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UNITED STATES
DEPARTMENT OF THE INTERIOR
Harold L. Ickes, Secretary

Fish and Wildlife Service
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Special Scientific Report No. 13

INDUSTRIAL AND ORGANIC POLLUTION OF THE BUFFALO RIVER, BUFFALO, NEW YORK

By

B. A. WESTFALL

Chicago, 1943

This is the thirteenth in a series of mimeographed Special Scientific Reports, published in limited quantities for the official use of Federal offices and cooperating agencies. The reports present the guides for administrative and legislative action. In many instances the data will be incorporated in complete scientific publications that will be printed and released at a future date. Previous reports in this series are as follows:

1. Pollution of Coeur d'Alene River and adjacent waters by mine wastes, by M. M. Ellis.

2. Water purity standards for fresh-water fishes, by M. M. Ellis.

3. Stream pollution studies in the State of Mississippi, by M. M. Ellis.

4. Report on Pensacola Dam impoundment of the Grand River with special reference to fishery problems in the completed reservoir, by M. M. Ellis.

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7. Pulp-mill pollution of the Rainy River near International Falls, Minn., by B. A. Westfall and M. M. Ellis.

8. A study of the Mississippi River from Chain of Rocks, St. Louis, Mo., to Cairo, Ill., with special reference to the proposed introduction of ground garbage into the river by the City of St. Louis, by M. M. Ellis.

9. Pollution studies of effluents from the Dickinson Salt Works, Malden, W. Va., by M. M. Ellis.

10. An investigation of fish-salvage problems in relation to Shasta Dam, by H. A. Hanson, O. R. Smith, and P. R. Needham.

11. Pollution survey of the Cumberland River in the vicinity of Nashville, Tenn., August 1936, by M. M. Ellis and B. A. Westfall.

12. Mine-waste pollution of Bear Butte Creek, Black Hills, South Dakota, by M. M. Ellis.

INDUSTRIAL AND ORGANIC POLLUTION OF THE BUFFALO RIVER, BUFFALO, NEW YORK[1]

By
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INTRODUCTION

At various times during the last ten years pollution catastrophes of considerable magnitude affecting aquatic life have been noted in the Niagara River in the vicinity of Buffalo, N. Y. (fig. 1). On November 14, 1937, large fish died by the thousands and minnows and fingerlings by the millions resulting in a loss of hundreds of tons of fish (Symons, 1938). Two unfortunate recurrences of these mass killings of river fish were reported later, namely, November 27 and December 18, of the same year. Following these catastrophes dead fish were observed floating in the Niagara River for miles downstream, some even being carried into Canadian waters off Toronto, Ont.

As these three disasters seemed to be traceable directly to pollution from the Buffalo River, the U. S. Commissioner of Fisheries detailed Dr. M. M. Ellis, Senior Aquatic Physiologist, U. S. Bureau of Fisheries to Albany, N. Y., for a conference with Mr. Lithgow Osborne of the State Conservation Department, to plan a study of this particular pollution problem at Buffalo, N. Y.

On Febeuary 19, 1938, Dr. M. M. Ellis proceeded from Albany to Buffalo where in company with Mr. Willard E. Tillman, District Game Protector of the State of New York, a field survey of the Buffalo River, the Niagara River and adjacent waters was made. Dr. Ellis and Mr. Tillman listed the various effluents which were being emptied into the River, inspected most of the plants involved and collected series of samples which were shipped to the U. S. Bureau of Fisheries Laboratories at Columbia, Mo., for analyses and bioassay tests. While in Buffalo, Dr. Ellis and Mr. Tillman visited the Bird Island Laboratory and obtained much helpful information from Dr. G. E. Symons, Chief Chemist, Buffalo Sewer Authority. Subsequently both Mr. Tillman and Dr. Symons sent additional samples to the Columbia Laboratories which, together with those samples collected by Dr. Ellis at Buffalo, formed the basis of a preliminary investigation of the problem.

During the week of November 25, 1938, the writer and three assistants operating from a laboratory truck provided with suitable equipment for

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[1] Submitted June 11, 1940.

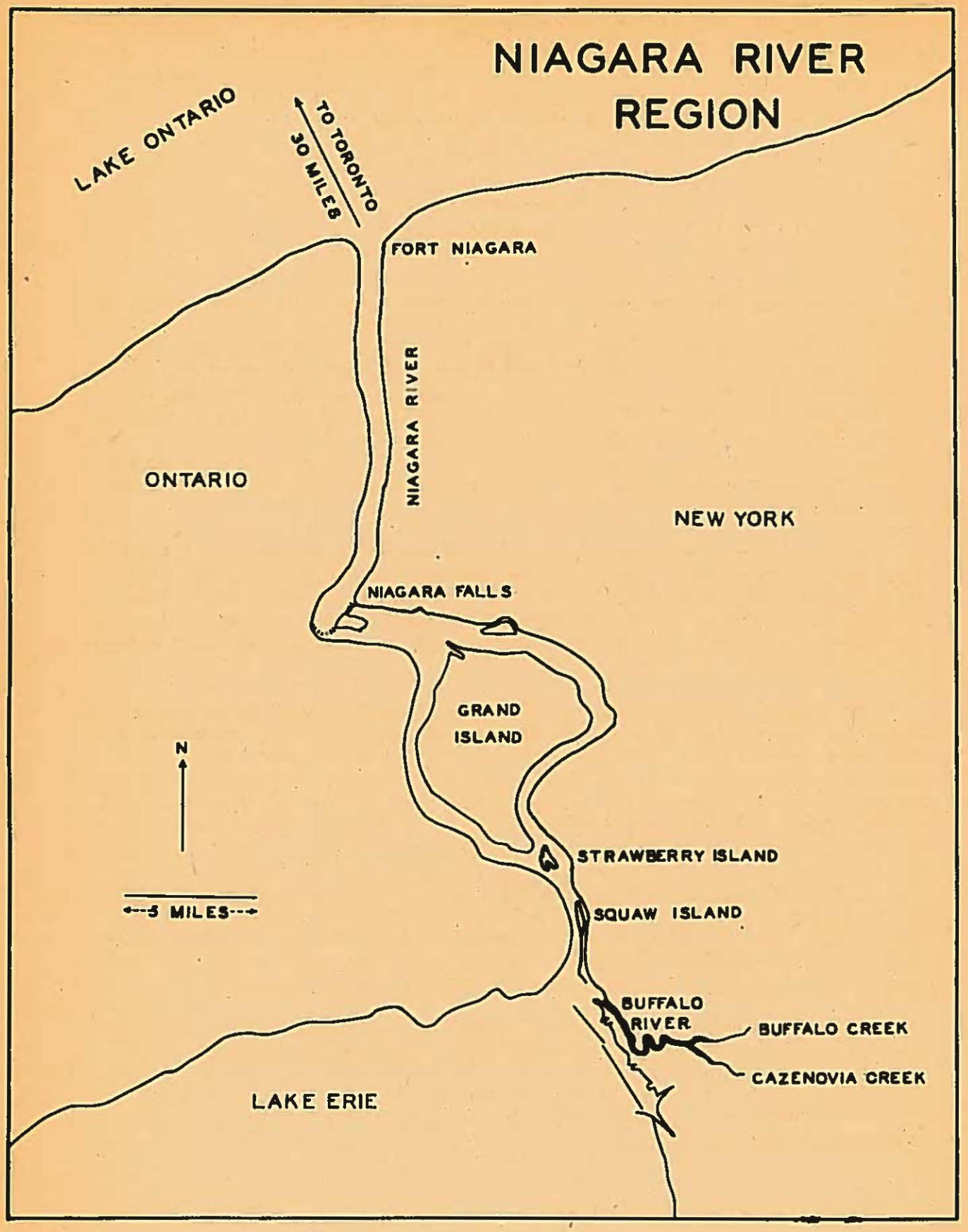
NIAGARA RIVER
REGION
LAKE ONTARIO
TO TORONTO
30 MILES
FORT NIAGARA
NIAGARA RIVER
ONTARIO
NEW YORK
NIAGARA FALLS
GRAND
ISLAND
N
STRAWBERRY ISLAND
5 MILES
SQUAW ISLAND
BUFFALO
RIVER
BUFFALO CREEK
CAZENOVIA CREEK
LAKE ERIE

