Summer Primary Productivity and Associated Data for Four Indiana Rivers

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Introduction

In-stream dissolved oxygen concentration has, historically, been one of the cornerstones of water pollution investigations. This constituent is often the most important chemical parameter controlling the presence, diversity, and health of aquatic populations and communities. Dissolved oxygen levels in flowing waters are affected by a myriad of factors such as velocity, reaeration (1), temperature, naturally occurring and anthropogenic oxygen demanding substances, sediment oxygen demand, organismal respiration, and primary productivity. It is the last factor, primary productivity, which is the subject of this paper and we will report a variety of summertime measurements from four Indiana rivers taken by the senior authors and others no longer with the agency during the years 1981 thru 1984.

Primary productivity was only indirectly addressed in the early wasteload allocation studies of the Indiana State Board of Health (ISBH) and others. The occurrence of a prolonged very low dissolved oxygen episode in the middle Wabash River in the summer of 1977 made it apparent to the authors and others that past wasteload allocation studies did not adequately address the situation. As time progressed and computer modelling techniques evolved, industrial dischargers to the middle Wabash River (e.g., Eli Lilly Company-ELANCO Division, Weston Paper Company, and Inland Container Corporation) became very concerned with potential increased wastewater treatment costs which might adversely affect their products' viability in the competitive marketplace when the increased costs were based on decisions not utilizing the best available computer model and the associated data inputs, for the middle Wabash River. Three of the major factors potentially affecting the dissolved oxygen regimen of the middle Wabash River which had not been measured were reaeration, primary productivity and sediment oxygen demand. An interdisciplinary team of scientists, engineers, modelers, and administrators from the State of Indiana, various federal agencies, industries, universities, and an experienced consultant (*i.e.*, HydroQual, Inc.) met to design, collect, and evaluate the data necessary to reach a sound decision on the assimilative capacity of the middle Wabash River for oxygen-demanding wastes. This experience greatly shaped the approach taken with other rivers by the Indiana State Board of Health and continued by the Indiana Department of Environmental Management.

Description of Study Areas

The Wabash River is a large free-flowing river and is a major tributary of the lower Ohio River. The four sampling locations discussed in this paper are outside the area of direct influence by oxygen demanding or nutrient enriched wastewaters. The East Fork of the White River is a medium size river with numerous low-head dams and drains south central Indiana before flowing into the White River at the junction of the Knox, Daviesss

and Pike Counties lines in southwest Indiana.

Trail Creek is a small river which flows into Lake Michigan at Michigan City, Indiana, a significant harbor for numerous pleasure boats and some commercial fishing tugs. The hydraulics of the mouth of Trail Creek are greatly complicated by a low gradient which results in the mixing of Trail Creek water and Lake Michigan water in a manner similar to that of an estuary. The St. Joseph River flows through Elkhart and St. Joseph Counties in northern Indiana with several hydroelectric dams which create unusual, for Indiana, diurnal river flow patterns. The water quality, effluent quality, aquatic life, flow characteristics, as well as the water quality standards and designated uses of these rivers have been recently described in other publications (2, 10, 5, 3) and will not be repeated here.

Materials and Methods

Photon flux density was measured by a LI-COR meter equipped with a submersible spherical quantum sensor. Light intensity and 1% light level was measured by Beckman Enviro-Eye. In-stream measurements of temperature, dissolved oxygen, conductivity, and pH were made with a Hydrolab Surveyor.

Primary productivity measurements were made by the oxygen method using light and dark bottles at 0.3 meter incremental depths thru the euphotic zone (4). Dissolved oxygen determinations, for primary productivity measurements, were made by the azide modification of the Winkler method (4).

In-situ and laboratory chlorophyll methods utilized a Turner Design Flourometer Model 10 instrument. *In-situ* measurements were made at the surface and at 0.3 meter interval depths to the bottom in the Wabash River. The samples for laboratory analysis were filtered and frozen in the field. These chlorophyll procedures have been previously described in detail (4). Whole water samples were collected and preserved with formalin for plankton analysis. The samples were later enumerated and identified to major taxonomic groups in a Sedgwick-Rafter counting cell (4).

