November 24, 1931

Report No. 106

THE EFFECTS OF THE WASTES OF SUGAR FACTORIES ON FISHES

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An investigation of the effects on fish life of the wastes from beat sugar factories has been requested by the Stream Control Commission, by Milton P. Adams, in charge. The Institute agreed to run the necessary experiments.

According to previous arrangements, the Stream Control Commission collected and brought to the Institute for Fisheries Research, two samples of sugar plant wastes. The samples were brought in by Mr. T. J. Powers, an employee of the Commission, and were accompanied by labels carrying the following information:

First sample: Beet Waste; Great Lakes Sugar Co., Blissfield; November 17, 1931, 1:10 P.M.; T. J. Powers; temperature at outfall; 35°C. [=95°F.].

Second sample: Steffen's Waste; Great Lakes Sugar Co., Blissfield; November 17, 1931, 1:20 P.M.; T. J. Powers; temperature at entrance to pond, 64°C. [=147°F.].

The beet waste was a somewhat opalescent liquid carrying a large amount of suspended material, apparently fragments and fibers of beets, which settled on standing.

The Steffen's waste was of the characteristic orange-amber color; had the sweetish odor smelled about the sugar plants; rapidly formed a suds-like foam on aeration; clouded on dilution with the water used, and then deposited out a lime-like precipitate. This sample was still decidedly warm when received at 4:30 P.M. on November 17.

The sample bottles were then placed in a water bath of 58°F., in order to retard the decomposition, until the dilutions could be made up.

EXPERIMENTS USING 700 CC. IN JARS

On account of the small size of the sample, the larger number of experiments were run in wide-mouthed fruit jars, using 700 cc. of waste solution (approximately 1 1/2 pints) in each. The water used had a temperature of about 70°F. and was taken from the circulating system of the Experimental Aquarium, and was, before the addition of the wastes well aerated, clear and very well suited for fish life. The dilutions were made up between 6:00 and 7:00 P.M. (except two at 8:00 P.M. and one at 10 P.M.) on the day the sample was obtained. A few minutes after each dilution was made up to its proper strength, a small fish was added to the jar. Each dilution was made up in duplicate, so that one series could be run with, and the other without, compressed air. When used, the air was kept on through the experiment, and was delivered through Filtros plugs so as to be broken up into fine bubles. The effects of the waste on the fish were carefully observed, and the time of each observation was recorded.

Beet Waste

For controls on the beet waste experiments, Exp. 1 and 2 were set up, but Exp. 14 and 15 apply equally well.

Experiment A 1: No waste (control experiment); aerated; long-eared sunfish (67 mm. standard length, 3.3 inches over all); started 6:46 P.M.

Hr.: Min.	
6 :43	Normal
13 :49	Normal
28 :39	Normal
35:14	Normal
39:59	Normal
49:34	Freshly dead

This control fish lived nearly 50 hours. Its death was no doubt due to the confinement of so large a fish in such a small quantity of water.

Experiment A 2: No waste (control experiment); no aerated; long-eared sunfish adult (75 mm. standard length, 3.7 inches over all); started 6:46 P.M.

Hr.: Min.		Hr.: Min.	
1:19	Breathing heavily near surface	4:37	Lapping again at surface
2:31	Lapping at surface	6:36	Do.
2:52	Water half-removed for oxygen test; then replaced with fresh water; dissolved oxygen, 1.9 p.p.m.	13:45	Dead for some time.

This control fish died in less than 14 hours. It was clearly too large for the jar, and its early death was no doubt due to the consumption of oxygen by the fish and the accumulation of waste products.

Experiment A 3: 0.1 % waste (virtually a control); aerated; rock bass (34 mm. standard length, 1.7 inches over all); started 6:49 P.M.

Hr.: Min.		Hr.: Min.	
1:46	Normal	40:31	Normal; fish then removed.
29:11	Normal		

This very weak solution of beet waste, using a fish of suitable size, acted very well as a control. The fish showed no marked distress during the 40 1/2 hours of confinement in the jar.

Experiment A 4: 0.1 % waste (virtually a control); not aerated; rock bass (35 mm. standard length, 1.9 inches over all); started 6:49 P.M.

Hr.: Min.		Hr.: Min.	
1:46	Normal	40:31	Normal; fish then removed to Exp. C 13.
29:11	Normal		

The remarks under Exp. 3 apply equally well to Exp. 4.

