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MECHANISM PRODUCING THE NEAR-700 nm BRIGHTNESS PEAK IN THE EMISSION SPECTRA OF WATER BODIES AND ITS POSSIBLE APPLICATIONS IN REMOTE SOUN丁NG OF SUCH BODIES

A.A. Gitel'son and Academician K. Ya. Kondrat'yev

Hydrochemical Institute, Rostov-na-Donu; and Institute of Limnology, USSR Academy of Sciences, Leningrad

In order to interpret multizonal video information from satellites and to develop remote methods for airborne monitoring of water bodies in terms of spectrometric data for the visible region, we need to elucidate the mechanism producing the "red peak" that occurs in the emission spectra of such bodies near 700 nm. Various explanations of this peak have been offered. Morel and Prie[1] attribute it to anomalous dispersion in the absorption band of phytoplankton and to chlorophyll A fluorescence. Gordon [2] and all other authors [3] believe that this is entirely due to phytoplankton fluorescence. Vasil'kov and Kopelevich [4] use a simple model to show that it could be produced by a corresponding minimum in the absorption spectrum at chlorophyll A concentrations greater than 1 mg/meter. They also show that the anomalous dispersion makes a negligible contribution to the red peak.

In the present paper we attempt to elucidate the mechanism producing the peak.

We made an extensive study of the spectral brightness coefficients $\rho(\lambda)$ of various water bodies with chlorophyll concentrations of 0.5 to 10 mg/m$^3$ (Sea of Azov), 10 to 40 mg/m$^3$ (the Don and Northern Donets rivers), 5 to 100 mg/m$^3$ (Lake Balaton), and 30 to 400 mg/m$^3$ (Lake Mangilsee).

The brightness spectra were measured from aircraft with a spectrometer whose wavelength resolution was 1 nm or better [5]. The intensity spectra clearly show a series of Fraunhofer lines that can be used for high-accuracy wavelength calibration (supplementing calibration with a reference light source and with interference filters); the $\rho(\lambda)$ spectra were recorded on a $x$-$y$ pen plotter and were also stored in a database [5] for further processing.

We also measured the concentrations of the active components. The chlorophyll concentration $C_{chl}$ was determined from the fluorescence at 685 nm excited by various wavelengths [6] and was also derived analytically [7]. The concentration of suspended matter $C_{sus}$ was found from the scattering index of water at 90° [5] and that of dissolved organic matter from its fluorescence between 470 and 560 nm [8]. The position of the peak was determined with an error of less than 0.5 nm in the fluorescence spectra of water samples at wavelengths from 600 to 800 nm [5]. In all spectra it lies at 685 nm, and its position did not vary with $C_{chl}$.

We attempted to test, over a wide range of chlorophyll A and phytoplankton concentrations, our earlier results [5, 9-11], which indicated that the position of the red peak in $\rho(\lambda)$ is strongly altered by changes in $C_{chl}$. A positive result would confirm the hypothesis of Vasil'kov and Kopelevich [4], for while we found no shift in the wavelength of plankton fluorescence in our measurements, the model in [4] does postulate that the wavelength of the peak $\lambda_{\text{max}}$ should increase with $C_{chl}$. Therefore, we made especially accurate measurements of $\lambda_{\text{max}}$ and compared them with the values of $C_{chl}$ obtained by various techniques.

All of our experiments showed two extrema of the $\rho(\lambda)$ function in the red region: a minimum between 665 and 675 nm and a peak whose position varied with $C_{chl}$. With a chlorophyll concentration of about 1 mg/m$^3$, the plot of $\rho(\lambda)$ shows an inflection at $\lambda = 685$ nm (Fig. 1a); with increasing $C_{chl}$, the position of the peak shifted, with $\lambda_{\text{max}}$ at 725 nm at $C_{chl} > 100$ mg/m$^3$ (Fig. 1c). When $C_{chl}$ was varied from 1 to 100 mg/m$^3$, the ratio $\rho(\lambda_{\text{max}})/\rho(560)$ (560 nm is the global maximum of $\rho(\lambda)$) increases by


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more than an order of magnitude. The increase in $\lambda_{\text{max}}$ and $\rho(\lambda_{\text{max}})/\rho(560)$ was found in all of the water bodies (more than 10) that we studied, in various stages of hydrobiont development, from early spring to late autumn, and with considerable differences in the species makeup of the phytoplankton.

