April 13, 1932

Report 135

THE EFFECTS ON FISH LIFE OF THE LIME SLUDGE DUMPED INTO GRAND RIVER BY THE FILTRATION PLANT OF THE CITY OF GRAND RAPIDS

This investigation was induced by local feeling against the practice employed by the city of Grand Rapids, of dumping the waste lime sludge from its city water filtration plant directly into Grand River.

The matter was brought to our attention by the Stream Control Commission. In explanation of the situation Mr. Milton P. Adams wrote on November 24, 1931, as follows:

> " The Director of Conservation and the writer have just received a copy of a resolution passed by the Dwight Lydell Chapter of the Izaak Walton League of America, of Grand Rapids, on November 20th, relative to getting the city water works there to adopt a new means of disposal for the filtration plant lime sludge which is now being discharged to the Grand River.
>
> "If you have gone over Leonard Street Bridge in Grand Rapids recently and looked to the North, you have noted the effect of this lime sludge in the stream, and periodically when the basins are discharged at the filtration plant, there ensues a day or two run of lime water down the river. Lime and alum are used in this plant, as you know, to assist in the purification of water and the removal of organic matter and to soften the river water for domestic use. The accumulated lime sludge which is now discharged periodically to the river, i.e., every two weeks during the summer months and at three or four week intervals during the winter, consists of spent lime and precipitated lime consisting largely of calcium carbonate, together with such other organic matter as is removed from the city water.
>
> "When Mr. Sperry was at the filtration plant in Grand Rapids, he was of the opinion, I recall, that this matter had no detrimental effect on fish life. The material is unsightly, however, and has been the source of complaint from several riparian owners along the river below the filtration plant where the water is used for boiler and condenser purposes. This complaint has arisen from the standpoint of the physical obstructive and coating caused by the lime in boilers, tubes, etc.
>
> "I am just wondering if such a problem has ever come to your attention and whether or not you have any comments you would care to make in this connection."

It was agreed soon afterward that the Institute would make an investigation of the effects of this pollution on fish life. The investigation was delayed, and field work by the Institute made impractical, by reason of the uncertainties existing at that time regarding the continuation of the state support for the investigations of the Institute.

Finally, in January, the agreement for the conduct of this particular investigation was resumed, and the Stream Control Commission brought a 5-gallon sample of the waste lime sludge to the University. The tests were made that month (January 21 to 25).

A large number of tests were made to determine the toxicity of this sludge waste to fish life, especially to minnows and to yearling sunfish. The end point of each of these 48 experiments and of the 12 controls is given in Table I. An examination of this Table will show that:

(1) all the controls lived through the experiments; that

(2) none of the fish died in either 1% or 2% waste solutions; that

(3) only 2 out of 9 fish tested in the 5% solution died; that

(4) all but 3 of the 15 tested in 10% waste died; that

(5) the time required for the 10% waste to kill is quite variable; that

(6) the 3 fish tested in 25% waste died quickly, and that

(7) the 4 fish tested in 50% waste died very quickly.

TABLE 1. END RESULTS OF EXPERIMENTS TO SHOW THE TOXICITY OF THE LIME SLUDGE TO FISH LIFE.

In series 1 the dilutions were made up to 1 liter (about 1 quart) and run in 2 quart jars; in series 2 these were made up to 5 liters in small aquaria.

