GUIDELINE FOR ASSESSING AND PREDICTING EUTROPHICATION STATUS OF SMALL SOUTHEASTERN PIEDMONT IMPOUNDMENTS

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INTRODUCTION

Post-impoundment water quality problems, especially eutrophication, one of the pervasive and world-wide water quality problems, are important to EPA relative to planning and managing impoundments (EPA 1989).

Region 4 conducted a two-year study of seventeen piedmont reservoirs (eleven in Georgia). This study developed a guideline for a common eutrophication indicator: corrected chlorophyll A. The guideline was set by using a risk analysis approach based on a classification system developed for South African impoundments and successfully used in Minnesota (Walmsley, 1984; Walker, 1985; Heiskary and Walker, 1988; Wilson and Walker, 1989).

The reservoirs were sampled during the growing seasons (April-October) of 1989 and 1991, usually on a weekly or biweekly basis. Most stations were located at mid-impoundment along the thalweg. Depth integrated water samples were collected from the mixing zone, but at no greater than two meters depth.

The impoundments studied were monomictic. Vertical zonation was in place by mid-June and remained until the latter part of September or October when water turnover occurred. With the onset of temperature zonation, a dissolved oxygen chemocline began to form at the 1-2 meter level. By mid-summer the hypolimnion was devoid of oxygen, and pH ranged from 4.88 to 9.76. All of the impoundments were freshwater, with conductivities of <300 umhos/cm @ 25° and usually <100 umhos. No fish kills or stressed fish were observed or reported under the above conditions. The impoundments studied ranged from a Carlson TSI of 50.2 to 71.6 (Table 1), which encompasses the classical eutrophication range from mesotrophic to hypereutrophic (Carlson, 1977; EPA, 1988).

The guideline was set after utilizing study data, expert opinion, and the literature. It was determined that with a mean growing season limit of ≤15 μg/L of chlorophyll A, very few problems would be incurred with respect to water supply. For other uses, a mean growing season chlorophyll A of <25μg/L is recommended to maintain a minimal aesthetic environment for viewing pleasure, safe swimming, and good fishing and boating.

ISSUE: NUISANCE BLOOMS AND SCUMS VARIABLE: GROWING SEASON MEAN CORRECTED CHLOROPHYLL A

Guideline

A mean growing season limit of ≤15 ug/L chlorophyll A is recommended for water supply impoundments. At this concentration few nuisance algal blooms or scums would be expected, thereby very few problems associated with filter clogging and taste and odor would be anticipated. For other uses a mean growing season chlorophyll A of ≤25 ug/L is recommended to maintain a minimal aesthetic environment for viewing pleasure, safe swimming, and good fishing and boating.

Rationale

One common indicator of eutrophication and its impacts is the variable chlorophyll A (Carlson, 1977: EPA, 1988; EPA, 1990). Because of the specificity and ease of the chlorophyll A analysis, it has become a common surrogate for estimating phytoplankton biomass. In practice, this pigment is a useful yardstick for estimating phytoplankton blooms (chlorophyll A concentrations ≥15 μg/L) and associated water quality problems. On the average, 1.5% of algal organic matter (ash-free-dry weight) is corrected chlorophyll A (APHA, 1989).

Based on the authors experience in phycology and limnology/oceanography over the past 30 years, generally, when chlorophyll A ranges from 0 to 10 μg/L, there is no discoloration of the water and no problems. At a range of 10-15 μg/L, water can become discolored and algal scums could develop. Between 20-30 μg/L, the water is deeply discolored, scums are more frequent and matting of algae can occur. Beyond 30 μg/L of chlorophyll A, discolorations are more intense and mats occur more frequently.

Walker (1985) working on the hypothesis that water use impacts are more directly related to instantaneous chlorophyll A concentrations than to seasonal mean values, examined data from South Africa, U.S. Corps of Engineers (COE) and Vermont Lakes. Statistical frequency distribution models were calibrated and the curves generated were found to be similar. Soon thereafter,

TABLE 1. CHARACTERISTICS OF SMALL SOUTHEASTERN PIEDMONT IMPOUNDMENTS, 1989-1991.

