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The dependence of the fluorescence spectrum of phytoplankton on external influences

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ABSTRACT

The concentration of phytoplankton is often used to assess the ecological status of water bodies; it is determined by the fluorescence intensity of chlorophyll-a, which is located in microalgae cells. Investigators do not usually take into account the effect of the medium on the fluorescence intensity when determining the concentration of *phytoplankton*. This article describes the use of a fibre-optic spectrometer developed by the authors to identify the relationship between the fluorescence of the chlorophyll-a *in phytoplankton cells and under* environmental conditions, such as temperature and illumination. A mathematical model is used to calculate the chlorophyll-a concentration based on fluorescence measurements and takes the temperature and amount of light into account. *Using the resulting proportionality coefficient* can reduce the error in the chlorophyll-a concentration determined using fluorescence methods by a factor of two. *In this article the, authors* describe the results of applying the method they developed to performance monitoring in the waters of the Gulf of Peter the Great in September and October 2013.

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Introduction

The scientists at the Institute of Automation and Control Processes FEB RAS have actively studied phytoplankton fluorescence since 2007 and have developed equipment for performing their studies. Their main objective is to create a universal instrument for monitoring the ecological state of water objects of any complexity based on the concentration of chlorophyll-a, as measured using a fluorescence method. During this time, several options for measuring systems were offered [1,2], patents were obtained [3,4], and an experimental model of a fluorescence meter was developed. In the period from 2010 to 2013, expeditions in which the device for measuring phytoplankton fluorescence was developed were made.

During the expedition, researchers noted a change in the fluorescence spectra of chlorophyll-a that was associated with changes in environmental parameters, such as the temperature and illumination intensity. Increased water temperature and illumination intensity led to a decrease in the spectral intensity of the chlorophyll's fluorescence. Figs. 1 and 2 show the fluorescence spectra of seawater containing phytoplankton at varying temperatures and illumination intensities.

Fluorescence measurements were carried out using a fluorescence sensor from WetLabs [5] and a submerged fibre-optic module [2]. The concentration was calculated by the formula in (1):

$$C = K * F, \quad (1)$$

where C is the concentration of chlorophyll-a; K is the constant of proportionality determined by the design of the measuring device; and F is the measured fluorescence intensity.

The calculated concentrations were compared with measured concentrations using extract spectrophotometry. When calculating the chlorophyll-a concentration in the natural environment based on fluorescence measurement, there is error due to the dependence of the fluorescence on environmental parameters. The measurements are shown in (Fig. 3).

As shown in Fig. 3, when the illumination intensity is changed (as in time interval 9–11), an error occurs in the calculation. Fluorescence measurements indicate that the concentration decreases during this time interval, but extract spectrophotometry dies not

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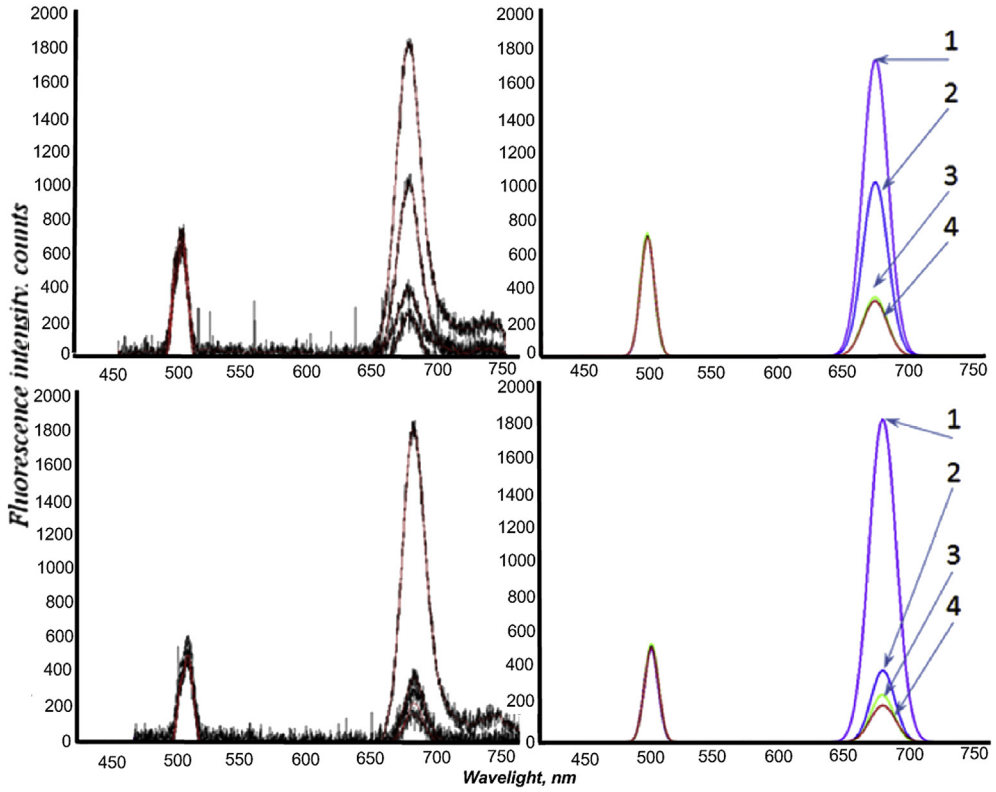

