

A PRELIMINARY STUDY OF INDUSTRIAL POLLUTION IN THE CLEVELAND HARBOR AREA, OHIO.

I. PHYSICAL AND CHEMICAL RESULTS

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Cleveland, Ohio, is a highly industrialized city with a large proportion of its industrial plants located in the valley of the Cuyahoga River. Although plans have been drawn up to rectify the situation, to date the city for the most part has not constructed the necessary pumping stations to connect the valley sewers with the three city-operated sewage disposal plants. Therefore, in practically the entire valley, industrial effluents, raw domestic sewage, and street drainage empty directly into the river through numerous outlets. Thence they are carried into Cleveland Harbor and Lake Erie. Some industrial and domestic sewage is emptied into the river upstream, though of this the industrial pollution comes from immediate suburbs.

The largest industries in the Cuyahoga River valley are steel mills, which use water for cooling purposes, and which dump acid pickling wastes into the river. Effluents are also provided by oil refineries, chemical works, metal plants other than steel, etc. The Pucel Committee (1946) estimated that in 1944 there was a total of 171,812,100+ gallons per day of effluents dumped into the river, of which 822,850 were from raw domestic sewage, 33,863,650 from industrial process wastes and 136,247,500 from cooling water. Their figures did not include a number of large and small plants in the suburbs of Cleveland, and they were "restricted essentially to the larger users of water." Furthermore, their figures were based upon voluntary questionnaires, and there was no attempt to check on their accuracy. Of the reported industrial process wastes, which concern us most herein, 43.3 percent were from the metal industries and 53.2 percent from oil refineries.

In spite of general recognition by the public of gross pollution of the waters in the vicinity of Cleveland, there has been very little scientific investigation of the condition. Raymond Osburn, in 1926, directed a survey of the west end of Lake Erie in relation to sewage pollution, during which 5 stations were occupied in the Cleveland Harbor area. His reports (Osburn, 1926a, 1926b) dealt quantitatively with water temperature, pH, O₂ content, and bacteria. Rough qualitative analyses of bottom samples and plankton tows were also dealt with briefly. His reports exist only in mimeographed form.

Apparently the only printed reports of studies conducted in the Cleveland Harbor area deal with the effects of domestic sewage effluents. Thus, van Gieson (1942) studied the sewage pollution of Cleveland bathing beaches and Metcalf (1942) reported on some biological effects of a treated domestic sewage effluent.

Industrial and domestic sewage effluents were studied by the Pucel Committee (1946). Their mimeographed report constitutes the only published statement on industrial pollution in the area, aside from newspaper articles. The Pucel Committee, however, was not established to make a scientific investigation. In 1947 the Department of Health of the State of Ohio made a survey of industrial and municipal sewage wastes tributary to the Cuyahoga River. According to Mr. Bruce M. McDill, Engineer in Charge, Water Pollution Control, in a private communication: "The sewages and wastes were not actually evaluated by analyses and flow measurements. River analyses to show the effects of the pollution loads

were limited to dissolved oxygen and biochemical oxygen demand determinations. The results have not been published in form for general distribution."

In eastern Lake Erie, Fish *et al.* (1929) found that the effects of pollution were practically confined to the water in the vicinity of the shore. Dilution of the pollutants by the water of the open lake made pollution of the offshore water negligible, with no apparent deleterious effect upon the life therein. The results of Fish *et al.* were also reported in a briefer form by the New York Conservation Department (1929). In addition, however, in the latter publication the Niagara River and the several creeks tributary to Lake Erie and to the Niagara River in New York State were examined. Rush Creek in the vicinity of Buffalo was found heavily polluted with oil and with steel mill acid pickling liquor, similarly to the Cuyahoga River.

It was felt desirable to attempt to discover the extent and some of the effects of industrial pollution in the Cleveland Harbor area. To this end arrangements were made through the Franz Theodore Stone Institute of Hydrobiology, Put-in-Bay, Ohio, for the loan of equipment and for the granting of necessary funds. The Cleveland Harbor survey became part of a larger project under the direction of the Stone Institute, in which general pollution problems of northern Ohio waters tributary to Lake Erie were being studied. This project was supported by funds appropriated for the purpose by the State of Ohio.

It is a pleasure to acknowledge our debt to others for their contribution towards the success of the present study. The interest and encouragement of Dr. T. H. Langlois of the Franz Theodore Stone Institute and of Dr. F. W. Bacon of Western Reserve University made the project feasible in the first place. Our assistant, Mrs. Sally May Davis, performed yeoman duty in making the bulk of the chemical analyses. Mr. Edward Kirstead, Mr. Ervin W. Powell and Mr. Robert A. Woodmansee assisted from time to time on the field trips. To all of these we express our gratitude.

Field trips were attempted every two weeks throughout the year. Four of the proposed trips were cancelled on account of weather, illness, etc. Altogether 23 trips were taken between Sept. 15, 1950 and Sept. 30, 1951, as follows:

1. Sept. 15, 1950 (a preliminary survey trip, with few collections).
2. Sept. 29, 1950.
3. Oct. 13, 1950.
4. Oct. 27, 1950.
5. Nov. 11, 1950.
6. Dec. 9, 1950.
7. Dec. 21, 1950 (the trip was taken up and down the Cuyahoga River, because of ice conditions in the harbor).
8. Jan. 5, 1951.
9. Jan. 20, 1951.
10. Feb. 17, 1951 (only stations 1 and 2 occupied because of ice conditions).
11. Mar. 3, 1951.
12. Mar. 17, 1951.
13. April 6, 1951.
14. April 28, 1951.
15. May 12, 1951.
16. May 26, 1951.
17. June 23, 1951.
18. July 7, 1951.
19. July 21, 1951.
20. Aug. 4, 1951.
21. Sept. 3, 1951.
22. Sept. 14, 1951.
23. Sept. 30, 1951.

Nine stations were established in the Cleveland Harbor area, as follows:

- Station 1. Under the railroad bridge near the mouth of the Cuyahoga River.
- Station 2. Between W. Pierhead Light and E. Pierhead Light at the mouth of the jetties.
- Station 3. Halfway between the jetties and the Intake Crib.
- Station 4. At the Intake Crib.
- Station 5. Off red bouy No. 2, off the foot of E. 17th St., inside the breakwater.
- Station 6. Off the foot of E. 40th St., inside the breakwater.
- Station 7. Off E. Entrance Light, inside the breakwater.
- Station 8. Outside the breakwater, opposite Sta. 6.
- Station 9. Outside the breakwater, opposite Sta. 5.

Figure 1 shows the locations of the regular stations.

On the trip of Dec. 21, 1950, ice conditions prevented leaving the Cuyahoga River, so a trip was made as far up the river as possible. In addition to regular station No. 1, the following stations were occupied in the river:

- Station R1. Just north of the Harvard-Denison Bridge.
- Station R2. About $\frac{1}{4}$ mi. downstream from the W. & L. E. R. R. Bridge, near Belt-Line Ave.
- Station R3. At the head of navigation for large boats (near Campbell Ave., where the W. & L. E. and the N. & S. S. R. R. Bridges cross the river together).
- Station R4. Under Clark Ave. Bridge.
- Station R5. Just S. of the DuPont sulfuric acid plant (near Dille Ave.).

Figure 2 shows the location of the river stations.

On each trip, at each of the regular stations, observations and collections were made at the surface and at a depth of 6.5 meters (which is about one meter off the bottom at all stations except the deeper stations 3 and 4). The following observations and collections were made:

1. Observations:
 - a. Temperature.
 - b. pH.
 - c. Qualitative test for ferrous iron (only at the most polluted stations).
2. Collections:
 - a. A sample for the determination of oxygen.
 - b. A sample for the determination of total iron. Used also to determine turbidity.
 - c. A filtered sample for the determination of soluble iron. Used also to determine sulfate.
 - d. A sample for the determination of centrifuge plankton.
 - e. A sample taken by means of a Juday plankton trap.
 - f. Qualitative net samples of the plankton, taken in the cleanest water visited on each particular trip.

In addition to the above, daily observations were made from the roof of the Standard Building for two periods during the year. By these observations the pattern of distribution of the gross pollution, indicated by water discoloration, could be determined and correlated with wind direction.

It has not been possible to make adequate analyses of the plankton samples to date, and so these will not be reported until later. All chemical analyses have been made. These will be reported in detail below.

PROCEDURES

Procedures used in making the chemical and physical observations and determinations were as follows:

Temperature was determined by means of a Negretti and Zambra reversing thermometer.

pH was determined in the field, at the time of taking the sample, by means of a Beckman pH meter, model M.

