Eutrophication in the Eau Gallie River and its Effect upon the Indian River Complex

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Pollution of many waterways throughout the United States has been widely investigated during the past decade as evidenced by the immense volume of material written on the subject. The Indian River Complex, a water body running parallel to the Atlantic Ocean throughout Brevard County in East Central Florida, has been the subject of considerable research by the Florida Institute of Technology. In addition to being a major water resource to the area, this complex attains national significance as a water refuge for a vast number of migratory water fowl (1). Being separated from the Atlantic Ocean by a barrier beach the Indian River is a classical lagoon with substantial salinity because of the presence of several inlets (2). This body of water also has certain estuarine characteristics due to a series of fresh water inputs (3).

Attention in this study was focused on the Eau Gallie River, which contributes approximately one quarter of the fresh water influx to the northern portion of the Indian River (4). The Eau Gallie River is divided into two sections by a dam. The current of the upper section of the river is gravitational and flows from west to east whereas the lower portion of the river and the lagoonal system into which it empties exhibit wind-driven currents (5). The existence of a prevailing easterly wind in this region causes the lower portion of the river to be saline and take on characteristics of the lagoonal system. Several sections in the upper portion of the river are shallow and excessive growth of fibrous algae, vascular plants such as water hyacinths (Eichornia pontederiacae), and cattails (Typha alba) dominate the area. The density of plant life diminishes sharply below the dam and species of algae that adapt more readily to brackish water predominate. The land adjacent to the river is primarily residential interspersed with several large sections of marshy land. However, minor segments of agricultural, commercial, and undeveloped property are also present.

The main objective of this study was to conduct a systematic analysis of selected chemical and physical parameters over a period of several months to determine the major polluting sources in the Eau Gallie River and the relative magnitude of each. The

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effects of these polluting sources in the river upon nutrient content and biomass production in the northern Indian River were also sought. Further, effort was made to ascertain if such variables as rainfall and the physical/chemical properties of several typical fertilizers had a significant effect upon nutrient content of the land runoff.

EXPERIMENTAL METHODS AND RESULTS

Fifteen sampling sites were established at strategic locations along the Eau Gallie River with site #1 at the source and #14 at the mouth. Samples were gathered by boat at midstream except at locations above the dam where they were obtained from the river bank. The samples were collected in quart plastic containers at a depth of six inches twice a week between October 1 and December 31, 1971. They were then brought to 25° and subjected to chemical analysis within four to six hours from the time of acquisition. Nitrate was determined using an Orion membrane electrode (Model 92-07). Nitrite, phosphate, and turbidity values were estimated from known procedures (6).

Rainfall data which were obtained from nearby John F. Kennedy Regional Airport are presented in Figure 1. The variation in the average values of the measured parameters with sample site is illustrated in Figures 2 and 3. Table 1 gives the average values and the standard deviations of all measured parameters at each sampling site. The monthly average values for each parameter and their standard deviations are given in Table 2.