FIGURE 1

various analyses and the collection of samples for laboratory tests and assays, made a detailed study of Buffalo River and various wastes which it was receiving. In addition to the field work, river waters, muds, and industrial effluents were collected and preserved for further chemical and bioassay analyses in the laboratories at Columbia, Mo.

Inasmuch as water conditions vary greatly with different seasons of the year Mr. G. C. Rau, Assistant Biological Aid, U. S. Bureau of Fisheries, and two assistants returned to Buffalo the following summer during the week of June 26, 1939, with a laboratory truck and equipment and collected additional series of samples at specific locations for a comparison with the data obtained from the previous work of Dr. Ellis and the writer. A final check on the condition of Buffalo River was made in early June, 1940.

All of these field operations were greatly facilitated by the cooperation of the New York Conservation Department which at times furnished a motor boat, as well as a boatman and a game protector who were familiar with the local problems and therefore were very helpful in locating and collecting the industrial effluents.

METHODS

Water samples were collected with a standard Foerst modification of the Kemmerer brass water sampler. Effluents were collected in glass-stoppered bottles. All samples which were returned to the central laboratories for analyses, i.e., waters, effluents and muds were carried in glass-stoppered bottles or glass-topped fruit jars without metal contacts.

The relative acidity (pH) of all waters and effluents was determined by means of the Beckman glass electrode. Colorimetric methods were used only when rapid field determinations on clear waters were to be made, and then only with fluids standardized against the glass electrode.

Specific conductance was measured with standard conductance cells in a microhummer circuit. All readings were corrected for temperature and reduced to 25° Centigrade.

The analytical procedures followed the standard methods of the American Public Health Association as far as possible. For many of the assays special methods described in current scientific literature or as developed at the Columbia Laboratories were used.

INDUSTRIAL EFFLUENTS ENTERING BUFFALO RIVER

In the following pages the various effluents which were being poured into the Buffalo River during the several field trips to Buffalo River area are considered in order, beginning with the flume farthest upstream (fig.2).

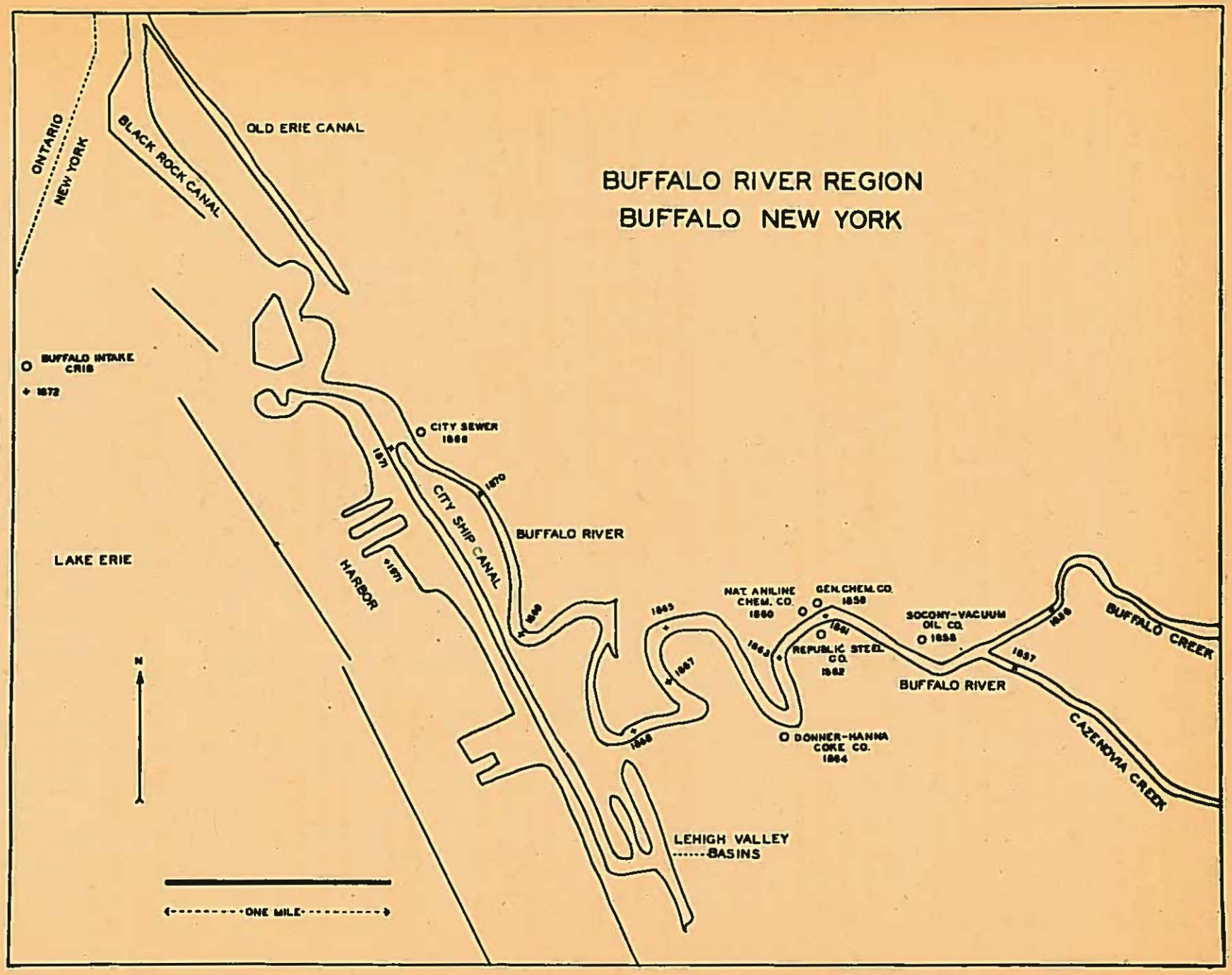
BUFFALO RIVER REGION
BUFFALO NEW YORK
ONTARIO
NEW YORK
BLACK ROCK CANAL
OLD ERIE CANAL
BUFFALO INTAKE CRIB
1872
LAKE ERIE
CITY SEWER
1868
1871
1870
CITY SHIP CANAL
BUFFALO RIVER
HARBOR
1871
1869
1865
1867
1866
NAT. ANILINE CHEM. CO.
1860
GEN. CHEM. CO.
1858
1861
1863
REPUBLIC STEEL CO.
1862
SOCONY-VACUUM OIL CO.
1858
1856
1857
BUFFALO RIVER
BUFFALO CREEK
CAZENOVIA CREEK
DONNER-HANNA COKE CO.
1864
LEHIGH VALLEY
BASINS
N
ONE MILE

FIGURE 2

It has not been deemed necessary to present and discuss in detail the voluminous data which have been accumulated in the course of these investigations both from the field work and from the laboratory analyses and assays. However, representative data from specific analyses of samples collected on dates indicated concerning particularly pertinent conditions have been summarized in tables 1, 2, and 3.