Ferrous ion (Fe^{++}) was determined qualitatively by means of a freshly-prepared solution of $\text{K}_3\text{Fe}(\text{CN})_6$. Small quantities of the solution were poured into the surface water, or into samples of the deeper water, the appearance of Prussian blue being a positive test.

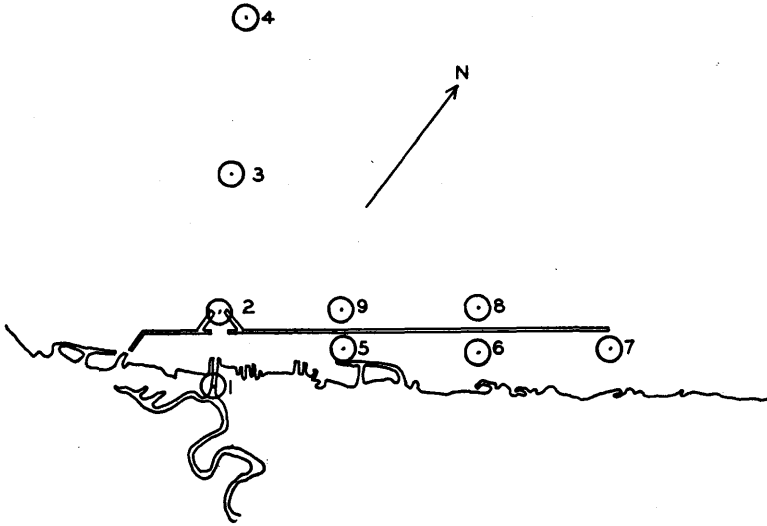


FIGURE 1. Map of the Cleveland Harbor area to show the location of the regular stations.

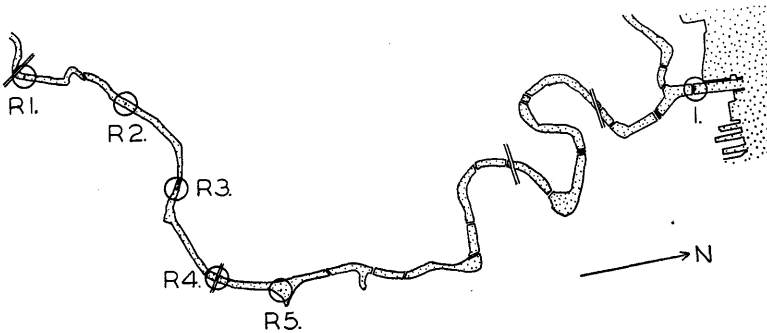


FIGURE 2. Map of the Cuyahoga River to just beyond the Harvard-Denison Bridge, showing the locations of the special river stations visited on Dec. 21, 1950.

Oxygen was determined by a modification of Winkler's method, whereby 4 ml of 85 percent H_3PO_4 were used as a substitute for the standard concentrated H_2SO_4 , in order to prevent interference by the large quantities of Fe present in many of the samples. 250 ml samples were obtained for O_2 analyses.

Turbidity was determined as soon after the field trip as a 110 volt AC outlet became available. It was determined by use of a Hellige Turbidimeter, results being determined in terms of ppm of SiO_2 .

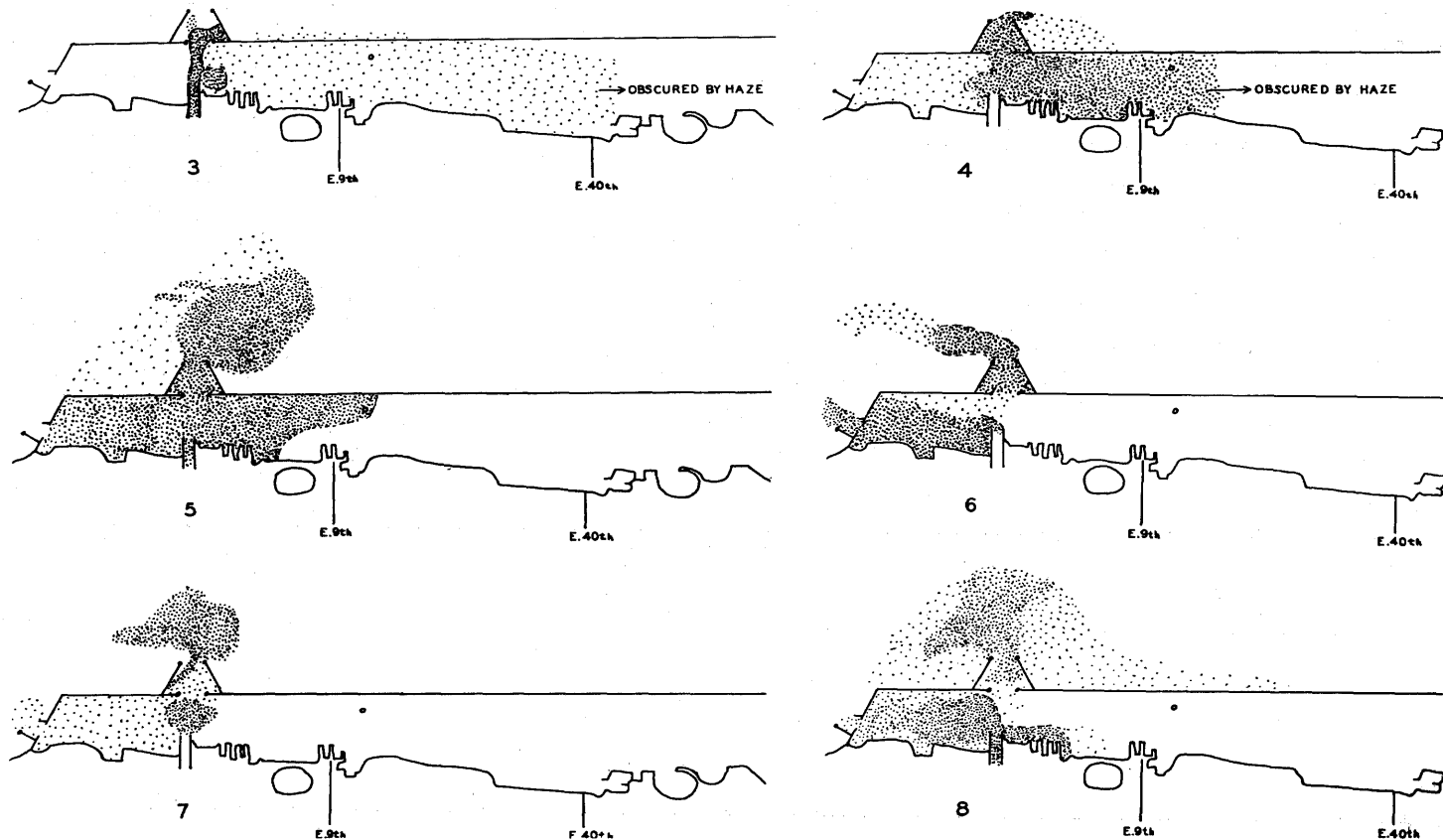


FIGURE 3. Distribution of discolored water in the vicinity of the Cleveland Harbor entrance on Aug. 8, 1951. The wind was NW and of moderate strength.

FIGURE 4. Same, on July 31, 1951. The wind was NW and of light strength.

FIGURE 5. Same, on Oct. 7, 1950. The wind was SW, moderate in strength.

FIGURE 6. Same, on July 17, 1951. The wind was strong and from the ENE.

FIGURE 7. Same, on July 24, 1951. The light wind was from the NE.

FIGURE 8. Same, on July 23, 1951. The wind was moderate, from the east.

Iron was determined colorimetrically by the thiocyanate method. Permanent standards were made, as described in *Standard Methods for the Examination of Water and Sewage*. Analyses were made for total iron, using an unfiltered sample of lake water, and for soluble iron by using a sample that had been filtered in the field at the time of collection. Particulate iron was calculated by taking the difference between total iron and soluble iron. The sample varied, as a rule, from 1 ml to 200 ml, depending upon the quantity of iron present. Samples of more than 100 ml were concentrated to 100 ml or less before analysis. 100 ml Nessler tubes were used for comparison with the standards.

Sulfate ion ($\text{SO}_4^{=}$) was determined by the analysis of a portion of the sample collected for the determination of soluble iron. The sample was refiltered before using. Analyses were made by use of the Hellige Turbidimeter, using the method described by the Hellige Company. Results are expressed in terms of ppm $\text{SO}_4^{=}$.

RESULTS

Thirty-four observations were made of the harbor area from the roof of the Standard Building.