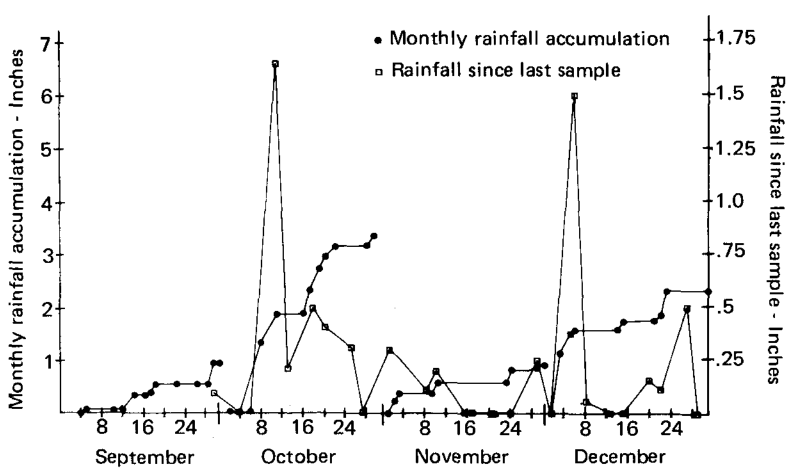

FIGURE I. Rainfall Data: September - December, 1971

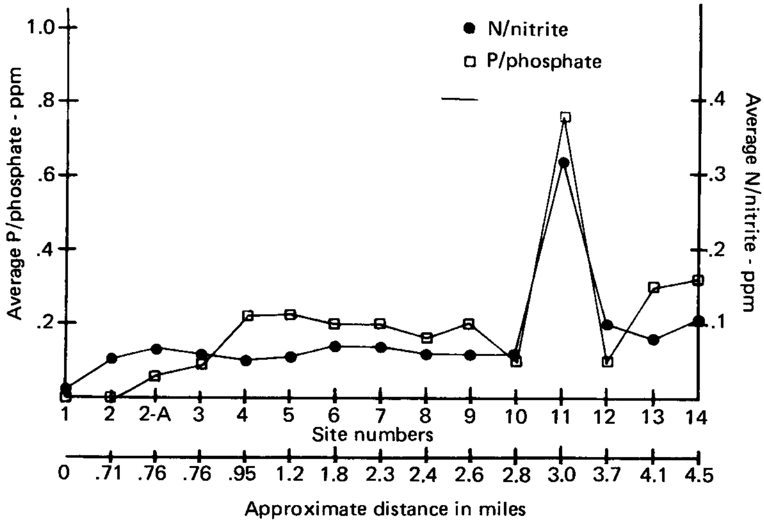

FIGURE 2. Average nitrite and phosphate observations in the Eau Gallie River

TABLE 1

AVERAGE PARAMETER VALUES AT EACH SAMPLE SITE

Site	Depth Feet	N/nitrate (ppm)		P/phosphate (ppm)		pH		N/nitrite (ppm)		Turbidity (J. U.)*	
		Average	S	Average	S	Average	S	Average	S	Average	S
1	0	8	.50	.02	.03	6.95	.97	0.0	0.0	101.5	34.5
2	0	2.6	.57	.10	.09	7.67	.15	0.0	0.0	63.5	20.7
2A	0	1.3	.34	.13	.11	7.68	.16	.03	.04	50.4	14.1
3	0	1.4	.56	.12	.06	7.72	.11	.04	.04	57.0	15.7
4	0	1.8	.54	.10	.06	7.84	.11	.11	.06	48.5	18.5
5	0	1.4	.39	.11	.04	7.67	.13	.11	.08	55.7	14.3
6	0	1.5	.44	.14	.04	7.59	.15	.10	.07	59.3	14.2
7	0	1.5	.35	.14	.08	7.61	.17	.10	.06	60.2	14.9
8	0	1.4	.33	.12	.08	7.54	.20	.08	.08	56.3	17.9
9	0	1.4	.34	.12	.05	7.44	.15	.10	.10	53.8	18.5
10	0	1.4	.42	.12	.06	7.47	.13	.05	.04	47.7	13.8
11	0	1.7	.30	.64	.13	7.51	.82	.38	.15	56.1	16.5
11A	3	1.8	.40	.37	.09	7.18	1.20	.20	.10	53.6	13.3
12	0	1.4	.34	.16	.06	7.75	.22	.15	.11	45.5	13.2
12A	3	1.5	.42	.16	.06	7.74	.20	.06	.03	47.0	14.1
13	0	2.0	.52	.20	.08	7.54	.10	.05	.05	45.6	11.6
13A	3	2.0	.46	.21	.07	7.41	.99	.06	.04	51.9	12.1
14	0	1.5	.43	.21	.07	7.86	.26	.16	.16	41.1	15.5
14A	3	1.6	.43	.18	.09	7.63	.95	.09	.08	45.4	13.0

*J. U. = Jackson Units

TABLE 2

MONTHLY PARAMETER VALUES

Month	Number of Analyses	N/nitrate		P/phosphate		pH		N/nitrite		Turbidity	
		Monthly Average ppm	S	Monthly Average ppm	S	Monthly Average	S	Monthly Average ppm	S	Monthly Average (J. U.)	S
October	72	1.70	.46	.17	.10	7.58	.20	.15	.11	65.2	14.7
November	171	1.43	.55	.16	.14	7.58	.41	.07	.09	52.1	22.3
December	171	1.65	.54	.17	.16	7.45	.11	.11	.13	52.8	21.0

