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THE SYSTEM OF THE BELOSLAV AND THE VARNA LAKES: AN EVOLVING WATER ENVIRONMENT

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Abstract

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Lake water to fulfill vital ecosystem functions and to serve human needs is of great importance. Study of the long-term evolution of the Beloslav and the Varna lakes' water environment has become increasingly challenging because of the significance both for a wide range of environmental and social activities and for a multi-sectoral concern. Monthly and seasonal research approach was applied to long-term investigations of key lake water characteristics that matter to broader issues like environmental protection, public and private regional business development, and stakeholder collaborations. The challenges related to the Beloslav and the Varna lakes imply environmental, social, and economic aspects to be taken into consideration that would result in more effective regulations, incentives, instruments, and investment plans in the region.

Key words: Beloslav Lake, Varna Lake, hydrology, hydrochemistry, long-term evolution
Abbreviations: T – Temperature; S – Salinity; O_2% – Oxygen saturation; COD-Mn – Chemical oxygen demand-Mn; St. – Station

Introduction

Lake water to fulfill vital ecosystem functions and to serve human needs is of great importance.

With purpose to ascertain the long-term evolution of the Beloslav and the Varna lakes‘ water environment, investigation of key lake water characteristics was done during the period 1992–2000. This research gives knowledge in the field of hydrology and hydrochemistry of the Beloslav and the Varna lakes, and contributes to understanding of the causality of water-related issues. The obtained results throughout the study are of great significance both for a wide range of environmental and social activities and for a multi-sectoral concern. The performed investigations are essential to broader issues like environmental protection, public and private regional business development, and stakeholder collaborations.

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Materials and Methods

Monthly and seasonal approach was applied to the long-term investigations of the system of the Beloslav and the Varna lakes. Samples were taken aboard the IFR R/V Prof. A. Valkanov.

Seasonal sampling was performed at St. A10, St. A14, St. A16, St. A18, and St. A22 (Figure 1) in the period 1992-2000.

According to the indicated hydrological seasons, winter (January, February, March), spring (April, May, June), summer (July, August, September), autumn (October, November, December), generally, seasonal sampling was carried out in February, May, August, and November. Station A22 was assumed for Control Station where monthly sampling was done during 1995–2000. Processing of samples was performed by unified methods (Oradovsky, 1977; Gashina, 1993). HITACHI-U 2001 UV/Vis Spectrophotometer (1995) was used for establishment of the concentrations of nutrients.

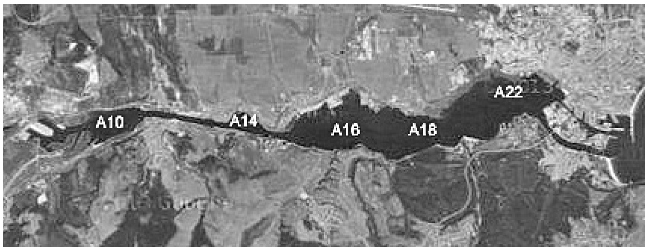

Fig. 1. Map of the sampling stations in the Beloslav Lake and the Varna Lake (St. A10, St. A14, St. A16, St. A18, St. A22). Source: Google Earth, 2014. Data SIO, NOAA, U.S. Navy, NGA

Results and Discussion

The Varna Lake current is a strong anthropogenic factor both for the southern area of the Varna Bay and for the coastal zone close to Cape Galata (Rozhdestvensky, 1986; Dineva, 1999; Dineva, 2007; Dineva, 2013a). During 1990s, the most significant loads on the lake system have caused by the Devnia River, the Provadia River, Port of Varna-West, Ferry Port, Devnia industry complex, Beloslav glass plant, Lazhata ship-repairing plant, and municipal wastewater treatment plants of Beloslav and Varna. The main nutrient export into the lakes was by rivers, Devnia chemical works and municipal wastewater treatment plants.

Water mass forming of these lakes is mainly by seawater while river influx is of secondary importance (Rozhdestvensky, 1986). Owing to insufficient wastewater treatment, agricultural practices in the region, industrial activities, and influence by rivers, the concentration of nutrients in the lake waters is high and gives rise to the excessive growth of algae. As a result, there was a deficit and sometimes lack of dissolved oxygen in the bottom layer during the summer. The main factor controlling the rate of consumption of O_2 in the water is the abundance and rate of supply of natural and introduced organic matter in relation to the mechanisms for subsurface water renewal (Topping, 1976; Dineva, 2013b). If the supply of organic matter is increased to a point where the consumption of O_2 is greater than the supply through aeration then deoxygenation begins. During the summer, a formed lakebed area of low or no oxygen can threaten or kill all lake life in it.