Experiment A 5: 1 % waste; aerated; large-mouth black bass (66 mm. standard length, 3.2 inches over all); started 6:45 P.M.

Hr.: Min.		Hr.: Min.	
6:44	Normal	47:15	Normal
13:50	Normal	52:00	Normal
29:15	Normal	61:35	Died; after last observation; dissolved oxygen 5.85 p.p.m.
40:50	Normal		

The keeping of this three-inch bass for between 52 and 61 1/2 hours in a fruit jar, in aerated water, would indicate that the toxi city of 1 % beet waste is slight, but perhaps present and slowly effective.

Experiment A 6: 1 % waste; not aerated; large-mouth black bass (107 mm. standard length, 5.3 inches over all); started 6:45 P.M.

Hr.: Min.		Hr.: Min.	
1:20	Breathing heavily	2:34	Freshly dead; sample taken 5 minutes later showed only 0.6 p.p.m. of dissolved oxygen.
1:27	Do.; near surface		
1:47	Weakening some		

This bass was too large for the jar; the 1 % of beet waste may have contributed to the oxygen removal and accumulation of poisons in absence of aeration.

Experiment A 7: 10 % waste; aerated; perch (87 mm. standard length, 4.9 inches over all); started 6:43 P.M.

Hr.: Min.		Hr.: Min.	
13:52	Rather wobbly; near surface	28:52	Dead; sample taken 1:10 later showed 5.40 p.p.m. of dissolved oxygen
26:52	Almost normal		

The killing of this perch in a little more than one day in aerated waste again suggests that the beet waste has weak toxic properties.

Experiment A 8: 10 % waste; not aerated; perch (62 mm. standard length, 2.6 inches over all); started 6:42 P.M.

Hr.: Min.		Hr.: Min.	
4:03	Lapping at surface	5:49	Dead; dissolved oxygen, 0.8 p.p.m.

The killing of this small perch in less than 6 hours in non-aerated 10 % beet waste indicates strongly that the waste has rather high oxygen consuming qualities and fish-killing propensities.

Experiment A 9: 50 % waste; aerated; pumpkinseed sunfish (48 mm. standard length, 2.4 inches over all); started 6:20 P.M.

Hr.: Min.	
0:10	Half breathing
0:36	Almost normal
0:39	Normal
3:05	Lapping at surface
7:09	Do.
14:15	Normal
41:15	Normal
47:40	Normal
52:25	Normal
74:00	Normal
85:10	Normal
98:10	Dead; dissolved oxygen, 5.90 p.p.m.

This experiment shows that some fish can live more than 85 hours in a 50 % solution of the beet waste, but that it apparently eventually kills the fish even though the water has been continuously aerated.

Experiment A 10: 50% waste; not aerated; pumpkinseed sunfish (55 mm. standard length, 2.8 inches over all); started 6:21 P.M.

Hr.: Min.	
0:09	Half breathing
0:35	Gasping at surface
0:38	Apparently normal
0:46	Lapping air at surface
1:55	Shaking violently; then lapping
2:33	Loss of equilibrium; spasms.
2:43	Almost dead
2:51	Dead; sample taken 15 minutes later showed 0.35 p.p.m. of dissolved oxygen.

Experiment 10, with others, shows that sunfish are killed rather quickly by a strong solution of beet waste, and that they are killed with the characteristic symptoms of asphyxiation.

Experiment A 11: 100 % beet waste; well aerated during and for some minutes prior to experiment; pumpkinseed sunfish (60 mm. standard length, 3.0 inches over all); started 6:35 P.M.

Hr.: Min.	
0:01	Breathing heavily
0:24	Apparently normal
1:01	Excited, but normal
1:36	somewhat weakened
3:10	Wild movements
3:20	Jumping, at surface
3:25	Turning over
4:10	Dead; 3.15 p.p.m. of dissolved oxygen.

This trial shows clearly that consumption of oxygen is not the sole effect of such organic wastes in fish life.

Steffens Waste

This, the B-series of experiments, was performed like the A-series in two-quart fruit jars. Each strength of solution was used with and without aeration. The first two experiments are the controls. Experiments A1 to A4 and B3 and B4 are virtually also controls.

Experiment B 1: No waste (control experiment); aerated; small-mouth bass (58 mm. standard length, 2.8 inches over all); started 6:16 P.M.

