UNITED STATES
DEPARTMENT OF THE INTERIOR
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FISH AND WILDLIFE SERVICE
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Special Scientific Report No. 8

A STUDY OF THE MISSISSIPPI RIVER FROM CHAIN OF ROCKS, ST. LOUIS, MISSOURI, TO CAIRO, ILLINOIS, WITH SPECIAL REFERENCE TO THE PROPOSED INTRODUCTION OF GROUND GARBAGE INTO THE RIVER BY THE CITY OF ST. LOUIS

By

M. M. Ellis

Chicago, 1943

Explanatory Note

This mimeographed Special Scientific Report has been published in limited quantity for the official use of Federal offices and cooperating agencies. It presents the results of an investigation of specific problems and is intended as a guide for administrative and legislative action. The data may be incorporated in a complete publication to be printed and released at a future date.

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A STUDY OF THE MISSISSIPPI RIVER FROM CHAIN OF ROCKS, ST. LOUIS, MISSOURI, TO CAIRO, ILLINOIS, WITH SPECIAL REFERENCE TO THE PROPOSED INTRODUCTION OF GROUND GARBAGE INTO THE RIVER BY THE CITY OF ST. LOUIS[1/]

By
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TABLE OF CONTENTS

[1/] Submitted December 1934.

Introduction

At the request of Captain B. M. Harloe, U. S. District Engineer at St. Louis, a conference was arranged between Mr. J. J. Zebas, from the St. Louis office of the U. S. Engineers and the writer in Minneapolis on August 14, 1934, to discuss the proposed changes in garbage disposal by the City of St. Louis, Missouri, and the effect of these changes on river conditions in the vicinity of St. Louis and below. At this time it was decided to supplement the previous observations of the U. S. Bureau of Fisheries on this section of the Mississippi River by additional field and laboratory work as soon after September 10 as feasible. On September 12 a second conference was held in the office of Captain Harloe at St. Louis. This meeting was attended by Mr. F. J. McDevitt, Director of Streets and Sewers and Mr. W. Scott Johnson, Sanitary Engineer, City of St. Louis, both representing the City of St. Louis, Captain Harloe and Mr. Zebas representing the Engineer Corps and the writer, the Bureau of Fisheries. A tentative plan of action was agreed upon and the cooperation of the City of St. Louis secured in connection with the taking of the desired samples.

Following this conference a field party was organized at the Columbia Field Unit, U. S. Bureau of Fisheries and dispatched under the direction of Dr. Walter A. Chipman to Cairo, Illinois, with suitable equipment for field examinations, and arrangements made to return proper specimens to the Columbia Laboratories for additional examination. While this field party was at work a second party consisting of Mr. Bertis A. Westfall, Mr. W. G. Davis, and the writer proceeded to St. Louis. A laboratory was set up in one of the Engineer Corps buildings at the foot of Arsenal Street and arrangements made for the use of boats and apparatus on the river. Active field work at St. Louis was begun September 19. On September 21 Mr. McDevitt conducted a demonstration run of the new garbage grinding plant, near Vandeventer Avenue and Forest Park, opening the sewers and providing for the collection of various samples desired. These samples were taken at once to the laboratory at Arsenal Street where they were properly prepared for the subsequent examination at the Columbia, Missouri, Laboratories. Field work at St. Louis was continued through September, a detailed survey of the water front and of the river conditions between the Chain of Rocks Bridge and the mouth of the Meramec River being made through the use of Engineer Corps speed boats and personnel, assisting the three representatives of the Bureau of Fisheries. Such determinations as required immediate completion were finished at the Arsenal Street Laboratory. All material which could be prepared for subsequent study was removed by auto truck to the Columbia, Missouri, Laboratories.

The writer wishes to thank Captain Harloe and Mr. Zebas of the Engineer Corps for the complete cooperation of the Engineer Corps in this survey, and Mr. McDevitt and Mr. Johnson for opportunity to see the garbage grinding machine in action and for cooperation and personnel required in the collection of samples from the sewers of the City of St. Louis.

The Problem

Under existing arrangements the garbage of the City of St. Louis is collected in trucks and wagons, taken to the river front, loaded on barges and carried across the river and downstream to a hog farm. These arrangements were to be terminated early in 1935 owing to several complications, legal and otherwise. In addition to this disposal of city garbage, wholesale merchants, markets and other institutions handling large quantities of perishable foodstuffs have been dumping their wastes directly into the Mississippi River from a municipal dock near the foot of Chouteau Avenue. Besides these perishable substances which were placed in the river in various stages of decomposition it had also been the practice to dump packing material, sweepings from hay lefts, crates, paper and other discarded materials which collected in the course of a city's business, into the river. These pieces varied from small particles to objects the size of egg cases or larger. As part of the present plan of readjustment, Captain Harloe as District Engineer, issued an order effective September 24, 1934, prohibiting the dumping of any sort of material into the Mississippi River from the public dock just mentioned.

In view of these various needs and the changes to be made in the existing arrangements, the City of St. Louis proposed to pass all bonafide city garbage through garbage cutters of the "Hammermill" type which will reduce the various elements of garbage to particles 1-inch cube, or less. This ground garbage was to be flushed into the city sewers with a considerable volume of water and was to be carried into the Mississippi River through the sewers, that is, the ground garbage would be flushed directly into the sanitary sewers of the city and carried into the Mississippi River after traversing from 1 to 5 milesof sewer. It was proposed to establish several grinding plants and to introduce the garbage of the various districts of the city into the sewers serving each district so that no one sewer would carry the entire garbage load of the city. The regular domestic garbage of the City of St. Louis amounts to approximately 600 tons daily, according to information given by the city officials. It was proposed to exclude all wastes from wholesale houses, markets and large foodstuff concerns from these grinder mills so that the wastes must be disposed of by some other means since they are now prohibited from the river under the order of September 24, 1934.

The desirability of this proposed plan of garbage disposal -- the introduction of ground garbage directly into the Mississippi River via the sanitary sewers -- is open to discussion from several angles, but the aspects of the question which have immediate bearing on fisheries and aquatic-life problems are:

1. The additional pollution of the Mississippi River,
2. The pollution of lateral areas and shore zones,
3. The projection of these wastes downstream to the detriment of waters below St. Louis.