Lake Site	State	TSI	Area (HA)	Mean Depth (meters)	Mean HRT (days)	N	Years	Mean TP ± SE (μg/L)	Mean SD ± SE (meters)	Mean CHL A ± SE (μg/L)	% ≥ 15	% ≥ 20	% ≥ 25	% ≥ 30	% ≥ 40
Bowen	SC	50.2	648	4.7	111	36	1	30±4	1.78±.14	7.38±0.89	8	3	3	3	0
Cunningham	SC	50.9	101	2.7	--	20	1	28±3	1.08±.04	7.94±0.87	5	0	0	0	0
Michie	NC	52.6	202	8.2	48.0	12	1	36±2	1.31±.11	9.39±1.46	25	0	0	0	0
Oglethorpe	GA	53.2	28	2.3	79.5	25	1	24±4	1.61±.10	9.98±1.62	28	8	4	0	0
Wheeler1	NC	53.5	219	3.5	72.0	18	4	33±4	0.71±.06	10.3±1.33	22	6	0	0	0
Chapman	GA	53.9	105	3.3	40.2	26	1	25±5	1.37±.09	10.8±2.06	38	12	12	4	0
Union Point	GA	54.9	13	0.85	13.9	23	1	28±3	1.05±.07	11.1±2.30	39	30	13	9	0
Wheeler3	NC	54.9	219	3.5	72.0	28	4	30±3	0.94±.08	11.9±1.39	28	6	6	0	0
Secession5	SC	55.1	356	6.7	44	15	5	52±13	1.88±.15	12.2±2.04	40	14	7	0	0
Devin	NC	56.9	51	3.0	--	12	1	45±4	1.25±.13	14.6±3.32	27	18	9	9	9
Colbert	GA	57.4	19	1.9	5.1	26	1	41±9	0.91±.10	15.3±2.80	38	31	23	19	8
Brantley	GA	61.2	18	1.3	4.7	14	1	36±6	0.56±.03	22.6±8.71	43	21	14	14	14
Blalock	GA	61.3	105	3.2	17.2	14	1	42±4	1.05±.08	22.9±3.51	64	50	29	21	14
Rutledge	GA	63.3	115	1.6	24.9	14	1	44±6	0.72±.07	27.1±3.54	79	79	57	43	21
Commerce	GA	63.7	149	1.5	15.2	26	1	81±7	0.41±.02	29.3±3.44	85	65	62	54	35
Shamrock	GA	63.9	28	3.0	2.9	13	1	47±3	0.98±.08	29.7±5.42	77	54	46	38	38
Secession4	SC	63.9	356	6.7	3102	15	5	76±9	1.08±.13	29.8±4.53	80	53	47	33	27
High Falls	GA	64.8	243	3.7	15.5	14	1	52±4	0.96±.08	32.8±6.21	79	57	50	43	36
Rock Eagle	GA	71.6	45	1.5	13.7	14	1	54±3*	0.74±.07	65.3±7.97	100	100	100	93	79

TSI Carlson Trophic State Index Based on Mean Chlorophyll A
HRT Hydraulic Residence Time
N Number of Samples used for Bloom Frequency Analysis
Years Number os years where data available
TP Total Phosphorus
SD Secchi Disc Transparency
ChlA Corrected Chlorophyll A
SE Standard Error for Growing Season Mean
% ≥ Percent of the Time Corrected Chlorophyll A equal to or greater than the instantaneous measurement
* Rock Eagle impoundment was fertilized with an additional 500 lbs of phosphorus; therefore the resulting corrected chlorophyll A probably reflects availability of phosphorus

Walker collaborated with the state of Minnesota (Heiskary and Walker, 1988; Wilson and Walker, 1989) using the bloom frequency approach to successfully estimate percent impairment.

This approach is reasonable because managers can better evaluate risk. Rather than making decisions based on just an average or maximum, they can evaluate bloom severity (maxima) and frequency in association with a growing season mean concentration. A few days of algal scums during the growing season may be tolerable, but 1-2 days per week of scums may be undesirable.

The EPA-Region IV population of impoundments shows that percent occurrence of algal blooms (i.e. ≥15 μg/L chlorophyll A) decreases as bloom frequency increases (Figure 1). Quenching of the bloom frequency curves begins at a mean chlorophyll A of 30 μg/L wherupon the curves converge toward the 100% ordinate. Figure 2 presents an interpolation of Figure 1 data between a seasonal mean of 10 to 30 μg/L chlorophyll A. The following straight line equations were derived for each exceedance class within the 10-30 μg/L chlorophyll A limit.

$$\% \geq 15 \pm .43 = 2.88\ (\bar{X}) - 12.92$$
$$\% \geq 20 \pm .36 = 2.77\ (\bar{X}) - 25.58$$
$$\% \geq 25 \pm .54 = 2.31\ (\bar{X}) - 24.46$$
$$\% \geq 30 \pm 4.3 = 1.90\ (\bar{X}) - 21.26$$
$$\% \geq 40 \pm .15 = 1.18\ (\bar{X}) - 14.16$$

Where: $\bar{X}$ = Mean season corrected chlorophyll A

EPA-Region IV data (Figures 1 and 2) show that a mixing zone growing season average of ≤15 μg/L of chlorophyll A should satisfactorily meet multiple uses (Carlson, 1977; Lillie and Mason, 1983; Burden *et al.*, 1985; Walmsley, 1984; Heiskary and Walker, 1988). At a growing season (April - Oct.) average chlorophyll A of 15 μg/L, one could expect that 30% of the time chlorophyll A would exceed 15 μg/L and 7% of the time it would exceed 30 μg/L.