Strength	Series	Aerated?	Species	Standard length	Last seen alive Hr.:Min.	Time of death Hr.:Min.
0%(control)	1	yes	Golden shiner	80	90:55	Did not die
0% "	1	"	" "	74	90:55	"
0% "	1	no	" "	64	90:55	"
0% "	1	"	" "	80	90:55	"
0% "	2	—	" "	60	88:55	"
0% "	2	—	" "	73	88:55	"
0% "	2	—	Steel-colored shiner	63	88:55	"
0% "	2	—	Pumpkinseed	32	88:55	"
0% "	2	—	"	29	68:30	"
0% "	2	—	Blunt-nosed-minnow	77	68:30	"
0% "	2	—	Golden shiner	65	68:30	"
0% "	2	—	" "	81	68:30	"
1%	1	yes	" "	53	90:34	"
1%	1	no	Steel-colored shiner	53	90:29	"
1%	2	yes	" "	64	68:30	"
1%	2	"	Golden shiner	66	68:30	"
1%	2	"	Blunt-nosed minnow	72	68:30	"
1%	2	"	Pumpkinseed	33	68:30	"
1%	2	no	"	36	68:30	"
1%	2	"	Blunt-nosed minnow	67	68:30	"
1%	2	"	Golden shiner	79	68:30	"
1%	2	"	" "	81	68:30	"
2%	2	yes	" "	66	87:15	"
2%	2	"	" "	73	87:15	"
2%	2	"	Steel-colored shiner	75	87:15	"
2%	2	"	Blunt-nosed minnow	50	87:15	"
2%	2	"	Pumpkinseed	25	87:15	"
2%	2	"	"	29	87:15	"
2%	2	"	"	34	87:15	"
5%	2	"	"	38-48	87:20	"
5%	2	"	"	"	47:40	"
5%	2	"	"	"	47:40	"
5%	2	"	"	85	1:14	1:32
5%	2	"	Steel-colored shiner	63	5:51	6:56
5%	2	"	" "	48	61:20	Did not die
5%	2	"	Blunt-nosed minnow	75	61:20	"
5%	2	"	Golden shiner	59	89:06	"
5%	2	"	" "	64	89:06	"
10%	1	"	" "	66	5:59	5:59
10%	1	no	" "	59	90:27	Did not die
10%	2	yes	" "	63	73:20	"
10%	2	"	" "	ab. 58	28:46	33:31

Table 1. (Continued)

Strength	Series	Aerated?	Species	Standard length	Last seen alive Hr.:Min.	Time of death Hr.:Min.
10%	2	yes	Golden shiner	ab. 58	24:18	25:56
10%	2	"	" "	58	18:56	21:51
10%	2	"	" "	66	7:11	7:51
10%	2	"	Blunt-nosed minnow	(yr.)	13:40	17:45
10%	2	"	Steel-colored shiner	68	0:28	1:19
10%	2	"	Bluegill	26	1:53	2:53
10%	2	"	Pumpkinseed	29	71:40	Did not die
10%	2	"	"	35	29:25	69:25
10%	2	"	"	47	17:45	21:25
10%	2	"	"	45	7:45	26:10
10%	2	"	"	38	2:53	6:04
25%	1	"	"	31	1:05	1:33
25%	1	"	Blunt-nosed minnow	54	0:50	1:04
25%	1	no	" "	55	2:29	2:51
50%	1	yes	Golden shiner	60	0:22	0:26
50%	1	"	Pumpkinseed	27	0:11	0:17
50%	1	no	"	29	0:16	0:23
50%	1	"	Golden shiner	67	0:33	0:35

We conclude that the lime sludge is poisonous to fish life, but that it would not form a high enough concentration in the Grand River at Grand Rapids to kill fish. It would not likely kill fish near the point of discharge of the waste, where the concentration ~~might~~ might run up to 5% or 10% for a short discharge, because as explained later fish show a strong negative reaction to the waste when strong and milky.

The lime sludge presumably acts as a direct chemical poison, and not through withdrawal of oxygen from the water. In our experiments bearing on this point, the fish died evenly more quickly in the aerated than in the non-aerated solutions of the same strength (see Table 2). The reason probably was that the bubbling air kept much of the lime in suspension, whereas in the unaerated tanks the lime soon precipitated to the bottom, and was only occasionally stirred up during the experiments.

TABLE 2. COMPARISON BETWEEN EFFECTS OF AERATED AND UNAERATED WASTE SOLUTIONS
(All experiments belong to Series 1-see Table 1)

Species	Strength	Aerated solution		Unaerated solution	
		Last seen alive Hr.:Min.	Found dead Hr.:Min.	Last seen alive Hr.:Min.	Found dead Hr.:Min.
Golden shiner	10%	5:59	5:59	90:27	Did not die
Blunt-nosed minnow	25%	0:50	1:04	2:29	2:51
Golden shiner	50%	0:22	0:26	0:33	0:35
Pumpkinseed	50%	0:11	0:17	0:16	0:23

Even when the solutions were aerated some of the lime gradually settled as a hard precipitate, and it was noted that the toxicity of the solution was concurrently decreased. Data bearing on this point are given in Table 3. Whether the precipitation of the lime was the sole reason for the decreased toxicity, we do not know. The results indicate, however, that the toxicity of the lime would be expected to decrease in the stream.