Field and Experimental Data

In order to attack these problems from the standpoint of Fisheries interests a survey of river conditions now existing between Cairo, Illinois and St. Louis, Missouri, was made, including the complications of sewage, industrial wastes, oil pollution and other known disturbing factors. Second, the waste material leaving the garbage grinder was assayed directly with reference to production of oxygen demand, liberation of gases and toxic substances detrimental to aquatic life. Third, consideration has been given to the various industrial effluents now reaching the river in the vicinity of St. Louis and the action of these substances correlated with the action of the additional load of organic matter which the ground garbage would place in the river. As a background for all of these studies data from the previous surveys of the Mississippi River between Cairo, Illinois, and Keokuk, Iowa, made from U. S. Quarterboat 348 have been utilized.

1. Present biochemical condition of the Mississippi River between St. Louis and Cairo.

a. Dissolved oxygen. -- As the City of St. Louis draws its municipal water supply from the Mississippi River near the Chain of Rocks that locality was taken as a starting point in the physical and chemical studies of the river water for this survey. The pollution of the Mississippi River by wastes from Alton, Illinois, and other cities above St. Louis and the addition of silt load and some wastes by the Missouri River above St. Louis have been considered for purposes of this discussion as part of the regular river complex since the City of St. Louis is not a contributor to these variables. Consequently water from the river at the Chain of Rocks, St. Louis, has been taken as the standard for downstream comparisons.

From table 1 (which indicates chemical conditions of the Mississippi River during the week beginning September 17, 1934, in the stretch of River between Chain of Rocks, St. Louis and Cairo, Illinois) it may be seen that the Mississippi River as it came to the City of St. Louis carried a little more than 7 parts of oxygen per million (7.14 p.p.m.). The limits of and the variation in dissolved oxygen in the vicinity of St. Louis will be discussed more in detail later, but the conditions in September will be followed first. Starting with a dissolved oxygen content of 7 p.p.m. this water received from the City of St. Louis in its 15 miles or more of water front a collection of effluents including the sewage of a city of a million inhabitants and the various wastes from numberous industrial concerns. In the immediate vicinity of St. Louis, that is, from a short distance below Chain of Rocks Bridge to Jefferson Barracks or slightly beyond the River receives the bulk of its waste load from the City of St. Louis and in this zone the dissolved oxygen content of the water dropped rather abruptly to a minimum of 4.8 p.p.m. As may be seen from the graph there is a distinct depression of the dissolved oxygen curve in the vicinity of the City of St. Louis. Owing to the volumes of effluents from the various sewers and the time required

Table 1. Averaged data for Mississippi River water. September 17-22, 1934

Locality No.	Name of place	Miles from Cairo	Depth	pH	Specific conductance x 10^{-6} at 25°C.	Fixed carbonates	Dissolved oxygen	Total ammonia
		miles	meters			cc. per liter	p.p.m.	p.p.m.
760	Chain of Rocks	190.9 above	1	7.53	342.7	16.99	7.14	0.24
"	" " "	"	5	7.53	370.0	18.90	7.14	0.36
761	Gingrass Creek	186.1	1	7.87	345.0	15.61	7.47	2.25
"	" "	"	4	7.79	340.6	15.08	6.59	0.58
762	Between Eads & McKinley Bridges	180.9	1	7.62	325.6	16.47	7.25	0.39
"	" " " "	"	5	7.56	319.6	16.13	7.03	2.12
770	100 yards below Eads Bridge	179.9	1	7.58	344.7	18.26	7.37	1.80
"	" " " " " "	"	4	7.79	348.3	19.10	7.58	0.58
307	Arsenal Street, St. Louis	177.0	1	6.90	320.8	15.10	4.80	1.28
763	Below M. P. car ferry, St. Louis	171.0	1	7.45	359.7	14.87	6.04	1.67
"	" " " " " " "	"	8	7.62	363.0	15.08	6.70	0.71
308	Jefferson Barracks, Missouri	169.7	1	6.90	378.3	20.90	5.30	1.67
759	Crystal City, Missouri	166.2	1	7.35	272.7	20.10	4.80	1.93
764	Twin Hollows, Missouri	165.9	1	7.70	365.5	15.22	5.94	0.96
"	" " "	"	7	7.26	369.8	14.91	6.15	1.54
767	Concrete Hurdle, Missouri	161.1	1	7.79	371.8	16.03	7.25	1.80
"	" " "	"	7	7.27	367.6	15.81	7.27	1.54
765	Waters Point Light	158.5	1	7.32	360.4	15.92	7.14	2.06
"	" " "	"	8	7.12	365.1	17.30	7.14	1.70
758	Ste. Genevieve, Missouri	125.3	1	7.50	378.6	26.40	6.00	2.83
757	Claryville, Missouri	109.0	1	7.50	372.5	26.80	5.40	3.86
756	Wittenburg, Missouri	81.4	1	7.60	372.5	26.80	5.20	2.60
315	Cape Girardeau, Missouri	52.0	1	7.50	389.3	27.20	4.80	2.60
753	Birds Point, Missouri	1.9	1	7.50	368.7		5.50	2.23
754	Wickliffe, Kentucky	4.3 below	1	7.45	222.6	15.10	6.60	1.28

for the mechanical mixing of these effluents with the River water the oxygen content of the River often varied within a few hundred yards, although a rather constant low level of dissolved oxygen was maintained to Crystal City or beyond. The reoxygenation of the river and the complete mixing of these various effluents resulted, however, in a rise in the dissolved oxygen in the vicinity of Kimmswick, Missouri, at which point the oxygen content of the river water was essentially the same as at the Chain of Rocks. The reoxygenation of the river at this point to almost or quite its former level could readily be misinterpreted were the observations not extended beyond Kimmswick, for the return of the river to its former state of oxygenation would suggest that the biochemical demand of the substances poured into the river by the St. Louis District had been met very largely by the time the polluted water arrived at Kimmswick. Owing to the swiftness of the current the river turns over rapidly in the vicinity of St. Louis which condition results in this rather rapid reoxygenation in the course of some 12 or 15 miles, that is, during the first 3 or 4 hours after receiving the waste load contributed by the City of St. Louis. Additional observations below Kimmswick, however, bring out the fact that the decomposition and disintegration of the sewage and wastes contributed by the City of St. Louis is not completed in this first 12 miles or during this first 3 or 4 hours of sojourn in the river. From Kimmswick south to Cape Girardeau a point approximately 110 miles below Kimmswick the dissolved oxygen of the river fell gradually to 4.8 p.p.m. in spite of the facts that several small, relatively unpolluted streams as the Meramec and Kaskaskia, join the Mississippi, and that no considerable additions of either sewage or industrial wastes are made to the waste load of the Mississippi between Kimmswick and Cape Girardeau. Beyond Cape Girardeau there was a slight rise in the dissolved oxygen although the City of Cape Girardeau contributes some waste material to the river, but even at Birds Point, Missouri, the Mississippi River had not recovered its former oxygen load as measured at Chain of Rocks Bridge, for at Birds Point the dissolved oxygen was only 5.5 p.p.m. The addition of water by the Ohio to the Mississippi at Cairo caused an abrupt rise in the dissolved oxygen just below the confluence of these two rivers. This rise in oxygen, however, was temporary for the organic material and substances producing oxygen demand in the Mississippi took up the extra oxygen supplied by the Ohio River in the course of the first few miles below the confluence of these two rivers, the dissolved oxygen falling to 5.3 p.p.m. at Henry Nye Light, 6 miles below the confluence, and the now greater Mississippi River coming to equilibrium with a dissolved oxygen content much the same as that of the Mississippi River just above the confluence of the Ohio and Mississippi. The higher dissolved oxygen values of the Ohio River and this speedy readjustment of the dissolved oxygen level of the Mississippi River below the confluence with the Ohio may be seen in table 2.

