LIMNOLOGY OF THE IOWA REACH OF THE MISSISSIPPI RIVER

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INTRODUCTION

The philosophy of the Iowa Water Pollution Control Commission is to assess water quality in terms of conformance to water quality standards. This philosophy encouraged formation of a Limnology Division, within the State Hygienic Laboratory, whose task was to conduct comprehensive evaluations of Iowa surface water quality and to determine whether quality standards were met. The first priority of this group was to investigate the effects on Mississippi River water quality of wastes produced by the six largest Iowa cities located on the Mississippi. All of these cities provided only primary waste treatment and, although their populations were not particularly large by today's standards, all except Burlington housed industries which generated heavy organic waste loads. Consequently, the wastes discharged to the river were equivalent to much greater than apparent populations as indicated in Table 1. The Dubuque area of the river was not studied because the city had voluntarily initiated construction of secondary treatment facilities. Although several other small Iowa towns are located along the Mississippi, they discharge relatively insignificant quantities of waste in relation to the available dilution capacity and are not considered in this paper.

Table 1

SEVEN MOST SIGNIFICANT IOWA MUNICIPAL-INDUSTRIAL WASTE LOADS TO THE MISSISSIPPI RIVER

City	Population	Waste Load to River After Primary Treatment (P.E.)*
Dubuque	62,800	304,000
Clinton	33,600	302,000
Davenport-Bettendorf	113,000	210,000
Muscatine	22,200	300,000
Burlington	33,300	16,000
Ft. Madison	15,200	165,000
Keokuk	16,300	240,000

Agricultural wastes and land runoff should certainly be mentioned as playing an important role in Mississippi River water quality. Approximately 24,900 square miles of eastern Iowa farmland drain to the Mississippi and following periods of heavy rainfall, tremendous quantities of silt, organics, nutrients and fecal coliform organisms are flushed to the river from Iowa and surrounding states in the Upper Mississippi watershed. This is a problem, however, which can be prevented only by good soil conservation practices rather than advanced waste treatment.

The Mississippi River borders Iowa for a distance of about 300 river miles. Within this reach are eleven lock and dam structures which were constructed by the Corps of

*One population equivalent equals 0.17 pounds biochemical oxygen demand per day.

Engineers for commercial navigation purposes. Each of these forms an impoundment or pool varying from 10 to 47 miles long. Each of the pools consists of a main navigational channel, a main channel border and many side channels, chutes and slough areas formed by the large numbers of islands throughout the river reach. This provides a habitat diversity which supports many species of fish and wildlife. In addition to being very scenic, the Iowa reach of the Mississippi receives heavy use by both sport and commercial fishermen, boaters, commercial barge traffic and also serves as a water supply for the cities of Davenport, Burlington, and Keokuk.

METHODS

The primary purpose for the river study in each of the areas was to determine whether the waste discharges were causing violation of chemical water quality standards, contaminating downstream areas with fecal coliform organisms or harming the biological community normally found in the river.

Sampling stations were selected in each of the areas both upstream and downstream from the discharges so that comparisons in water quality could be made. Because of the width of the river, it was necessary to sample across the river as well as longitudinally. Following the selection of sampling stations, water samples were collected for chemical and bacteriological analysis. These samples were preserved by refrigeration and delivered to the laboratory as soon as possible after collection. Routine analyses included pH, alkalinity, turbidity, solids, organic-nitrogen, ammonia-nitrogen, nitrate nitrogen, soluble and total phosphates, dissolved oxygen, biochemical oxygen demand (BOD), and chemical oxygen demand (COD).

Complete mineral analysis, phenol analysis and heavy metal determinations were made on a less than routine basis. Analytical procedures followed Standard Methods (1) whenever applicable.

The fecal coliform determinations followed the membrane filter procedure with incubation at 44.5°C described by Geldreich (2).

Several methods of biological study were employed due to the variety of bottom substrates in the Mississippi and the types of biological problems which were encountered. The object of this phase of the study was to determine the numbers and types of macro invertebrate bottom organisms (benthos) present in control areas and then assess the changes in their populations in areas affected by the waste discharges. Substrate samples for semi-quantitative evaluation were taken with a 9 x 9 inch Ponar dredge. The dredge samples were seived through a No. 30 mesh wire screen to separate the organisms from the mud and other debris and the organisms were preserved in 70% ethyl alcohol. Dredge samples were supplemented by qualitative collections from the rocks and other substrate types which were accessible near the shore.

The Sphaerotilus growths which were known to occur downstream from Dubuque, Clinton, Muscatine and Keokuk required a different approach. In order to determine the extent of the river affected by drifting Sphaerotilus, which had broken loose from its point of initial attachment and growth, wire mesh cylinders nine inches long by three and one-half inches in diameter were suspended about one foot from the river bed. These cylinders were held in place by a concrete block anchor and a gallon plastic float and were left in the river for 24 hours. After that time they were removed, examined for Sphaerotilus and photographed for the record.

