Effect of Power Plant Passage on Algal Primary Productivity

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Abstract

The effect of condenser passage on phytoplankton was studied for an 18-month period at the Palisades Nuclear Power Plant near Covert, Michigan.

Fifty-two sets of ^{14}C samples were collected on 25 separate days. If the samples are averaged collectively for the entire study period (using samples showing increases and decreases in discharge primary productivity over intake samples), but divided up into effects of a heated discharge and a non-heated discharge the average loss for the heated discharge was 32.7 percent and the average loss for the non-heated discharge was 17.9 percent, indicating that mechanical stress caused approximately one-half the decrease in primary productivity.

Introduction

Carbon 14 tests were conducted to determine the effects on photosynthetic activity of algae exposed to the once-through cooling process used at the Palisades Nuclear Power Plant.

The plant is located in Van Buren County on a 487-acre site on the eastern shore of Lake Michigan in the southwestern part of Michigan. The site is approximately 4½ miles south of South Haven and 16 miles north of Benton Harbor and St. Joseph.

The Palisades facility, which has a rated capacity of about 700 megawatts electric (MWe) with an ultimate electrical output up to 821 MWe, began operations at 60 percent of rated power early in 1972. The plant utilized a pressurized water nuclear reactor system and the steam was condensed by means of a once-through condenser cooling system using Lake Michigan water to dissipate the waste heat. The waste heat at rated capacity increased the cooling water temperature a maximum of 25°F above ambient at the intake. The intake is submerged offshore about 3,300 feet at a minimum depth of about 25 feet. The heated discharge entered Lake Michigan directly at the shoreline. The total flow rate through the once-through cooling system was about 405,000 gallons per minute (gpm). This system was used until completion of mechanical draft evaporative cooling towers in early 1974. These towers converted the circulating water system to essentially closed cycle cooling with only a small blowdown discharge to the lake which is not more than 5°F above ambient lake temperature.

Methods

Samples of surface water were collected from the intake bay near the plant, and 90 seconds later from the discharge at the shoreline. Residence time in the plant was approximately 90 seconds. It was assumed the intake and discharge samples represented the same water mass, differing only in respect to passage through the plant.

Relative photosynthetic rates were measured with ^{14}C; following in general the light and dark bottle procedure described by Strickland and Parsons (6). Each sample set included two light bottles, one control bottle, and one dark bottle from the intake and the discharge. The dark bottles were wrapped in extra-heavy duty aluminum foil. Both sample sets were incubated 4 hours in a glass 20-gallon aquarium at intake water temperature after the addition of 2 ml of ^{14}C solution of 2 microcuries strength. All sample bottles were wrapped in double layered hardware store nylon screening to eliminate direct sunlight inhibition of photosynthesis, and were illuminated in incident sunlight.

After incubation each sample was filtered in a darkened area using a HAWP 0.47-μ membrane filter. After filtration the apparatus and filter were washed with 50 ml of distilled water to remove any ^{14}C adhering to the cell surfaces. The filters were placed in 1 dram vials, dissolved in 5 ml of laboratory grade acetone to break down the filter and organic matter and then prepared for counting on a Packard-Bell liquid scintillation counter.

After counting the two light samples, counts were averaged, adjusted for background count, and corrected for uptake in the dark bottle. A percentage reduction of photosynthetic activity was calculated using the following formula as presented by Hamilton, et al. (3).

$$\%\ \text{reduction} = \left(1 - \frac{\text{mean of effluent rates}}{\text{mean of intake rates}}\right) 100$$

Results

The dominant algal groups observed in the intake water samples were primarily diatoms, especially *Asterionella formosa*, *Cyclotella* sp., *Fragillaria crotonensis*, *Melosira* sp., *Tabellaria* sp., and *Diatoma* sp. Figure 1 and Table I show the results of 52 sets of samples collected on 25 separate days from May 24, 1972 to August 27, 1973. When no heat was present (17 sets of samples), change in productivity varied from a 68.1 percent loss to a 109 percent gain in the discharge samples, with an average loss of 35.6 percent (based on 12 samples) and an average gain of 35.4 percent (based on 4 samples), with no change in one sample. With the introduction of heat, (35 sets of samples) change in productivity varied from an 89.3 percent loss to a 76 percent gain in the discharge samples, with an average loss of 47.9 percent (based