1. The Socony-Vacuum Oil Company (Lno. 1858)[2/] had one large flume about 4 feet in diameter carrying a stream of waste fluid approximately 8 to 10 inches deep and emptying into the Buffalo River, a little over a quarter of a mile below the junction of Buffalo and Cazenovia Creeks. The effluent discharged from this flume carried a large amount of oil and gave off a gaseous, creosote-like odor. This waste had a pH of 6.32 (table 1) and a specific conductance of 509 mho x 10^{-6} at 25° C., which values are well within the limits tolerated by fish life.

Bioassays of this effluent revealed no lethal effects on goldfish subjected to 10-day tests in dilutions of either 1:1,000 or 1:100, but in 1:100 dilutions of this waste fish became sluggish and displayed definite loss of equilibrium. Although the fish did not die during a 10-day exposure to the 1:100 dilution of the Socony- Vacuum Oil Company effluent, this waste produced definite changes in the physiological condition of these fish. When confined in the effluent mixture (1:100) the fish not only showed the disturbances of equilibrium noted above, but developed marked anorexia (lack of appetite) and refused food. Ultimately, a continuance of this reaction on the part of the fish would result in death. When killed at the end of 10 days for autopsy, these fish were definitely in poor condition as regards strength, activity, and nutrition, and their flesh gave off a disagreeable odor of oil, which would have rendered them unfit for human consumption had they been food fishes. The absorption by fish of substances causing a disagreeable oily or phenolic taste from oil-polluted waters has been reported by various workers and has been confirmed in tests at the Columbia, Mo., Laboratories of the U. S. Bureau of Fisheries.

In general, the most striking responses by the fish themselves to oil pollution are those enumerated above, namely, disturbances of the central nervous system and of the gastro-intestinal tract. The effects of the effluent from the Socony-Vacuum Oil Company's plant at Buffalo were, therefore, not unusual for oil wastes and showed clearly the toxic nature of this particular waste to fishes and other aquatic organisms.

In addition to the specific toxic effects just discussed, oil wastes produce films on the surface of the water thereby preventing the oxygen of the air from entering the water; kill out marginal and stream vegetation essential to the production of certain types of fish food; and blanket the bottom of the stream bed eliminating all food for fishes from that part of

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2/ Lno. = Locality No.

the aquatic complex. In the case of Buffalo River, from the point of entrance of the effluent released by the Socony-Vacuum Company flume to the mouth of this river at its junction with the Niagara River the banks on both sides of the stream were devoid of vegetation, and were black and oily several inches back from the water. Bottom conditions in that sector of Buffalo River were such that no bottom organisms were found in the bottom mud which was black with an oily sludge and seemed entirely devoid of living plants or animals. If the Socony-Vacuum Oil Company were the only concern emptying an effluent into Buffalo River the pollution from that source alone would probably be sufficient to: (1) kill out all fish food in the stream below the point of entrance of this waste; (2) produce conditions intolerable for young fish, and (3) affect detrimentally the general physiological condition of any larger fish which might stray into this stream from the Niagara River.

It must be noted in this connection that oil and grease from the numerous steamers and other commercial vessels entering the Buffalo River also contribute to the oil pollution of the river bottom and marginal area, particularly since the river is very narrow. However, oil pollution of the Buffalo River from the boats navigating this stream is of trivial magnitude compared with that traceable to the Socony-Vacuum Oil Company's plant.

2. The General Chemical Company (Lno. 1859) was discharging its wastes into the river through seven of eight different outlets, all of which were sampled with the assistance of Mr. C. W. Long, superintendent of the plant. According to company officials these seven outlets discharged only cooling water from the various coils of the acid towers of the plant and contained no added material other than a little sewage from the sales office toilets and such acid as might be spilled accidentally during plant operations. For the purpose of identification in connection with this investigation the effluent pipes were numbered from 1 (upstream) to 8 (downstream). The third pipe carried no effluent at this time.

Analyses of these samples revealed an acidity of pH 1.73, 2.93, 3.50, 5.60, and 5.50, for samples 4, 5, 6, 7, and 8 respectively, (table 1). All of these effluents were more acid than pH 6.0 which is near the limit of acidity compatible with favorable conditions for fish life, and samples 4, 5, and 6 were so acid as to be well below the lethal limit of acidity for fresh-water fish life, (circa pH 4.0). The specific conductance in all of the samples except No. 1 was definitely greater than that of either Buffalo Creek or Cazenovia Creek and corresponded to the increase in acidity. However, only the samples from No. 4 and No. 5 would be considered exceptionally high from the standpoint of ionizable salts if the solution into which the effluent were discharged were well buffered. Effluent No. 4 was by far the most acid (pH 1.73) and had a very high specific conductance 6,980 mho x 10^{-6} at 25° C., either characteristic being especially dangerous to aquatic life if the effluent were placed in a poorly buffered stream like Buffalo River.

As can be seen in table 1, effluent No. 4 from this plant carried a considerable quantity of acid, amounting to 41 milliequivalents, which acid would require much dilution or definite neutralization before it would cease to be a marked acid hazard to aquatic life.

Bioassay tests of these effluents on goldfish in well-buffered tap water showed no lethal effect in a dilution of 1:100 or greater. Such results suggest that the danger to fish life in these effluents is easily overcome by simple dilution and neutralization of excess acid present. However, the acid pollution is a definite hazard unless it is corrected by proper steps. For example, nitric acid (which is probably the chief offender in these effluents, with some sulphuric acid) in tap water in sufficient quantity to bring the pH to 4.4 has been shown to kill the minnow, Leuciscus phoxinus, in a few hours (Carpenter, 1927). Ellis (1937) has shown that most of the mineral acids kill first through coagulation and precipitation of mucous on the gills and in more acid conditions will coagulate the gill membranes themselves. Sulphuric acid is even more toxic than nitric acid, as shown by the fact that 59 p.p.m. in soft water have been found to kill Carassius auratus, in about one hour (Ellis, 1937). The effluents from the General Chemical Company's plant, therefore, represent a definite hazard to fish life and should be diluted sufficiently or neutralized before they are discharged into the river.