Long-term seasonal research approach

Beloslav Lake

Due to the similarity of the water environment at St. A14 and at St. A10, St. A14 was considered to the Beloslav Lake.

Long-term seasonal variability of temperature in the Beloslav Lake is presented in the adjacent Table 1. 1992–2000 mean seasonal surface temperature has ranged from 6.33°C to 24.35°C. Surface temperature minimum of 3.17°C has come in February 1996 and surface temperature maximum of 26.20°C – in August 2000. Long-term (1992–2000) average seasonal bottom temperature has varied from 5.94°C to 22.19°C. Bottom temperature minimum was 2.88°C (February 1996) and bottom temperature maximum – 24.06°C (August 1995). Difference between surface and bottom temperature was biggest in spring – 4.28°C while temperatures were almost the same over the autumn and winter.

Precipitation and river discharges have freshening influence upon the Beloslav Lake. Peak freshening has affected the lake throughout during the spring, with drop both in surface salinity to 13.21 psu and in bottom salinity to 14.89 psu. Unlike the other seasons, spring surface salinity was about 2 psu lower. Bottom salinity seasonal variation was up to 1.37 psu.

Because of excessive growth of algae, oxygen super-saturation of the surface water was kept over much of the year, reaching 165.82% in the spring. Based on long-term (1992-2000) average, hypoxic setting has come in the bottom layer during the summer, but anoxic conditions have occurred in the summer of 1994 and in the summer of 1999 so that the situation was much different, with oxygen saturation ranging from 0.00% to 63.25%.

Table 1

Long-term seasonal variability of temperature (°C), salinity (psu), oxygen saturation of water (%), nitrite nitrogen (µM), nitrate nitrogen (µM), and COD-Mn in neutral medium ($mgO_2.l^{-1}$) in the Beloslav Lake during 1992–2000

Parameter	Depth	Winter	Spring	Summer	Autumn
T, °C	0 m	6.33	18.19	24.35	12.07
	bottom	5.94	13.91	22.19	12.48
S, psu	0 m	15.22	13.21	15.16	15.35
	bottom	16.26	14.89	15.94	15.82
O_2, %	0 m	108.41	165.82	145.12	79.22
	bottom	94.82	66.24	24.69	61.00
NO_2-N, µM	0 m	0.35	0.47	0.43	0.61
	bottom	0.23	0.26	0.23	0.54
NO_3-N, µM	0 m	23.10	29.21	19.85	18.50
	bottom	25.39	24.40	20.67	16.29
COD-Mn, $mgO_2.l^{-1}$	0 m	3.62	4.06	2.97	5.04
	bottom	1.60	1.95	3.92	3.89

Lake's hydrochemical regime reveals much high concentrations of nutrients because of strong anthropogenic influence. In the surface-bottom layer, concentrations were higher than in the Varna Lake as long-term mean seasonal nitrite nitrogen concentration has ranged from 0.29 µM to 0.58 µM and long-term average seasonal nitrate nitrogen concentration was between 17.40 µM and 26.81 µM. Nitrite nitrogen was vastly increased during the autumn because of Devnia plant campaign. Under impact of industrial and municipal waters, the detected nitrate nitrogen levels were much high. Organic matter in water can be assessed by COD-Mn (Alekin, 1970; Rozhdestvensky, 1986). Quantity of organic carbon is equal to COD-Mn in neutral medium multiplied by 3 (Rozhdestvensky, 1986; Skopintsev, 1975).

Generally, organic matter at the surface was higher than in the bottom water, with long-term average seasonal COD-Mn (in neutral medium) maximum of 5.04 $mgO_2.l^{-1}$ in the autumn.

Varna Lake

As shown in Table 2, 1992–2000 mean seasonal surface temperature in the Varna Lake has varied between 5.47°C and 24.97°C. Surface temperature minimum of 1.77°C has come in February 1996 and surface temperature maximum of 26.6°C – in August 1999. Long-term (1992–2000) average seasonal bottom temperature has ranged from 4.76°C to 20.89°C. Bottom temperature minimum of 1.89°C has come in February 1996 and bottom temperature maximum of 24.22°C – in August 1992.

Salinity of the Varna Lake was kept higher than in the Beloslav Lake over all season as the highest difference was in the spring – up to 1.38 psu at the surface and up to 1.15 psu in the bottom layer. Freshening of the lake has come in the spring, more significantly in the surface water, with drop in 1992–2000 mean surface salinity to 14.59 psu and drop in long-term (1992–2000) average bottom salinity to 16.04 psu.