Copperas ($\text{FeSO}_4 \cdot 7\text{H}_2\text{O}$) is a common industrial waste and appears as a pollutant in the pickling liquors from steel mills, as well as in several other industrial effluents. Consequently, large quantities are present in the effluents dumped into the Cuyahoga River. As Olson, Brust and Tressler (1941) have shown, the FeSO_4 hydrolyzes and oxidizes when mixed in natural waters, thus removing free oxygen from the water, and producing a red-brown precipitate of $\text{Fe}(\text{OH})_3$. This precipitate imparts a distinctive reddish-brown coloration to the water. Thus observations of gross pollution could be made and its distribution in space could be determined. Lesser degrees of pollution could not be detected in this manner. Wagner (1929) has observed a similar discoloration of Lake Erie water at the mouth of Rush Creek, near Buffalo.

As seen from the vantage point described, the discolored water remained for the most part within the confines of the harbor breakwater. However, some of it usually flowed out through the harbor entrance opposite the mouth of the Cuyahoga River, and occasionally also through the small entrance at the western end of the harbor. Discoloration was never apparent at the relatively distant eastern entrance.

Both inside and outside the breakwater the distribution of the discolored water was affected to a considerable degree by the direction and power of the wind. The prevailing water movement, however, was from west to east. Such a prevailing current also has been described by van Gieson (1942) in the vicinity of Cleveland's Easterly Sewage Disposal Plant. Towards the eastern end of the lake Fish *et al.* (1929) demonstrated it off Erie, Pa., and off Long Point on the Canadian side. They also pointed out the general easterly migration of creek mouths as an indication of the regular occurrence of such a current.

At times the line of demarcation between the discolored water and the more normal water would be very sharp whereas at other times the discoloration would gradually fade out and merge with the normal blue or green. Often a wind with a northerly component would prevent the discolored water from escaping through the main harbor entrance. The following are representative observations:

Figure 3 shows the distribution of discolored water on August 8, 1951, when there was a moderate NW wind. Discolored water did not escape through the main harbor entrance, though there was some evidence of a little discoloration outside the breakwater just to the east of the entrance. Heaviest discoloration was inside the harbor opposite the mouth of the river, with a slight easterly displacement in the inner half of the harbor. Lighter discoloration occurred inside the breakwater nearly as far as E 40th St., though a tongue of blue water just

inside the breakwater extended westward about half the distance between E 40th St. and E 9th St. Practically no discoloration extended westward from the river mouth.

Figure 4 shows the situation on July 31, 1951 when there was a light NW wind. Again, most of the discoloration extended to the east of the river mouth. Some heavy discoloration was extending out through the harbor entrance, and the easterly movement of the outside water mass is clearly shown.

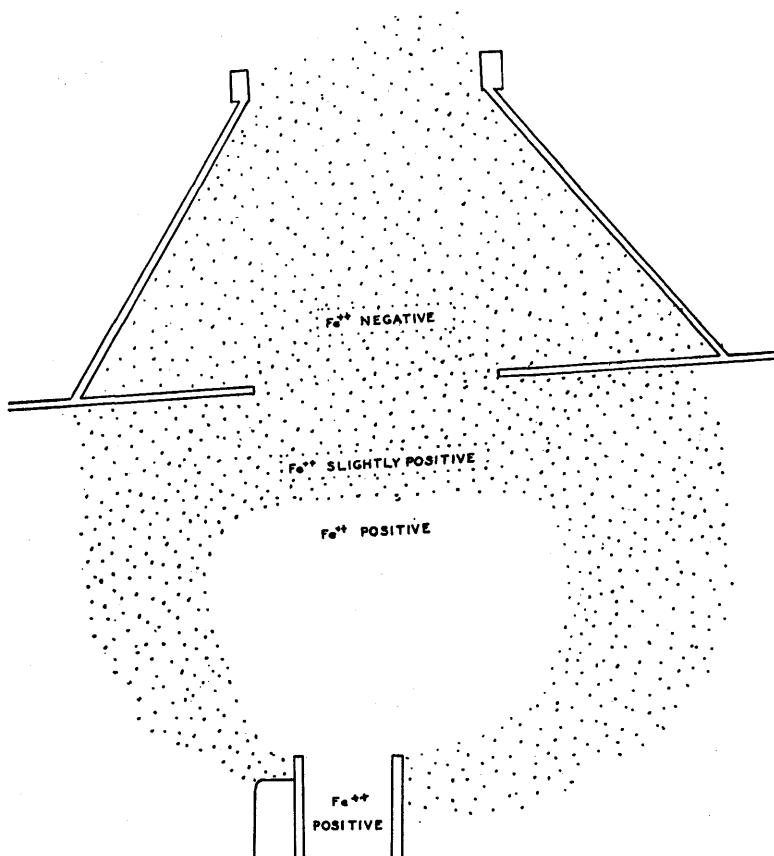


FIGURE 9. Distribution of discolored water and Fe^{++} at the mouth of the Cuyahoga River on Sept. 3, 1951.

Figure 5 shows the situation on Oct. 7, 1950 when there was a moderate SW wind. The discoloration extended farther out into the open lake than with northerly winds, but the easterly water movement was clear. Inside the breakwater the easterly movement was not clear.

Figure 6, on the other hand, shows the conditions on July 17, 1951, when there was a moderately strong ENE wind. Both inside and outside the breakwater the discolored water extended to the west, extruding through the westerly harbor entrance as well as through the main entrance. As shown by figures 7 and 8, however, all northeasterly and easterly winds did not produce such sharp results.

Thus figure 7 shows conditions on July 24, 1951 when there was a light NE wind and figure 8 shows conditions on July 23, 1951, when there was a moderate E wind. In both cases there was an evident easterly component of the water movement, both inside and outside the breakwater.

Closer observations were made of the distribution of discolored water near the mouth of the river on the regular field trips. It was usual for red water to flow from the mouth of the river into the harbor, but on Aug. 4 and Sept. 3, 1951, the water flowing from the river was relatively clear, while water in the harbor and out to station 2 and beyond was very turbid and red-brown. Figure 9 is drawn from a sketch made in the field on Sept. 3rd. The relatively clear river water gave strongly positive tests for Fe^{++} . The edge of the red water gave weakly positive tests, while farther away from the edge all tests were negative. On this date the water at station 1 gave no indication of any trace of oxygen. It appears evident that the ferrous iron (and other) pollution in the river was so heavy that all O_2 was exhausted in the surface waters so that the oxidation of Fe^{++} to Fe^{+++} , and the subsequent formation of $\text{Fe}(\text{OH})_3$ precipitate, could not proceed until the river water had mixed with the relatively oxygen-rich harbor water. Subsequent to such mixture, oxidation and formation of precipitate proceeded rapidly.

The chemical and physical results are best shown in tabular form, except for the limited results of the field trip of Sept. 15, 1950. The main purpose of this preliminary trip was to explore the area and establish stations. No equipment had yet arrived with which to make observations or with which to test samples. Therefore only surface temperature readings were made, and centrifuge plankton samples were collected. The following temperatures were taken:

Station 5—20.65° C,
Station 6—20.15° C,
Station 7—20.15° C.

The results obtained on subsequent cruises are shown in table 1.

TABLE 1
Physical and chemical data for all stations on all trips

Date	Sta	Depth	Temp (° C)	pH	Turbidity (ppm SiO_2)	O_2			Fe^{++}	Fe			SO_4^{--} (ppm)
						ml/l	ppm	% sat		Tot	Sol	Part	
9-29-50	1	s	22.8	7.05	35 cm.*	0.0	0.0	0.0	Neg				
		d	18.2	7.50		2.2	3.0	31.9					
	2	s	18.6	7.30	100 cm.*	1.5	2.0	22.0	Neg				
		d	17.4	7.75		4.7	6.5	70.5					
	3	s	18.1	8.40	100 cm.*	6.4	8.9	95.3					
		d	18.8	8.40		6.4	8.8	96.4					
	4	s	18.5	8.71	314 cm.*	6.4	8.8	95.5					
		d	18.0	8.72		6.3	8.7	93.3					
	5	s	19.7	7.43	44 cm.*	3.4	4.7	52.5	Neg				
		d	17.9	7.83		4.5	6.2	66.0					
	6	s	18.7	8.38	200 cm.*	6.4	8.9	96.4					
		d	17.5	7.98		5.0	6.9	86.1					
	7	s	18.4	8.30	170 cm.*	5.9	8.2	88.4					
		d	17.6	8.31		6.1	8.4	89.3					
	8	s	18.2	8.40	200 cm.*	6.3	8.7	93.6					
		d	17.8	8.40		6.1	8.4	90.3					
10-13-50	1	s	23.8	6.78	90	0.0	0.0	0.0		13.0	5.0	8.0	2960
		d	16.3	7.30	53	4.2	6.0	60.6					
	5	s	15.0	7.78	38	5.6	8.0	77.8		1.5	0.4	1.1	42
		d	15.0	8.00	37	5.3	7.6	74.5					
	6	s	13.9	8.15	40	6.1	8.8	83.8		0.6	0.4	0.2	34
		d	15.0	8.25	37	6.4	9.1	88.7					
	7	s	15.1	8.19	35	6.4	9.1	89.1		0.8	0.4	0.4	22
		d	15.2	8.19	35	6.5	9.2	90.7					