Reduction of organics in waters with chlorophyll A concentrations of 15 μg/L would be necessary most of the time to comply with the Safe Drinking Water Act standard of 0.1 mg/L for trihalomethanes (THM's) in finished drinking water (Arruda and Fromm, 1988). Based on the work of Walker (1983) and Arruda and Fromm (1988), 15 μg/L of chlorophyll A is equivalent to approximately 7 mg/L of total organic carbon (TOC) which converts to approximately 0.2 mg/L of THM's after chlorination. According to Singer (1992), concentrations of TOC ≥10 mg/L (40-50 ug chlorophyll A/L) are problematic and relatively expensive to reduce, and at concentrations ≥25 mg/L of TOC, reduction is very difficult and very expensive. To remain within the standard THM, it is necessary to maintain waters with standing crops of approximately 4-5 ug/L of chlorophyll A equivalent to approximately 4 mg/L of TOC (Walker, 1983; Arruda and Fromm, 1988).

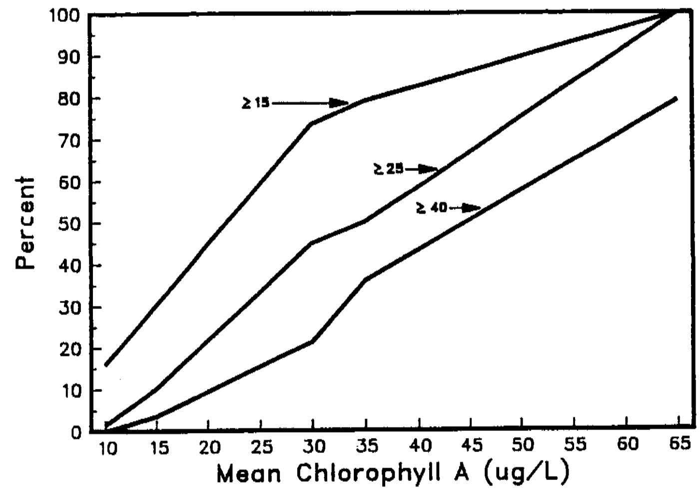

Figure 1. Percent occurence of bloom frequencies (i.e. ≥ 15 ug/L chlorophyll A) for Southeastern Piedmont Growing Season Mean Chlorophyll A Concentrations.

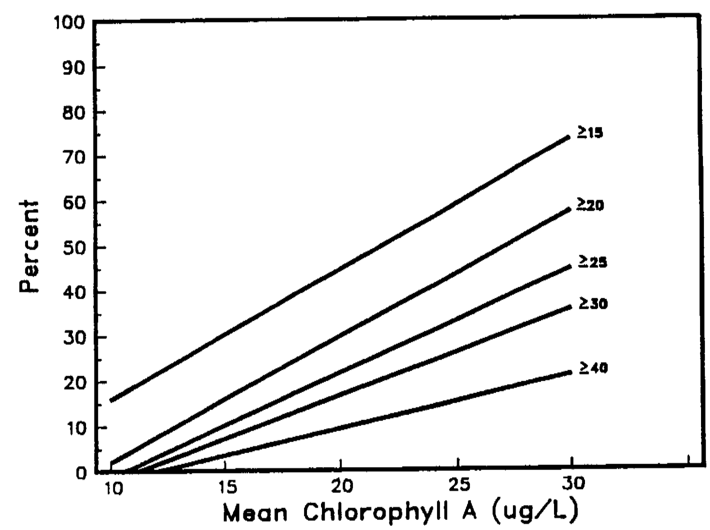

Figure 2. Predicted percent occurence of bloom frequencies of chlorophyll A concentrations as a function of mean chlorophyll A.

At an average growing season concentration of 25 μg/L, one could expect that 26% of the time or approximately 2 days per week (Figures 1 and 2), chlorophyll A would be ≥30 μg/L, and 59.1% of the time said waters would be discolored by algal growth accompanied with a few scums.

North Carolina has put a high priority on nutrient impacts as evidenced by their annual bloom reports (North Carolina, 1988-1991) and their numerical chlorophyll A standard for the nutrient sensitive waters classification (North Carolina, 1991). Presently, they are reassessing this standard because most warm waters at sometime would have a small probability of exceeding 40μg/L (Figure 2).

An examination of Carolina's bloom reports (North Carolina, 1989-1991) revealed no discernable relationship between fish kills and chlorophyll A concentrations, but a greater frequency of fish kills were associated with occurrences of 25 μg/L chlorophyll A. The standard (North Carolina, 1991) applicable to North Carolina piedmont waters states that corrected chlorophyll A should not be >40 μg/L as an absolute upper limit. At a growing season mean of 10 μg/L one would not expect exceedances ≥40 μg/L (Figure 2), but at mean chlorophyll A concentrations of 15, 20, 25, 30 μg/L the percent ≥40 μg/L would be 3.5 (0.25 days/week), 9.4 (0.7 days/week), 15.3 (1.1 days/week), and 21.2 (1.5 days/week) of the growing season respectively.

A mean chlorophyll A of <25 μg/L is a generous upper limit that should minimize water quality problems, and maintain a minimal aesthetic environment.

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