# Power Plants: Effects of Chlorination on Estuarine Primary Production

Abstract. *Steam electric stations may reduce primary production of cooling water by 91 percent as a result of chlorine applications for control of fouling organisms. Bacterial densities and concentrations of chlorophyll a are also reduced. Slight stimulation of production may occur in the absence of chlorination. Based on the available supply of "new" water, we calculate a maximum loss of primary production of 6.6 percent for the adjacent tidal segment of the Patuxent River.*

In 1965 a steam electric station with a capacity of 730 Mw went into operation at Chalk Point on the Patuxent River, Maryland. Its location near commercially productive oyster bars, rate of water use of 1125 $m^3$ $min^{-1}$, and numerous other factors have made it the subject of continuous study since construction started in 1961. We report here the results of experiments designed to examine the effect of plant operations on primary productivity.

Samples of surface water were taken in the intake canal next to the intake structures and, 15 minutes later, in the effluent canal, near the point of discharge from the plant. Residence time in the plant is approximately 15 minutes. We assume the intake and effluent samples represent the same water mass, differing only in respect to passage through the plant. Samples were taken without prior knowledge of chlorination schedules. Chlorine is applied intermittently at this plant to control the growth of fouling organisms in the condensers.

Portions of each sample were measured for content of active chlorophyll a and bacteria count. Chlorophyll was estimated with a fluorometric method (*1*). Counts of bacterial colonies were made on 10 ml of diluted sample [$(\frac{1}{2})^5$] passed through a gridded 0.45-$\mu$m

Table 1. Studies of water samples from intake and effluent canals at the steam electric generating plant at Chalk Point, Maryland. Each determination of rate of photosynthesis is a mean of two light bottles corrected for uptake in the dark and for background and adjusted to correspond to a 1-hour incubation period. Within each experiment, photosynthetic rates designated by a different letter (A, B, C, or D) are significantly different. $\alpha = .05$. Test is Duncan's Multiple Range. Experiments 1–3 were conducted in August 1969, experiments 4 and 5 were conducted in September 1969, and experiments 6–11 were conducted in October 1969. NCM, no count made.

