramoecium*	*Metopus sigmoides*	*Caenomorpha*	*Strichotricha*	*Eschaneustyla brachytoma*	*Gastrostyla*	*Oxytricha*	*Opercularia (dead)*	*Rhabdolaimus minor*	*Nematode*	pH to Brom-thymol blue
Bottom	x	x	x						x	x	x			x			x				x								x				x	x								7.5
5 to 8 ft. above bottom	x	x	x		x				x	x	x						x							x																		7.6
9 to 11 ft. above bottom	x	x	x		x				x	x	x						x											x				x										7.6
13 to 14 ft. above bottom	x	x	x	x		x			x	x		x					x			x	x				x		x				x							x				6.8
15 to 17 ft. above bottom	x	x	x			x			x	x	x						x	x	x				x								x		x			x		x		x		6.7
19 to 21 ft. above bottom	x	x					x		x	x	x	x	x		x		x					x				x				x			x					x	x			6.8
23 to 29 ft. above bottom	x	x	x								x	x	x			x	x (small flagellates)									x					x	x	x		x		x	x	x		x	6.8

NOTE: The sludge line in the six tanks varied from 12 to 13.5 ft. above the bottom.

of the quinhydrone electrode. A similar loss could be produced by handling the solution in the same manner and then adding the indicator. Therefore pH determinations on sludge liquor should be made as soon as possible on liquor pipetted from considerably below the surface of the sample bottles.

The Imhoff tank effluent contained very few protozoa, as would be expected from their absence in the influent sewage. Except for this feature, the results on the Decatur tanks are very similar to those reported by J. B. Lackey[5] for tanks operating normally and without foaming.

Pre-aeration Plant.—The pre-aeration plant operates similarly to an activated sludge plant except that the aeration period and quantity of air used are only about one-third to one-fourth that necessary for complete activated sludge treatment. This reduced aeration under Decatur conditions gives B. O. D. reductions of about 20 to 30 per cent and produces an under-aerated sludge which is brownish black, at times slightly septic, and only about 60 to 80 per cent of which will settle in the settling tanks. This bulking sludge has been a most interesting problem and if conditions can be made such that a better settling sludge can be obtained, the efficiencies of the process can be materially increased.

The, organisms found in the aeration tanks from June 28 to July 9, 1928, are listed in Table III. This table is a summary of all organisms.

TABLE III

ORGANISMS IN AERATION TANKS JUNE 28 TO JULY 9, 1928

Near Inlet End of Aeration Tanks

Higher Bacteria, Fungi, Algae	Protozoa	Metazoa
Bacilli, cocci	*Hartmanella hyalina*	*Rotifera*
Sphaerotilus natans	*Vahlkampfia albida*	
Zoogloea ramingera	Small flagellates	
	Bodo caudatus	
Filamentous algae	*Petalomonas*	
Binuclearia tetrana	*Dinomonas vorax*	
Trentipohlia	*Distigma proteus*	
Pandorina	*Chilodon cucullulus*	

Near Outlet End of Aeration Tanks

Higher Bacteria, Fungi, Algae	Protozoa	Metazoa
Bacilli, cocci	*Hartmanella hyalina*	Nematode
Sphaerotilus natans	*Protamoeba primitive*	(occasional)
Beggiatoa alba	*Vahlkampfia limax*	
Filamentous algae	*Vahlkampfia guttula*	
A blue-green algae	*Biomyxa*	
A green algae	*Bodo*	
	Bodo caudatus	
Diatoma	*Physomonas*	
Richteriella globosa	*Oikomonas*	
Phytogloea	*Cercomonas*	

TABLE III (Continued)

Higher Bacteria, Fungi, Algae	Protozoa	Metazoa
Palmodictyon (?)	*Petalomonas*	
Radiofilum	*Dinamonas vorax*	
Trentipohlia	*Monas*	
Oscillatoria prolifica	*Pleuramonas jaculans*	
Phytozoogloea	*Chilomonas*	
	Astasia	
	Rhabdostyla vernalis	
	Plagiopyla nasusta	
	Euglena	
	Blepharisma	
	Chilodon	
	Colpidium	
	Hexotricha	
	Bursaria	
	Metopus sigmoides	
	Oxytricha	
	Carchesium	
	Vorticella	

found in samples taken during this period. All organisms listed are not found in any one sample, therefore, the two parts of the table are not directly comparable. The samples, however, did consistently show a larger variety of organisms after the 2.5 hours of aeration. *Zoogloea ramingera* and *Sphaerotilus natans* are the most common inhabitants of the tanks with *Metopus sigmoides* omnipresent. The aeration favors an increase in the small flagellates, the hypotrichous and peritrichous ciliates. The flora and fauna are stimulated toward the more aerobic organisms.