TABLE 1—(Continued)

Date	Sta	Depth	Temp (° C)	pH	Turbidity (ppm SiO ₂)	O ₂			Fe ⁺⁺	Fe			SO ₄ ⁼ (ppm)	
						ml/l	ppm	% sat		Tot	Sol	Part		
10-27-50	1	s	20.3	7.05	88	0.0	0.0	0.0	Neg	15.0	11.3	3.7	81	
	2	s	14.4	7.52	26	4.6	6.5	62.6	Neg	1.0	0.3	0.7	54	
		d	14.3	7.78	20	4.7	6.7	64.6		0.8	0.3	0.5	54	
	5	s	13.9	7.95	12	6.0	8.6	82.1		0.2	0.1	0.1	26	
		d	13.7	7.85	17	5.5	7.8	74.5		0.3	0.1	0.2	32	
	6	s	14.3	8.05	11	6.2	8.8	85.3		0.2	0.1	0.1	23	
		d	14.3	8.02	13	6.1	8.7	83.9		0.2	0.1	0.1	25	
	7	s	14.1	8.00	11	6.2	8.9	85.0		0.1			25	
		d	14.1	8.12	13	6.1	8.7	83.5		0.1	0.1	?	21	
11-11-50	1	s	18.2	6.99	57	0.0	0.0	0.0	Pos	15.0	15.0	0.0	288	
		d	13.0	7.23	55	3.0	4.3	40.2	Sl. pos.	6.3	0.1	6.2	89	
	2	s	10.0	8.72	34	7.0	10.0	87.7		0.4	0.1	0.3	18	
		d	10.2											
	5	s	10.5	8.28	30	6.4	9.2	81.5		0.6	0.2	0.4	30	
		d	10.5	8.60	34	6.1	8.7	77.0		0.8	0.2	0.6		
	6	s	10.5	8.42	26	6.6	9.5	83.9		0.4	0.1	0.3	38	
		d	10.7	8.40	28	5.7	8.2	72.8		0.6	0.1	0.5	26	
	7	s	10.6	8.50	29	6.6	9.4	83.5		0.3	0.1	0.2	18	
	d	10.6	8.45	23	6.5	9.3	82.3		0.2	0.1	0.1	20		
12-9-50	1	s	3.0		100	6.8	9.7	71.5		4.8	1.5	3.3	161	
		d	2.9		90	6.7	9.5	70.3		4.0	1.5	2.5	96	
	2	s	2.1		53	8.0	11.4	82.5	Neg	0.5	0.2	0.3	27	
		d	2.2		80	7.7	11.0	79.7		1.5	0.6	0.9	43	
	5	s	2.2		57	7.6	10.8	78.4	Neg				60	
		d	2.2		93	7.8	11.1	80.2		2.0	0.8	1.2	76	
	6	s	2.2		60	8.0	11.4	82.2		0.8	0.5	0.3	33	
		d	2.2		85	8.2	11.7	84.6		1.0	0.4	0.6	39	
	7	s	2.2		80	8.0	11.4	82.6		0.8	0.4	0.4	71	
	d	2.3		60	8.2	11.7	85.2		0.8	0.5	0.3	35		
12-21-50	1	s	10.0	6.50		1.9	2.7	23.8	Pos.	15.0	7.0	8.0	186	
		d	8.1	6.62		2.2	3.2	26.5	Sl. pos.	5.0	5.0	0.0	212	
	R1	s	2.2	7.89		5.9	8.5	61.6	Pos	12.0	7.5	4.5	192	
	R2	s	2.6	4.53		3.7	5.3	38.6		32.5	30.0	2.5	267	
	R3	s	3.0	6.12		4.2	6.0	44.3	Pos	80.0	25.0	55.0	225	
		12 ft.	3.0											
	R4	s	7.4	6.69		3.6	5.1	42.2		30.0	7.5	22.5	276	
		15 ft.	7.4											
	R5	s	10.9	6.42		3.4	4.9	43.4		15.0	15.0	0.0	267	
	15 ft.	10.8												
1-5-51	1	s	4.4	7.76	103	6.7	9.6	73.4	Pos	5.0	2.5	2.5	98	
		d	4.4	7.95	116	6.8	9.7	74.0	Sl. pos.	5.0	2.5	2.5	93	
	2	s	0.6	8.38	70	8.7	12.4	86.2	Neg				39	
		d	1.6	8.23	83	8.1	11.5	82.0		1.5	1.0	0.5	39	
	3	s	0.6	8.48	14	8.6	12.3	85.1					18	
		d	0.6	8.36	17	9.3	13.3	92.2		0.2	0.1	0.1	18	
	1-20-51	1	s	8.3	7.10	70	5.7	8.1	68.2	Pos	7.5	5.0	2.5	130
			d	8.3	7.15	62	5.7	8.1	68.0	Sl. pos.	8.0	3.8	4.2	98
		2	s	2.2	7.92	24	8.6	12.3	89.1	Neg	1.2	0.4	0.8	72
		d	2.2	7.92	17	8.7	12.4	89.9		0.8	0.5	0.3	30	
4		s	0.4	8.18	5	9.4	13.4	92.6	T	T	T	?	19	
		d	0.4	8.10	12	9.3	13.3	91.6	T	T	T	?	20	
5		s	4.8	7.57	45	7.7	11.0	85.1	Neg	2.5	2.0	0.5	76	
		d	4.7	7.75	47	7.7	11.1	85.3		3.0	2.0	1.0		
6		s	3.7	7.71	52	5.6	8.0	60.2	Neg	1.8	1.5	0.3	58	
	d	3.6	7.70	47	7.6	10.8	81.0					74		
7	s	1.6	7.94	37	7.8	11.2	79.8		0.6	0.4	0.2	27		
	d	1.7	8.13	19	9.0	12.8	91.5		0.6	0.4	0.2	30		
8	s	1.1	8.22	21	9.0	12.9	92.0					25		
	d	1.0	8.27	25	9.3	13.3	93.3		0.4	0.2	0.2	28		
9	s	1.0	8.28	25	9.1	13.1	91.9							
	d	1.0	8.38	19	9.4	13.4	94.1		0.4	0.2	0.2	26		
2-17-51	1	s	4.8	7.14	83	6.5	9.3	69.2	Pos	10.0	3.5	6.5	106	
		d	4.8		100	6.5	9.3	69.2		7.5	3.5	4.0	136	
	2**	s	3.0	8.18	41	7.4	10.5	78.1	Neg	3.0	2.0	1.0	92	
	d	4.0	8.38	47	7.2	10.3	77.8		3.5	2.0	1.5	95		

TABLE 1—(Continued)