Hr.: Min.		Hr.: Min.	
7:13	Normal	17:29	Normal; removed to Exp. C 9.
14:19	Normal		

Experiment B 2: No waste (Control experiment); not aerated; small-mouth bass (51 mm. standard length, 2.5 inches over all); started 6:16 P.M.

Hr.: Min.		Hr.: Min.	
7:13	Normal	17:30	Normal; removed to Exp. C.11.
14:19	Breathing a little heavily		

These two control experiments indicate that the experimental proceedure was satisfactory.

Experiment B 3: 0.1 % waste; aerated; rainbow darter (about same size as fish in Exp. B 4); started 6:24 P.M.

Hr.: Min.		Hr.: Min.	
12:11	Breathing a little heavily	17:25	Normal; removed.

Experiment B 4: 0.1 % waste; not aerated; rainbow darter (63 mm. standard length, 3.0 inches over all); started 6:23 P.M.

Hr.: Min.		Hr.: Min.	
0:27	Normal	4:00	Breathing heavily; on side, moving on stimulus
1:20	Breathing heavily	4:25	Dead; dissolved oxygen, 1.5 p.p.m.

This pair of experiments is not very significant, as the very sensitive darters were not used in other experiments.

Experiment B 5: 1 % waste; aerated; pumpkinseed sunfish (69 mm. standard length, 3.4 inches over all); started 6:24 P.M.

Hr.: Min.		Hr.: Min.	
0:36	Normal	14:11	Somewhat uneasy
7:05	Normal	17:26	Normal; removed

Experiment B 6: 1 % waste; not aerated; pumpkinseed sunfish (55 mm. standard length, 2.7 inches over all), started 6:22 P.M.

Hr.: Min.		Hr.: Min.	
0:08	Uneasy	14:13	Same
7:07	Breathing somewhat labored	17:28	Normal; removed

Experiments B 5 and B 6 show that sunfish can withstand living for at least about 18 hours in a 1 % solution of Steffens waste in good water.

Experiment B 7: 2 % waste; aerated; perch (101 mm. standard length, 4.8 inches over all); started 8:02 P.M.

Hr.: Min.		Hr.: Min.	
5:27	Normal	26:48	on side; convulsive
12:38	Normal	27:05	Much recovered
23:28	Normal	27:58	Apparently normal
26:33	Normal	36:03	Dead for some time; dissolved oxygen, 4.90 P.p.m.

Experiment B 8: 2 % waste; not aerated; large-mouth bass (100 mm. standard length, 4.9 inches over all); started 8:03 P.M.

Hr.: Min.		Hr.: Min.	
1:42	Wild movements	5:26	Lapping at surface
2:00	Lapping at surface	12:37	Dead for some time

The two preceding experiments indicate that 2 % Steffens waste is lethal to fishes, killing in less than 12 hours unless well aerated, and in less than 36 hours even if so well aerated as to hold the dissolved oxygen as high as 5 p.p.m.

Experiment B 9: 2 % waste; not aerated; golden shiner (77 mm. standard length, 3.7 inches over all); started 10:10 P.M.

Hr.: Min.		Hr.: Min.	
0:20	Lapping at intervals	24:25	Constantly lapping air
3:19	Do.	43:50	Same
10:25	Do.; breathing labored	48:20	Dead for some time.

The relatively long life (2 days) of the golden shiner in the same strength of solution as killed a sunfish in 24 minutes is due apparently not so much to greater inherent resistance as to the ability of the minnows to breath atmospheric air after the dissolved oxygen is exhausted.

Experiment B 10: 5% waste; aerated; bluegill (67 mm. standard length, 3.4 inches over all); started 7:05 P.M.

Hr.: Min.		Hr.: Min.	
0:38	Partial loss of equilibrium	0:42	Dead; dissolved oxygen, 3.9 p.p.m.
0:40	Jumping excitedly		

Experiment B 11: 5 % waste; not aerated; pumpkinseed sunfish (62 mm. standard length, 3.1 inches over all); started 7:06 P.M.

Hr.: Min.	
0:24	Dead; dissolved oxygen, 2.9 P.p.m.

These were critical experiments, showing the quick killing power of dilution of Steffen's Waste, whether or not these are aerated. The aeration apparently delayed death, for a few minutes only, and only retarded the oxygen consumption. In both experiments, sufficient oxygen

was left for the fish according to ordinary standards and experience, but apparently not enough when this amount of oxygen was combined with the specific polluting substance involved.