Since plant officials admitted that from time to time acid was lost accidentally through these flumes and both Dr. Ellis and the writer were informed that these losses had amounted to several hundred gallons at various times during the past, the effluents from the General Chemical Company must be regarded with concern as regards the pollution of Buffalo River, until corrective and preventive steps are taken by the plant. Relatively small quantities of strong acid can produce lethal conditions in a considerable portion of a stream like Buffalo River, and although these conditions may cease to be dangerous to aquatic life after a few days or even a few hours, as long as they exist they can readily produce a catastrophe which the fish and other organisms some distance downstream cannot survive. Besides sudden changes in acidity to even a sublethal point as far as the acid itself is concerned, may enhance the action of other detrimental conditions and through this synergistic action suddenly kill large numbers of fish.

3. The National Aniline and Chemical Company (fig. 3) had nine effluents coming from pipes set in a concrete wall along the river bank. The dye wastes were all heavily colored and were quite hot as they entered the river, temperatures ranging from approximately 50 to 75° C. (122 to 167° F.). The bank of the river below the dye works was discolored with dye waste deposits and the water of the stream had a saffranine red shade. The effluent entering at a point farthest downstream had an unpleasant odor of rubber and carbon tetrachloride. Samples from outlets 1, 7, 8, and 9, were very acid as shown by pH readings 1.52, 1.89, 2.48, and 2.59 respectively. The wastes from the other outlets were within the range of relative

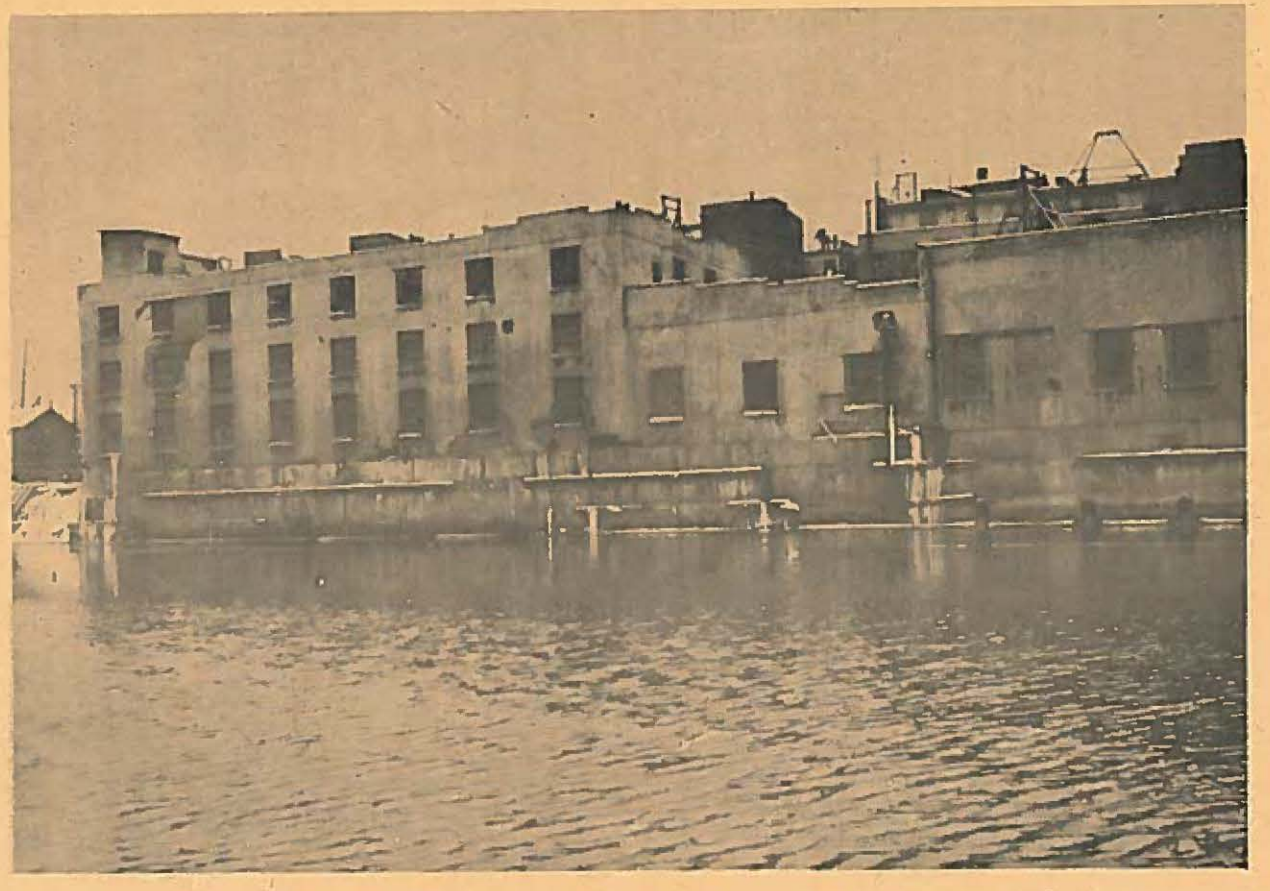

Figure 3. — The National Aniline and Chemical Company's plant on the Buffalo River, Buffalo, New York. One of the industrial plants which empty relatively large volumes of wastes directly into the river through several outlets.

acidity tolerated by fish life. The effluents which had a high degree of acidity as mentioned above also had a high specific conductance indicating a large amount of ionized material, especially Nos. 1 and 7, the specific conductances of which were 20,800 mho x 10^{-6} at 25° C. and 4,860 mho x 10^{-6} at 25° C., respectively. The remaining effluents had specific conductances from two to three times as high as the Buffalo Creek and Cazenovia Creek above the polluted area. Effluents 1, 7 and 8 had high milliequivalent values for contained acid, and all of the effluents from this plant except Nos. 5 and 6 would require marked dilution or neutralization to reduce their respective acid hazards alone.

Bioassay tests on these effluents collected November 25 and 26, 1938, when diluted to 1:100 showed Nos. 1, 2, 3, 4, and 5 lethal for the goldfish in 10 days. The rest of the effluents collected from this company on those dates were not lethal to goldfish in dilutions of 1:1,000 or greater. However, other studies of these aniline dye effluents showed great variability in toxicity, a fact which has been established for similar effluents from other aniline dye plants in various parts of the United States, as assayed by the U. S. Bureau of Fisheries laboratories. The figures given, therefore, for the November 1938 samplings of the National Aniline Company's effluents have been recorded here intentionally as representing minimal toxicities of these effluents.

4. The Republic Steel Corporation had three outlets for waste materials flowing into the Buffalo River (fig. 4). None of the samples taken was lethal to goldfish in dilutions of 1:100 or greater although the specific conductance of the effluents was somewhat higher than that of Buffalo River at the point where the wastes enter the stream.