Results and Discussion

Figure 1 illustrates the correlation of *in-situ* chlorophyll measurements with laboratory results in 1981 samples from the Wabash River where chlorophyll *a* concentration ranged from 20 to 60 ug/1. The correlation coefficient was 0.923 in the range studied. Figure 2 illustrates the correlation of *in-situ* measurements of chlorophyll *a* with laboratory results from Wabash River samples in 1982 where chlorophyll *a* concentration ranged from 50 to 150 ug/1 and had a correlation coefficient of 0.868. These findings were similar to those previously reported at lower concentrations with marine phytoplankton (6, 7, 9). The *in-situ* technique was very useful in demonstrating the cross-sectional and depth distribution of the phytoplankton over a long stretch of river.

The chlorophyll *a* concentrations at different depths as well as physical and chemical data for three stations on the Wabash River are shown in Table 1. It was apparent from these and many other similar measurements that the Wabash River was well mixed for physical, chemical and phytoplankton components during summer low flow conditions from surface to bottom and from bank-to-bank when you were not in the immediate vicinity of mixing zones.

Table 2 lists the chlorophyll *a*, pheophytin *a*, primary productivities and phytoplankton cell counts data for the four rivers. Only four locations on the Wabash River are included in this paper but these sites are representative of the upper, middle and lower sections of the over one hundred and fifty miles of study area outside the areas of direct influence of effluent and tributary mixing zones.

It should be noted that the middle Wabash River can routinely generate a significant amount of net primary production (*i.e.*, 400 to 784.1 mg $C/m^2/hr$) under summer-

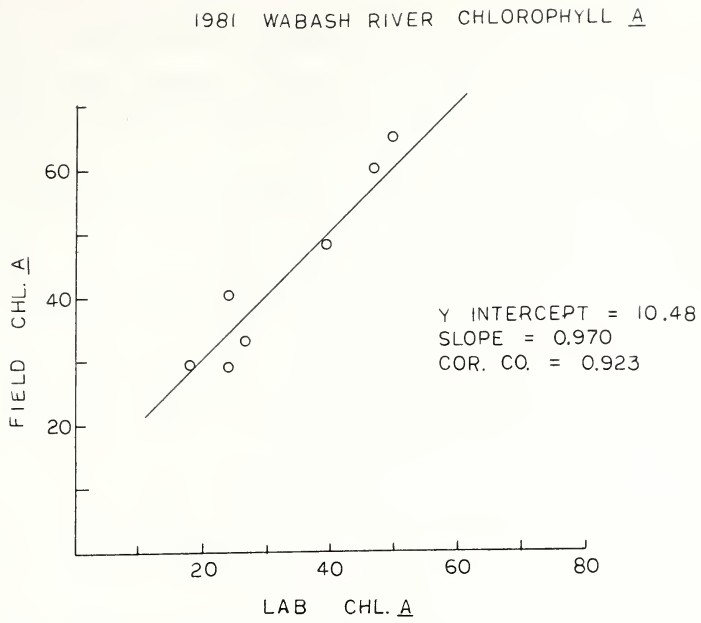

FIGURE 1. Correlation of *in-situ* measurements of Chlorophyll *a* with laboratory determinations for middle Wabash River samples in 1981.

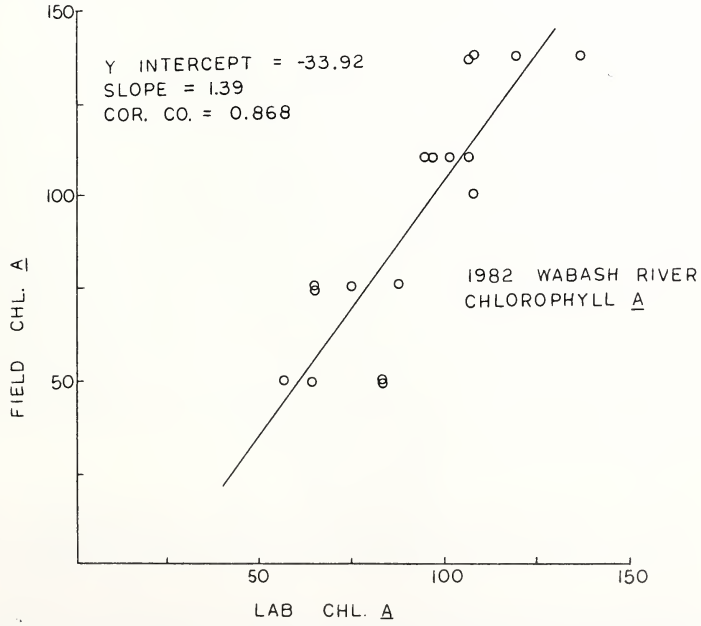

FIGURE 2. Correlation of *in-situ* measurements of chlorophyll *a* with laboratory determinations for middle Wabash River samples in 1982.