Ardern[8] has summarized the protozoal characteristics of activated sludge as follows:

(a) *"Sludge in bad condition.* Preponderance of Flagellates, *Amoeba* (and other Rhizopods); relatively few Ciliates, *e. g., Carchesium, Chilodon, Choenia** absent."

(6) *"Sludge in unsatisfactory condition.* Flagellates and *Amoeba* (and other Rhizopods); some ciliates *e. g:, Stentor, Paramoecium, Chilodon, Carchesium,* Vorticella; *Choenia* absent."

(c) *"Sludge in satisfactory condition.* Few Flagellates and Amoeba; preponderance of Ciliates, *e. g., Carchesium, Vorticella, Chilodon, Colpoda, Colpidium;* some *Aspidisca* and *Loxophyllum;* occasional *Choenia;* few Suctoria."

{d) "Sludge in good condition. Very few Flagellates; Amoeba are rare; preponderance of Ciliates, *e. g., Carchesium, Vorticella, Aspidisca, Loxophyllum, Choenia;* few Suctoria."

The sludge described in Table III would be judged as unsatisfactory

* *Chaenia* (in Ward and Whipple's "Fresh Water Biology").

according to this classification. This is to be expected from a plant designed for partial aeration unless sufficient reaeration of the sludge is given to keep the sludge entirely activated. A discussion of the biology of the sludge during reaeration will be published later. See also Agersborg (1929).[7]

During the time the studies reported in Table III were being made, there was very little sludge in the sludge liquor being returned to the aeration tanks. On one hour's settling of the aeration tank effluent there was only 2 or 3 cc. of sludge per liter even though at that time 2.0 M. G. D. (20%) of settled sludge from the settling tanks was being returned to the aeration tanks. The B. O. D. reduction due to pre-aeration at this time was 31 per cent. This reduction was very gratifying when the small amount of sludge in the process was considered. The return sludge was mostly water which on one hour's settling gave 8 to 10 cc. per liter of sludge. Immediately after a heavy rain a heavier brownish near-activated sludge would build up in the more dilute sewage. This sludge soon became infected with *Sphaerotilus,* bulking followed, and most of the sludge would be lost over the weirs of the settling tank to the sprinkling filters.

Morgan and Beck[11] have shown that heavy growths of *Sphaerottlus* caused bulking of the sludge and reduced efficiencies at the activated sludge plant of Maywood, Illinois, and that the trouble was caused by the presence of large quantities of sugar in the sewage from illicit stills. The Decatur sewage contains variable amounts of dextrose from the starch waste and in all probability this is the cause of both the *Sphaerottlus* growths, which are found all though the plant, and of the continuous bulking of the sludge.

The real problem in the operation of a pre-aeration plant is to reduce sludge bulking to a minimum. Even though a removal of 31 per cent B. 0. D. by pre-aeration at Decatur is satisfactory and is about the efficiency expected from the testing station results[10] nevertheless if conditions could be established so that a better sludge could be produced the efficiencies of the plant could be increased and the total load on the plant increased above the 150,000 population for which it was designed. Therefore, some studies were made on the organisms in the aeration liquor under various conditions of aeration.

Experimental Pre-aeration Studies.—*1. Prolonged aeration at normal rate of agitation.*—The inlet and outlet valves of one of the aeration tanks were closed and the tank liquor allowed to aerate at the normal aeration rate (normal agitation) for 6 days. During these days samples were examined under the microscope. The results are summarized in Table IV. These data show that:

Sphaerotilus natans began' to decrease after 4 hours aeration and continued to decrease until few were left on the 6th day.

A few amoeba were present but never in sufficient numbers to be significant. Some of them may have been flagellates in their amoeboid stage.

Small flagellates increased the first day and were very numerous on the 3rd day, then declined until almost absent on the 6th day.