Although no lethal effects of the effluents were noticeable at the time the samples were collected most of the iron salts are quite toxic to fish in small quantities if present in soft water. Clark and Adams (1913) found that less than 1 p.p.m. ferric sulfate killed shiners, carp, and suckers in 12 to 24 hours, while 2.9 p.p.m. ferrous sulfate in distilled water was lethal to the same types of fishes in 24 hours or less. However, Ellis (1937) has shown that the situation is quite different in hard water, since 100 p.p.m. of ferrous sulfate in such water were apparently not harmful to goldfish in a 96-hour exposure, although in strong enough concentrations, 1,000 p.p.m. proved fatal to goldfish in a few hours. (See Lno. 1862 for location of this plant.)

5. Donner-Hanna Coke Company (Lno. 1864). This concern had only one outlet emptying into the Buffalo River. The waste was of a very dark color, had a disagreeable odor of creosote and coal gas and was believed to be "very poisonous" by the local people in the vicinity of the plant. Many coke and gas companies (and possibly this one at times) discharge pyridine, quinolines, creosotes, cyanides (Tupholme, 1933) and various other wastes, which if in sufficient quantity will kill fish (Shelford, 1917; Powers, 1917; Demyanenko, 1931). Often these wastes from coke and gas plants, when

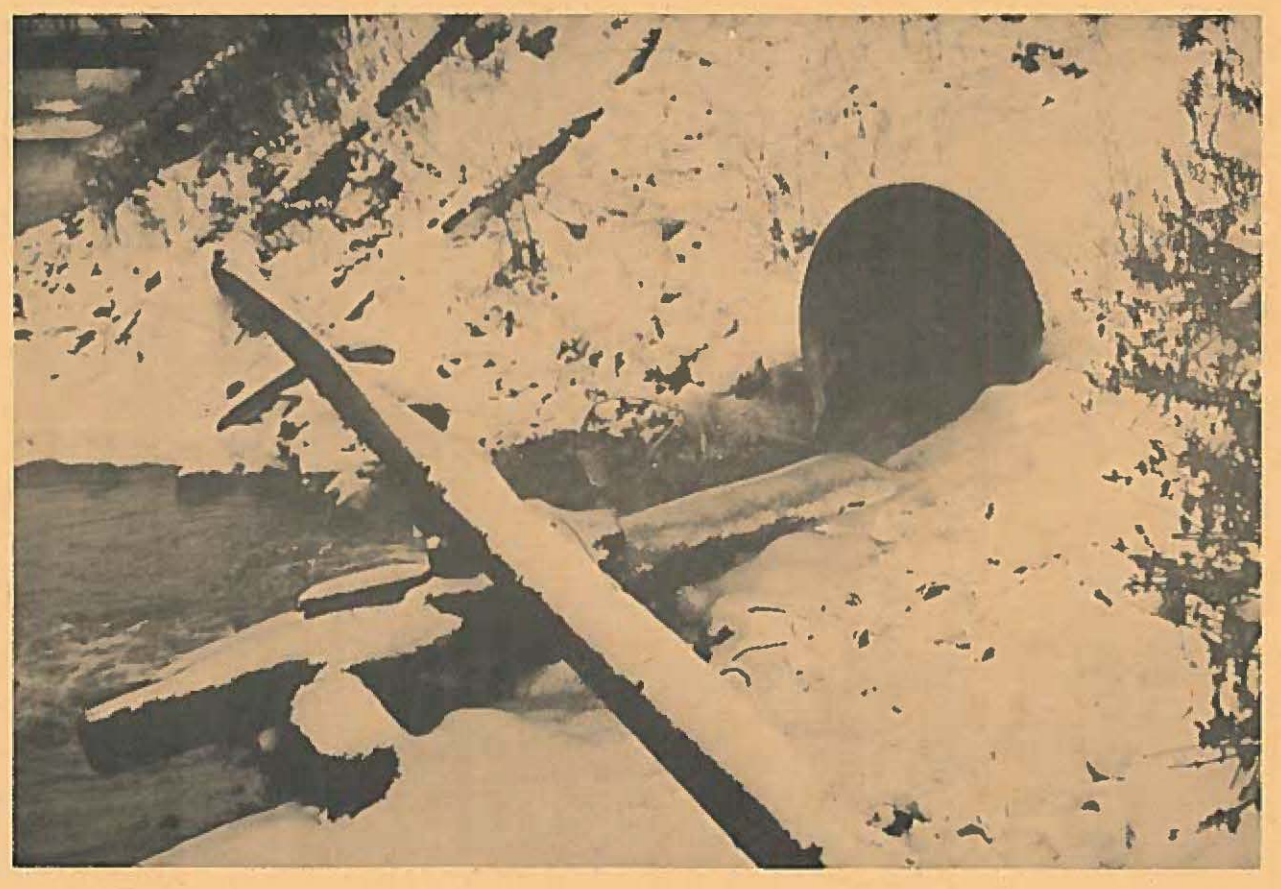

Figure 4. — Outlet carrying effluent No. 1 from the Republic Steel Company's Buffalo, New York, plant into the Buffalo River. Several companies in this area flume their wastes 60 yards or more into the river.

not present in sufficient quantities to be lethal to fish, even in very small quantities produce very undesirable tastes in the flesh of fish which are thereby unsuitable for human food. Fish exposed to high dilutions of the Donner-Hanna effluents showed incoordination and their flesh developed a phenolic odor.

Effluents from coke plants have been studied extensively (as noted above) and are known to be both highly poisonous to aquatic life, at times, and also very variable in composition. Because the effluent from the Donner-Hanna plant was found to be typical of coke plants, it should be regarded as a potential hazard of great magnitude to fish life.

MISCELLANEOUS POLLUTANTS

1. Buffalo City sewer, which empties into the Buffalo River opposite the mouth of the city ship canal, carried a waste fluid typical of unoxidized sewage as to odor, general appearance, and oxygen demand. This sewer, one of several emptying into the Buffalo River, contributes a large amount of organic material to the river thereby increasing the already heavy organic load carried at this point. Inasmuch as the Buffalo River was carrying sewage from about 75,000 people (Symons, 1938) the well known detrimental effects of such volumes of sewage need not be summarized here. The biological oxygen demand is very high for sewage; many breakdown products are deleterious to fish and fish food; and diseases are more common in fish inhabiting sewage-polluted waters than among fish in unpolluted streams.

In sewage-polluted streams ammonia, one of the chief breakdown products of sewage wastes, is a serious hazard to fish life being lethal to goldfish in hard water at a concentration of only 2.5 p.p.m. (Ellis, 1937). Even if the breakdown products of organic sewage were not toxic the mechanical effects of the suspensoids which sink to the bottom and blanket it to the extent of killing out much of the bottom fauna, must be considered. In addition, sewage when mixed with oil pollution (as noted under Socony-Vacuum Company) becomes a very great hazard to aquatic life because the regular decomposition of the organic material is altered by the admixed oil and anoxic conditions persist much longer than when the sewage is unmixed with oil.

2. From various elevators many wheelbarrow loads of dust, chaff, and debris frequently were dumped directly into the river. These wastes further increased the organic load and resultant drain on the dissolved oxygen in the water.