From this study of the dissolved oxygen content of the river between Chain of Rocks, and Cairo, Illinois, it may be seen that the decomposition and disintegration of the wastes contributed to the river by the St. Louis district continued to cause a heavy drain on the oxygen of the

Table 2. Demonstration of the oxygen demand made by the Mississippi River on the Ohio River at the confluence of these streams. September 5, 1931. All samples collected within 2 1/2 hours.

Locality No.	Name of place	River	Miles from Cairo	Depth	pH	Specific conductance x 10^{-6} at $25^{\circ}C.$	Dissolved Oxygen
			miles	meters			p.p.m.
513	Cairo Point Light	Mississippi	0.8 above	1.0	7.40	355.5	5.08
"	" " "	"	" "	3.0	7.35	390.8	4.81
"	" " "	"	" "	5.0	7.37	374.2	4.90
5[illegible]	Mississippi 0.5 miles below Ohio	"	2.3 below	1.0	7.23	283.3	7.09
"	" " " " "	"	" "	3.0	7.29	286.2	7.00
"	" " " " "	"	" "	6.0	7.25	296.4	6.65
"	" " " " "	"	" "	9.0	7.25	289.5	6.91
515	Henry Nye Light	Mississippi	8.0 below	1.0	7.20	379.8	5.35
"	" " "	"	" "	3.0	7.32	367.7	5.34
"	" " "	"	" "	6.5	7.34	387.4	5.25
512	Ohio River below Cairo	Ohio	1.6 below	1.0	7.27	264.1	7.26
"	" " " "	"	" "	3.0	7.22	267.9	7.26
"	" " " "	"	" "	6.0	7.20	260.3	7.18
"	" " " "	"	" "	8.25	7.18	259.4	7.26

river to a point over 100 miles downstream from the point of introduction of these wastes, so that the reoxygenation of the river by current, wind, and other agencies did not offset the growing oxygen demand of the organic material during this 100 miles or so. Considering the average speed of the river as 4 miles per hour the garbage, sewage, and other effluents contributed by the St. Louis district could have reached Cape Girardeau or beyond during the first 24 hours and Cairo, Illinois, during the first 48 hours assuming, of course, that all of these effluents were moved in the main channel and were not allowed to settle out in the quiet waters back of hurdles and other lateral obstructions in the stream. The continued oxygen demand of these various wastes and effluents in the river from the St. Louis district to a point below Cairo, Illinois, was therefore to be expected in view of the rate of river flow and in view of the laboratory experiments on biochemical oxygen demand of these wastes. It is well known (Amer. Pub. Health Assoc., p. 77, 1925) that average American municipal sewages have a biochemical oxygen demand which is satisfied to the extent of some 37 percent during the first 2 days, to some 68 percent in 5 days, and 90 percent during the first 10 days of incubation at 20°C. There are various other factors which might hasten the disintegration of sewage and other waste material in a rapidly moving river as compared with the disintegration of these same substances under the laboratory conditions demanded as standard procedure in the determination of biochemical oxygen demand. Nevertheless it seems quite reasonable to expect that even under the existing conditions of stream flow in the Mississippi River, waste materials would continue to have a biochemical oxygen demand for at least 3 days, and consequently effluents added to the river at St. Louis could reach a point below Cairo, Illinois, before the stabilization and saturation by oxygen from the river was accomplished. Table 1, which notes conditions during the week beginning September 17, 1934, in this stretch of river shows exactly the expected picture.

b. pH values. -- Returning to the Chain of Rocks again, it may be observed that throughout this run of 195 miles between Chain of Rocks and Cairo, Illinois, the waters of the Mississippi showed little change in the pH value, that is, the relative acidity of the river water varied slightly. In view of the determinations of total carbonates and conductivity (table 1) no large change in pH would be expected since the analyses at various points in this zone proved the Mississippi River water to be rather well buffered. Moreover the river channel in this region passes through a limestone area which would contribute additional calcium salts for buffers to the main river and the lateral tributaries as well.

c. Total ammonia. -- The third variable is the total ammonia contained in the river water from Chain of Rocks to Cairo, Illinois. The total ammonia values were fairly low at Chain of Rocks as compared with readings elsewhere in the Mississippi River but were higher than expected in unpolluted lakes and rivers (table 1). In the vicinity of St. Louis the ammonia values varied considerably from station to station which is to be expected in view of the varying volumes of wastes mixing with the river water along the river front. The ammonia values continued to fluctuate as far downstream as Crystal City, but the trend of the ammonia curve is definitely upward even in this mixing zone. From Crystal City to Claryville there was a progressive rise in the ammonia content of the river water to a maximum of 3.86 p.p.m. This total ammonia of approximately 4 p.p.m. represents a considerable nitrogenous load and shows definitely that the nitrogenous wastes from the St. Louis area are projected downstream 65 or 70 miles before the maximum ammonia production is reached. Compared with other streams 4 p.p.m. total ammonia is well above average for polluted streams although not as high as reported for some rivers. The Mississippi River at Fairport, Iowa, carried a maximum of 0.224 p.p.m. in 1931 (Wiebe, 1931) and the writer has found values ranging from 0.36 to 1.16 p.p.m. in the Mississippi at Davenport, Iowa, during very low water in the month of July, 1934. The Wisconsin River carries up to 0.77 p.p.m. and East River in Wisconsin 3.64 p.p.m. (Wisconsin State Board of Health, 1927), while values as high as 8 p.p.m. are reported from the highly polluted Charles River near Boston (Mass. Pub. Health Dept., 1912).