The Chloroflagellates occurred in large numbers on the 3rd and 4th days but were gone the 5th day.

The peritrichous Ciliates increased gradually until on the 6th day they were very numerous. On the sixth day sewage was again turned into the tank. Within three to seven hours 5. *natans* was on the increase, small flagellates were reappearing and *Vorticella* had developed the basal circle of cilia.

TABLE IV

ORGANISMS OBTAINED ON PROLONGED AERATION (NORMAL AGITATION)

Temperature of Sewage, 32 to 34° C.

Hours Aeration	Higher Bacteria, algae	Protozoa
0	*Beggiatoa arachnoidea*	*Oikomonas*
	Beggiatoa sp.	*Trachelomonas*
	S. natans	*Metopus sigmoides*
	Z. ramingera	
4–8 hrs.	Fewer *S. natans*	Increase in small flagellates
	Beggiatoa	Many small amoeba
	Z. ramingera	*Vahlkampfia albida*
		Amoeba radiosa
		A. limax
		Metopus sigmoides
		Vorticella, Opercularia
24–48 hrs.	*S. natans* moderate in number	*A. limax*
		Small flagellates
		Euglena
		Phacus
		Colpidium
		Metopus sigmoides
		Vorticella
		1 dead *Paramoecium*
48–54 hrs.	*S. natans* and other filamentous organisms becoming scarce	*A. limax*
		Large number of small flagellates
		Petalomonas irregularis
	Z. ramingera	*Anisonema*
	Gonium and *Pandorina* in large numbers	*Metopus sigmoides*
		Metopus sp.
	Eudornia	*Oxytricha*
	Spondyloniorum	*Vorticella telescopica*
	Spirillum major	*Vorticella Microstoma*

TABLE IV (*Continued*)

Hours Aeration	Higher Bacteria, algae	Protozoa
72 hrs.	Organisms about the same as 54-hour sample	
120 hrs.	*S. natans* (few) *Z. ramingera* (few) *Chloroflagellates* gone	*A. radiosa, A. limax* *Oikomonas* and many small flagellates *Chaenia, Colpidium, Colpoda, Paramoecium aurella* and *caudatum, Vorticella*
148 hrs.	Filamentous bacteria still present but not numerous	*Vorticella*, many *Opercularia* Other Ciliates missing
	SEWAGE FLOW INTO TANKS AGAIN	
3 hrs. later	*S. natans* on rapid increase	*A. limax, Astasia, Euglena* Clusters of *Vorticella*, 40 in a bunch
7 hrs. later	*S. natans*, many	*Metopus sigmoides, Vorticella*, some have a 2nd row of cilia

2. *Prolonged Aeration with Greatly Increased Rate of Agitation.*—A study similar to the above was made with about twice the normal agitation by aeration, to determine whether excessive agitation might not inhibit development of the protozoa. The results were similar to those in Table IV except that a larger number of Chloroflagellates occurred. The results showed conclusively that growth was not inhibited by even greatly increased agitation over that normally used in the Decatur tanks.

3. *Prolonged Aeration with Greatly Decreased Agitation.*—The effect of greatly decreased aeration was studied by closing the inlet air valves until only enough air was maintained to show a few bubbles through the aeration plates. The air meter read zero, but there was sufficient air passing to keep the aeration liquor rolling very gently. One tank was cut out of service for prolonged aeration similar to the above studies, while the other tank received sewage at the regular rate (2.5 hours detention period).

Specimens from the tanks were collected and examined after 24, 48, 72 and 96 hours. The samples showed little or no change in flora and fauna and are summarized as follows:

AFTER 96 HOURS OF AERATION WITH GREATLY REDUCED AGITATION

1st Tank	2nd Tank
Prolonged aeration	Continuous sewage flow
Bacteria	Bacteria
S. natans	*S. natans*
Zoogloea ramingera	*Z. ramingera*
Small Amoeba	*Z. globosa*
Small flagellates	*Beggiatoa*
One *Vorticella*	Small Amoeba

Sufficient air was not present in these experiments to maintain or even approximate an aerobic flora. In order to maintain a good sludge that settles rapidly and efficiently, it seems necessary to give the process longer aeration at a moderate (normal) rate of agitation. This might be accomplished by prolonged reaeration of the sludge.