Experiment B 12: 10 % waste; aerated; pumpkinseed sunfish (54 mm. standard length, 2.7 inches over all); started 6:18 P.M.

Hr.: Min.		Hr.: Min.	
0:04	Distressed; at surface	0:20	Dead; sample taken 52 ~~mm.~~ min. later showed 0.5 p.p.m. of dissolved oxygen.
0:18	Moving sporadically		

This experiment shows that Steffens Waste has such a high and unsaturated oxygen demand that bubbling air through a 10 % solution is insufficient to hold more than a trace of oxygen in the solution.

Experiment B 13: 10 % waste; aerated; rock bass (40 mm. standard length, 2.0 inches over all); started 6:50 P.M.--A direct continuation of Exp. B 12, using same jar and solution.

Hr.: Min.		Hr.: Min.	
0:20	Weakening	0:26	Dead; sample taken 14 minutes later showed 0.5 p.p.m. of dissolved oxygen.

This experiment is a complete confirmation of Exp. B 12.

Experiment B 14: 10 % waste; aerated; brook stickleback (42 mm. standard length, 1.9 inches over all); started 8:07 P.M.--A direct continuation of Exp. B 12 and B 13, using same jar and same solution, but the latter reduced to about one-half by the oxygen sample taken at 7:30.

Hr.: Min.		Hr.: Min.	
0:03	Swimming excitedly	0:47	Nearly dead
0:25	Beginning to lose equilibrium.	0:57	Dead; dissolved oxygen, 0.6 p.p.m.

For Exp. B 14 an especially resistant little fish was chosen, but even it could not survive one hour in 10 % aerated Steffen's Waste. The second oxygen test showed again that this solution consumes oxygen faster than it can be added by air-bubbling.

Experiment B 15: 10 % waste; not aerated; pumpkinseed sunfish (48 mm. standard length, 2.4 inches over all); started 6:19 P.M.

Hr.: Min.		Hr.: Min.	
0:01	Jumping	0:14	Dead; sample taken 57 min. later showed 0.5 p.p.m. of dissolved oxygen.
0:11	Uneasy		

Experiment B 16: 10 % waste; not aerated; bluegill (66 mm. standard length, 2.6 inches over all); started 6:52 P.M.—A direct continuation of Exp. B 15, using same jar and solution.

Hr.: Min.		Hr.: Min.	
0:22	Wildly dashing	0:23	Dead, in rigor; sample taken 15 min. later showed 0.5 p.p.m. of dissolved oxygen.

Experiments B 15 and B 16, like the several preceding ones, exemplify the rapid killing power of Steffen's Waste.

Experiment B 17: 50 % waste; aerated; pumpkinseed sunfish (71 mm. standard length, 3.5 inches over all); started 6:26 P.M.

Hr.: Min.		Hr.: Min.	
0:07	Almost dead, moving sporadically	0:18	Dead (dissolved oxygen not testable, owing to excess organic matter).

Experiment B 18: 50 % waste; aerated; pumpkinseed sunfish (66 mm. standard length, 3.3 inches over all); started 6:55.—A direct continuation of Exp. B 17, using same jar and solution.

Hr.: Min.		Hr.: Min.	
0:00	Lost balance in 5 sec.	0:03	Movements sporadic.
0:01	Very weak.	0:10	Dead.

Experiment B 19: 50 % waste; aerated; goldfish (85 mm. standard length, 4.2 inches over all); started 7:12.—A direct continuation of Exp. B 17 and B 18, using same jar and solution.

Hr.: Min.		Hr.: Min.	
0:00	Immediate wild reaction	0:09	Lying on side; moving sporadically.
0:05	Breathing weakly	0:19	Dead.

These three experiments (B 17 to B 19) further prove the toxicity of Steffen's waste, even to a fish so resistant as the goldfish. It is of importance to note that none of the three fish killed in this experiment showed any lapping at the surface, which is a good indication of the effects of low oxygen as such. The quick reaction of the fish to the solution also indicates definite poisons.

Experiment B 20: 50 % waste; not aerated; pumpkinseed sunfish (50 mm. standard length, 2.5 inches over all); started 6:27 P.M.

Hr.: Min.		Hr.: Min.	
0:00	Almost at once lying flat on surface	0:06	Almost dead, sporadically moving
		0:14	Dead.

Experiment B 21: 50 % waste, not aerated; rock bass (75 mm. standard length, 3.75 inches over all); started 6:53.—A direct continuation of Experiment B 20, using same jar and solution.