From Claryville the total ammonia fell gradually to 2.23 p.p.m. at Birds Point, Missouri, and abruptly after the introduction of the Ohio River water to 1.28 p.p.m. at Wickliffe, Kentucky.

Considering the dissolved oxygen and ammonia values together table 1 points out the sudden loading of the Mississippi River in the vicinity of St. Louis with substances capable of producing a biochemical oxygen demand greater than the reoxygenation of the river for over 100 miles downstream, and with material liberating at the end of the first 24 hours downstream enough ammonia to raise the total ammonia content of the river well above that of the Mississippi River in relatively unpolluted areas elsewhere. These September, 1934, values are typical of the condition found in this sector of the Mississippi River between St. Louis and Cairo as shown by comparison with the analyses obtained during the months of July and September, 1931, on this same stretch of river by the field party of the U. S. Bureau of Fisheries aboard U. S. Quarterboat 348. The close agreement of the 1931 and 1934 values may be seen in table 3 in which the dissolved oxygen and pH values for the Mississippi River between Chain of Rocks, St. Louis, and Cairo, Illinois, for the middle of September, 1931 and the middle of September, 1934, are compared.

2. Biochemical oxygen demand and ammonia production of the ground fresh garbage.

Samples of the garbage as released from the electric grinder at the Vandeventer Street Station of the Department of Streets and Sewers of St. Louis, were collected during a trial run of this plant on the morning of September 21, 1934. Typical garbage collected from the residential district of St. Louis was brought onto the platform, freed from cans and other objects that could not be ground, and passed into the electric mill. Several wagon loads of average city garbage were introduced into the mill before the samples were taken from the mill conduit at a point some 75 feet below the mill. These "garbage-hash" samples were unmixed with any other waste or sewage, but were diluted with the

Table 3. Comparison of dissolved oxygen content and pH range of Mississippi River for middle of September, 1931, with middle of September, 1934. Averaged data.

Locality No.	Name of place	Miles from Cairo	Dissolved oxygen		pH	
			Sept. 1931	Sept. 1934	Sept. 1931	Sept. 1934
		miles	p.p.m.	p.p.m.	p.p.m.	p.p.m.
760	Chain of Rocks	190.9 above	6.02	7.14	7.54	7.53
761	Gingrass Creek	186.1 "	----	7.47	----	7.87
762	Between Eads & McKinley Bridges	180.9 "	----	7.25	----	7.62
770	100 yards below Eads Bridge	179.9 "	----	7.32	----	7.58
307	Arsenal Street St. Louis	177.0 "	4.05	4.80	7.65	6.90
763	Below M.P. car ferry, St. Louis	171.0 "	----	6.04	----	7.45
308	Jefferson Barracks, Missouri	169.7 "	4.11	5.30	7.50	6.90
759	Crystal City, Missouri	166.2 "	----	4.80	----	7.35
764	Twin Hollows, Missouri	165.9 "	----	5.94	----	7.70
767	Concrete Hurdle, Missouri	161.1 "	----	7.25	----	7.79
765	Waters Point Light	158.5 "	----	7.14	----	7.32
758	Ste. Genevieve, Missouri	125.3 "	----	6.00	----	7.50
757	Claryville, Missouri	109.0 "	----	5.40	----	7.50
756	Wittenburg, Missouri	81.4 "	----	5.20	----	7.60
516	Grand Tower, Illinois	79.5 "	5.33	----	7.47	----
315	Cape Girardeau, Missouri	52.0 "	4.51	4.80	7.56	7.50
753	Birds Point, Missouri	1.9 "	----	5.50	----	7.50
513	Cairo Point Light	0.8 "	5.35	----	7.38	----
514	Mississippi 0.5 miles below Ohio	2.3 below	6.91	----	7.58	----
754	Wickliffe, Kentucky	4.3 "	----	6.60	----	7.45
515	Henry Nye Light	8.0 "	5.34	----	7.25	----

city water passing through the mill during its operation. According to information given by the city officials in attendance at the trial run, the grinder mill was using 10 tons of garbage per hour and 125 gallons of water per minute. As a flow of 125 gallons of water per minute through the mill would mix appaoximately 25,000 pounds of water per hour with the 10 tons of garbage, the ratio of dilution of the original garbage was 20,000 pounds of garbage (wet weight) to 25,000 pounds of water, or a 4:5 dilution. This ratio was used in computing the oxygen demand and ammonia production on the basis of wet weight of fresh garbage.

The biochemical oxygen demand of the garbage mixture as obtained from the electric grinder was determined from nine series of four dilutions each, run in duplicate, each test unit carrying four liters of fluid, (dilution method of Amer. Pub. Health Assoc., Water Analysis). The total ammonia, pH, and conductivity values of these samples and their controls were also taken. The averaged values from these tests have been used as the basis of the calculations of biochemical oxygen demand and total ammonia as given in tables 4 and 5.

From table 4 it may be seen that the biochemical oxygen demand developed much more rapidly in these garbage samples from the electric grinder, than the biochemical oxygen demand of average American municipal sewage. Several factors enter into this rapid rise in oxygen demand, two of which are the differences in bacterial flora of fresh garbage and sewage, and the fine suspension to which a considerable portion of the garbage was reduced by the grinder, the fine suspension putting a large fraction of the garbage in a physical condition optimum for bacterial action. The biochemical oxygen demand of the samples studied was, therefore, quite completely met (99 percent) by the end of the fifth day of incubation. On the other hand, after 21 days of incubation many, large pieces of garbage still remained. These were, however, for the most part of high cellulose content as pieces of green corn cobs, and such relatively resistant objects as feathers, that is, the material remaining after the fifth day of incubation had a low oxygen demand potential.

The total ammonia content of the garbage mixture also rose rapidly for the first three days of incubation, 86 percent of the ammonia found being recovered at the end of the third day and 90 percent at the end of the tenth day of incubation.

The ground garbage as collected would, therefore, present two possible hazards to fisheries and aquatic life, namely, through a high oxygen demand and rapid ammonia production during the first 5 days due to the decomposition of the finely divided material in suspension and solution, and, a second potential oxygen demand of the larger pieces of garbage which are not destroyed during this first 5-day period, were these large pieces to become grounded and mired in the silt deposits along the stream margin. These two hazards are in addition to any direct toxic action of the decomposition products themselves.

Table 4. Stability values from standard incubation tests for biochemical oxygen demand and ammonia production.