RESULTS

In general, the Iowa reach of the Mississippi River contains water of excellent quality. Compared to streams within the borders of the state, the Mississippi waters are relatively low in dissolved materials and nutrients although at times extensive algal populations are present. Table 2 depicts the typical chemistry of the Mississippi waters over this reach of the river. The particular sample from which this analysis was made came from the Burlington area and was collected in early fall under relatively low flow conditions.

Dissolved oxygen studies have been conducted during the winter months while the river was under heavy ice cover. During such times the river receives little aeration from atmospheric oxygen and photosynthesis is inhibited because the ice reduces light penetration. Under these conditions significant oxygen demands from waste materials can readily deplete a river of oxygen. The winter surveys demonstrated oxygen concentrations

TABLE 2

TYPICAL WATER CHEMISTRY OF THE IOWA REACH
OF THE
MISSISSIPPI RIVER
(values in mg/l unless otherwise stated)

Alkalinity:	
Phenolphthalein	2
Total	160
Bicarbonate	190
Biochemical Oxygen Demand (BOD)	4
Calcium	51.2
Carbonate	2.4
Chemical Oxygen Demand (CODO	33.5
Chloride	12
Fluoride	0.2
Hardness as $CaCo_3$	200
Magnesium	17.5
Manganese	< 0.05
Nitrogen as N:	
Organic	1.1
Ammonia	0.07
Nitrate	0.2
pH	8.2 units
Phosphate as PO_4:	
Soluble	0.2
Total	0.5
Potassium	2.6
Silica as SiO_2	1.0
Solids:	
Total	230
Dissolved	178
Suspended	52
Specific Conductance	420 micromhos
Sulphates	52

in the main flow of the river were invariably greater than 8 mg/l and often higher than 10 mg/l. These values can be compared to water quality standards which for Iowa and many other states specify a minimum concentration of 5 mg/l dissolved oxygen. During the summer months oxygen concentrations are generally lower, particularly in the early morning hours, but dissolved oxygen standards are met except in a few localized bay areas which are out of the main river flow and which are affected by waste discharges. There have not been any fish kills in the past few years which were the result of insufficient oxygen concentrations in the Iowa reach of the Mississippi River.

The general findings in each of the study areas are summarized below in upstream to downstream order. As mentioned earlier, Dubuque was not included in these studies because the city had voluntarily started construction of a secondary treatment facility.

The major water quality problem downstream from Clinton was a luxurious growth of the slime bacteria, *Sphaerotilus natans*, which was stimulated by wastes originating from a grain processing industry. The growth zone of this organism extended for 7 miles below the discharge but drifting slime tufts were collected as far as 10 1/2 miles downstream. Only the Iowa side of the river was affected by this material.

The slime bacteria, *Sphaerotilus*, has many undesirable characteristics. Luxuriant growths effectively smother the benthic organisms which normally are found in the river and which provide food for the fish populations. Slime tufts which break loose from the initial point of attachment drift downstream and readily collect on anchor and fishing lines and the nets and traps of commercial fishermen. This latter condition makes commercial fishing virtually impossible in or immediately downstream from slime infested areas. Eventually the drifting slime settles to the bottom and decomposes, exerting an oxygen demand which may further deteriorate water quality in that area.

Downstream from Clinton outfalls there was a severe reduction in the numbers of benthic organisms for three miles. As expected, large increases in numbers of fecal coliform organisms occurred below the point of municipal waste discharge, however, this condition was also restricted to the Iowa side of the main channel. Chemically, at the time of the study, very little difference could be observed in chemical water quality. There were no violations of water quality standards for ammonia or dissolved oxygen yet there was biological damage.

There was no Sphaerotilus problem in the Davenport area. Although the river downstream from Davenport discharges met the standards for chemical quality, areas along the Iowa shore were near the minimum limits set for dissolved oxygen. Major bacteriological contamination resulted from the large volume of domestic waste from Davenport and there was substantial degradation of the benthic populations along the Iowa bank for about 6 miles resulting from treated waste discharges, storm sewer runoff and city dump drainage. Similar conditions on the Illinois side of the river were caused by discharges from the Moline, East Moline and Rock Island areas.

Muscatine was very similar to Clinton by virtue of being a relatively small town with a grain processing industry producing a large waste load. The problems in the river below Muscatine were almost identical to those below Clinton. There were heavy Sphaerotilus growths extending 6 miles below the waste outfall and drifting slime was observed 15 miles below the outfall. There was heavy fecal coliform contamination, particularly during the summer months when some multiplication of these organisms apparently occurred in heavily enriched waters. Again, chemical quality standards were not violated by the waste discharge to the rivers. As observed at Davenport and Clinton, all effects of the wastes were restricted to a relatively narrow strip of water along the Iowa bank.