Hr.: Min.		Hr.: Min.	
0:00	Excited immediately	0:02	Lying on side; breathing weakly.
0:01	Shaking head; then losing equilibrium.	0:04	Dead.

Experiment B 22: 50 % waste; not aerated; goldfish (50 mm. standard length, 2.5 inches over all); started 7:13.—A direct continuation of Exp. 20 and Exp. 21, using same jar and solution.

Hr.: Min.		Hr.: Min.	
0:04	Breathing weakly	0:17	Dead.

Experiments B 20 to 22 fully confirm the results obtained and discussed for Exp. B 17 and B 19.

EXPERIMENTS WITH STEFFEN'S WASTE, USING 5000 CC.

IN AQUARIA

In order to confirm the results on the toxicity of Steffen's Waste, and to make quite certain that the results obtained in the B-series of experiments just outlined were essentially valid despite the use of such small containers and such a diversity of fish, a new or C-series of experiments were carried out. The dilutions were all made up at first to 5000 cc. (roughly 5 quarts), and kept in small rectangular aquaria, so that the water was about 4 inches deep and the surface exposure therefore large. As a measure of double caution, six controls were used (three aerated). Solutions of 2 %, 4 % and 6 % were used, and the 4 % solutions were made up by further diluting the 6 % solutions after the first set of fish had been killed therein. The 2 % and 6 % dilutions were made up at 10 A.M. on November 18, nearly 21 hours after the concentrated sample was collected and 17 1/2 hours after it had been received at the Institute and placed in a cool water bath. The fish used in most of these experiments were very uniform – all hybrid sunfishes (bluegillx pumpkinseed), and all were small adults about 105 mm. in standard length and 5 inches over all. Only one fish was placed in each aquarium (one exception). In the 4 % solution other species were tried.

Experiments C 1 to C 3: no waste (control experiments); aerated; small adult hybrid sunfish; started 10:20 A.M.

Hr.: Min.	
13:40	Normal
21:45	Normal
29:40	Normal; dissolved oxygen, 6.45, 6.50 and 6.65 p.p.m.
31:40	Normal
36:25	Normal
46:25	Normal; Exp. C1 and C2 ended (fish from Exp. C2 and C3 used for Exp. C14).
48:10	Normal (C 3 only)
57:10	Normal (C 3 only)
70:10	Normal; dissolved oxygen, 6.40 p.p.m. (C 3 only), experiment ended.

Experiment C 4 to C 6: No waste (control experiments); not aerated; small adult hybrid sunfish; started 10:20 A.M.

Hr.: Min.		Hr.: Min.	
13:40	Normal	46:00	Normal; dissolved oxygen, 0.33, 0.47 and 1.58 p.p.m.
21:25	Normal	48:10	Somewhat weakened; occasionally lapping at surface.
24:15	Normal; dissolved oxygen in C 5, 0.40 p.p.m.	57:10	No change
29:40	Normal; dissolved oxygen 0.40, 0.40 and 0.70 p.p.m.	70:10	Still almost normal; dissolved oxygen, 0.25, 0.40 and 2.50 p.p.m.; experiments ended.
31:40	Normal		
36:25	Normal		

These six control experiments were very satisfactory (as controls), and furthermore showed the high resistance of fish to low oxygen in the absence of marked impurities in the water.

Experiment C 7: 2 % waste; aerated; small adult hybrid sunfish; started 10:20 A.M.

Hr.: Min.		Hr.: Min.	
0:28	Signs of weakening.	36:25	No change.
13:40	Normal.	46:25	No change.
21:45	Normal.	57:10	No change
29:40	Nearly normal; dissolved oxygen, 5.85 p.p.m.	70:10	Still almost normal; oxygen 2.50 p.p.m.; experiment ended.

Experiment C 8: 2 % waste; not aerated; small adult hybrid sunfish; started 10:20 A.M.

Hr.: Min.		Hr.: Min.	
0:28	Signs of weakening.	21:45	Dead for some time; dissolved oxygen (sampled twice, at 10 minutes and at 2 hours after removal of fish), no trace.
13:15	Lapping at surface; weak.		
13:40	Do.		

Experiments C 7 and C 8 show that adult sunfish can tolerate a 2 % solution of Steffen's Waste, but only when aerated.