Item	1st day	2nd day	3rd day	5th day	10th day
Biochemical oxygen demand, in percentage of total					
Normal American sewage*	---	37.0	68.0	90.0	---
Ground fresh garbage, St. Louis	78.0	---	88.0	99.0	99.5
Ammonia production in percentage of total					
Ground fresh garbage, St. Louis	11.4	---	86.6	90.0	98.0

* American Public Health Assn., Water Analysis, p. 77, 1925.

Table 5. Biochemical oxygen demand and ammonia production of ground fresh garbage in parts per million, standard incubation tests.

1st day	3rd day	5th day	10th day
Biochemical oxygen demand p.p.m. wet weight of garbage			
130,946	147,734	166,201	167,880
Ammonia production p.p.m. wet weight of garbage			
477	3,521	3,764	4,182

a. The 5-day biochemical oxygen demand. -- The U. S. Engineer Office at St. Louis (J. J. Zebas) reports a minimum flow of 40,000 cubic feet per second during low water in the Mississippi River in front of St. Louis (Arsenal Street). The city officials state that the bonafide domestic garbage to be handled by this grinder-mill method, if approved, will average 600 tons daily from the entire city of St. Louis (W. Scott Johnson's report, p. 3). The U. S. Public Health Service (see table 6) from a series of observations on the dissolved oxygen of the Mississippi River approximately 40 miles above the confluence of the Mississippi and the Illinois Rivers, found the lowest average monthly value for dissolved oxygen in the Mississippi at that point in the month of July, and that the average September value was practically the same as the July value. The writer has made similar observations on the dissolved oxygen in the Mississippi River at Keokuk, Iowa, and several other points on the Mississippi River above St. Louis, and can confirm these findings of the U. S. Public Health Service. The low dissolved oxygen during the month of September in the Mississippi River may be taken as representing the critical low oxygen value in these relatively unpolluted sections of the Mississippi River, since the minimum flowage, that is, the extreme low water, usually occurs in September before the fall rains set in. It seems fair, therefore, to compute the maximum hazard to fisheries and aquatic life which the daily introduction into the Mississippi River at St. Louis of 600 tons of ground garbage might produce, on the basis of the September dissolved oxygen values and the minimum flowage.

Starting with an average dissolved oxygen of 7.14 p.p.m. at the Chain of Rocks, St. Louis (the September, 1934 value) and considering the river to be at a minimum stage of 40,000 cubic feet per second (a condition approximated at least early in September) the Mississippi

Table 6. Seasonal variation in the dissolved oxygen content of Mississippi River water at a point 40 miles above the junction of the Illinois River. Data fide U. S. Public Health Service

Month	Dissolved Oxygen p.p.m.
August	7.25
September	6.59
October	9.18
November	11.58
December	12.74
January	13.31
February	13.66
March	11.06
April	10.86
May	7.58
June	6.68
July	6.54

River as it passes the Chain of Rocks Station would carry an average of 1,540,000 pounds of dissolved oxygen per day. Mr. Graf of the St. Louis Water Works reports an average dissolved oxygen in the Mississippi River at Chain of Rocks of 8.07 p.p.m. during the month of May, 1934, (W. Scott Johnson's report, p. 5). Reducing this May dissolved oxygen value to a September value in terms of the U. S. Public Health determinations (table 6) Mr. Graf's 8.07 p.p.m. for May would become 6.97 p.p.m. for September, a value slightly lower than the average found by the writer for September, 1934, (7.14 p.p.m.) and slightly higher than the average found by the writer for the same station in September, 1931, (6.02 p.p.m., table 3). From these three sets of averages it would seem that the actual load of dissolved oxygen carried by the Mississippi at Chain of Rocks would be slightly less than 1,540,000 pounds daily, (Mr. Johnson estimates the minimum for July as 1,480,000 pounds, in his report, p. 6). However, the total oxygen load as computed from the writer's September values, namely, 1,540,000 pounds of dissolved oxygen per day has been used in the following discussion.

From the assays of the ground garbage as collected on September 21, 1934, at the trial run of the electric mill the biochemical oxygen demand of 600 tons of such ground garbage would be approximately 157,000 pounds (table 5) on the basis of the first day oxygen demand, or 200,000 pounds on the basis of the 5-day oxygen demand. Taking an average of these two values since the entire daily load of 600 tons of garbage would not be dumped into the river at any time, and since the main current of the river and the various counter-currents would influence the age and amount of the ground garbage passing any one point on the river, approximately 178,500 pounds of dissolved oxygen would be required to meet the daily biochemical oxygen demand of 600 tons of ground garbage of the type analyzed. Were this ground garbage introduced into the Mississippi River under existing conditions, that is, were the present volumes of sewage and other pollutants to remain unchanged, this 600 tons of ground garbage would make an additional demand on the now existing oxygen supply of the river to the extent of some 178,500 pounds daily. The changes in the dissolved oxygen of the Mississippi River, were such an additional load placed on the river, during conditions as found in September, 1931 and 1934, are shown in table 7.

From table 7 it may be seen that the addition of this load of ground garbage would have forced the dissolved oxygen down to a minimum of 3.87 p.p.m. at Arsenal Street, at Crystal City and at Cape Girardeau, under conditions as found in September, 1934, while under conditions obtaining in September, 1931, the dissolved oxygen would have reached a minimum of 3.12 p.p.m. at Arsenal Street, and would have been below 4 p.p.m. at Jefferson Barracks and at Cape Girardeau. It is well to point out here that the Cape Girardeau samples were taken just above the city and represent water arriving at Cape Girardeau and not water that had received the contributions of that city. Dissolved oxygen values of 4 p.p.m. or less have particular significance in stream pollution for when the dissolved oxygen drops to 4 p.p.m. stream conditions for fish and most aquatic organisms have become definitely adverse, and if the dissolved oxygen falls below this value, conditions rapidly become critical. Thompson (1925, p. 431) in his studies on

Table 7. Reduction in dissolved oxygen level in the Mississippi River produced by the daily introduction of 600 tons of ground garbage having a minimum, average and maximum B.O.D. of 157,000, 178,500, and 200,000 pounds, respectively, under existing conditions as of September, 1931 and September, 1934. Oxygen stated in parts per million.