| Experiment | Sample | Incubation at (°C) | Rate of photosynthesis (count/min) | | Active chlorophyll a ($\mu$g/liter) | Bacterial count (colonies/ml) | Chlorination* at time of sampling | Rate (kg/hour) | Reduction in photosynthesis (%) |
|---|---|---|---|---|---|---|---|---|---|
| 1 | Intake | 27 | 3817 | A | 75.0 | 1877 | No | | |
| | Intake | 33 | 3869 | A | 75.0 | 1877 | No | | |
| | Effluent | 27 | 754 | B | 19.4 | 739 | Yes | 170 | |
| | Effluent | 33 | 610 | B | 19.4 | 739 | Yes | 170 | 82.2 |
| 2 | Intake | 27 | 4841 | A | 50.0 | 1031 | No | | |
| | Intake | 33 | 3193 | A | 50.0 | 1031 | No | | |
| | Effluent | 27 | 428 | B | 21.6 | 292 | Yes | 170 | |
| | Effluent | 33 | 401 | B | 21.6 | 292 | Yes | 170 | 91.3 |
| 3 | Intake | 27 | 3216 | A | 48.8 | 1631 | No | | |
| | Intake | 33 | 2568 | B | 48.8 | 1631 | No | | |
| | Effluent | 27 | 346 | C | 23.8 | 63 | Yes | 170 | |
| | Effluent | 33 | 305 | C | 23.8 | 63 | Yes | 170 | 91.1 |
| 4 | Intake | 23.5 | 3141 | A | 37.7 | 5073 | No | | |
| | Intake | 30.5 | 3838 | B | 37.7 | 5073 | No | | |
| | Effluent | 23.5 | 1347 | C | 24.3 | 1527 | Yes | 129 | |
| | Effluent | 30.5 | 1360 | C | 24.3 | 1527 | Yes | 129 | 50.0 |
| 5 | Intake | 23.5 | 5919 | A | 99.1 | 2315 | No | | |
| | Intake | 30.5 | 6119 | A | 99.1 | 2315 | No | | |
| | Effluent | 23.5 | 2741 | A | 59.8 | 443 | No | | |
| | Effluent | 30.5 | 5620 | A | 59.8 | 443 | No | | 30.5 |
| 6 | Intake | 14 | 1081 | A | 9.2 | NCM | No | | |
| | Intake | 21 | 1376 | B | 9.2 | NCM | No | | |
| | Effluent | 14 | 1299 | B | 13.9 | NCM | No | | |
| | Effluent | 21 | 1737 | C | 13.9 | NCM | No | | |
| 7 | Intake | 14 | 1712 | A | 19.9 | NCM | No | | |
| | Intake | 21 | 1835 | A | 19.9 | NCM | No | | |
| | Effluent | 14 | 1455 | B | 18.0 | NCM | No | | |
| | Effluent | 21 | 1781 | A | 18.0 | NCM | No | | |
| 8† | Intake | 14 | 1347 | | 21.0 | NCM | No | | |
| | Intake | 21 | 1466 | | 21.0 | NCM | No | | |
| | Effluent | 14 | 958 | | 15.0 | NCM | No | | |
| | Effluent | 21 | 1101 | | 15.0 | NCM | No | | |
| 9 | Intake | 14 | 1242 | A | 21.0 | NCM | No | | |
| | Intake | 21 | 1647 | B | 21.0 | NCM | No | | |
| | Effluent | 14 | 1008 | C | 14.6 | NCM | No | | |
| | Effluent | 21 | 1123 | A | 14.6 | NCM | No | | |
| 10 | Intake | 14 | 1201 | A | 14.5 | 17,826 | No | | |
| | Intake | 21 | 1481 | A | 14.5 | 17,826 | No | | |
| | Effluent | 14 | 1300 | A | 11.4 | 27,084 | No | | |
| | Effluent | 21 | 1528 | A | 11.4 | 27,084 | No | | |
| 11 | Intake | 14 | 1615 | A | 12.8 | 14,015 | No | | |
| | Intake | 21 | 2005 | B | 12.8 | 14,015 | No | | |
| | Effluent | 14 | 1135 | C | 11.8 | 19,465 | No | | |
| | Effluent | 21 | 1515 | A | 11.8 | 19,465 | No | | |

* Chlorination schedules supplied by Potomac Electric Power Co. † No statistical evaluation was made of this experiment due to unequal replication resulting from loss of one of paired bottles.

membrane filter in a sterilized filtration apparatus. Membranes were mounted in petri plates that contained a few milliliters of the following media: (i) sterilized river water, (ii) 1.5 percent agar, (iii) 0.1 percent peptone, and (iv) 0.1 percent dextrose. These were incubated in inverted position for 48 hours at room temperature, prior to counting under a dissecting microscope. The average density of 15 squares was used to estimate the total number of colonies on the filter.

Relative photosynthetic rates were measured with $^{14}C$; we followed, in general, the light and dark bottle procedure described by Strickland and Parsons (*2*) for measurement of productivity by means of the $^{14}C$ method. Twelve bottles were used in each experiment. One set of three (two light and one dark) filled with intake water was incubated at ambient water temperature, another set of three at the temperature of the effluent. Similar sets of bottles filled with effluent water were incubated at ambient and at effluent temperature.

The wood and plexiglass incubators were filled with tap water circulated through a reservoir fitted with a cooling unit and a heating unit to maintain the desired temperature. Temperatures were maintained within 2°C of that designated during the course of incubation. Although the absolute temperature of the incubators was different on the several experimental days, the differential was nearly the same (Table 1). Each incubator contained eight 40-watt fluorescent lamps. Average light intensities were $0.89 \times 10^4$ erg cm$^2$ sec$^{-1}$ and $1.12 \times 10^4$ erg cm$^2$ sec$^{-1}$ (*3*). No correction has been made in the data for the slight difference in light value.

Following a 3- to 4-hour period of incubation, experiments were concluded by filtration of 25 or 50 ml from each bottle through a 0.45-$\mu$m membrane. These were mounted on ring and disk assemblies, desiccated, and counted in a thin end-window, gas-flow counter (Nuclear-Chicago).

