DEVELOPMENT OF ANOXIA IN THE SMALL COASTAL SEA LAKE, ROGOZNICA LAKE (EASTERN ADRIATIC COAST)

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Abstract

Variations of temperature, salinity and concentration of dissolved oxygen, as well as vertical distribution of dissolved organic matter (DOC), surface active substances (SAS), phytoplankton, nutrients (NH_4^+, NO_3^-, NO_2^-, PO_4^{3-}, SiO_4^{4-}) and reduced sulfur compounds in the small, intensely eutrophicated, 15 m deep sea-lake, Rogoznica Lake, have been investigated during different seasons in 1996. Anoxic conditions in the lake and high concentrations of sulfur compounds (up to 10^{-4} M, mainly in the form of sulfide) were detected below 12 m depth during periods of stable stratification. Also, at the same time below 10 m depth, relatively high concentrations of organic matter (SAS up to 0.3 mg dm^{-3} equiv. Triton-X-100, DOC up to 0.22 mM), SiO_4^{4-} (up to 112 μM) and PO_4^{3-} (up to 1.9 μM) were detected, indicating the start of more pronounced remineralization. The stratification and mixing of lake water in 1996 were greatly influenced by rainfall as shown from decreased salinity in deeper waters. During the spring 1996 high phytoplankton activity over the entire water column and extremely high production of oxygen (oxygen saturation up to 300%) probably prevented the expected development of anoxia from occurring.

Key-words: anoxia, phytoplankton, Adriatic Sea

Introduction

Rogoznica Lake is a small, intensely eutrophicated sea-lake situated on the eastern coast of the Adriatic Sea (Fig.1). The lake is surrounded with sheer cliffs (4 - 23 m high) and has an area of about 5300 m^2 and the maximum depth of 15 m. Rogoznica Lake is a very interesting area for the study of biogeochemical processes owing to permanent stratification [1]. Vertical mixing occurs during winter when cold, oxygen-rich water from the surface sinks downwards. Despite of permanent water exchange between Rogoznica Lake and the surrounding sea through the porous karst [2], anoxic conditions are established in deeper layers of the lake, probably due to remineralization of organic matter produced in periods of intensive primary production. During thermohaline stratification, the surface water is well oxygenated while the layer below 9 m depth is anoxic [3, 4]. Anoxic deep water is rich in sulfur (up to 900 μM), especially sulfides and elemental sulfur [3]. The distribution of iodine species was found to be strongly influenced by the occurrence of anoxic conditions in the lake [4]. Phytoplankton was composed of a relatively small number of species which were mostly distributed above 10 m depth. The heterotrophic dinoflagellate *Hermesinum adriaticum* is mostly found near the oxic/anoxic interface of Rogoznica Lake [5].

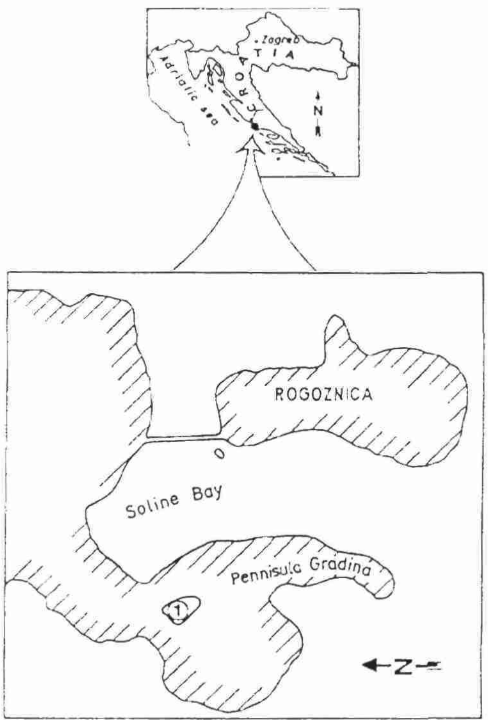

Fig. 1. Geographical position of the Rogoznica Lake.

This study describes the development of anoxic conditions, as well as the seasonal vertical distribution of dissolved organic matter, surface active substances (SAS), phytoplankton cell-density, nutrients and sulfur compounds in Rogoznica Lake during 1996.

Experimental

Electroanalytical methods of a.c.- and linear sweep voltammetry were used for the determination and speciation of sulfur compounds (sulfide, polysulfide, elemental sulfur, thiosulfate, organic sulfur) in the lake water [6-9]. The determination of each of these sulfur species is based on the intereaction between sulfur and the mercury electrode. Analytical determination of elemental sulfur, sulfide and polysulfide was based on acidification of the sample and elimination of sulfide with purging by nitrogen [3-9].

Electrochemical determination of $S_2O_3^{2-}$ is based on the cathodic stripping of formed $Hg(S_2O_3)_2^{2-}$ during the negative scan from 0 to -1 V vs.Ag/AgCl [9]. The appearance of voltammetric peaks of HS- and $S_2O_3^{2-}$ on the different potentials enables their determination in the mixtures. Rogoznica Lake samples were collected with Niskin bottles with over pressurized N_2. All samples were immediately measured unfiltered within 24 h to prevent biotic and abiotic processes which can change the content and speciation of sulfur species. Samples with very high concentrations of sulfur (up to $1 \cdot 10^{-6}$ M) were measured either by dilution with 0.5 M NaCl or by changing the measurement conditions (accumulation time).

Oxygen content was determined by the standard Winkler method. The content of surface active organic matter (SAS) was determined by a.c. voltammetry (out of phase mode and expressed as equiv. to Triton-X-100) [10] and DOC measurements were performed using a Shimadzu TOC-500 Analyzer which includes a high temperature oxidation system.

Phytoplankton cell counts were obtained by the inverted microscope method according to Utermöhl [11]. Nutrients were determined by standard oceanographic methods outlined by Strickland and Parsons [12]. Temperature and salinity were measured *in situ* with a Hg-thermometer and refractometer (Atago, Japan).

Results and discussion

During the study anoxic conditions with high concentrations of sulfur compounds (up to 10^{-4} M, mainly in the form of sulfide) were detected only below 12 m depth during the summer months as the result of increased stratification of the water column in spring. Besides the strong stratification, high phytoplankton activity (diatom bloom, 10 million cells/dm^{-3}) with extremely high production of oxygen (oxygen saturation up to 300%) and organic matter (SAS up to 0.3 mg dm^{-3}) was detected in the entire water column (0-12 m) during the spring months. After the spring, the diatom bloom decreased and remineralization of organic matter and development of anoxia with more pronounced production of reduced sulfur compounds and amonia, as well as higher values of DOC, phosphate and silicate were observed below 10 m depth (Fig. 2 A-F). In comparison to the situation in Rogoznica Lake recorded during 1994 and in April 1995, when the boundary between oxic and anoxic sulfur rich water (concentration of