We found the same phenomenon in experiments in the so-called mesocosms, i.e., parts of a water body or watercourse that were separated from it and were affected by some pollutant [12]. The brightness spectra (Fig. 2) were measured in three different ecosystems (the test ecosystem, a control, and the lake from which the two other systems were separated) for a minute under ideal survey conditions (solar angle, condition of surface and atmosphere, and the like). In this case too, the different phytoplankton concentrations showed up in the spectra $\rho(\lambda)$ as considerable differences in $\lambda_{\text{max}}$.

Calculations of $\rho(\lambda)$ by means of a published program [13] (see Fig. 3; the size distribution of phytoplankton particles is log-normal with $R_0 = 6 \mu m$, and that for mineral suspended matter is a Junge distribution $f(r) = r^{-\nu}$ with $\nu$ ranging from 0.1 to 5.0) for various values of $C_{\text{chl}}$ and $C_{\text{susp}}$ clearly reproduced the two observed extrema of $\rho(\lambda)$. Figure 4 compares the measured plots with $\lambda_{\text{max}}(C_{\text{chl}})$ (Lake Balaton, July 1986) with the calculated plots (for $\nu = 1.0$, $C_{\text{susp}} = 10$ mg/liter). They are in good agreement.

Our measurements and calculations indicate (without ruling out a contribution of phytoplankton fluorescence to the emission intensity of water at 685 nm) that the maximum of $\rho(\lambda)$ near 700 nm is caused, when $C_{\text{chl}} > 1$ g/m³, by light absorption by phytoplankton pigments, producing a corresponding minimum of the absorption index.

The correlation between $C_{\text{chl}}$ and $\lambda_{\text{max}}$ is very close. For example, in Lake Balaton, $\lambda_{\text{max}} = 649.2$ $C_{\text{chl}}^{0.81}$, nm, with a coefficient of correlation higher than 0.96.
Fig. 2. Brightness spectra. 1) Lake, $C_{chl} = 18 \text{ mg/m}^3$; 2) Control "mesocosm," $C_{chl} = 24 \text{ mg/m}^3$; 3) Test mesocosm, $C_{chl} = 40 \text{ mg/m}^3$.

Fig. 3. Brightness spectra calculated by program of [13] for $v = 1.0$, $r_0 = 6 \mu m$, $C_{sus} = 10 \text{ mg/liter}$, $C_{chl} = 1 (1), 2 (2), 5 (3), 10 (4), 20 (5) and 50 (6), \text{ mg/m}^3$.

Fig. 4. Wavelength at which red peak of spectrum occurs versus concentration of phytoplankton chlorophyll A. Points represents measurements, curve is calculated [13] for $v = 3$, $C_{sus} = 10 \text{ mg/liter}$.

Calculations with the help of the same computer program [13] indicate that the parameters of this correlation are virtually independent of the size distribution of mineral particles or on their concentration at $C_{sus}$ between 5 and 20 mg/liter, but are governed primarily by the behavior of the absorption index $\kappa(\lambda)$, i.e., the species makeup of the phytoplankton.

The relationship of $\lambda_{\text{max}}$ to $C_{chl}$ that we have identified makes possible remote determinations of phytoplankton chlorophyll A from $\lambda_{\text{max}}$. $C_{chl}$ can be determined at concentrations between 5 and 100 mg/m$^3$ with a standard deviation of less than 10 mg/m$^3$.

This phenomenon must be taken into account when choosing the wavelengths at which the spectral brightness coefficient is to be determined in remote determinations of the concentration of optically active substances in aquatic ecosystems [9-11].
REFERENCES