The Burlington area study resulted in quite different findings than those discussed above. The city of Burlington has no heavy waste producing industry and after primary treatment, discharges a waste load equivalent to 16,000 P.E. to the Mississippi. Studies to date have indicated that Burlington wastes have little significance to chemistry, biology and bacteriology in the river. Chemically, the waste can seldom be detected as far as 0.5 mile downstream. There are occasional evidences of increased fecal coliform contamination along the shoreline but this disappears within 1-2 miles. On more frequent occasions, no increases of fecal coliforms over upstream levels have been observed even when samples were taken within 100 yards of the discharge. Biologically, there is some reduction in numbers of benthic organisms within the first half mile below the outfall, however at the last sampling, an abundance of immature aquatic insects were present at the station one half mile below the discharge. All observable effects of the Burlington wastes are restricted to a strip of water approximately 100 yards wide along the Iowa shore. The entire river at this point is approximately 750 yards across so a very small area is affected even to a negligible degree.

In addition to wastes produced by a population of approximately 15,000 people, there is a paper mill at Ft. Madison. After primary treatment, the waste load to the Mississippi is in the range of 165,000 P.E. Both the paper mill and the municipal sewage treatment plant discharge wastes into bay areas of the river which is more than 2 miles across just below the city. The area which receives the waste is shallow and very little mixing occurs except from wind action. As a result, this shallow side of the river is polluted by Ft. Madison wastes. Within an area 3 miles long by several hundred yards wide, there are violations of dissolved oxygen standards and the area was heavily contaminated with fecal coliform organisms. From a biological standpoint, the two bays which directly received the waste were in poor condition but downstream areas which were affected by the waste supported tremendous numbers (up to 2000 per sq. ft.) of fingernail clams, although populations of burrowing mayfly (Hexagenia) nymphs were suppressed.

Even though polluted conditions were found downstream from five of the Iowa cities, these conditions by no means affected the entire cross-section of the river. The river current, which ordinarily has a velocity of 2-4 miles per hour, tended to hold the wastes along the shore for many miles below the outfalls. Consequently the effects were generally restricted to a narrow strip along the Iowa bank often less than 100 yards wide.

No changes in water quality, attributable to waste discharges, have been observed when water quality in the upper Iowa reaches is compared to downstream areas. Biologically, the Ft. Madison and Keokuk areas of the river (in the southern reach) are extremely productive and there are no indications that upstream wastes have suppressed the number or diversity of bottom dwelling organisms in that area.

As soon as sufficient information was gathered from each of the study areas, a full report was made to the Iowa Water Pollution Control Commission (IWPCC) on the findings.

Based on this evidence, the Commission cited violations of water quality standards for all the cities except

Burlington. These cities were called in for negotiations by the Environmental Engineering Section of the Iowa State Department of Health which handles the enforcement actions of the Commission. Consent orders were drawn up which detailed the type of treatment required and the time schedules set out for the various phases of planning and construction. The consent orders were mutually agreed upon by the Commission and the violator and signed by both. After this phase is completed it becomes the responsibility of the State Department of Health Engineer to approve the plans for construction and completed facilities. After plant start-up, the Limnology Division will again evaluate the river to determine the degree of improvement in water quality.

No legal action was taken by the Commission toward Burlington for several reasons. First, the Water Pollution Commission has no legal authority to act unless pollution can be established. Burlington wastes did not significantly affect water quality in the Mississippi River. Second, in terms of priority, waste loads to the River could be more significantly reduced by requiring tertiary treatment for other Iowa Mississippi River cities before ordering secondary treatment at Burlington. For example, after secondary treatment facilities are operating at Dubuque, the discharge to the river will still be in the range of 50,000 P.E. whereas Burlington now discharges 16,000 P.E. after only primary treatment.

The Iowa Water Pollution Control Commission has staunchly maintained that the condition of the receiving stream and NOT the degree of treatment is the proper yardstick for water quality assessment. Standards should be set at a high level so that all intended uses of the water can be adequately achieved, and then waste discharges should be treated to whatever level necessary to achieve this desired quality in the stream.

SUMMARY

1. Limnological surveys were conducted on the Mississippi river downstream from six Iowa cities to determine effects of wastes receiving only primary treatment on water quality.
2. Conditions of pollution reflected by <u>Sphaerotilus</u> <u>natans</u> growth, fecal coliform contimination and/or degradation of benthic communities were observed downstream from five of these municipal-industrial complexes on the Iowa side of the river. Violations of chemical water quality standards were found only in one study area.
3. Biological parameters were much more valuable than water chemistry measurements in establishing waste water effects in these sgudies.
4. On the basis of data which demonstrated damage to the Mississippi, the Iowa Water Pollution Control Commission ordered additional waste treatment for five of these

cities. Secondary treatment was not ordered for the sixth because no significant damage to the river was proven.

5. The condition of the receiving stream and not the degree of waste treatment is the appropriate measure for water quality control.

LITERATURE CITED

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