Locality No.	Name of place	Miles from Cairo		September, 1931 Oxygen as found	September, 1931 Oxygen reduced to minimum	average	maximum	September, 1934 Oxygen as found	September, 1934 Oxygen reduced to minimum	average	maximum
		miles		p.p.m.	p.p.m.	p.p.m.	p.p.m.	p.p.m.	p.p.m.	p.p.m.	p.p.m.
760	Chain of Rocks, St. Louis	190.1	above	6.02	5.10	5.19	5.30	7.14	6.20	6.35	6.40
761	Gingrass Creek	186.1	"	----	----	----	----	7.47	6.54	6.65	6.74
762	Between Eads & McKinley Bridges	180.9	"	----	----	----	----	7.25	6.32	[illegible].41	6.52
770	100 yards below Eads Bridge	179.9	"	----	----	----	----	7.32	6.40	6.42	6.58
307	Arsenal Street, St. Louis	177.0	"	4.05	3.12	3.22	3.32	4.80	3.87	3.96	4.07
763	Below M.P. car ferry, St. Louis	171.0	"	----	----	----	----	6.04	5.11	5.21	5.13
308	Jefferson Barracks, Missouri	169.7	"	4.11	3.18	3.28	3.33	5.30	4.37	4.45	4.57
759	Crystal City, Missouri	166.2	"	----	----	----	----	4.80	3.87	3.96	4.07
764	Twin Hollows, Missouri	165.9	"	----	----	----	----	5.94	5.01	5.11	5.31
767	Concrete Hurdle, Missouri	161.1	"	----	----	----	----	7.25	6.32	6.42	6.52
765	Waters Point Light	158.5	"	----	----	----	----	7.14	6.20	6.35	6.40
758	Ste. Genevieve, Missouri	125.3	"	----	----	----	----	6.00	5.07	5.17	5.27
757	Claryville, Missouri	109.0	"	----	----	----	----	5.40	4.47	4.56	4.67
756	Wittenburg, Missouri	81.4	"	----	----	----	----	5.20	4.27	4.37	4.47
516	Grand Tower, Illinois	79.5	"	5.33	4.40	4.57	4.60	----	----	----	----
315	Cape Girardeau, Missouri	52.0	"	4.51	3.58	3.68	3.82	4.80	3.87	3.96	4.07
753	Birds Point, Missouri	1.9	"	----	----	----	----	5.50	4.57	4.67	4.77
513	Cairo Point Light	0.8	"	5.35	4.40	4.57	4.60	----	----	----	----

the oxygen requirements of the fishes of the Illinois River (most of the species in his study are represented in the unpolluted portions of the Mississippi River) states that, "it seems quite certain that dissolved oxygen concentrations between zero and two parts per million will kill all kinds of fishes", and also that "a variety of fishes were found only when there were four parts per million or more (of dissolved oxygen)". Suter and Moore (1922) discussing polluted streams in New York State, separate the "septic zone" of a polluted stream, that is, the portion of the stream which is heavily and unfavorably polluted considering the requirements of fish and other aquatic animals, from the "recovery zone", that portion of the stream in which the pollution is clearing up, at the point where the dissolved oxygen is 3.5 p.p.m. Various researches on this subject show that very few fish are found in water carrying less than 4.5 p.p.m. and almost no fish in water carrying 3.5 p.p.m. or less. The species most likely to be found in water having a dissolved oxygen content between 3.5 and 3 p.p.m. are carp and buffalo in the fresh-water streams of the Mississippi drainage.

Considering all of these findings collectively, it may be concluded that while the daily introduction of 600 tons of ground garbage into the Mississippi River at St. Louis during the September period of low water and low dissolved oxygen would not have forced the dissolved oxygen down to the lethal point for fishes, 2 p.p.m., in two zones of this sector of river between St. Louis and Cairo, namely, the Arsenal Street to Crystal City and again between Wittenburg, Missouri and Cape Girardeau the dissolved oxygen would have been forced down to 4 p.p.m. or lower, that is, there would have been two zones in this sector in which the dissolved oxygen would have fallen low enough to create definitely adverse conditions for fish and other aquatic life. The first of these zones would include the first 12 or 15 miles below Arsenal Street, St. Louis and the second zone would begin some 100 miles below St. Louis and continue on down stream for 30 miles or more.

b. <u>The ammonia production by the ground garbage</u>.--The ammonia production of the ground garbage during the incubation tests rose to 3.764 p.p.m. wet weight of fresh garbage at the end of the 5th day, (table 5). At this rate 600 tons of the ground garbage would produce 4,516 pounds of ammonia and ammonium compounds (computed as NH_3). The ammonia production during the first day was only 477 p.p.m., or 572 pounds from 600 tons. It is evident, therefore, that the additional ammonia contributed by the ground garbage to the River would change the ammonia content of the river downstream more than in the immediate vicinity of St. Louis. During September, 1934, the highest ammonia content was found near Claryville some 65 miles down stream from Arsenal Street, St. Louis, where the total ammonia was 3.86 p.p.m. If the ground garbage were carried downstream at once by the main current of the river the garbage would probably pass Claryville before the ammonia production began to rise rapidly. However, from the analytical data on the river water as taken in the field it seems that the settling out of wastes above Claryville delays the movement of enough of the sewage and other nitrogenous wastes now carried by the river to cause a rise in the ammonia content of the river water by the decomposing slimes trapped in the silt deposits in the quieter portions of the stream between Arsenal Street and Claryville. Consequently for the present discussion the 3rd day ammonia production has been superimposed onto the Claryville value as found in September, 1934, as representing probably the maximum ammonia rise which would be produced by garbage of the type of the samples analyzed. The third day ammonia production by 600 tons of ground garbage would amount to 4,225 pounds, which would add less than 0.02 p.p.m. of ammonia to the river water at Claryville already carrying 3.86 p.p.m. The ammonia production by the ground garbage seems almost negligible, therefore, when compared with the ammonia production from sewage, packing-plant effluents and other nitrogenous wastes now being poured into the river at St. Louis. Were the ground garbage the only source of ammonia for the river, 600 tons of the type tested would not produce ammonia enough to be detrimental to fisheries and aquatic life when turned into water as well buffered as the Mississippi River.