Life in the Sprinkling Filter Effluent.—Time was not available to make a thorough study of the organisms on the stones of the filter beds. Noticeably present on the stones near the surface were various species of algae and fungi; rotifiers in large numbers and a yariety of species; a few nematodes, water mites and fly larva. During the last week of June large numbers of *Opercularia plicatiles* and *Colpoda* were present.

The Decatur sprinkling filters operate at rather high temperatures all the year round so that there is not the periodic spring and fall sloughing-off of the slime, but instead a rather continuous sloughing. In Table V are reported seven examinations made of the organisms in the sprinkling filter effluent. These data show that the flora and fauna have changed on passing through the filter beds from that of rather typical sewage types to that more analogous to normal pond water. These data check fairly well with those of Frye and Becker[12] on an experimental sprinkling filter purifying diluted milk, even though these are effluent samples and theirs were samples of slime from the filter media. This difference probably explains the fewer number of species found at Decatur. As has already been indicated, a more thorough examination of the effluent would have disclosed a larger number of species. (Compare also with Agersborg (1929)[7].)

TABLE V

LIFE IN SPRINKLING FILTER EFFLUENT

Date	Bacteria and Algae	Protozoa	Metazoa
June 28	*Aeronemum polymorphum*	*Amoeba sp.*	Nematodes
		Arcella vulgaris	Rotifers different species
	Oscillatoria limosa	*Difflugia*	*Polychaeta*
		Amoeba proteus	*Cyclops*
		Monas	Larva in cyst
		Peranema	
		Paramoecium	
		Stentor	
		Lionotopsis anser	
		Oxytrichida	
		Vorticella	
		Pyxidium	
		Scyphidia fromentellii	
July 5	*Oscillatoria limosa*	*Arcella* shells	Rotifer
	Microthamnion kützingianum	*Chaenia*	Nauplius of Cyclops
		Stentor	Ecdysis of Cyclops
		Vorticella	*Polychaetus*

TABLE V *(Continued)*

Date	Bacteria and Algae	Protozoa	Metazoa
July 6		*Euglena* *Plagiopyla* *Metopus sigmoides* *Loxophyllum*	
July 13	*Sphaerotilus natans* *Zoogloea ramingera*	*Amoeba proteus* *Arcella vulgaris* *Arcella discoides* *Peranema trichophorum* *Chilodon* *Paramoecium* *Lionotopsis* *Amphileptus meleagris* *Colpoda* *Vorticella* *Vorticella elongata* *Opercularia berberina*	*Rotifera* *Doro limosa* Nauplius of Cyclops Male and female of Cyclops *Torrenticula anomala*
July 14	*Richteriella* An attached cyst	*Amoeba limax* *Arcella vulgaris* *Arcella dentata* *Vahlkampfia minuta* *Colpidium* *Colpoda*	*Dorylainus* Nauplius of Cyclops
July 16	*Zoogloea ramingera*	*Arcella vulgaris*	Nematodes *Philodina roseola* *Doro limosa*
August 3	*Zoogloea ramingera*	*Arcella vulgaris* *Difflugia* *Vorticella*	Nematodes *Philodina roseola* *Pristina longisata*

Life in the River at the Plant Outlet.—No study was made of the life in the secondary settling tanks since it should be similar to that of the sprinkling filter effluent. A single sample of the mixed effluent and river water taken near the outlet of the sewage plant contained the following organisms:

Algae	Protozoa	Metazoa
Asterionella gracillima A green cyst	*Astasia* *Euglena minuta* *Peranema trichophorum* *Euglena sp.* *Trachelomonas* *Coleps hirtus*	A rotifer A nematode

A larger number of samples and a more thorough search would have shown a larger variety of species. A sample from a mud bank near the outlet from the plant revealed the following:

Algae	Protozoa	Metazoa
Diatoms	*Amoeba limax*	*Diglena rostrata*
Oscillatoria	*Amoeba proteus*	*Rotifer neptinius*
	Euglenoids	*Lepidoderma*
	Peranema	*Anguillula*
	Synura	
	Paramoecium caudatum	
	Several small ciliates	
	Loxocephalus granulosus	
	Stentor	
	Uroleptus longicaudata	
	Oxytricha pellionella	
	Aspidisca costata	

This summary shows that the flora and fauna of the river near the outlet resemble the flora and fauna of the sprinkling filter effluent. Many of these organisms serve as food for the large numbers of aquatic beetles, (Dytiscids, Hydrophilids and Gyrnids) which frequent the surface of the river near the outlet.

