THE RELATIONSHIP OF LIGHT EXTINCTION DATA WITH SECCHI DISK DEPTH IN A CIRCUMNEUTRAL STRIP MINE LAKE IN SOUTHERN ILLINOIS.[1]

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ABSTRACT

1. Beer-Lambert vertical absorption coefficients (k) were calculated using light data collected over a three year period (46 dates) from a circumneutral strip mine lake in southern Illinois.

2. Estimates of light extinction (k_e) in surface waters (0 - 4 m) were also derived using Secchi disk depth (Z_{SD}) and the Poole-Atkins (1926) equation.

3. k values throughout the surface water zone were not statistically different from their mean ($k_{\bar{x}}$) on each date.

4. Z_{SD} exhibited a significant exponential relationship ($r = 0.820$) with $k_{\bar{x}}$ over a wide range of light conditions.

5. k_e was highly correlated with ($r = 0.844$), and not statistically different from, $k_{\bar{x}}$; k_e was a satisfactory approximation of surface water light extinction in this lake.

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Circumneutral strip mine impoundments have physio-chemical, morphometric and edaphic characteristics that can differ significantly from other freshwater lakes and ponds. In Illinois, investigations of circumneutral strip mine lakes have been largely limited to surveys of community diversity (Bell 1956; Coss 1981; Konik 1980; Lewis and Peters 1954; Rickett 1968) and selected physio-chemical parameters, such as O_2 concentration, temperature and chemical composition (Gibb and Evans 1978; Konik 1980; Lewis and Peters 1954). Few investigators have collected other than baseline data (e.g. Dreschel 1980; Stahl 1979; Larson 1974); a great deal remains to be learned about the limnology of these lentic systems. From 1977 to 1979, data on a number of physio-chemical and biotic parameters were collected from a small, circumneutral strip mine lake in southern Illinois. This paper presents an analysis of light extinction in this lake.

Because light is the primary energy source for freshwater ecosystems, its behavior in lakes is of great interest to limnologists. Radiant energy is extinguished exponentially as it passes through water as described by the classic Beer-Lambert equation:

$$I_z = I_o e^{-kz} \qquad (1)$$

which can be rearranged to the form:

$$k = \frac{(\ln I_o - \ln I_z)}{z} \qquad (2)$$

where z = depth in meters, I_o and I_z = light intensity at the surface and depth z respectively, and k = the vertical absorption coefficient, a measure of light extinction at depth z (Cole 1979). Instrumentation has not always been available to measure light intensity. Poole and Atkins (1929) developed a empirical formula to estimate k in "surface waters" based on its relationship with Secchi disk depth (Z_{SD}):

$$k = \frac{1.7}{Z_{SD}} \qquad (3)$$

While the Poole-Atkins equation has been demonstrated to be useful for estimating k in turbid freshwater ponds and coastal oceanic waters (Idso and Gilbert 1974), no previous study has applied it to circumneutral strip mine waters. This paper will examine the applicability of the Poole-Atkins equation, and the relationship of k with Z_{SD}, in such a system.

METHODS AND MATERIALS

This study was conducted on Moroni's Big Lake, a circumneutral strip mine impoundment (5.5 ha), located approximately 2 km north of DeSoto, in Jackson County (T85-R2W-Sec. 8,17), Illinois. Data were collected at a single, open-water station from June to November 1977 (6 dates), May to December 1978 (16 dates), and March to December 1979 (24 dates). Light intensities were measured at meter intervals (0 to 13m) as percentages of surface illumination (taken as 100%) with a Whitney LMA-8A underwater photometer. Secchi disk depths were recorded from the shady side of the boat between 0900 and 1200 hours. Beer-Lambert vertical absorption coefficients (k) and Poole-Atkins estimated k (k_e) were calculated for each date. All statistics and data plots were generated using SAS (Statistical Analysis System) (Barr *et al.* 1979) supported on an IBM S/370 computer. The critical level of significance (α) for all statistical tests was set at 0.01. Additional information on Moroni's Big Lake, and the methods employed in this study, can be found in Chimney (1980).