TABLE 1. *Summary of Loss or Gain of Photosynthetic Activity.*

Average of All Samples	—27.1
Average of All Heated Discharge Samples	—32.7
Average of All Non-heated Discharge Samples	—17.9
Average of All Samples With Loss of Productivity	—44.2
Average of All Samples With Gain in Productivity	+35.9
Average of Heated Discharge Samples With Loss of Productivity	—47.9
Average of Heated Discharge Samples With Gain in Productivity	+36.2
Average of Non-heated Discharge Samples With Loss of Productivity	—35.6
Average of Non-heated Discharge Samples With Gain in Productivity	+35.4

on 28 samples) and an average gain of 36.2 percent (based on 6 samples) with no change in one sample. If the samples are averaged collectively for the entire study period, but divided up into effects of a heated discharge and a non-heated discharge the average loss for heated was 32.7 percent and the average loss for non-heated was 17.9 percent, indicating, that mechanical stress caused approximately one-half the decrease in primary productivity.

FIGURE 1. *Loss or gain of photosynthetic activity.*

				Reduction or Gain in Photosynthesis (%)			
				Sample Number			
Date	Intake Temp.	Discharge Temp. (°F)	T(°F)	1	2	3	Average (%)
5/24/72	44	44	0	+10.0			+10.0
6/ 2/72	56	56	0	—13.4			—13.4
6/13/72	56	70	14	—65.4			—65.4
6/15/72	54	70	16	—47.5			—47.5
6/16/72	58	72	14	+ 0.6			+ 0.6
7/14/72	64	84	20	—34.2	+ 1.2	—79.0	—37.3
7/21/72	74	91	17	—52.5	+63.4		+ 5.5
8/ 4/72	45	61	17	—10.9	—24.6	—23.1	—19.5
8/17/72	64	82	18	—29.1			—29.1
8/23/72	64	88	24	—88.0	—55.0	+36.0	—35.7
8/29/72	70	70	0	—24.0	—19.0	+109.0	+22.0
9/ 6/72	66	82	16	+40.0	—22.0	+76.0	—31.3
9/19/72	65	65	0	—23.6			—23.6
4/18/73	46	72	26	—65.4	—53.0	—15.1	—44.5
5/24/73	50	50	0	—68.1	—46.6	0.0	—38.2
5/31/73	49	60	11	—35.6	—16.1		—25.9
6/ 8/73	62	87	25	—65.9	—81.0		—73.5
6/20/73	66	93	27	—64.1	0.0		—32.1
6/22/73	68	90	22	—54.3			—54.3
7/ 5/73	67	89	22	— 5.3	—18.5	—82.5	—35.5
7/13/73	62	86	24	—63.6			—63.6
8/ 8/73	75	100	25	—30.6	—68.6	—89.3	—62.8
8/16/73	47	47	0	—17.1	—49.2	+ 9.4	—19.0
8/21/73	48	48	0	—62.1	+13.2	—18.9	—22.6
8/27/73	59	59	0	—17.2	—67.9		—42.6

The results are similar to those of Gurtz and Weiss (2) Hamilton, et. al. (3), and Morgan and Stross (4) who also found both inhibition and stimulation in primary productivity in comparable work.

Gurtz and Weiss (2) found that a rather constant inhibition occurred for a 10 or 20°F ΔT, regardless of the initial temperature, but that at ΔT's of 30°F successively greater inhibitions occurred with increasing intake temperatures. Morgan and Stross (4) found that an increase in temperature of approximately 14°F stimulated photosynthesis when conditions were 61°F or cooler, and inhibited photosynthesis when ambient conditions were 68°F or warmer. Patrick (5) suggested that algae are little damaged if the temperature does not exceed 93°F, and that diatoms are more sensitive than green and blue-green algae, which have temperature, growth, and photosynthetic optima of the order of 90-95°F and above 95°F, respectively. In this study sets of samples taken above ΔT's of 20°F showed a 48.3 percent reduction in activity. The sets of samples from higher temperatures 85°F and above show percent losses higher than those at lower temperatures and smaller ΔT's. The overall percent reduction coincides with a 32.7 percent average loss noted at Waukegan Station (1).

It seems evident from the data collected in this study and the others cited that mechanical stress and heat effect algal primary productivity, but each is related to the ambient conditions and the ΔT of the individual generating plant. The extreme variability in photosynthetic response to the stresses of entrainment and condenser passage indicates that phytoplankton patchiness may be large and thus reduce the significance of available data on Lake Michigan.

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