Oxygen regime was like in the Beloslav Lake but the situation was worse in the bottom layer during the summer – only 19.49% oxygen saturation, based on long-term (1992–2000) average, with oxygen saturation ranging from 0.00% to 46.27%. Anoxic conditions have come in the summer of 1994.

Under anthropogenic influence, long-term average seasonal nitrite nitrogen concentration was 0.12 µM – 0.50 µM in the surface-bottom layer and long-term mean seasonal nitrate nitrogen concentration was between 5.92 µM and 20.57 µM in the surface-bottom layer. Vastly increased nitrite nitrogen of the lake waters in the autumn because of Devnia plant campaign has affected the Varna Lake, as well. Owing to industrial and municipal influence, nitrate nitrogen levels were much high. Nutrients have decreased during the summer because of accelerated consummation by the phytoplankton.

Like the Beloslav Lake, organic matter at the surface was higher than in the bottom water as long-term average seasonal COD-Mn has reached 5.30 mg $O_2.l^{-1}$ in the spring – 3 times higher compared with bottom layer that means much more organic loads and algae growth.

Table 2

Long-term seasonal variability of temperature (°C), salinity (psu), oxygen saturation of water (%), nitrite nitrogen (µM), nitrate nitrogen (µM), and COD-Mn in neutral medium ($mgO_2.l^{-1}$) in the Varna Lake during 1992–2000

Parameter	Depth	Winter	Spring	Summer	Autumn
T, °C	0 m	5.47	17.91	24.97	12.54
	bottom	4.76	11.13	20.89	12.51
S, psu	0 m	15.98	14.59	15.67	15.94
	bottom	16.65	16.04	16.69	16.25
O_2, %	0 m	129.60	163.84	135.62	94.93
	bottom	98.98	69.56	19.49	73.07
NO_2-N, µM	0 m	0.20	0.31	0.16	0.54
	bottom	0.10	0.12	0.07	0.45
NO_3-N, µM	0 m	18.98	22.36	6.96	18.57
	bottom	18.12	18.78	4.87	14.31
COD-Mn, $mgO_2.l^{-1}$	0 m	4.03	5.30	3.10	1.82
	bottom	2.16	1.80	1.93	1.64

Long-term monthly research approach, applied to the Control Station

Figure 2 shows long-term monthly variability of surface temperature at the Control St. A22 in the Varna Lake during 1995-2000. Sharp warm of the lake water has occured from March to June – from 6.44°C to 23.26°C. While surface waters were kept warm during June-August, bottom layer was kept warm in August-September (Figure 3). Cooling of the lake water by November has reached 12.26°C at the surface and 12.58°C in the bottom layer.

Long-term (1995–2000) average monthly surface salinity minimum of 14.48 psu was in June and 1995–2000 mean monthly surface salinity maximum of 15.98 psu – in October. Bottom salinity monthly dynamics was much different, with long-term minimum of 15.84 psu in April and long-term maximum of 16.93 psu in March.

During 1995–2000, nutrients were at a much high level, leading to algae growth and further lakebed became short of oxygen, especially in August when hypoxic zone has formed – oxygen of bottom layer was depleted to 23.62%. Surface water was oxygen super-saturated from February to September, with long-term monthly maximum of 169.23% in June.