TABLE 3. DECREASE IN TOXICITY OF 10% LIME SOLUTION ON AERATION.

5 liters of solution used in small aquarium.

Species (and standard length)	Time fish were added after start of experiment: 0 to 2 min.		27 hr.:51 min.		29 hr.:31 min.	
	Last seen alive Hr.:Min.	Found dead Hr.:Min.	Last seen alive Hr.:Min.	Found dead Hr.:Min.	Last seen alive Hr.:Min.	Found dead Hr.:Min.
Steel-colored shiner (68)	0:28	1:19	—	—	—	—
Blunt-nosed minnow (yearling)	—	—	13:40	17:45	—	—
Golden shiner (58 to 68mm.)	7:11	7:51	73:20	Did not die	—	—
" " "	18:56	21:51	—	—	—	—
	24:18	25:56	—	—	—	—
	28:46	31:31	—	—	—	—
Bluegill (26)	1:53	2:53				
Pumpkinseed (29-47)	2:53	6:04	17:45	21:25	7:45	26:10
	—	—	—	—	29:25	69:25
	—	—	—	—	29:25	71:40

The symptoms shown by the fish preceding death are different from those exhibited

by fish being killed by certain other wastes, for example the ponded Steffen's waste dealt with in Report 134. In solutions of that waste the fish usually appeared almost normal until shortly before their death. In the lime sludge dilutions, however, the effect showed up at once, and the killing was a long drawn out affair. To illustrate this statement we give two characteristic examples (Table 4).

TABLE 4. SYMPTOMS SHOWN BY FISH BEING KILLED BY A 10% SOLUTION OF THE SLUDGE.

Time from start of experiment	Steel-colored shiner	Golden shiner
0:02	Distressed; at surface part time	Distressed; at surface part time
0:20	At surface; weak	At surface; weak
0:25	Losing equilibrium	———
0:28	Up side down; very weak	———
1:19	Dead some time	———
6:06	———	Gapping badly
7:11	———	Weakening
7:51	———	Dying
17:51	———	Bare signs of life
21:51	———	Dead

Even in 1% and 2% solutions, which did not kill in the course of the experiments, the fish showed at once a much greater nervousness than in the controls, and sometimes lapped at the surface. The pH of the clear liquid after the lime had settled was markedly increased even in the 1% waste. One test gave a pH of 8.7. In 10% solutions the pH was raised to some point above 9.2.

Despite its high pH (above 9.2), the crystal clear water which had been repeatedly shaken with lime, but from which the lime had resettled and been removed, was not strongly poisonous. One liter samples in 2 quart jars were used. One aerated and one not; in each a blunt-nosed minnow and a pumpkinseed yearling was placed, and kept alive for 52 hours (when the experiment was ended). They showed some wild dashing, and in the unaerated solution lapped at the surface, as would be expected, but none of the fish showed signs of impending death at the end of the experiment. We have no reason to think that the clear solution made by the river water washing over sludge beds would kill fish.

Pollutions may affect fish in ways other than merely killing them. The solutions of some wastes induce a negative reaction, that is they cause the fish to swim away from them. The reaction of fish to the waste was tested out in a zinc-lined tank, 12 inches wide and nearly 16 feet long, and containing water about 2 1/2 inches deep. Into one end was run the clear liquid from which the lime had settled after being frequently stirred up, while into the other end, also serving as outlet, was run water of similar temperature untreated with lime. The differences in the water in the different quarters of the tank was shown by pH tests. The method of recording and presenting the data was to determine the time in seconds that the majority of the fish remained in a given quarter of the length of the tank; and entering this in the column of the table corresponding to the quarter of the tank occupied. Then after the fish moved into the next quarter, the time the majority spent there was entered in the next column, and in the next lower row. Thus, at the beginning of the main experiment (which followed preliminary trials), the fish stayed 17 seconds in the end quarter into which the freshwater entered; then moved into the next quarter for 8 seconds, into the next quarter for 5 seconds, then into the opposite end (lime-water inlet) where they stayed 19 seconds, etc. (follow Table 5). The fishes used were a considerable number of shiners (mostly golden shiners) along with a few sunfish and others.