A conspicuous reduction of photosynthetic rate is apparent in experiments 1–4 (Table 1). As the plant was chlorinating at these times, we believe this is a direct effect of chlorine in the effluent sample. The reductions are statistically significant and are paralleled by reductions in bacterial densities and concentrations of chlorophyll a. A similar though smaller reduction in photosynthesis occurred in experiment 5. Although this is not statistically significant, it is paralleled by a lower bacterial count and chlorophyll concentration. We are unable to explain this result; no application of chlorine was recorded at this time. The percentage reduction in photosynthesis (ignoring the difference in incubation temperatures) was calculated as follows:

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

Rates of photosynthesis, concentrations of chlorophyll a, and bacterial counts are nearly identical in experiments 6–11, although some of the differences in rates of photosynthesis are significant.

Most of these differences may be interpreted as being due to temperature increase. In the last six experiments (as well as four of the initial five) heated intake water has a higher rate of photosynthesis than does intake water incubated at ambient temperature. The same is true of effluent water in experiments 5–11. Any effect temperature might have had in effluent water in experiments 1–4 is evidently overshadowed by the effect of chlorine.

Our results are similar to those of Warinner and Brehmer (*4*) in the York River. Comparability is limited, however, since they employed generally larger temperature differentials. Also, the differentials were induced in the laboratory, rather than by plant operations, which thus excluded any influence of chlorine. Morgan and Stross (*5*) also found reductions and increases in primary productivity in work more comparable to our own at the same site.

The maximum rate of water use by this plant has been estimated to be 30 percent of the rate of supply of new water to the adjacent segment of the river (*6*). Chlorination records (*7*) show that only rarely is chlorine applied more than 6 hour day$^{-1}$ at Chalk Point; application 25 percent of the time would thus be a reasonable maximum. Ignoring intensity and timing of application, and assuming 91 percent loss of production when chlorination occurs, a maximum loss of primary production of 6.6 percent may be calculated for the affected area of the river. Whatever the exact magnitude of this loss in the condenser water, we have not detected a consistent reduction of primary production in the vicinity of the outfall of the effluent canal in field studies.

D. H. Hamilton, Jr., D. A. Flemer
Carolyn W. Keefe, J. A. Mihursky
*Chesapeake Biological Laboratory, University of Maryland Natural Resources Institute, Solomons 20688*

**References and Notes**

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2. J. D. H. Strickland and T. R. Parsons, *Bull. Fish. Res. Board Can.* **167** (1968).
3. Light intensities were measured in situ in the incubator with a Yellow Springs Instrument radiometer.
4. J. E. Warinner and M. L. Brehmer, *Int. J. Air Water Poll.* **10**, 277 (1966).
5. R. P. Morgan and R. G. Stross, *Chesapeake Sci.* **10 (3-4)**, 165 (1969).
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7. The 6 hour day$^{-1}$ estimate is based on examination of monthly records covering daily operation for a 2-year period. These records are available at the Department of Water Resources, State Office Building, Annapolis, Md.
8. Supported by contract No. 14-01-0001-1969 with the Office of Water Resources Research, U.S. Department of the Interior. Contribution No. 420, Natural Resources Institute of the University of Maryland. We thank D. R. Heinle (Chesapeake Biological Laboratory) and J. Carpenter (Chesapeake Bay Institute) for comments and suggestions and R. C. Whaley (Chesapeake Bay Institute) for constructing the incubators.

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## Acetylsalicylic Acid: No Chromosome Damage in Human Leukocytes

Abstract. *Acetylsalicylic acid was added to cultures of human leukocytes at several time periods over a wide range of concentrations (0.1 to 300.0 micrograms per milliliter). Leukocytes were also cultured from human volunteers during the ingestion of two 300-milligram tablets four times daily (2400 milligrams per day) over a 1-month period. No significant increase in chromosome aberrations was detected in vitro or in vivo.*

The potential for carcinogenesis and long-term genetic damage in man from environmental agents (radiation, viruses, chemicals, drugs, food additives, and other substances in common usage) is a subject of widespread concern. One means of assessing this potential is through short-term cytogenetic tests, with primary reliance placed on the effect of such agents on the chromosomes and growth of peripheral leukocytes in vitro. We have