3. Boats navigating Buffalo River contribute to the amount of waste in this river as much organic material was swept or shoveled directly into the river while these vessels were being prepared for loading. The constant

activity of boats in this stream creates another hazard which is probably more severe than that of direct pollution mentioned above, that is, the heavy load of organic material and oily sludge which is on and near the bottom of the Buffalo River is agitated frequently by the propellors of the large boats so that water low in oxygen and rich in these wastes and debris is mixed into the cleaner water near the surface, the resulting mixture being almost devoid of dissolved oxygen.

4. The old canal at the point where it crosses Ferry Street was sampled to determine whether some toxic material might be entering Niagara River by way of this stream. However, it was found that the pH, the oxygen (although somewhat low) the fixed carbonates, free carbonates, and specific conductance were all within normal range for fish life. Inasmuch as the samples from the canal thus collected were not lethal to goldfish placed directly in them, it can be concluded that the material entering the Niagara River from this canal at the time of this investigation was not lethal to the fish.

5. The Iroquois Gas and Coke Company was discharging no effluents into Buffalo Creek at the time of these investigations. However, were this plant to pour its effluent into Buffalo River, the hazards to aquatic life would be the same as those discussed under Donner-Hanna Coke Company.

RIVER CONDITIONS

Detailed data representative of river conditions that support the following discussion are presented in tables 2 and 3.

The waters of Buffalo Creek at Elk and Seneca Streets about one half mile above the junction with Cazenovia Creek had a pH of 6.6; dissolved oxygen content of 5.7 p.p.m.; fixed carbonates, 16.05 cc. per liter; free carbonates, 2.48 cc. per liter; and specific conductance of 418 mho x 10^{-6} at 25° C. all of which are within the normal range for waters in which good fish faunae may be found in many unpolluted streams. Buffalo Creek at this point was about 100 feet wide. The banks were rather black with an oily incrustation which was hard and seemed to have been deposited there at least several weeks to months previously. Local people reported that this material had come downstream from the Iroquois Gas and Coke Company or had backed up the Buffalo River into Buffalo Creek from the Socony-Vacuum Company's plant (Lno. 1858).

However, upon investigation at the Iroquois Gas and Coke Company, Mr. W. Graves, assistant superintendent, informed the writer that there was no effluent entering Buffalo Creek from the Iroquois Gas and Coke plant at that time, and that months had elapsed since any effluent had been poured into Buffalo Creek by the Iroquois Gas and Coke. Besides, there would be no future pollution of Buffalo Creek by this plant as the Iroquois

TABLE 1. - Physical and chemical characteristics of industrial effluents entering the Buffalo River. November 25, 1938.

Lno.	Name of Concern	Color of effluent	pH	Milli-equivalents of acid*	Specific Conductance mho x 10^{-6} at 25° C.
1858	Socony-Vacuum Oil Co.	Brownish	6.32	1.6	509
1859	General Chemical Co.				
	Effluent 1	Colorless	7.39	---	382
	" 2	Yellowish	7.19	---	516
	" 3	---	----	---	---
	" 4	Colorless	1.73	41.0	6,980
	" 5	Pale brown	2.93	4.4	877
	" 6	Yellowish brown	3.50	4.0	646
	" 7	Brownish	5.62	2.4	598
	" 8	Brownish	5.51	2.4	560
1862	Republic Steel Co.				
	Effluent 1	Blackish	5.59	5.2	1,305
	" 2	Reddish brown	6.69	4.4	1,223
	" 3	Blackish brown	6.12	5.6	946
1860	Nat.Aniline Chem. Co.				
	Effluent 1	Purplish black	1.52	67.2	20,800
	" 2	Blackish	6.70	2.0	810
	" 3	Pinkish	6.00	2.8	738
	" 4	Pinkish	6.17	2.8	862
	" 5	Brownish	7.25	---	920
	" 6	Brownish	7.10	---	1,000
	" 7	Brown	1.89	27.6	4,860
	" 8	Blackish	2.48	11.2	2,090
	" 9	Reddish-Brown	2.59	5.2	1,404
1864	Donner-Hanna Coke Co.	Blackish brown	6.55	2.9	1,382
1866	City Sewer**	-----	6.78	0.2	727

* U. S. P. H. Standard, 1938.

** For comparison with industrial effluents.

Gas and Coke Company had installed a new sewage system which connected directly with a new city sewer line emptying into Niagara River. At the time of these investigations the Iroquois plant was not running and had been shut down for months hence no samples of effluent were available from that concern.

Mr. G. C. Rau, on June 29, 1939, found much oil on the banks of Buffalo Creek and a thin film of oil on the water of this stream. The contaminations apparently had backed up from the Socony Vacuum Company as the water level in Buffalo Creek was fluctuating due to the movements of large boats in Buffalo River, changes in wind, and variations in the water level in Lake Erie.

Cazenovia Creek, 200 yards above its junction with Buffalo Creek was about 50 feet wide. In this stream the pH, oxygen, carbon dioxide (free, fixed and half-bound) and specific conductance of the water (table 2) were well within the limits which ordinarily support fish life. The banks of this creek were oily, however, but less so than those of Buffalo Creek.

From the point where Cazenovia Creek flows into Buffalo Creek, Buffalo River proper was studied at strategic points above and below the points at which the major industrial effluents entered this river.

Buffalo River is a very slow moving, sluggish stream approximately 20-25 feet in depth. At the time of these various investigations it had a strong odor of oil and creosote and a dark color. The banks from above the Socony-Vacuum Oil Company plant (Lno. 1858) to the mouth of the river were definitely oily and the bottom was covered by a black oily sludge. No living organisms, not even those which live in mildly polluted waters, were seen in any of the mud samples dredged from the bottom of Buffalo River nor along the water edge at any point in this area.

The pH of the waters of Buffalo River (table 2) varied between 6.4 and 7.3 regardless of the effluents. The specific conductance increased about 100 per cent, that is, from 418 mho x 10^{-6} at 25° C. at Buffalo Creek at 838 mho x 10^{-6} at 25° C. at a point opposite the entrance of the middle outlet of Republic Steel Company. However, when the various effluents were thoroughly mixed with the river water the specific conductance of the stream decreased at the mouth of Buffalo River to 518 mho x 10^{-6} at 25° C. or only about 20 per cent higher than the water above the Socony Vacuum Company's flume. The dissolved oxygen at the surface of the River varied between 2.9 p.p.m. and 8.7 p.p.m. depending upon the amount of stirring by boats moving in the stream. For example the oxygen at Bridge No. 3 was 8.7 p.p.m. but at Ohio Street just a short distance away 5 minutes after a large lake freighter drawing 19 feet of water had passed the dissolved oxygen dropped to 2.9 p.p.m. at the surface. These low oxygen readings obtained at the surface confirmed the anoxic conditions noted in the bottom samples, which were practically oxygen free.