It is clear from the data, presented as Table 5, that the fish showed no evident negative reaction to the strong lime sludge water, when only the clear liquid was used. In this table, at property points, the pH concentration as colorimetrically measured is inserted.

TABLE 5. SHOWING REACTION OF FISH TO CLEAR WATER WHICH HAD BEEN REPEATED MIXED WITH THE LIME SLUDGE.

The number of seconds the fish remained in each quarter of the tank is shown. The four columns correspond to the quarters of the tank. The pH determinations are interpolated.

Lime water entered this end	Clear water entered this end	Lime water entered this end	Clear water entered this end
pH 9.1	pH 7.9	pH 7.9	
19	17	7	1
21	7	15	15
34	12	26	13
17	20	19	15
54	15	12	15
15	2	18	23
11	17	17	11
26	1	10	
38	13		

TABLE 5 (continued)

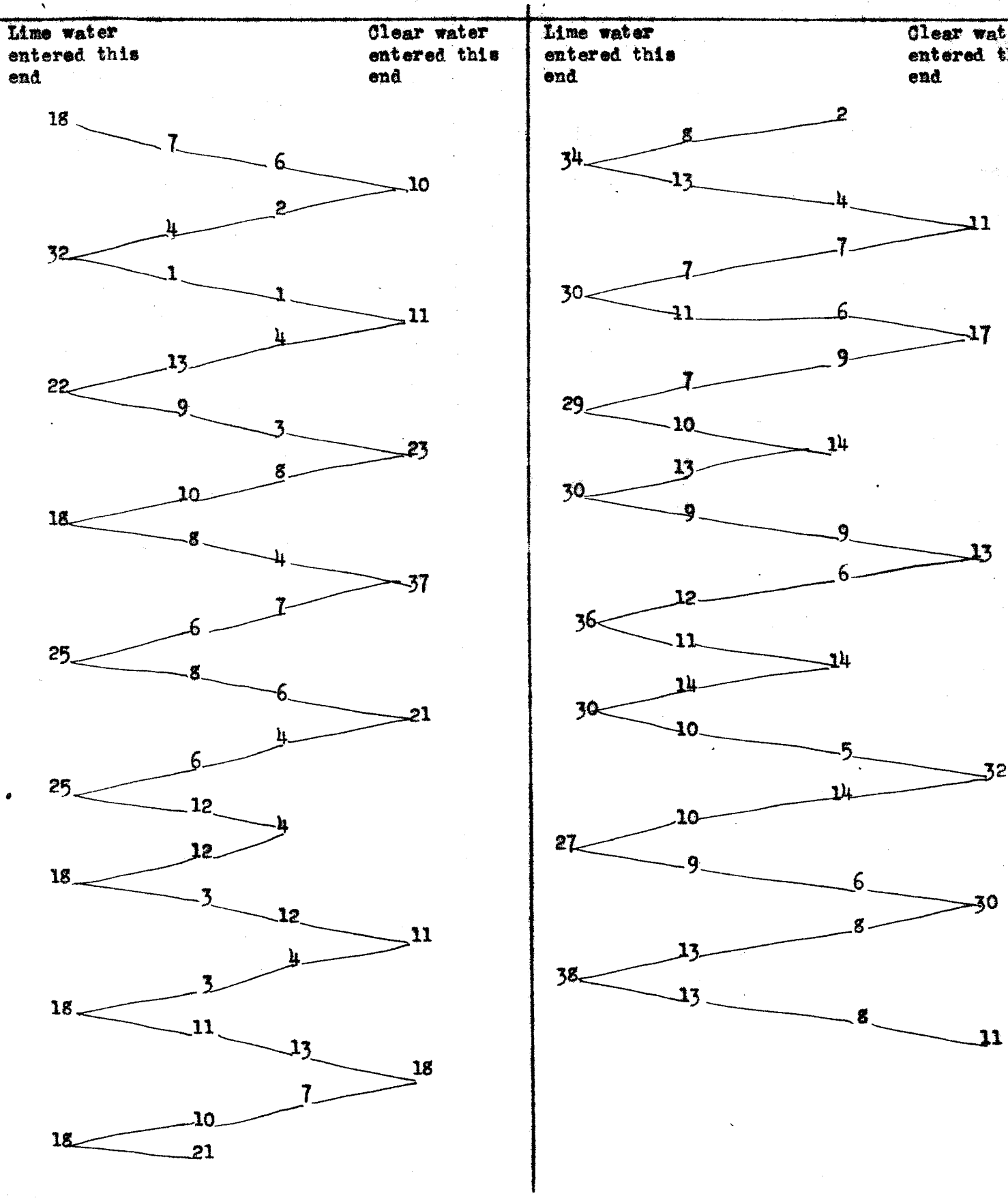
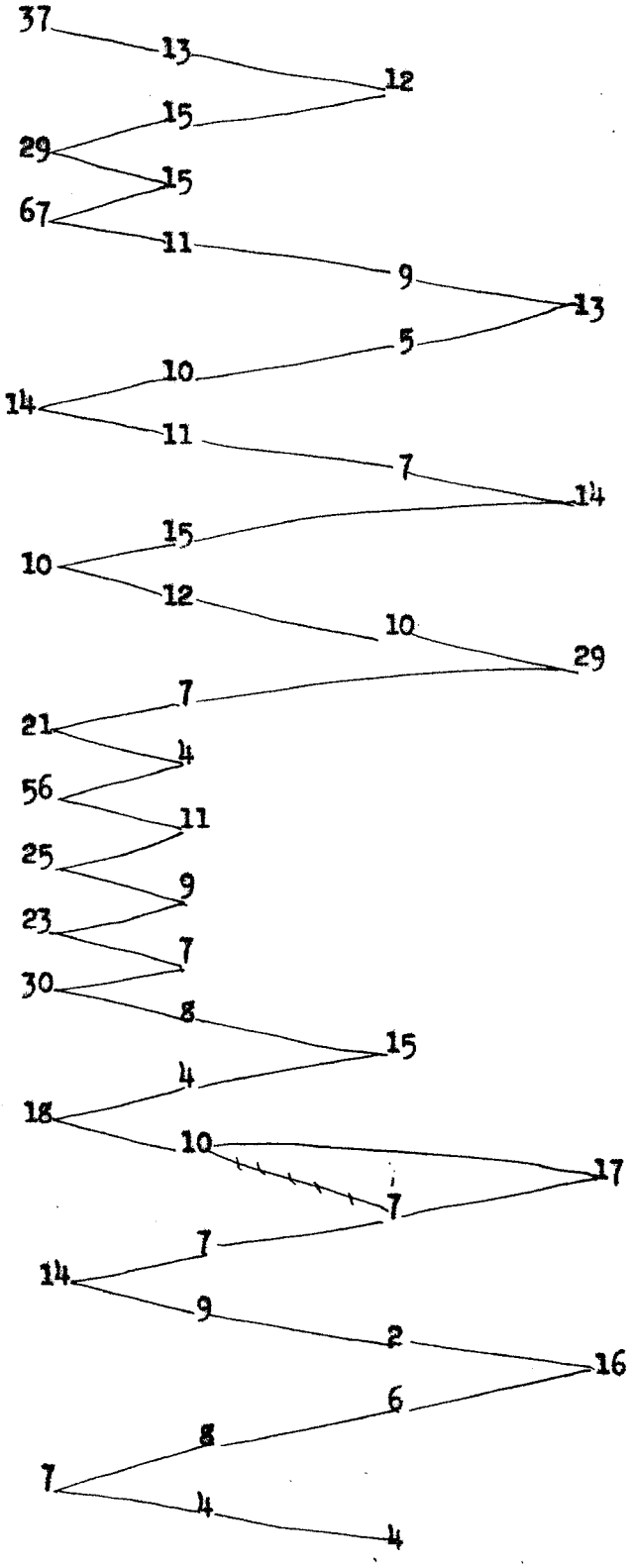