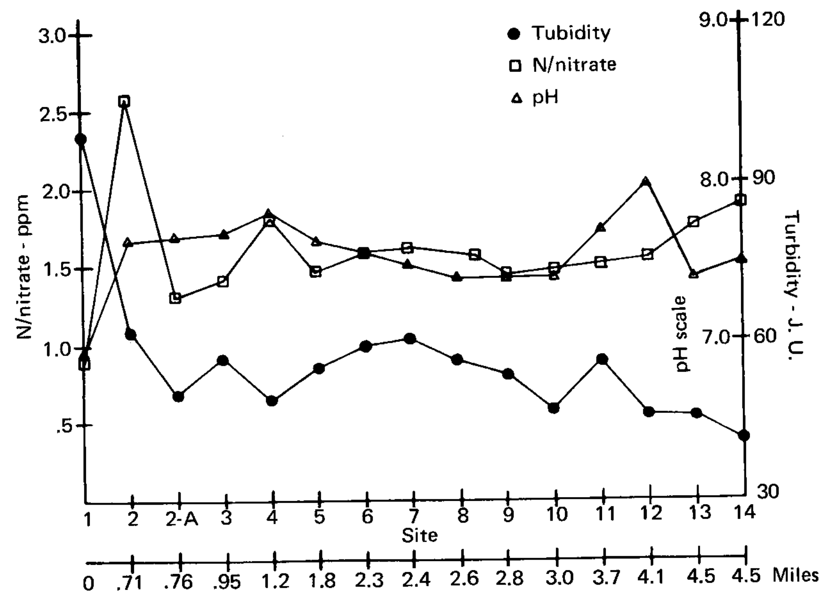

FIGURE 3. Nitrate, pH, and tubidity variation in the Eau Gallie River

Since the average parameter values in the Eau Gallie River, especially those upstream from the sewage effluent site, indicated appreciable fertilizer runoff contribution, a study was made of the elution rates of nutrients present in three typical fertilizers used in the vicinity (Table 3).

TABLE 3

FERTILIZER COMPOSITION

Type of Fertilizer	Per Cent Composition							
	Total Nitrogen	Nitrate	Ammonical Nitrogen	Water-Soluble Organic Nitrogen	Water-Insoluble Nitrogen	Phosphoric Acid	Water-Soluble Potash	Chlorine
6-6-6 (Pellet)	6	1.10	4.90	0	0	6	6	Not Over 8
6-6-6 (Powder)	6	1.85	2.65	.3	1.2	6	6	6
15-7-7 (Liquid)	15	0	1	14	0	7	7	Not More Than 1

Initially, a soil sample was extracted from the banks of the Eau Gallie River, but because of nutrient contamination an experimental medium of sanitized, well-graded, light quartz sand was employed. A one square foot area with a thickness ranging from one centimeter at the top of the slope to one-half centimeter at the bottom was chosen for the experiment. The sand was situated on a glass surface and three sides of the sand were enclosed by strips of aluminum alloy sealed to the glass with putty.

After testing the sand for initial nutrient content, the recommended dosage of fertilization per square foot was uniformly distributed onto the sand. Distilled water was sprinkled evenly over the sand and allowed to slowly trickle down the slope. After a maximum contact interval of ten minutes, the runoff was collected and analyzed for nitrate and phosphate. The average nutrient values in the runoff of the various fertilizers are given in Table 4.

TABLE 4

NUTRIENT CONCENTRATIONS IN FERTILIZER RUNOFF

Fertilizer Type	Nutrient*		Ratio of N:P in Runoff
	N/nitrate (ppm)	P/phosphate (ppm)	
Powder	35.0	.90	39:1
Pellet	13.5	.94	14.4:1
Liquid	0.0	.86	—

*Nutrient values are resultant averages of 2 determinations.

The solubilities of the two solid fertilizers were also compared by placing each in an excess of water and stirring at equal rates for various time intervals. A graph of the solubility data is shown in Figure 4.

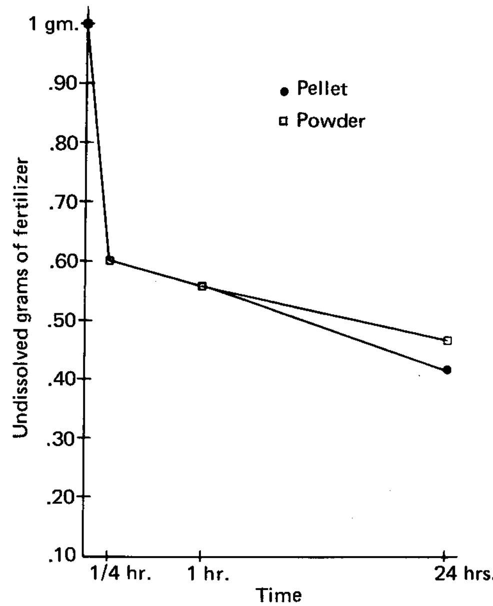

FIGURE 4. Solubility comparison of solid fertilizers.