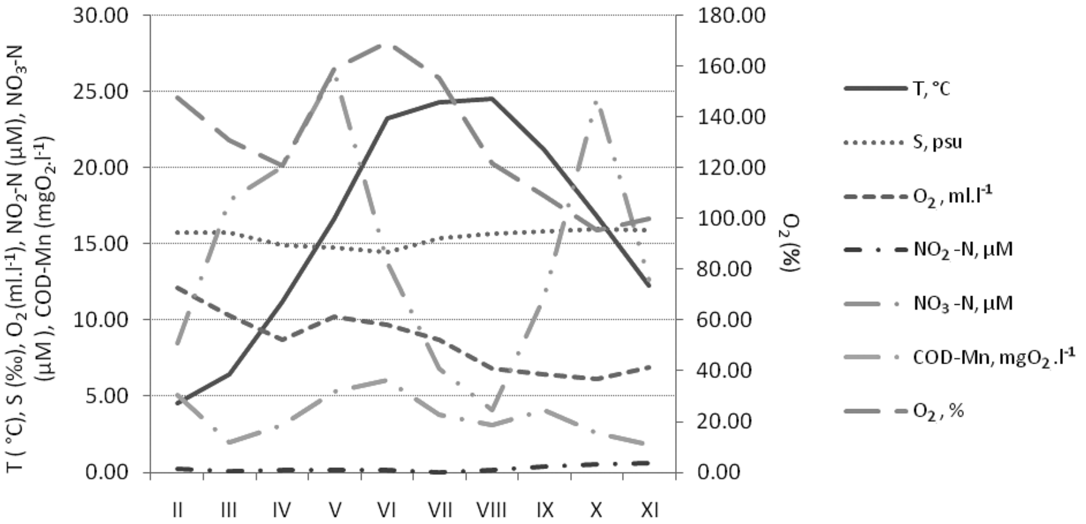

Fig. 2. Long-term monthly variability of temperature (°C), salinity (psu), dissolved oxygen (ml.l^{-1}), oxygen saturation of water (%), nitrite nitrogen (μM), nitrate nitrogen (μM), and COD-Mn in neutral medium (mgO$_2$.l^{-1}) in the surface water of the Control St. A22 in the Varna Lake during 1995–2000

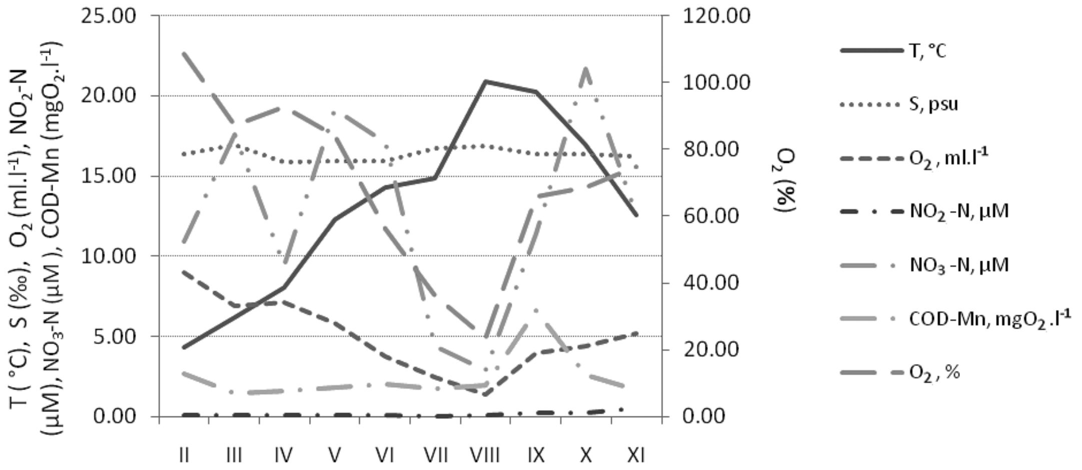

Fig. 3. Long-term monthly variability of temperature (°C), salinity (psu), dissolved oxygen (ml.l^{-1}), oxygen saturation of water (%), nitrite nitrogen (μM), nitrate nitrogen (μM), and COD-Mn in neutral medium (mgO$_2$.l^{-1}) in the bottom water of the Control St. A22 in the Varna Lake during 1995–2000

Long-term (1995–2000) average monthly nitrite nitrogen concentration has varied from 0.03 μM (July) to 0.60 μM (November) and long-term mean monthly nitrate nitrogen concentration was between 4.12 μM (August) and 26.32 μM (May) at the surface. Over 1995–2000, monthly nitrite nitrogen concentration has ranged from 0.02 μM (July) to 0.53 μM (November) and monthly nitrate nitrogen concentration was between 2.87 μM (August) and 21.69 μM (October) in the bottom layer.

Long-term mean monthly surface COD-Mn maximum of 6.06 mgO$_2$.l^{-1} in June was similar to long-term mean monthly bottom COD-Mn maximum in September – 6.61 mgO$_2$.l^{-1}. June surface maximum (during the longest days) and November surface minimum (during the shortest days) point to relationship between COD-Mn and photosynthesis, respectively the phytoplankton.

Conclusions

Economic activities and population growth in the Varna region during the 1990s, positive from many viewpoints, in turn, have caused environmental pressure, with negative long-term consequences for the Beloslav and the Varna lakes. The restoration of the lakes remains a challenge because of interrelation of environmental, economic and social factors. Urbanization, industrialization, and usage of the lakes for public and private business were setting pressure on the water environment. The challenges related to the Beloslav and the Varna lakes imply environmental, social, and economic aspects to be taken into consideration that would result in more effective regulations, incentives, instruments, and investment plans in the region so as to come up with sustainable solutions.

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