Date	Sta	Depth	Temp (° C)	pH	Turbidity (ppm SiO ₂)	O ₂			Fe ⁺⁺	Fe			SO ₄ ⁼⁼ (ppm)	
						ml/l	ppm	% sat		Tot	Sol	Part		
3-3-51	1	s	10.0	7.16	64	4.6	6.6	57.5	Pos	6.0	3.5	2.5	62	
		d	10.0	7.22	57	4.7	6.7	58.3						7.5
	2	s	1.3	8.66	36	8.7	12.4	87.7		0.4	0.2	0.2	29	
		d	1.3	8.66	38	8.1	11.6	82.0						7.5
	5	s	4.9	7.15	61	6.3	9.0	69.5		3.2	2.0	1.2	36	
		d	5.2	7.48	69	6.1	8.8	68.3						3.0
	6	s	1.4	8.30	35	7.8	11.2	79.0		0.8	0.5	0.3	37	
		d	3.0	7.96	38	7.0	10.1	74.3						1.8
	7	s	2.2	7.87	33	7.9	11.2	81.1		0.8	0.6	0.2	34	
		d	2.3	8.14	33	7.4	10.6	76.9						1.0
	8	s	1.0	8.17	24	8.7	12.4	86.8		0.3	0.2	0.1	31	
		d	1.0	8.22	24	8.6	12.3	86.4						0.3
	9	s	2.6	8.02	40	7.7	11.1	80.9		1.2	0.8	0.4	44	
		d	2.7	8.21	42	7.7	11.0	80.8						1.0
	3-17-51	1	s	8.0	7.04	57	5.8	8.3	69.6	Pos	6.3	3.8	2.5	75
			d	8.0	7.08	65	5.8	8.3	69.5					
		2	s	2.6	7.49	43	8.4	12.0	88.0		1.0	0.5	0.5	34
			d	3.4	7.53	52	8.3	11.8	88.4					
3		s	2.2	8.53	38	8.9	12.8	92.6		0.4	0.2	0.2	31	
		d	2.2	8.47	32	8.7	12.5	90.5						0.4
4		s	2.0	8.59	25	9.0	12.9	93.3		0.2	T	0.2	29	
		d	2.0	8.48	22	9.2	13.1	94.3						0.2
5		s	4.0	7.68	62	7.4	11.6	79.2	Neg	2.0	1.2	0.8	75	
		d	4.0	7.57	50	7.2	10.3	78.1						2.5
6		s	3.3	7.73	38	8.2	11.7	87.0		1.5	0.8	0.7	57	
		d	3.8	7.64	48	7.3	10.4	78.3						3.0
7		s	3.8	7.92	36	8.5	12.2	91.8		0.9	0.6	0.3	52	
		d	3.0	8.18	44	7.8	11.2	82.7						1.2
8		s	2.5	8.20	41	8.9	12.7	92.9		0.5	0.3	0.2	64	
		d	2.4	8.21	42	8.7	12.4	90.3						0.8
9		s	2.4	8.17	42	8.8	12.5	91.1		0.6	0.2	0.4	31	
		d	2.3	8.18	43	8.9	12.7	91.9						0.6
4-6-51	1	s	11.4	7.22	64	3.3	4.7	42.5	Neg	7.5	2.5	5.0	138	
		d	11.3	7.34	62	3.2	4.5	40.7						5.0
	2	s	4.8	8.03	50	4.9	7.0	53.7	Neg	2.5	1.0	1.5	47	
		d	4.7	8.12	52	4.9	7.0	53.5						1.5
	3	s	3.3	8.53	24	5.0	7.2	53.5		0.2	0.1	0.1	22	
		d	3.3	8.53	19	5.9	8.4	62.6						0.2
	4	s	2.4	8.76	27	5.5	7.8	56.8		0.2	0.1	0.1	21	
		d	2.5	8.75	16	4.9	7.0	51.1						0.2
	5	s	7.5	7.72	64	5.7	8.1	67.1	Neg	3.8	2.0	1.8	65	
		d	5.3	7.74	57	5.9	8.5	66.1						3.0
	6	s	4.6	8.05	31	7.9	11.4	87.9	Neg	0.5	0.4	0.1	36	
		d	4.8	7.90	45	7.2	10.3	79.7						1.5
	7	s	4.4	8.07	41	7.6	11.1	84.8		0.7	0.6	0.1	33	
		d	4.3	8.08	41	4.9	7.1	53.9						0.8
	8	s	3.6	8.39	23	7.8	11.1	83.2		0.2	0.1	0.1	22	
		d	3.5	8.40	26	7.0	10.1	75.5						0.3
	9	s	4.0	8.36	40	5.8	8.2	62.4		0.4	0.2	0.2	26	
		d	3.9	8.25	31	7.4	10.6	79.8						0.4
4-28-51	1	s	17.2	6.72	83	0.0	0.0	0.0	Neg	7.5	3.0	4.5	122	
		d	11.4	7.23	60	2.6	3.7	33.5						5.0
	2	s	8.0	8.08	38	8.2	11.7	98.6	Neg	0.8	0.4	0.4	29	
		d	8.0	8.14	24	8.3	11.8	99.0						0.6
	3	s	7.0	8.43	21	9.4	13.3	109.6		0.3	0.1	0.2	24	
		d	6.4	7.85	15	9.1	12.9	104.8						0.3
	4	s	6.1	8.36	37	9.4	13.3	107.1		0.2	0.2	0.0	23	
		d	4.8	8.39	19	9.1	12.9	104.8						0.4
	5	s	11.4	7.55	28	4.1	5.9	53.2		3.3	1.5	1.8	68	
		d	9.8	7.75	26	5.3	7.6	65.8						2.5
	6	s	9.4	7.75	24	6.3	9.0	78.0		1.0	0.6	0.4	40	
		d	9.3	7.64	20	6.4	9.2	79.5						0.8
	7	s	9.0	7.92	28	7.4	10.6	90.8		0.6	0.2	0.4	35	
		d	8.6	7.94	19	7.4	10.7	90.3						0.5
	8	s	7.8	8.29	23	8.4	12.1	100.2		0.4	0.3	0.1	26	
		d	7.3	8.31	25	8.7	12.3	102.1						0.5
	9	s	7.4	8.25	28	7.4	10.6	87.3		0.6	0.6	0.0	34	
		d	7.3	8.27	25	7.9	11.3	92.5						0.8
5-12-51	1	s	16.0	6.80	95	2.5	3.3	35.7	Neg	3.8	2.5	1.3	124	
		d	16.9	6.91	88	2.3	3.3	33.8						3.8
	2	s	12.2	7.64	36	4.7	6.7	62.1	Neg	2.5	0.8	1.7	74	
		d	11.8	8.02	54	6.2	8.8	80.6						2.5
	5	s	13.6	7.21	34	3.4	4.8	45.6		2.5	1.0	1.5	92	
		d	12.5	7.40	34	5.0	7.2	66.8						2.5
	6	s	11.9	7.61	26	6.0	8.5	77.9		1.5	0.4	1.1	48	
		d	11.6	7.63	22	6.5	9.3	84.7						1.3
	7	s	12.5	7.66	22	5.2	7.4	68.3		1.5	0.4	1.1	57	
		d	11.3	7.98	22	6.9	7.8	88.9						1.0

TABLE 1--(Continued)