Experiment C 9: 4 % waste; aerated; small-mouth bass, from Exp. B 1 (58 mm. standard length, 3.4 inches over all); started at 11:45 A.M.—This dilution

made up at 11:40 A.M. from the 6 % solution after the one fish tried therein was killed (Exp. C 15).

Hr.: Min.		Hr.: Min.	
0:34	Wild dash; partial loss of equilibrium.	0:36	Dead; oxygen analysis not completed owing to breakage of bottle, but carried far enough to see by color that it was higher than 2.35 p.p.m.

Experiment C 10: 4 % waste; aerated; pumpkinseed sunfish, same fish used earlier in B 5 (69 mm. standard length, 3.4 inches over all); started at 12:49 P.M.—A direct continuation of Exp. C 9, using same aquarium and solution.

Hr.: Min.	
1:02	Dead; dissolved oxygen, 3.65 P.p.m.

Experiment C 11: 4 % waste; not aerated; small-mouth bass, from Exp. B 2 (51 mm. standard length, 2.5 inches over all); started 11:46 A.M.—This dilution made up at 11:40 A.M. from the 6 % solution after the one fish tried therein was killed (Exp. C 16).

Hr.: Min.		Hr.: Min.	
0:12	Lapping at surface	0:24	Dead; dissolved oxygen, 2.35 p.p.m.

Experiment C 12: 4 % waste, not aerated; pumpkinseed sunfish, same fish used earlier in Exp. B 6 (55 mm. standard length, 2.7 inches over all); started 12:50 P.M.—A direct continuation of Exp. C 11, using same aquarium and solution.

Hr.: Min.	
1:22	Just died; dissolved oxygen, 3.15 p.p.m.

Experiment C 13: 4% waste; not aerated; rock bass, from Exp. # 4 (35 mm. standard length, 1.9 inches over all); started 11:20 A.M.—A continuation, after a nearly one day interval, of Exp. C 12, using same jar and solution.

Hr.: Min.		Hr.: Min.	
0:40	Normal	3:10	Dead for some time.

Experiment C 14: 4% waste; not aerated; small adult hybrid sunfish; started at 8:45 A.M., Nov. 20.

Hr.: Min.		Hr.: Min.	
0:07	Lapping at surface.	5:37	Just died; dissolved oxygen, no trace.
4:26	Rolling; spasmodic		

Experiments C 9 to C 14 show that a 4 % solution of Steffen's Waste (1 part to 24 of good water) is quickly lethal to fishes, even though the solution is aerated.

Experiment C 15: 6 % waste; aerated; small adult hybrid sunfish; started 10:20 A.M.

Hr.: Min.		Hr.: Min.	
0:03	On side; up later.	0:28	Somewhat spasmodic.
0x05	Weak	0:48	In rigor.
0:25	Lapping at surface.	0:55	Dead; dissolved oxygen, 1.45 p.p.m.

Experiment C 16: 6 % waste; not aerated; small adult hybrid sunfish; started 10:20 A.M.

Hr.: Min.		Hr.: Min.	
0:01	On side; up later.	0:28	Somewhat spasmodic.
0:05	Weak.	0:48	Wildly dashing; then in rigor.
0:25	Lapping at surface.	0:55	Dead; dissolved oxygen, 2.00 p.p.m.

The last two experiments show that a 6 % solution of Steffen's Waste kills adult sunfish in less than an hour, whether the solution is aerated or not. The fact that the death occurred as quickly in the aerated as in the non-aerated solution, and that at the end of the experiment the aerated solution showed slightly less oxygen than the latter, was due probably to the churning up of the sediment in the former aquarium by the bubbling air.

CONCLUSIONS

The wastes of the sugar factories prove by experiment to be toxic to fish life. When well aerated the beet wastes are only weakly toxic, but on standing, solutions of this waste in good water kill fishes. Whether aerated or

not, Steffen's Waste, even when much diluted, kills fishes rapidly. A 2 % solution is not quickly fatal when aerated, but a 4% solution kills quickly whether aerated or not. The killing of the fish is not wholly due to the consumption of oxygen by the waste, because a high residual oxygen of as much as 3 to 5 parts per million remained on the death of the fishes. Steffen's Waste must in our opinion be classed as a definite poison to fish life.

The experiments here recorded were performed, and the report prepared by the undersigned.

INSTITUTE FOR FISHERIES RESEARCH

Carl L. Hubbs

Director

Report sent to Milton P. Adams