3. Settling out of garbage and other wastes along the stream margin.

The Mississippi River from St. Louis southward has a strong central current which scours the bottom of the river channel so completely that dredge samples brought up from the bottom of the channel consisted of coarse sand, gravel and small rocks. This is, of course, the intent of the engineering construction along shore, the hurdles and other lateral obstructions forcing the water back into the main channel as the dry or marshy land advances from behind and below the hurdles. Consequently the main volume of waste from the St. Louis area is carried by the mid-channel stream. However, there is a definite settling out of waste material in various stages of decomposition back of hurdles and along both banks of the river below St. Louis wherever the current speed is even slightly reduced. These wastes are mixed with erosion silt which complicates the problem by slowing up the decomposition and prolonging the oxygen demand of the organic matter so grounded. It is very difficult to compute the total amount of organic matter thus held and slowly contributing sulphur derivatives and methane to the river water as well as drawing on the total oxygen supply of the river, but with each rise quantities of the polluted mud are swept back into the stream and their products mixed with the water of the oxygen channel. Field work between St. Louis and the mouth of the Meramec River near Kimmswick, Missouri, showed that the 15 miles of shore was heavily polluted with wastes from the St. Louis area. Mud samples taken from the bottom of the river in the shallow water along shore in this zone yielded almost no animal life except Tubificid worms, which were often present in enormous quantities. These worms are regularly used as indicators of bottom and water conditions and when found mark the complex as one at the extreme lower limit for fish life as regards pollution. In general, therefore, the conditions now existing below St. Louis for 15 miles or more along shore are such that only the most tolerant forms of aquatic life can survive, except at the mouths of unpolluted streams where clean water is added. Sensitive forms like bass, dragonflies and daphnia are wanting. Below the Meramec blood-worms begin to appear indicating some recovery and some conversion of wastes into fish food. What change in these lateral conditions the daily addition of 600 tons of garbage would make can not be readily estimated, but with conditions definitely adverse to critical for aquatic life in the first 15 miles below the city any additional organic matter settling out with the silt in these lateral areas would only make matters worse.

4. Industrial effluents.

As the biological assays of the industrial effluents added to the river in the vicinity of St. Louis are being discussed in a separate report these pollutants need not be considered here except in one particular. Several of these effluents are not only very toxic to aquatic life but have powerful bactericidal action, as shown by tests in the bacteriological laboratory of the Columbia Field Unit of the U. S. Bureau of Fisheries. The bactericidal action of these industrial wastes materially alters the rate of decomposition of sewages and other wastes which are being acted upon by bacteria, in the zone where the industrial effluent is sufficiently concentrated. One of the industrial wastes of this type collected near St. Louis in September, completely inhibited the bacterial decomposition of ground garbage when one part in 100,000 of this waste as it came from the factory, was added during incubation to the ground garbage. Industrial wastes of this type should be excluded from the river as they materially slow down and complicate the natural stream recovery from the load of organic wastes usually disintegrated by bacteria. Similarly oil pollution which is sometimes present in the Mississippi River near St. Louis as the result of certain industrial activities alters the rate of river reoxygenation and consequently plays an important role in delaying the ultimate disintegration of various organic wastes, in addition to the specific damage to aquatic life by the oil itself.

Summary

1. Field studies of the Mississippi River between Chain of Rocks, St. Louis and Cairo, Illinois, made during September, 1931, and September, 1934, show that during the period of low water and low dissolved oxygen the Mississippi River loses a considerable portion of its oxygen load in the immediate vicinity of St. Louis, makes a temporary recovery, and then loses a large amount of its dissolved oxygen between Crystal City and Cape Girardeau.

2. The zones of low oxygen in the Mississippi River between Chain of Rocks and Cape Girardeau are definitely correlated with the addition and composition of the combined wastes from the St. Louis area.

3. The oxygen demand of the Mississippi River below St. Louis is not satisfied even after the waters of the Ohio have been completely mixed with the Mississippi.

4. Samples of ground garbage of the type which the City of St. Louis proposes to pour into the Mississippi River through the sanitary sewers were found to have a high biochemical oxygen demand which developed very rapidly.

5. The oxygen demand of this garbage was such that the addition to the Mississippi River at St. Louis under existing conditions of 600 tons of such garbage daily would reduce the dissolved oxygen in the river at several points to 4 p.p.m. or below during the low oxygen period July to September inclusive. Water carrying 4 p.p.m. of dissolved oxygen or less presents conditions which vary from adverse to critical for fishes and most forms of aquatic life. Were the stated quantity of garbage, 600 tons daily, augmented by the growth of the City of St. Louis, or, by the addition of the wastes from the wholesale districts and other establishments which have until recently been dumping their wastes directly into the River but which concerns are now prohibited this use of the River, very little additional load of such ground garbage above the 600 tons daily, as now proposed, would be required to lower the dissolved oxygen to the critical level (3 p.p.m. or less) for fishes and aquatic life in at least two zones within this 190 mile sector of the Mississippi River, and would extend the reduction of the dissolved oxygen to the adverse level many miles below St. Louis. To be specific the daily addition of 705 tons of such garbage would have reduced the dissolved oxygen at Arsenal Street in September, 1934, to 4 p.p.m. and in September, 1931 to 2.9 p.p.m.

Supplementary Statements

These supplementary statements answer several questions which have been raised concerning the information submitted in our report on the river pollution conditions in the St. Louis area.

The first question concerns the actual amount of garbage to be disposed of by the City of St. Louis. It has been claimed by the St. Louis officials that 600 tons daily is too high and that figure has been questioned. That value (600 tons average daily summer output) is the figure given on page 6 of the report signed by Mr. W. Scott Johnson, Sanitary Engineer of the City of St. Louis, signed and approved by Dr. J. F. Bredeck, M.D., Health Commissioner of the City of St. Louis and submitted to the Army Engineers on June 11, 1934. Additional discussion of this value will follow shortly. A second question has been raised concerning the use of 40,000 c.f.s. for the daily low water river flow of the Mississippi River at St. Louis. This value was obtained from the U. S. Army Engineers Office at St. Louis and is vouched for by Mr. J. J. Zebas of the District Engineers Office, St. Louis, Missouri.

In a supplementary report submitted by Mr. McDevitt of the City of St. Louis, on December 8, 1934, comparison of our findings (U.S.F.B.) using these values, with values obtained from the mean average amounts of water and sewage are made, and the use by Bureau of Fisheries of 40,000 c.f.s.

river flow which is an acknowledged low water value and 600 tons of garbage per day, which is an acknowledged maximum summer value as submitted by the City of St. Louis authorities, is questioned. There is also a statement in this supplementary report on page 3, paragraph 1 that "The U. S. Public Health has found monthly mean flows satisfactory for use in stream pollution studies".