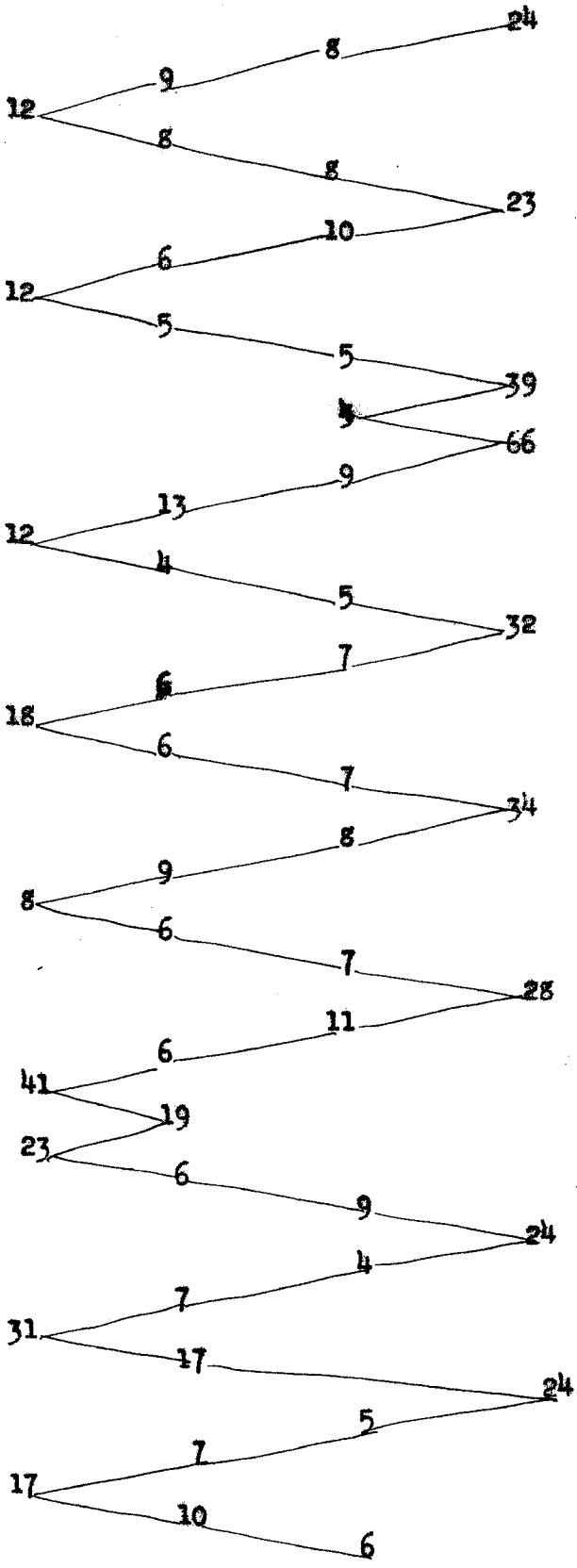
TABLE 5 (Continued)

Lime water entered this end	Clear water entered this end	Lime water entered this end	Clear water entered this end

pH 9.24 pH 8.6 pH 8.0

lime water now stopped and more system water in





When a milky mixture of lime sludge and water was used at one end of the tank, instead of the clear lime water, the reactions of the fish were entirely different. They showed very strong and unmistakable avoidance of the milky water. They rarely swam into it, usually turning about and retreating on first entering the clouded edge. Whether the response was chemical or visual was not determined. Nor is this perhaps important. It seems safe to conclude, that when the river is made milky by releasing the lime sludge, that the fish of the stream move out of the affected section. The loss to this section may be as serious as though the fish were killed.

The data are shown in Table 6, which presents the results of the main experiment, which followed preliminary trials indicating the same conclusions.

TABLE 6. SHOWING REACTION OF FISH TO MILKY LIME SLUDGE WATER

The number of seconds the fish remained in each quarter of the tank is shown.

Milky water entered this end	Clear water entered this end	Milky water entered this end	Clear water entered this end
7	20	13	5
7	12	13	5
5	7	19	5
2	21	10	11
5	4	6	2
4	26	1	7
8	8	20	16
4	17	17	10
7	23	9	23
5	9	8	59
6	10	13	56
14	13	40	15
17	15	19	80
6	8	7	169
3	4	8	195
		15	71