Date	Sta	Depth	Temp (° C)	pH	Turbidity (ppm SiO ₂)	O ₂			Fe ⁺⁺	Fe			SO ₄ ⁼ (ppm)
						ml/l	ppm	% sat		Tot	Sol	Part	
5-26-51	1	s	23.6	3.98	44	0.0	0.0	0.0	Pos	15.0	9.0	6.0	66
	2	s	17.7	7.32	36	3.8	5.5	56.3	Neg	3.0	0.8	2.2	72
		d	14.5	8.00	15	4.5	6.4	61.7		0.3	0.2	0.1	27
	4	s	13.4	8.22	6	5.9	8.4	79.7		T	T	?	16
		d	13.1	8.20	6	7.4	10.6	99.7		0.1	T	0.1-	20
	5	s	17.2	7.16	18	3.7	5.3	52.2	Neg	3.0	1.3	1.7	68
		d	14.2	7.61	17	4.8	6.8	65.8		0.8	0.2	0.6	36
	6	s	15.8	7.90	14	4.4	6.3	61.9		1.0	0.4	0.6	31
		d	15.4	7.94	20	4.6	6.6	64.4		0.9	0.3	0.6	27
7	s	15.8	7.49	18	4.5	6.5	64.0		0.8	0.2	0.6	38	
	d	14.4	7.50	15	5.2	7.4	71.9		0.8	0.5	0.3	27	
8	s	14.4	8.18	18	7.1	10.2	98.0		0.4	0.1	0.3	19	
	d	14.0	8.10	13	4.7	9.2	63.6		0.2	T	0.2-	21	
9	s	14.2	8.24	17	6.7	9.5	91.6		0.4	T	0.4-	22	
	d	13.9	8.22	15	6.7	9.5	90.9		0.5	T	0.5-	23	
6-23-51	1	s	26.8	6.72	151	0.0	0.0	0.0	Pos	10.0	6.0	4.0	200
		d	22.5	6.90	165	0.2	0.3	3.2		12.5	4.0	8.5	150
	2	s	21.6	7.14	70	2.3	3.3	35.9	Neg	2.0	0.8	1.2	119
		d	20.3	7.60	14	3.6	5.3	55.9		0.8	0.2	0.6	30
	5	s	21.2	7.40	60	2.2	3.1	33.9	Neg	1.2	0.7	0.5	68
		d	19.8	7.61	23	3.2	4.7	49.3		1.0	0.3	0.7	31
	6	s	20.0	7.82	4	4.6	6.7	70.5		0.2	T	0.2-	25
	d	19.6	7.76	6	4.0	5.7	60.3		0.2	0.1	0.1	28	
7	s	20.2	7.94	3	4.6	6.7	71.6		T	T	?	23	
	d	20.0	7.92	3	4.8	6.9	73.2		0.2	0.1	0.1	34	
7-7-51	1	s	25.2	7.04	87	0.0	0.0	0.0	Neg	6.0	3.0	3.0	103
		d	23.8	7.22	60	0.5	0.7	8.6		7.5	1.0	6.5	57
	2	s	21.8	7.80	26	4.1	5.8	64.9	Neg	1.0			41
		d	21.4	8.26	15	5.3	7.6	83.8					18
	3	s	21.0	8.34	3	5.7	8.1	88.7		T	T	?	36
		d	20.8	8.32	5	5.6	8.0	87.0		T			17
	4	s	21.0	8.37	3	5.7	8.1	89.1		T			26
		d	20.9	8.33	2	5.7	8.2	89.7		T			14
	5	s	22.5	7.56	21	3.0	4.2	47.5	Neg	1.0	0.4	0.6	17
		d	21.2	7.83	19	4.4	6.3	69.1			0.2		26
	6	s	21.2	7.78	13	4.2	6.1	67.8		0.4	0.3	0.1	26
		d	21.3	7.88	17	4.5	6.4	70.9			0.1		23
	7	s	22.1	7.90	13	4.4	6.3	70.1			0.1	0.3	32
	d	21.5	8.09	18	4.8	6.9	75.8		0.4	0.1	0.3	23	
8	s	22.2	8.22	18					0.1	0.1	0.0	20	
	d	21.2	8.22	17	5.3	7.6	83.0		0.2	T	0.2-	20	
9	s	21.2	8.10	17	5.2	7.4	81.0		0.3	T	0.3-	23	
	d	21.5	8.06	20	5.1	7.2	79.9		0.3	T	0.3-	18	
7-21-51	1	s	28.4	6.92	90	0.0	0.0	0.0	Pos	12.5	7.5	5.0	129
		d	22.6	7.44	24	1.6	2.3	25.8	Neg	1.5	0.2	1.3	41
	2	s	22.7	7.70	19	3.2	4.6	52.1	Neg	0.8	0.3	0.5	50
		d	22.2	8.30	14	4.9	7.1	79.0		0.8	T	0.8-	17
	4	s	21.8	8.49	2	5.8	8.3	92.7		T	0.0	T	22
		d	21.8	8.39	1	5.8	8.2	91.6		0.0	0.0	0.0	17
	5	s	23.2	7.41	26	2.3	3.3	37.5	Neg	1.5	0.6	0.9	57
		d	21.6	7.73	13	3.2	4.5	50.3		0.8	0.3	0.5	33
	6	s	22.2	8.03	8	5.1	7.2	81.0		0.8	T	0.8-	10
		d	22.1	8.06	8	4.9	7.0	78.3		0.5	T	0.5-	23
	7	s	22.2	8.33	5	5.8	8.3	92.8					31
		d	21.6	8.29	5	3.2	4.6	52.1		0.1	T	0.1-	23
	8	s	22.0	8.41	3	5.8	8.3	92.0		T	0.0	T	23
	d	21.9	8.29	5	5.5	7.8	86.9		0.5	T	0.5-	22	
9	s	22.1	8.49	6	5.9	8.5	94.4		0.6	T	0.6-	23	
	d	22.0	8.43	7	5.9	8.4	93.6		0.3	T	0.3-	20	
8-4-51	1	s	29.9	6.75	80	0.0	0.0	0.0	Pos	15.0	10.0	5.0	
		d	25.2	6.90	47	0.0	0.0	0.0	Sl. pos.	7.5	3.0	4.5	112
	2	s	24.7	7.18	20	1.9	2.6	31.0	Neg	3.0	0.8	2.2	84
		d	24.0	7.42	24	2.8	4.0	45.6		1.5	0.4	1.1	48
	5	s	24.6	7.50	12	3.7	5.2	59.0		0.6	T	0.6-	45
		d	23.6	7.45	17	3.9	5.6	64.5			0.2	T	42
	6	s	23.4	7.80	13	4.6	6.6	75.8		0.8	T	0.8-	24
	d	23.5	7.84	15	4.7	6.7	76.6		0.8	0.5	0.3	26	
7	s	23.5	7.62	38	4.6	6.5	74.9		1.5	0.2	1.3	29	
	d	23.2	7.80	64	4.4	6.3	71.6		2.0	1.0	1.0	26	
9-3-51	1	s	28.3	6.88	45	0.0	0.0	0.0	Pos	15.0	7.5	7.5	164
		d	22.2	7.47	12	3.0	4.3	47.6	Neg	1.5	0.1	1.4	27
	2	s	22.8	7.29	15	2.0	2.8	31.9	Neg	2.0	0.6	1.4	82
		d	21.6	7.64	7	3.5	5.0	54.9		0.8	T	0.8-	25
	5	s	22.9	7.36	13	2.4	3.4	38.4	Neg	1.5	0.4	1.1	66
		d	19.8	7.50	10	1.4	2.0	21.9		0.6	T	0.6-	19
	6	s	22.6	7.41	10	2.7	3.9	43.6		1.0	0.3	0.7	56
	d	21.0	7.63	6	3.5	4.9	54.2		0.2	T	0.2-	23	
7	s	22.2	7.72	7	4.2	6.0	67.4		0.1	T	0.1-	26	
	d	21.2	7.70	7	3.6	5.2	56.8		0.4	T	0.4-	24	

TABLE 1—(Continued)

Date	Sta	Depth	Temp (° C)	pH	Turbidity (ppm SiO ₂)	O ₂			Fe ⁺⁺	Fe			SO ₄ ⁼ (ppm)	
						ml/l	ppm	% sat		Tot	Sol	Part		
9-14-51	1	s	29.3	6.72	100	0.0	0.0	0.0	Pos	14.0	12.5	1.5	203	
		d	23.7	7.17	45	1.6	2.2	25.6	Neg	6.5	1.1	5.4	74	
	2	s	23.7	7.08	52	6.0	8.6	98.9	Neg	5.0	2.0	3.0	130	
		d	20.8	7.64	7	5.0	7.2	78.6		0.5	0.3	0.2	31	
	5	s	21.7	7.43	19	2.6	3.7	41.2	Neg	1.9	0.8	1.1	54	
		d	21.0	7.69	8	3.5	5.0	55.3		0.5	0.3	0.2	41	
	6	s	21.7	7.63	5	3.7	5.3	59.1		0.4	0.1	0.3	42	
		d	21.1	7.65	7	3.4	4.8	53.0		0.4	0.1	0.3	45	
	7	s	21.3	7.91	4	4.5	6.4	70.3		0.2	T	0.2—	46	
		d	20.8	8.14	4	4.7	6.8	74.0		0.1	T	0.1—	31	
	8	s	20.9	8.48	4	5.8	8.3	90.9		T	T	T	21	
		d	20.7	8.42	4	5.7	8.1	88.2		T	0.0	T	26	
	9	s	20.8	8.32	4	5.6	8.0	87.3		T	T	T	21	
		d	20.6	8.26	5	5.6	8.0	87.3		T	T	?	25	
	9-30-51	1	s	21.5	7.70	100	0.0	0.0	0.0	Sl. pos.	13.5	6.5	7.0	178
			d	17.6	8.43	29	4.4	6.2	64.1	Neg	2.5	0.4	2.1	40
		2	s	17.7	7.62		4.4	6.3	64.8	Neg	2.0	0.8	1.2	54
			d	17.4	7.65		5.0	7.1	72.8		1.6	0.4	1.2	31
3		s	17.3	8.08		6.1	8.7	89.2		T	T	?	22	
		d	17.4	8.27		6.1	8.7	89.5		0.1	T	0.1—	27	
5		s	17.5	8.61		5.7	8.2	84.2	Neg	0.3	T	0.3—	37	
		d	17.2	8.63	9	5.5	7.8	79.7		0.3	0.1	0.2	37	
6		s	17.4	8.72		5.7	8.2	83.8		0.3	T	0.3—	33	
		d	17.5	8.72	8	5.7	8.2	84.0		0.1	T	0.1—	30	
7		s	17.5	8.70	13	5.9	8.4	86.2		T	T	?	25	
		d	17.5	8.60		5.9	8.4	86.2		0.3	T	0.3—	31	
8		s	17.4							0.1	T	0.1—	23	
		d	17.5	8.62		5.9	8.4	85.8		T	T	?	19	
9		s	17.3	8.19		6.1	8.7	89.2		T	T	?	22	
		d	17.4	8.10		6.1	8.7	88.7		T	T	?	30	

*Secchi disc readings.