DISCUSSION

The Eau Gallie River nutrient observations ranged from relatively low to moderate values for the tested interval except at the sewage outlet site #11.

Site 1 was established purposely to obtain nutrient values relatively unaffected by the various sources of pollution. Thus it was not surprising that nutrient observations at this point were the lowest values recorded.

The nutrient values at site 2 are of special interest because of the limited number of possible polluting sources. The water chemistry at this point was characterized by a sharp rise in nitrate and a moderate increase in phosphate. Since most of the contiguous land upstream was covered by indigenous vegetation, the above phenomena probably can be attributed to fertilizer runoff from the surrounding citrus groves. However, a more thorough examination of the effect of citrus groves on eutrophication appears warranted.

Significance is also accorded the nutrient determinations at station 2A because, again, of a lack of polluting possibilities. The stream ceases to flow immediately beyond the residential section directly upstream from this site and the surrounding area is basically marshy in character. Except for the possibility of drainage from Aurora Road, it is believed the moderate phosphate and nitrate values at this point should be attributed to residential drainage.

Little variation was observed in the nutrient determinations made at sites 2A and 3. Thus there is no definite indication of pollution caused by the livestock operation located on this stretch of the stream.

At site 4, a sharp increase in nitrite occurred accompanied by a more graduate increase in nitrate. The phosphate value remained essentially constant. The origin of the increase in nitrogen is difficult to determine because of the existence of several possible polluting sources in the vicinity which include a shopping center, several large pipes draining Wickham Road, a trailer park, and residential area.

Relatively small variation in nutrient values was observed at sites 5 through 10. But at sites 7 through 10 numerous algal blooms occurred during the testing interval as well as throughout the year. It must be assumed that a great quantity of nutrients is accumulated in these and was thus not measured in the collected water samples (7). The surrounding land at this interval and directly upstream is mainly a combination of swamp and residential sections. From an assessment of the observable environmental characteristics of this section of the river, it can be stated that one major cause of the algal blooms must be excess nutrients derived from lawn fertilizer runoff.

At site 11, the phosphate and nitrite levels increased substantially. The nitrate value, while above average for the river, did not represent such a dramatic increase. All increases can be attributed to the sewage effluent piped into the river at this point. The relatively high nitrite and low nitrate values can possibly be explained by the presence of near anoxic conditions at the sewage site (8). The phosphate and nitrite contributions of the sewage effluent must be considered the major source of these nutrients in the lower Eau Gallie River.

The influence of the sewage effluent was seen at site 12 where both phosphate and nitrite values were above average. The below average nitrate values at this site gave evidence that in contrast to phosphate and nitrite, the sewage effluence appeared to exert little effect on nitrate concentrations.

At station 13, located at the source of Elbow Creek, relatively high nitrate and phosphate values were observed. Nitrite was found to be surprisingly low. The effect of the sewage effluent was considered inconsequential at this site because of the inverse relative magnitudes of the nitrite and nitrate values from those of the sewage effluent. One possible polluting source at this site is an overflow pipe from a sewage lift station feeding into one of the canals emptying into Elbow Creek (9). Furthermore, an extensive system of canals draining several residential areas empties into Elbow Creek near this station. This represents another feasible polluting source as well as a possible explanation of the sudden inversion of relative nitrate and nitrite values. The period of time between the elution of fertilizer and/or sewage into the canal system and its eventual drainage into Elbow Creek may be substantial. Thus it is possible that ample time is available for the conversion of nitrite to nitrate ion by biological processes (10).

The nitrogen values at site 14 were similar to those at site 12. Phosphate values on the other hand rose significantly which indicates additional sources of pollution aside from the sewage effluent. While it is impossible to designate the additional pollutants with certainty, several potential sources are existent including a public park, several boat marinas and residential areas. Another possible source of the increased phosphate value at site 14 is the liberation of phosphates from suspended sediments. The uptake of phosphates by suspended sediments has been determined to be reversible with desorption being favored by an increase in pH (11).