Schools of fish are fond of the final effluent as it enters the river with its large supply of fish food. The following fish have been caught at the plant outlet; catfish, carp, buffalo fish, golden shiner, crappie, bluegill, gizzard-shad, sunfish, chubs and minnows.

Conclusions

1. The crude sewage of Decatur contains fewer organisms than other investigators have reported. This is probably due to inhibitory substances in the industrial wastes.

2. The flora and fauna of the digestion compartments of the Imhoff tanks are quite similar to the flora and fauna reported by Lackey (1925) for non-foaming tanks, except for *Zoogloea* and *Sphaerotilus.*

3. The sludge in the pre-aeration system consists almost entirely of *Zoogloea* and *Sphaerotilus.*

4. Increased aeration favors the succession of small flagellates, hypotrichous and then peritrichous ciliates.

5. This sludge, although relatively free from protozoa and classified as a poor activated sludge, causes a reduction of about 30 per cent of the total B. O. D. in the crude sewage.

6. The presence of about 8 p. p. m. of dextrose in the sewage probably encourages the abundant growth of *Sphaerotilus* in the aeration tanks and may also account for its presence in the Imhoff tanks.

7. The flora and fauna of the sprinkling filter effluent contain mostly protozoa of the mesosaprobic purification zone, and is similar to that of other filters reported in the literature.

8. Ten species of fish have been caught in the river at the plant outlet feeding on the life in the filter effluent.

9. The final effluent from the plant during these studies was better than 90 per cent stable and contained about 11 p. p. m. nitrates.

References

[1] Buswell, A. M., "Microbiology of Activated Sludge," *Ill. State Water Survey, Bull.* 18, 26, 82-92 (1920-22).

[2] Buswell, A. M., "Biological Data on Sprinkling Filters," *Ibid.,* 26, 95 (1928).

[3] Housman, L. A., "Fauna of Sprinkling Filters," *N. J. Agr. Exp. Sta., Bull.* 390, 28 (1923).

[4] Haenseler, Moore and Gains, "Fungae and Algae of Sprinkling Filters," *Ibid.,* 390,39(1923).

[5] Lackey, J. B. "The Fauna of Imhoff Tanks," *Ibid.,* 417 3-39 (1925); Lackey, J. B., "Fauna of Imhoff Tanks and Sprinkling Filters," *Ibid.,* 403, 40 (1924); Lackey, J. B., "Distribution and Succession of Protozoa in Imhoff Tanks," *Ibid.,* Report June 30, 1926, p. 507; Lackey, J. B. "Sprinkling Filter Bed Studies," *Ibid.,* 427, 41 (1926).

[6] Rudolfs, W., *Ibid.,* 390, 403, 417 and Report for 1926.

[7] Agersborg, H. P. K., "The Biology of Sewage Disposal," *Trans. Amer. Microscopical Soc,* 48, 158-79 (1929).

[8] Ardern, E., "Activated Sludge Process," City of Manchester, Rivers Department Report, 1928, p. 40.

[9] Hatfield, W. D., "Gases from Sludge Digestion," *Ind. Eng. Chem.,* 20, 174 (1928); Hatfield, W. D., "Partial Aeration of Strong Sewage with Activated Sludge," *Ibid.,* 20, 832 (1928).

[10] Greeley, S. A., and W. D. Hatfield, "The Sewage Disposal Works of Decatur, Illinois," *Proc. Am. Soc. Civil Engrs.,* 54, 2237 (1928).

[11] Morgan, E. H., and A. J. Beck, "Carbohydrate Wastes Stimulate Growth of Undesirable Filamentous Organisms in Activated Sludge," THIS JOURNAL, 1, 46 (1928).

[12] Frye, W. W., and E. R. Becker, "The Fauna of an Experimental Trickling Filter," *Ibid.,* 1, 286 (1929).

[13] Kolkwitz, R., "The Biology of Activated Sludge," *Kl. Mitt. Ver. Wasserversorg. Abwasserbeseitig.,* 3, Beiheft 70-4 (1926).