TABLE 1. Physical and chemical data collected at various depths from the center of the channel in the Wabash River during primary productivity investigations.

Location	Date	Depth Meters	Photon Flux Density uE/cm²/sec	Temperature °C	Dissolved Oxygen mg/1	Conductivity uS/cm (umhos/cm)	pH S.U.	In-situ Chlorophyll *a* ug/1
Lafayette: Mascouten Park	8/11/81	Surface	1,050	23	9.0	580	8.2	47.0
		0.5	265	23	8.9	575	8.2	50.0
	8/3/82	Surface	1,150	27	10.2	722	7.6	76.0
		0.3	355	26	9.8	727	7.8	78.0
		0.6	95	26	9.5	735	7.8	78.0
		0.9	31	26	9.4	733	7.8	79.0
Montezuma: Boat Ramp	8/13/81	Surface	600	25	7.5	605	8.2	19.0
		0.15	35	24	7.5	605	8.2	19.0
Just Below Manhattan Island	9/11/82	Surface	1,500	25	7.7	810	7.3	55.0
		0.3	340	25	7.7	813	7.3	58.0
		0.6	23	25	7.7	817	7.3	59.0
		0.9	15	25	7.7	819	7.3	59.0
		1.0	2.4	25	7.7	821	7.3	60.0
		1.2	0.2	25	7.7	821	7.3	—
Terre Haute: West Ramp (U.S. 40)	8/20/81	Surface	700	22.5	9.3	605	8.0	55.0
		0.5	520	—	—	—	—	57.0
		1.0	1.2	—	—	—	—	57.0
		1.5	—	22.5	9.3	600	8.0	59.0
	8/19/82	Surface	1,000.0	28.0	10.0	—	—	27.0
		0.3	310.0	—	9.8	—	—	28.0
		0.6	20.0	—	9.9	—	—	28.0
		0.9	6.0	—	—	—	—	—
		1.0	—	—	9.9	—	—	28.0

time conditions. On August 30 and August 31, 1984, measurements were made at three locations in the vicinity of the Cayuga Generating Station (G.S.) and the confluence of Mill Creek and are shown in Table 3. The station upstream of the Cayuga G.S. had primary production rates higher than any ever measured during previous investigations by this office. The other high values for primary production, chlorophyll and phytoplankton densities (Tables 2 and 3) are quite comparable to those reported for the Thames River (8) or a eutrophic lake (11). The other two sampling locations were in the vicinity of the stretch of river where serious dissolved oxygen depletion had been observed in the past.

The East Fork of the White River, Trail Creek, and the Saint Joseph River have lower chlorophyll *a* concentrations, primary productivity rates and phytoplankton densities in comparison to the middle Wabash River. All three of these smaller rivers also receive municipal and industrial effluents but never generate the same level of planktonic densities, chlorophyll *a* concentration or planktonic primary production rates. It should also be noted that none of the rivers in the locations studied, including the Wabash, had any significant amount of periphyton or macrophytes.

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TABLE 2. Chlorophyll *a*, primary productivity, and algal cell count data from four Indiana rivers. (Locations are listed upstream first for each river). Values are mean values for the euphotic zone.