TABLE 2. - Physical and chemical characteristics of the Buffalo River, November 25 and 26, 1938

Lno.	Locality	Dissolved oxygen p.p.m.	pH	Milli-equivalents of acid*	Specific conductance mho x 10^{-6} at 25°C.
1856	Buffalo Creek at Elk and Seneca Streets				
	Surface	5.7	6.6	0.4	418
1857	Cazenovia Creek, 200 yds. above junction with Buffalo Creek				
	Surface	7.7	7.6	---	359
1861	Buffalo River at Abbot Road Bridge				
	Surface	8.0	7.3	---	640
	Bottom	Less than 1.0			
1863	Buffalo River opposite Republic Steel Company				
	Surface	5.6	6.6	1.2	838
	Bottom	Less than 1.0			
1865	Buffalo River at N. Y. Central Bridge				
	Surface	7.2	6.5	0.8	803
	Bottom	Less than 1.0			
1867	Buffalo River at Bridge Number 3.				
	Surface	8.7	6.4	0.7	726
	Bottom	Less than 1.0			
1868	Buffalo River at Superior Elevator Company				
	Surface	4.2	7.0	---	578
	Bottom	Less than 1.0			
1869	Buffalo River at Ohio Street Bridge				
	Surface	2.9	6.6	0.8	577
	Bottom	Less than 1.0		-	

* U. S. P. H. Standard.

TABLE 2. (Continued) - Physical and chemical characteristics of the Buffalo River, June 29, 1939

Lno.	Locality	Dissolved oxygen	pH	Milli-equivalents of acid*	Specific conductance mho x 10^{-6} at 25°C.
1870	Buffalo River at Michigan Ave.				
	Surface.....	6.6	6.8	0.8	518
	Bottom.....	Less than 1.0			
1871	City Ship Canal near Dakota Elevator Co.				
	Surface.....	2.9	7.0	---	462
	Bottom.....	Less than 1.0			
1856	Buffalo Creek at Elk and Seneca Streets				
	Surface.....	5.6	7.1	---	441
1857	Cazenovia Creek, 200 yds. above junction with Buffalo Creek				
	Surface.....	3.8	7.4	---	354
1861	Buffalo River at Abbot Road Bridge				
	Surface.....	Less than 1.0	5.3	1.4	1,357
	Bottom.....	Less than 1.0	6.3	1.6	1,217
1867	Buffalo River at Bridge No. 3				
	Surface.....	Less than 1.0	6.4	0.6	726
	Bottom.....	Less than 1.0	6.6	0.3	563
1869	Buffalo River at Ohio Street Bridge				
	Surface.....	Less than 1.0	6.4	0.6	1,430
	Bottom.....	Less than 1.0	6.4	0.3	1,297
1870	Buffalo River at Michigan Avenue				
	Surface.....	Less than 1.0	6.4	1.0	1,221
	Bottom.....	Less than 1.0	6.3	0.8	925

* U. S. P. H. Standard.

The carbonates and the specific conductivity of the water above the industrial effluents were found to be rather low thereby marking this stream as normally a poorly buffered river. The data in table 1, which show some of the effluents from the General Chemical Company and National Aniline Dye Company, to have a higher specific conductance and acidity than the waters of Buffalo Creek, indicate that the increase in conductivity in Buffalo River is due definitely to the influx of material from those companies.

As water conditions, especially dissolved oxygen and specific conductance vary markedly with temperature, Mr. G. C. Rau and two assistants on June 29, 1939, selected strategic points for study of Buffalo River. Some of the results of this survey appear in table 2. At that time (June, 1939) the pH varied from 5.3 to 7.4 at the surface and from 6.3 to 6.6 near the bottom. As was expected the specific conductance, which is a measure of the load of ionized salts, had increased in June over the November readings and the dissolved oxygen content had fallen to less than 1 p.p.m. (actually zero in most cases), at all points where samples were taken in the river proper, both surface and bottom.

The study of effects of Buffalo River on Niagara River was made at various points starting a few hundred yards below the outlet of Lake Erie (fig. 1). It was found (table 3) that the relative acidity of Niagara River water decreased gradually from pH 7.6 at a point about 150 yards south of the city water intake in Lake Erie to pH 6.6, 4 miles above Niagara Falls. However, just below the Falls which afford marked aeration to the waters of Niagara River the pH was 7.2. The dissolved oxygen content decreased very definitely from 10.2 p.p.m. at Peace Bridge to 5.04 p.p.m. at Westside Ferry, and varied little from that point on down and even below Niagara Falls. It is quite probable that this marked decrease in dissolved oxygen content of the Niagara River water to approximately 50 per cent of that above the mouth of Buffalo River is due to the enormous quantity of organic and industrial wastes coming into Niagara River from Buffalo River. The specific conductance of Niagara River increased but slightly from 241 mho x 10^{-6} at 25° C. at the Lake Erie city water intake to 289 mho x 10^{-6} at 25° C. 4 miles above the Falls. The bottom and banks of Niagara River were carefully observed and were found to be clean and rocky throughout the entire area with here and there some sand and mud, with the exception of a few hundred yards on the downstream side of the DuPont Rayon Company, 2 miles downstream from the International Bridge.

DISCUSSION

Throughout these studies on the Buffalo River the objectives were not reviews of previous disasters in the Niagara River but the determination of existing pollution hazards in Buffalo River which might be expected to cause a repetition of these catastrophes in the Niagara River and the accumulation of sufficient data on which recommendations for preventive measures could be made.

TABLE 3. - Physical and chemical characteristics of Lake Erie and Niagara River Waters.

Lno.	Locality	Dissolved oxygen p.p.m.	pH	Milli-equivalents of acid*	Specific conductance mho x 10^{-6} at 25°C.
	November 25 and 26, 1938				
1872	Lake Erie near city water intake	9.7	7.6	---	241.0
1873	Niagara River at Peace Bridge	10.2	7.6	---	272.0
1874	Niagara River at International Bridge	9.4	7.2	---	264.0
1876	Niagara River at Westside Ferry	5.0	6.8	0.2	272.0
1878	Niagara River, 4 miles above Falls	6.4	6.6	0.2	290.0
1879	Niagara River just below Falls	5.7	7.2	---	288.0
	June 29, 1939				
1971	Lake Erie, Buffalo Harbor, Michigan Street Docks	5.8	7.1	---	281.0

* U. S. P. H. Standard

The physical characteristics of Buffalo River as brought out both by the field operations and laboratory analyses of samples collected under winter and summer conditions, are such that sudden serious pollution of the Niagara River by the Buffalo River can be expected at any time. Catastrophes similar to those of November and December, 1937, or of even greater magnitude will recur at irregular intervals in the Niagara River unless the introduction of wastes into Buffalo River be stopped.

Buffalo River normally has little current and has a channel in which the water stands over 20 feet deep. These two features together with the small surface area of this stream, which is less than 300 feet wide throughout its 5 miles of tortuous meanderings in an industrial district, not only make for stagnation but preclude all but a negligible reaeration of the water. It was not surprising therefore in view of the organic wastes which are given entrance into Buffalo River to find the dissolved oxygen in this stream almost wanting at all levels during the summer, and from the 3-foot level to the bottom during mid-winter.

However, Niagara River would not suffer greatly from the waters of Buffalo River even though Buffalo River be essentially devoid of dissolved oxygen and heavily polluted with industrial wastes were it not for another set of factors. Sudden rains swelling Buffalo Creek and Cazenovia Creek can flush out large masses of foul water from Buffalo River into the Niagara River, with of course disastrous results to the aquatic fauna of Niagara River. The magnitude of these disasters will depend upon the particular composition of the pollution load of Buffalo River at the time.