Considering all of these factors and criticisms collectively it must be stated first of all that mean average values are not satisfactory for the determination of hazards to Fisheries and to aquatic life. It is not our province to question the use of these mean values by the Public Health Service for the particular types of determinations in which they are interested. However, from the standpoint of Fisheries interests the maximum oxygen demand and the minimum river flow must be considered together, as they were in the report submitted by fisheries in October, since in this way the maximum hazard to fish and other aquatic life is presented. It is well established for many forms of industrial pollution and even for sewage pollution that the mean average values may be well below the danger limit for aquatic life, and that some sudden rise in the quantity of any of these wastes may wipe out the entire fauna for miles downstream. From a biological standpoint it would be just as sensible, therefore, to consider the mean average value of oxygen in a room into which poison gas might be introduced by accident or on occasion, for the oxygen value during the hundreds of days during which no poison gas entered the room would offset in an average, the one day in which poison gas might enter the room, that is, the average gas content of the room throughout the year would be well below toxic limit and yet all of the individuals in such a room would be killed within a few minutes by the toxic gas at the time of its admission. Precisely the same condition obtains in determining the hazards to aquatic life from stream pollutants. Another specific case may be mentioned. The pollution material added by certain beet sugar factories to some of our western streams during the 6 or 7 weeks of active sugar refining from the beet crop of the year have in a specific instance killed all of the fish, aquatic insects, crustacea and other forms of aquatic life for 35 miles downstream. Yet taking the total flow of this stream throughout the year and the total amount of effluent added by these factories the mean average below the toxic limits obtained experimentally and by actual tests in the field. In a recent article in the Journal of Ecology Dr. Van Cleave points out this same hazard from sewage pollution in the Illinois River. Working with a particular species of river snail he finds that these snails live to a ripe old age in unpolluted streams and that they live satisfactorily in the Illinois River between rises in sewage pollution, but he adds that whole colonies are entirely wiped out by temporary rises in the sewage pollution in different parts of this river. Many examples could be given, suffice it to say that it is well established from the biological standpoint that the maximum hazard which represents the maximum acute conditions to which the aquatic fauna are exposed must be reckoned as the determining liability rather than any mean average value. This is of course axiomatic in our physiological and biochemical work dealing with poisons. Consequently the maximum figure as stated by the St. Louis authorities, 600 tons of garbage during the summer and the minimum river flow which also occurs at the same time, were used justifiably in computing the maximum oxygen demand hazard to fish and aquatic life in St. Louis area and below. We have of course no reason to doubt the statements of the St. Louis authorities and consequently accepted their maximum of 600 tons as stated in their own signed reports as a working basis. It is still necessary, therefore, to insist that the oxygen demand created during the period of low water by the maximum summer daily load of garbage must be considered as the critical determination from the standpoint of Fisheries, for were the oxygen reduced to the critical point for only a few hours the entire fish fauna and other aquatic animals as well would be wiped out in the area in which the oxygen was so reduced.

No attention is given in the supplementary report submitted by the City of St. Louis to the detrimental effects of the wastes as now projected downstream for over 100 miles. It is pointed out in the report that there is a spurious recovery of dissolved oxygen near Jefferson Barracks, but that actual analyses show that organic material is still present in the river water below Jefferson Barracks in large quantities, and that the oxygen demand produced by the wastes from the St. Louis area continues to be large even below the confluence of the Ohio and Mississippi Rivers. While this fact may be of little consequence to the City of St. Louis, all parts of the river involved must be considered by the Bureau of Fisheries from the standpoint of Fisheries interests. It is well to point out here that from the standpoint of fisheries biology biochemical oxygen demand and dissolved oxygen content of the river water, which values have been used for the basis of certain types of pollution studies, do not constitute either a complete or satisfactory determination of the total pollution picture for fisheries problems. As has been pointed out by the writer in a recent report to a National Committee on Pollution of our streams, there are industrial wastes entering the river in the St. Louis area which have very small or negligible oxygen demands, yet these same industrial wastes are seriously interfering with the disposal of some of the garbage and other waste material now entering the river, in that the bacterial flora is materially altered by the presence of these industrial effluents and the normal oxidation and disposal of these organic substances by the river seriously interfered with. The introduction of additional organic wastes by the City of St. Louis will complicate the existing trade waste situation still farther and the computation of the oxygen demand of the garbage of the City of St. Louis in itself is only one factor, serious enough, but nevertheless not the only factor to be considered in the pollution of the river as regards aquatic life, by the proposed disposal of garbage by the City of St. Louis.

Inference has been made that the Bureau of Fisheries findings are based on very limited data. This inference is incorrect. The Bureau of Fisheries has been determining dissolved gases, ammonia, carbonates, pH, and other physical factors as conductivity on the waters of the St. Louis area and from thence south to Cairo for the past four years and our observations include samplings at some 25 stations in this area and cover all sorts of conditions at various months throughout the year. In the report the figures for the month of September were taken specifically because the low level of the river and the peak load of garbage for the summer months come at that time as has already been discussed. Our findings are not based alone on the analyses which were made at the request of the Corps of Engineers during the month of September, 1934, but have for a background extensive data for the past 4 years. It was also stated in a report of the City of St. Louis that "However, the meager data available on oxygen demand would indicate that this figure (the average oxygen demand of St. Louis garbage as used in the Fisheries report) is too high". The Bureau of Fisheries agents took the samples of garbage on which their determinations are based at the time and places chosen by the City of St. Louis, with the staff of St. Louis officials looking on. Ample samples were taken and in all some 40 determinations were made on these particular samples covering their oxygen demand. From these values the average value for oxygen demand of the ground garbage from the St. Louis grinding mill, used in the report of October, 1934, was obtained. The Bureau of Fisheries had no control over the garbage samples offered by the City of St. Louis and took these in good faith as representing a typical grinding from the particular mill. Whether or not these were typical samples must be decided by the St. Louis officials as they supplied the samples. However, our entire staff is willing to vouch for the accuracy of the determinations on the samples as collected. Again it must be pointed out that no matter what the average oxygen demand of garbage samples may be, the oxygen demand of the samples collected represented an oxygen demand of material which we were assured was typical of what the City of St. Louis was about to put into the river. It is of no consequence to the Bureau of Fisheries what the average oxygen demand of garbage may be elsewhere for the specific case must be handled in view of the specific effluent added and we were given this effluent at a trial run arranged by the City of St. Louis and which run was represented to us as being typical of their proposed method of disposal.

In conclusion, average values are of no particular significance in this problem as far as fisheries are concerned. In view of the known minimum flowage of the river which will occur annually at a time when the garbage to be disposed of by the City is at its peak, we must repeat that our stand has to be based on the maximum oxygen demand which would clearly be fatal within a few minutes in some parts of the river and once the aquatic life was killed out, months or years would be required for the return of the normal river fauna, were oxygen demand the only factor to be considered. As pointed out in several places in this report oxygen demand is only one factor of river pollution from fisheries standpoint, and pollution as regards aquatic life can not be measured by certain standards which are set for the determination of pollution with reference to other types of interests.

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