River	Location	Date	Depth Meters	Chlorophyll *a* ug/l	Pheophytin *a* ug/l	Primary Productivity Gross mgC/m²/hr	Primary Productivity Net mgC/m²/hr	Phytoplankton Cells/ml
Wabash River	Lafayette-Mascoutten Pk.	8/11/81	0-1.0	66.0	6.2	449.0	341.0	—
		8/3/82	0-1.2	76.2	26.6	663.0	469.0	66,254
		9/13/83	0-0.7	141.4	35.5	444.6	400.0	72,534
Wabash River	Montezuma-boat ramp	8/13/81	0-0.5	18.4	11.0	82.0	91.0	—
		8/18/81	0-0.3	18.4	9.3	129.0	124.0	—
		8/17/82	0-1.0	114.2	51.2	680.0	674.0	74,712
		9/14/83	0-1.0	160.7	29.1	766.4	705.2	32,446
		9/20/83	0-0.7	80.9	13.6	177.2	157.2	19,140
Wabash River	Terre Haute-U.S. 40 bridge	8/18/81	0-1.0	21.1	6.5	70.0	—	—
	U.S. 40 bridge	8/20/81	0-1.0	53.8	9.6	403.0	256.0	—
	U.S. 40 bridge	8/19/82	0-1.0	120.2	50.0	789.0	663.0	119,750
	S.R. 63 bridge	9/15/83	0-0.7	191.2	20.7	444.6	400.0	55,840
	I-70 bridge	9/15/83	0-0.9	247.0	23.7	847.5	784.1	60,027
Wabash River	Merom	8/20/81	0-0.2	22.9	10.8	—	—	—
		8/19/82	0-0.8	132.5	70.0	738.0	613.0	125,981
East Fork of White River	Above Columbus STP	7/12/83	0-0.9	30.1	7.8	181.0	87.0	6,435
	Above Columbus STP	7/14/83	0-1.2	—	—	160.0	160.0	9,570
	Above Columbus STP	8/9/83	0-1.2	—	—	39.0	69.0	5,544
	Below Haw Creek	7/12/83	0-1.1	128.9	2.4	163.0	163.0	6,369
	Below Clifty Creek	7/12/83	0-1.5	17.8	2.9	183.0	183.0	7,738
	Azalia	8/9/83	0-1.0	24.7	9.8	181.0	138.0	2.310
Trail Creek	0.25 mile upstream of STP	6/28/83	0-1.0	5.57	4.68	28.94	—	—
	0.25 mile upstream of STP	8/4/83		7.44	2.78	—	—	1,254
	E Street bridge	6/28/83	0-1.0	3.73	3.04	12.86	—	NA
	E Street bridge	8/4/83	0-2.0	4.61	2.43	14.65	12.52	1,023
	Naval Reserve Armory	6/28/83	0-2.1	10.65	0.82	78.01	—	—
St. Joseph River	Bristol	7/30/83	0-2.0	5.6	4.7	28.9	—	—
	C.R. 17	7/30/83	0-1.4	17.4	12.4	128.0	114.0	19,503
	Elkhart Dam	7/30/83	0-1.4	20.8	9.9	270.0	229.0	14,765
	Sherman Street	8/1/83	0-1.0	20.7	9.1	228.0	144.0	14,438
	State Route 219 Bridge	8/6/83	0-1.8	30.1	12.5	184.0	108.0	12,375
	1 and M Dam	8/6/83	0-1.8	29.2	14.2	403.0	367.0	11,781
	Mishawaka Avenue	8/6/83	0-2.1	28.7	14.6	253.0	218.0	9,554
	Twyckenham Bridge	8/6/83	0-2.2	21.9	13.6	309.0	271.0	4,595
	Below Kayak Run	8/8/83	0-1.8	NA	NA	485.0	436.0	12,556
	St. Patrick's City Park	8/8/83	0-1.2	33.2	17.1	428.0	320.0	16,004

TABLE 3. Primary productivity and chemical data collected from the Wabash River on August 30, 31 1984, in the vicinities of Cayuga and Montezuma, Indiana (Vermillion County).

Location	Primary Productivity $mgC/m^2/hr$ Gross	Net	Alkalinity Total $CaCO_3$ mg/l	Hardness $CaCO_3$ mg/l	Total Organic Carbon mg/l	Dissolved Oxygen mg/l
Upstream of Cayuga Generating Station	1,144.0	1,226.0	160.	250.	8.6	12.5
At confluence with Mill Creek	733.0	543.0	150.	250.	8.5	14.1
At confluence with Sugar Creek	656.0	574.0	150.	220.	7.2	6.4

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