One other factor to be considered is the very high concentration of phosphate present in estuarine muds, e.g., levels 10^5 times those in the overlying waters have been found (12). Thus, even a very small release of this nutrient could have a great effect on the phosphate concentrations in the upper waters.

Because of the increasing evidence that nutrient contribution from fertilizer runoff is a major source of nutrients in the river, an attempt was made to correlate nutrient values with rainfall data. A comparison of the overall average nutrient values with extreme rainfall variation indicates that there is a direct correlation between rainfall and nutrient concentration in the river (Table 5).

TABLE 5

CORRELATION OF EXTREME RAINFALL VARIATION WITH AVERAGE NUTRIENT VALUES

Rainfall Since Last Sample	Average Nutrient Values (ppm)		
	Nitrate	Nitrite	Phosphate
Over 1"	2.0	.14	.22
0"	1.5	.07	.14

The data shown and the predominance of well fertilized acreage in the lagoonal area are further evidence that the contribution of fertilizer runoff to eutrophication should be substantial especially during the rainy seasons.

From Table 4 it can be easily seen that the nitrate concentration of the fertilizer runoff varied considerably more than did phosphate. By reference to Table 3, this variation can be partially attributed to the per cent nitrate composition of the fertilizers. But the ratio of the per cent nitrate composition of the powdered and pelletized fertilizers and the nitrate concentration in the runoff were not directly proportional. Although there may be several explanations to account for this disproportionate distribution of nitrate in the runoff, none is completely satisfactory.

As previously stated the phosphate concentrations in the runoff varied to a much smaller degree than did nitrate. Moreover, while the liquid fertilizer had the smallest concentration of phosphate in the runoff, it contained the largest percentage composition of phosphoric acid initially, which suggests that the phosphate variations in the runoff, however small, seem to be more of a function of the physical state of the fertilizer than its chemical composition. The possible importance of the physical properties of fertilizers upon the nutrient content in runoff motivated further investigation of the characteristic solubilities of the powdered and pellet solid fertilizers. Quite unexpectedly, the solubilities were found to be initially the same, and the powdered form proved to be actually less soluble than the pelletized form after a twenty-four hour time interval.

By combining the previously determined flow rates of the Eau Gallie River and Elbow Creek (1), the total water flow into the Indian River was determined. This flow rate multiplied by the nitrogen and phosphorus concentrations on the surface at site 14 (located near the mouth of the river) gave an approximation of the amount of both nutrients flowing into the Indian River per day. Surface concentrations of the nutrients from site 14 were used in the calculations because it is believed they most nearly represent the concentration of nutrients in the fresh water outflow. With these values and the known relationship that one kilogram of nitrogen produces 20 kilograms of dry weight biomass and one kilogram of phosphorus produces approximately 167 kilograms of dry weight biomass (13) the total resultant biomass potential was determined. Similarly, the relative effect of the sewage effluent on the Indian River nutrient concentration was determined. Results of these calculations are given in Table 6.

TABLE 6

NUTRIENT INPUT AND BIOMASS POTENTIAL RESULTING FROM THE EAU GALLIE RIVER INFLUX INTO THE INDIAN RIVER

Sample Site	Flow X 10^6 kg/day	Total Nitrogen Output kg/day	Total Phosphorus Output kg/day	Dry Weight Biomass Potential of Nitrogen kg/day	Dry Weight Biomass Potential of Phosphorus kg/day
14 (mouth of river)	106.6	177	22.2	3540	3698
11 (sewage effluent)	8.74	18.2	5.6	364	935

It is readily apparent that the Eau Gallie River is a large source of nutrients to the Indian River. The fact that the contribution of this river, which is only one of four fresh water streams flowing into the northern portion of the lagoon, has the potential to produce over 3000 kilograms of biomass per day indicates the overall effect of the fresh water influx could be extremely significant. That large quantities of biomass are produced in the Indian River is supported by the high concentrations of rich organic settlement on the river bottom (6).

A comparison of the nutrient output contained in the sewage effluent to the total nutrient output of the river suggests that the effect of sewage effluent upon the Indian River is relatively minor. The sewage effluent only contributes approximately 25 per cent of the phosphorus and 10 per cent of the nitrogen influx. It appears that the major nutrient effect is derived from a combination of other sources, chief among which are agricultural and lawn fertilizers.

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