** Ice conditions forced occupation of this station at a point about 100 meters south of the usual position.

DISCUSSION

In the Cleveland area, the major portion of the industrial effluents is dumped into the Cuyahoga River, though other portions are carried through municipal sewage disposal plants, and are dumped after treatment into Lake Erie or the river. The present report deals primarily with river effluents, though other effluents also had their effects.

The most highly polluted locality regularly studied was station 1. Here the iron content of the water was always much higher than at any other location, as was the content of SO₄⁼. Fe⁺⁺ occurred frequently, indicating proximity to the source of pollution. This ion never occurred at any other regular station. At times Fe⁺⁺ was encountered just outside the mouth of the river also. Because of the consumption of oxygen by the ferrous ions, and by other oxygen-consuming agents as well, the water at station 1 was always low in oxygen content. Conditions were best on Jan. 5, 1951, when the O₂ was 73.4 percent of saturation. Out of the 22 times that oxygen was tested at this station, only five times was the figure greater than 50 percent of saturation, and 13 times there was no trace of oxygen at the surface, and sometimes at the bottom as well. Furthermore, the river water almost always gave off a strong odor, probably of phenols, etc. The pH at station 1 was always lower than elsewhere, but only once was it excessively low. The temperature was nearly always relatively high, due to the dumping of large quantities of cooling water. The maximum temperature was encountered on Aug. 4, 1951, when the surface water was 29.85° C. On this date the surface temperature at station 7, the clearest water visited, was 23.52° C. On Dec. 21, 1950, when ice conditions prevented exit from the river into the harbor, the surface temperature at station 1 was 9.95° C. The air temperature at the time was -12° C.

Figure 10 shows the seasonal distribution of temperatures at station 1. Note that the deeper water in the warmer months was much cooler than the water on the surface, whereas in the winter the surface and bottom temperatures were nearly or quite identical. It would seem that during the warm months there was a greater intrusion of lake water along the bottom.

Conditions for the existence of aquatic life were in general unsatisfactory at station 1. This is indicated by the results of those plankton analyses that have been completed, and also by the appearance of dead fish floating in the water on several occasions. On the trip of Sept. 3, 1951 thousands of minnows were dead or dying and had been washed up on the strand just to the west of the mouth of the river. On this day the water at this position gave off strong river odors.

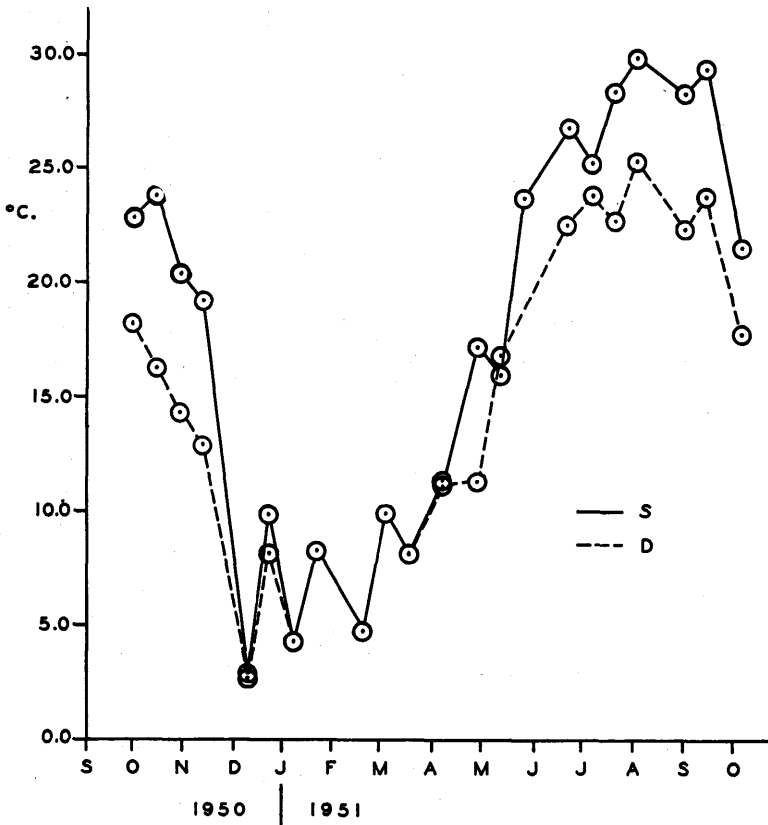


FIGURE 10. Seasonal distribution of temperatures at station 1.

A few crude experiments were performed in which living plankton Crustacea were mixed with water obtained from station 1. In one experiment the Crustacea were placed into three dishes. One dish contained river water, a second contained river water which had been thoroughly aerated, and a third was a control. The animals lived for some time in all three containers, but they survived much longer in the control than in either of the two experimental dishes.

Cutler (1929) found that industrial pollution in Rush Creek, near Buffalo, resulted in "an almost total absence of any form of animal or plant life" on the adjacent lake bottom, but that the very acid water near the mouth of the creek

supported an unusually rich growth of *Euglena* sp. "which the acidity appears to favor."

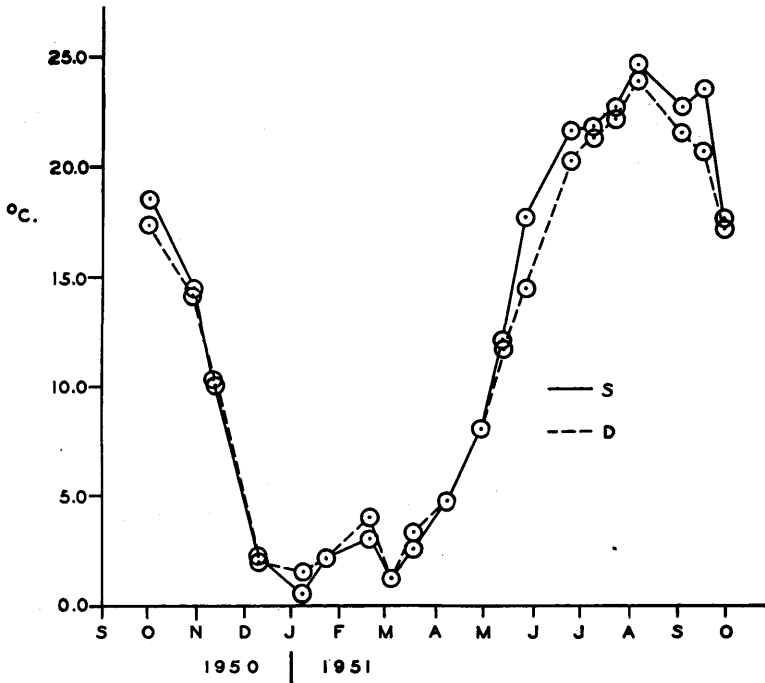


FIGURE 11. Seasonal distribution of temperatures at station 2.

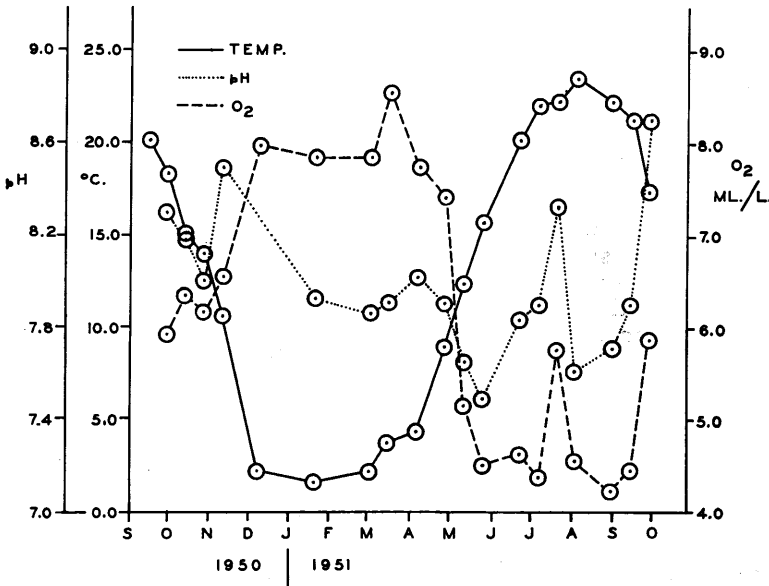


FIGURE 12. Seasonal distribution of temperature, O₂ and pH in the surface water at station 7.