RESULTS AND DISCUSSION

For this analysis, "surface waters" were considered to extend from 0 to 4 m. It was observed that 93.5 percent of all Z_{SD} values were within this depth zone, which, during periods of thermal stratification, include the entire epilimnion and most of the metalimnion. A one-way ANOVA found no significant differences between k values at each surface water depth and their mean ($k_{\bar{x}}$) (df= 5/270; F= 1.22; P= 0.2970); $k_{\bar{x}}$ was used as the best measure of light extinction on each date in all subsequent analyses. Descriptive statistics of surface water k values, $k_{\bar{x}}$, k_e, and Z_{SD} can be found in Table 1.

Plots of Z_{SD} with $k_{\bar{x}}$ and $k_{\bar{x}}$ with k_e are shown in Figures 1 and 2. Correlation coefficients were quite high for regressions of both sets of data; r = -0.820 (P<0.001) for Z_{SD} with $k_{\bar{x}}$ (both variables were ln transformed) and r = 0.844 (P<0.001) for $k_{\bar{x}}$ with k_e. Furthermore, a t-test indicated that $k_{\bar{x}}$ and k_e were not statistically different from each other (df = 46, T= 1.48, P = 0.1410).

These data indicated that the exponential relationship Z_{SD} exhibited with $k_{\bar{x}}$ was significant over a wide range of light conditions in Moroni's Big Lake. In addition, k values, derived from the Poole-Atkins equation, were satisfactory approximations of light extinction in surface waters when compared to those calculated from light intensity data.

Table 1. Means, standard deviations, and range of values for light absorption coefficients and Secchi disk depth in Moroni's Big Lake.

	$\bar{x}$	S.D.	Range
k_1	0.93	0.43	0.12-2.21
k_2	0.87	0.40	0.22-1.91
k_3	0.90	0.41	0.34-1.85
k_4	1.00	0.37	0.32-1.78
$k_{\bar{x}}$	0.93	0.37	0.39-1.92
k_e	0.82	0.33	0.26-1.79
z_{SD}	2.42	1.08	0.95-6.50

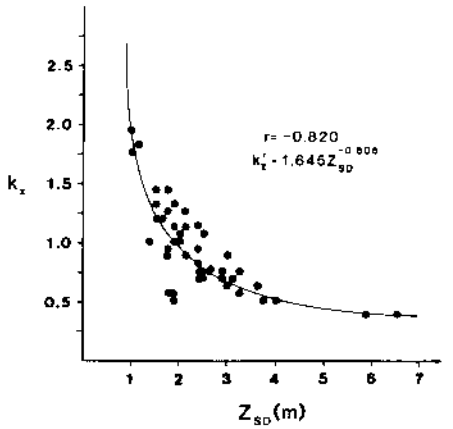

Figure 1. Relationships between Secchi disk depth (Z_{SD}) and mean surface water light extinction ($k_{\bar{x}}$) in Moroni's Big Lake. The correlation between Z_{SD} and $k_{\bar{x}}$ was calculated using ln transformed data for both variables.

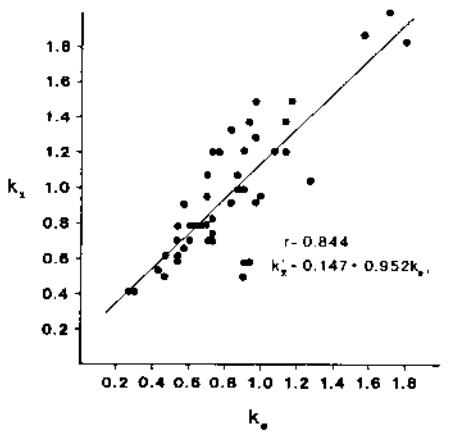

Figure 2. Relationships between Poole-Atkins estimated k (k_e) and mean surface water light extinction ($k_{\bar{x}}$) in Moroni's Big Lake.

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