Fig. 1. The dynamics of sea water fluorescence spectra at different temperatures (top - at 1 am; bottom – 11 am). 1–15 °C; 2–16 °C; 3–17 °C; 4–17 °C.

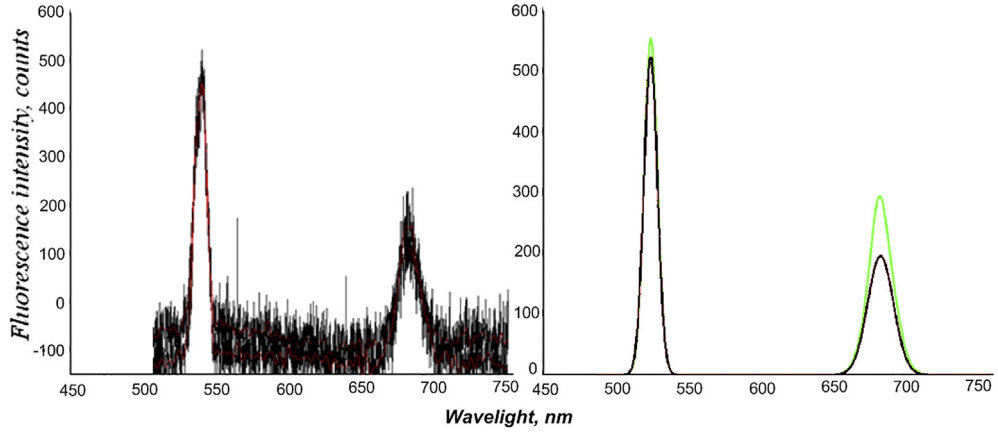

Fig. 2. The dynamics of sea water fluorescence spectra under different lighting conditions 1–200 mol photons/m^{2}*s; 2–385 mol photons/m^{2}*s.

detect this decrease in the concentration. The maximum deviation from the mean value of the concentration is equal to 0.16. The value of the maximum error (at 11:00, when the illumination intensity 385 mmol photons/m^{2}*s) in the SBE was 0.4 and, for the fibre-optic module, 0.49.

To resolve this problem, considering the proportionality factor K as a function that depends on the environmental parameters was proposed. In a number of papers [6,7], it is specified that the constant of proportionality (K) has different values depending on the type of phytoplankton present when the water was tested. The observed dependence of fluorescence intensity allows the existence of a functional dependence of the coefficient (K) on the illumination intensity and temperature to be assumed. When this is done, K can be presented by the function in (2):

$$K = s_0 \cdot s_1(Q) \cdot s_2(T), \quad (2)$$

where s_0 is the constant of proportionality determined by the design of the measuring device and the type of phytoplankton; $s_1(Q)$ is the function that depends on the illumination intensity; and $s_2(T)$ is the function that depends on the temperature.

The coefficient (K) can be interpreted as a function characterizing the effectiveness of the phytoplankton cells' fluorescence. When K is greater, the intensity of the chlorophyll-a fluorescence is less.

In this article, the authors attempt to reveal the impact of the illumination intensity and temperature on the intensity of fluorescence of chlorophyll-a, which is in phytoplankton cells, and to

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