Stations 2 and 5 were also highly influenced by the river effluents. Here again the iron content of the surface, and often (especially at station 5) the bottom water as well, was high. SO_4^- was also relatively high. O_2 values usually were low, but oxygen was never entirely missing. At station 2 it was not unusual to find in the summer and fall months that the surface water was much warmer than that near the bottom. Similar temperature differences occurred also occasionally at station 5, but seldom at the other stations. Also, at station 2 the pH at the surface was lower than in the deep water while at the same time the surface water was much more turbid, this being obvious even to the naked eye as the samples were filtered. In the winter these conditions sometimes were reversed. It would appear that the relatively warm water flowing from the river in the summer and the fall flowed out over the cool water from the open lake, whereas in the winter the

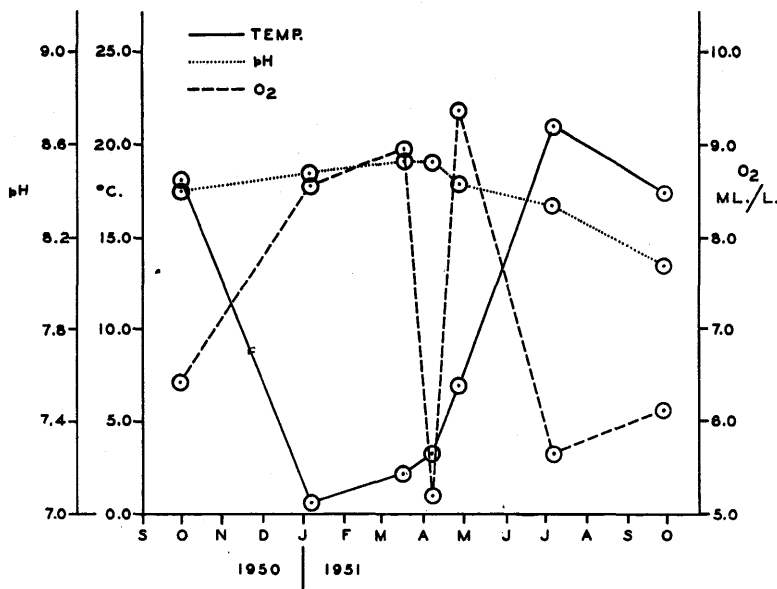


FIGURE 13. Seasonal distribution of temperature, O_2 and pH in the surface water at station 3.

relatively warm river water would be heavier than the cold lake water, and would sink. These relationships are shown clearly in figure 11, which shows the seasonal distribution of temperatures at station 2.

Conditions for the existence of resistant forms of aquatic life were rather favorable at station 2 and 5 though the high turbidity of the water would be sufficient to retard the life activities of algae. Examples of bottom muds obtained from stations 2 and 5 smelled very strongly, and that at station 5 was filled with a great deal of oil. At both locations there was a rich growth of annelid worms, along with other organisms, such as small pelecypods. These samples were collected after the regular series of trips reported upon herein, and are being studied by Dr. Harland B. Roney.

Stations 6 and 7, located in the harbor, were also somewhat polluted, but conditions were never extreme. Figure 12 shows the seasonal distribution of temperature, oxygen and pH at station 7. The great fluctuations of the pH undoubtedly were a reflection of the influence of inshore conditions and of pollution from the harbor. Stations 8 and 9 were located outside the breakwater. Open

lake conditions were approximated, especially at station 8. Stations 3 and 4 were located far out in the lake. Frequently weather conditions prevented visiting them. Both showed a very low content of iron, which at times amounted to only a trace (i. e., less than 0.1 mg Fe per liter of water), or even was undetectable. Sulfate ion, which would be less likely to precipitate out of the water than would the iron compounds, was somewhat higher, but this also averaged lower than at any other station. Turbidity was uniformly lower than at most other stations. Figure 13 shows the seasonal distribution of temperature, oxygen and pH at station

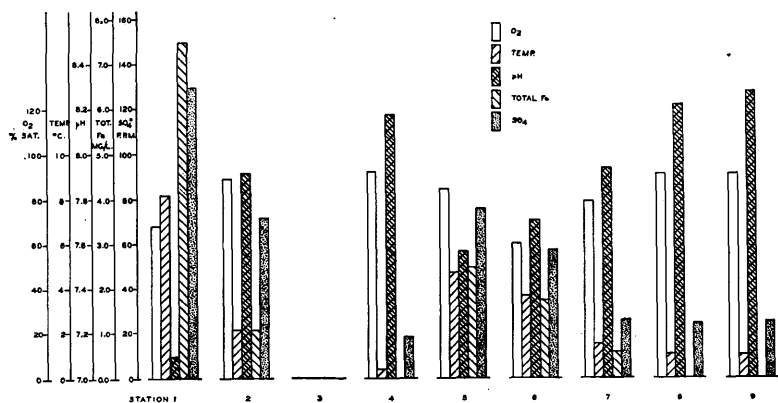


FIGURE 14. Distribution of O₂, temperature, pH, total Fe and SO₄²⁻ in the surface water in the Cleveland Harbor area on Jan. 20, 1951.

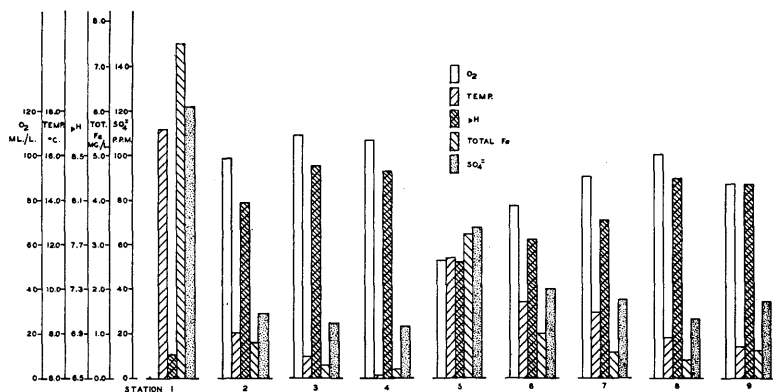


FIGURE 15. Distribution of O₂, temperature, pH, total Fe and SO₄²⁻ in the Cleveland Harbor area on April 28, 1951.

3. The sudden drop of O₂ on April 6 also occurred at station 4, and perhaps was caused by as yet undetected biological influences. At any rate, there was little evidence of any pollution.

There was some evidence that phytoplankton blooms appeared earlier at these outer stations than at the inner ones, and that the first large increase of zooplankton in the spring also occurred here. On the other hand, bottom samples obtained at stations 3 and 4 showed very little animal life compared to stations 2, 5 and 9.

Figures 14 and 15 show the distribution of oxygen, temperature, pH, total iron and SO₄²⁻ at the several stations on Jan. 20 and April 28, 1951 respectively. In the winter a high degree of pollution (shown by high Fe, high SO₄²⁻ and low pH)

caused less immediate depletion of O₂ than did similar conditions in the spring. However, it would appear that the O₂ depletion was merely delayed, and eventually it showed up clearly (station 6). In neither case was station 2 highly polluted.

CONCLUSIONS

It seems evident from the above analysis of the collected data that the industrial pollutants poured into the Cuyahoga River could be and undoubtedly are very deleterious to the existence of aquatic life in the river itself. These deleterious effects are certainly effective as far up the river as the steel mills in the vicinity of the Clark Avenue Bridge, and probably even far beyond the Harvard-Denison Bridge. Beyond the mouth of the river, aside from the unpleasant appearance and sickening odor of the water, there certainly are harmful effects from oil deposits in the bottom muds, the extent of which needs to be determined.

Another harmful result, extending over a considerable area, accrues from a reduction of photosynthesis, and hence of the productivity of the phytoplankton and of the attached algae, caused by high turbidities. The reduction in the oxygen content of the water also may be deleterious to animal life. Furthermore, it is evident that fish (especially game fish) are driven away, or poisoned by untested pollutant chemicals, such as the phenols. Cleveland oldtimers speak of the "good old days" in the early years of the present century when the best pike fishing in the vicinity was just inside the mouth of the Cuyahoga River, a location characterized today by nauseous odors, an oil-streaked surface, opaque water, and frequent complete lack of oxygen.

In small part these deleterious effects may be compensated for by the increased availability of plant nutrients in the raw and treated domestic sewage effluents that are poured into the Cuyahoga River by Cleveland and by villages and cities upstream from Cleveland. These questions can better be answered after analyses have been completed of the plankton samples and of the benthic organisms that were collected. It has been shown by Davis (1948) that copperas pollution may carry certain planktonic algae, such as diatoms, to the bottom muds, but that this process does not necessarily reduce the overall productivity of the water.

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