Similarly fluctuations in the levels of Lake Erie and of the Niagara River either can back up large masses of water into Buffalo River or can draw out huge slugs of polluted water from Buffalo River into the Niagara River with a surprising suddenness. Again, the effects of the sudden withdrawal of water from Buffalo River into the Niagara River will depend upon the specific pollution loads of Buffalo River at the time.

It has been argued that since fluctuations of water level in both the Buffalo and Niagara Rivers occur at irregular intervals without apparent catastrophes to the aquatic life in Niagara River that the pollution hazards of Buffalo River are not serious. The analyses and assays of samples from various stations in the Buffalo River and of various effluents entering this stream readily explain this apparent discrepancy.

Our analytical studies of the Buffalo River waters and effluents entering this stream show conclusively that the existing industrial concerns discharging wastes into Buffalo River provide at times sufficient quantities of either the substances themselves (as listed below) or their precursors, to produce concentrations of these compounds in Buffalo River which would kill readily large quantities of fish and other aquatic life if slugs of Buffalo River water were suddenly moved into the Niagara River. From our

analyses the following substances have been determined as occurring in Buffalo River waters in sufficient quantities at times to be highly toxic to fish, namely, cyanides; phenols, cresols, and other tar extractives; benzol derivatives; hydrogen sulphide, organic sulphides and other sulphur derivatives; mineral acids; and oil extractives.

It must be pointed out that all of the substances just enumerated do not occur in Buffalo River waters at all times in lethal or even dangerous concentrations. The various effluents entering Buffalo River were very variable in composition but on occasion any or all of the substances enumerated above which can be derived from the effluents now entering Buffalo River may reach concentrations in Buffalo River waters lethal to fish and other aquatic life even if the Buffalo River waters were diluted extensively by Niagara River water.

In addition to the specific toxic substances which were found to occur at times in dangerous quantities in these various effluents, the oil pollution of the Buffalo River is a serious hazard not only in itself but also because it enhances the pollution of the River by organic sewages. Oil binds these organic wastes into undesirable sludges and greatly delays the oxidation of the enmeshed organic particles.

Even without the complications attendant on the oil pollution the sewage poured into Buffalo River is sufficient to cause a high oxygen demand and to reduce the dissolved oxygen of this sluggish river to practically zero.

The disastrous effects of slugs of Buffalo River water on the biota of the Niagara River when Buffalo River water is suddenly forced out or drawn into the Niagara River will depend therefore on the amount of any or all of the highly toxic substances derived from the effluents themselves, on the volume of oil sludge, and on the quantity of dissolved oxygen, present at the time in the Buffalo River water, when it enters the Niagara River.

Finally there is a biological factor which adds to the variability of the severity of the pollution catastrophe produced in the Niagara River by influx of water from the Buffalo River. Owing to a combination of many conditions such as food, wind, season, temperature, and current flow, fish move from Lake Erie into the Niagara River or out of the Niagara River into the lake, that is, there are times when the fish population of the Niagara River is large and also times when there are few fish in this stream. If a sufficient quantity of Buffalo River water moves into the Niagara River following a previous back up into Buffalo River, and if any toxic constituent of the effluents be high at the time, and if the fish population in the Niagara River be temporarily large, the catastrophe as regards fish life will be of major proportions, and the number of fish killed will be enormous. Even slight alterations of any of the variables just enumerated may greatly lessen the magnitude of the disaster, or it may pass unnoticed.

RECOMMENDATIONS

Owing to the physical features of Buffalo River enumerated in the discussion, if the existing systems of effluent and sewage disposal now practiced by the various industrial concerns along this stream be continued recurrences of major biological catastrophes in the Niagara River like those of 1937, are certain. Because of the geographic position of the Niagara River, such catastrophes have an international significance in that the fish and other aquatic organisms killed by pollution from Buffalo River can be readily carried, across the international boundary into Canadian waters. It is highly desirable, therefore, from the standpoint of boundary relations that these pollution disasters be avoided in the future. The disagreeable conditions and even health hazards which these disasters bring to the residents of the City of Buffalo and of the towns along the Niagara River are all too evident. There are consequently numerous justifications beyond any sentimental interest in fish life, which demand immediate action in the case of the Buffalo River pollution situation.

The following recommendations based on large masses of both field and laboratory data are made:

1. All human, domestic and organic sewage should be excluded from the Buffalo River. With the splendid system of trunk sewers which the City of Buffalo has, it seems inexcusable that sewage should be given access to Buffalo River, particularly in view of the known physical characteristics of that stream. However, in June 1940, both industrial and domestic sewage were still being poured into this River at various points.

2. All oil pollution should be excluded from the Buffalo River. The systems of settling basins and baffles in use by the Socony-Vacuum Oil Company were not adequate to remove all of the oil lost by this concern at the time of these investigations. As even small quantities of oil present a cumulative pollution problem in a sluggish stream like the Buffalo River, because oil is not readily destroyed on the bottom of such a stream, this condition should be corrected at once. The "clear" water from such settling and baffle systems should be well aerated if it is to be given entrance into the Buffalo River because our bioassay tests demonstrated the presence of various highly toxic oil extractives in the "clear" water from the Socony-Vacuum effluents. It would be much better as regards Buffalo River and probably more economical to run the "clear" water from these oil settling systems into the city sewer where dilution and flow would help dispose of these extractives.

3. The wastes from the General Chemical Company should be neutralized to pH 7.4 before being given entrance into Buffalo River. This concern should provide settling basins into which acids and other chemicals could be flumed in the event of accident or breakdown. Strong acids and other chemicals from this plant should not be poured into Buffalo River at any time.

4. All wastes from the National Aniline Company plant should be excluded from Buffalo River. Owing to the complex variable and frequently highly toxic nature of various wastes from this plant they present a very serious hazard to Buffalo River water conditions. Aniline wastes are notoriously dangerous to aquatic life and should be excluded not only from Buffalo River but from all streams, unless high dilution is accomplished. Under existing conditions at Buffalo the wastes from this concern should be deflected into the sewer system where these wastes would have the beneficial action of both dilution and stream flow.

5. The industrial wastes from the Republic Steel Company if properly neutralized to pH 7.4 are not particularly dangerous.

6. The effluents from the Donner-Hanna Coke Company should be excluded from Buffalo River and flumed into the sewer system. At times the wastes from this plant are highly toxic and much dilution and aeration will be required to reduce them to levels tolerated by aquatic life.

ACKNOWLEDGMENTS

The writer wishes to express his thanks and obligations to Dr. M. M. Ellis, In Charge Interior Fishery Investigations, U. S. Bureau of Fisheries, for his continued assistance and advice during these investigations; to Mr. Willard E. Tillman of the New York State Conservation Department for his cooperation in the field studies; to Dr. G. E. Symons, of the Buffalo City Sewer Authority for helpful information concerning the previous catastrophes in Niagara River; and to the staff of the Columbia, Missouri, Field Unit of the U. S. Bureau of Fisheries for painstaking analytical work both in the field and in the laboratories.

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