

Microbiological and Chemical Water Quality of Lake Ohrid and its Tributaries in 2014

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Abstract: The microbiological and chemical study was conducted in 2014, with the aim to assess the water quality of Lake Ohrid and its tributaries. The following parameters were studied: number of heterotrophic bacteria, total number of coliform bacteria, enterococci, *Escherichia coli*, chemical oxygen demand, and ammonia. The presence and composition of the studied microorganisms had spatial and seasonal dynamics depending on the biotic and abiotic factors, the degree of eutrophication and anthropogenic impact. The lake parts, which are far from settlements and river inflows, were classified as pure waters. The worse water quality was registered in the area of Grashnica locality, where relatively high organic and faecal pollution was registered. This part of the lake is under the pressure of communal and industrial waste waters rich with pollutants and nutrients, which originate in the Velgoska River. This river was highly polluted, exclusively faecal pollution. Similar conditions were found in the Cherava River, while the rivers Koselska and Sateska were less polluted. In order to prevent further worsening of the ecological status of Lake Ohrid, certain preventive measures, mainly rehabilitation of the communal waste waters and regular monitoring of the water and sediments, are necessary.

Key words: River, water quality, microbiological and chemical indicators

Introduction

The ancient Lake Ohrid is the only lake in Europe extremely rich in endemic species. This lake is a natural phenomenon and represents ecological and cultural heritage of worldwide importance. Characterised with very pure water, the lake is one of the largest natural reservoirs for drinking water in the world. The major quantity of the drinking water in the Municipality of Ohrid originates in the lake. Furthermore, the lake is very important from other aspects, including tourism, sport, and fishery. Because of the facts mentioned above, the microbiological and chemical monitoring of the water quality is very important and mandatory.

Organic matter is transformed constantly throughout the biosphere (RHEINHEIMER 1985). In the aquatic ecosystems, microorganisms are essential components of the cycle, in which bacteria play the

most important role (KANG & SEKI 1983). Heterotrophic bacteria are the most widely spread group of bacteria in nature regarding the metabolism type. They control the flow of substantial portion of organic matter in the aquatic ecosystems as the only biological population which is able to transform the organic matter from biogenic and abiogenic origin (MÜNSTER & CHRÓST 1990). The organic matter concentration correlates with the presence of heterotrophic bacteria, i.e. they are indicators of organic pollution and initial indicators of eutrophication. There were some microbiological studies in Lake Ohrid and its tributaries in the previous years (LOKOSKA 2000, 2011, 2013, 2015). The aim of our study was to assess the water quality of Lake Ohrid and its tributaries, using microbiological and chemical indicators, and compare with previous results.

Materials and Methods

The microbiological and chemical samples were collected at nine localities: five in the littoral of Lake Ohrid (Sateska, Daljan, Grashnica, Velidab, St. Naum), and four in its tributaries (the rivers Sateska, Koselska, Velgoshka and Cherava). The area of the lake littoral at Grashnica locality is in front of the inflow of the Velgoshka River. Daljan locality coincides with the inflow of the Koselska River, and Sateska locality – with the inflow of the Sateska River. The Velidab locality is far from settlements and river inflows, while the littoral St. Naum locality is close to the outflow of the springs of Lake Ohrid, nearby the Cherava River.

The samplings and analyses were conducted in 2014 with seasonal dynamics.

The analyses were made in accordance to the standard limnological methods (RODINA 1972, APHA 2005). The heterotrophic bacteria (at 22°C) were determined on meat-peptone agar (MPA). The total number of coliforms and the indicator for fresh faecal pollution – *Escherichia coli* were determined on selective chromogen substrate (COLI ID); the enterococci were determined on selective medium of Slanetz and Bartley. The chemical oxygen demand (COD), using KMnO_4 , which determines the amount of degradable organic matter, and the concentration of ammonia were analysed titrimetrically.

New classifications have been provided by the European Union (EU) (KAVKA et al. 2008): for faecal (*E. coli*, enterococci, total coliforms; CFU in 100 ml) and for organic (heterotrophic bacteria; CFU in 1 ml) pollution, based on the studies of KOHL (1975, modified), KAVKA & POETSCH (2002, modified) and in consideration of the EU Directive 2006/7/EC concerning the management of bathing water

quality (EU 2006). In this study the categorisation of water was made in five quality classes for pollution (I–V: little, moderate, critical, strong and excessive), according to KAVKA et al. (2008).

Results and Discussion

The obtained results show a high seasonal and spatial variability in abundance of the heterotrophic bacteria (Fig. 1). In the lake, they were the least presented near the Velidab locality (19 colony forming units [CFU]·ml⁻¹, in winter) and the best presented in the area of Grashnica (19,560 CFU·ml⁻¹, in summer). These bacteria were much more abundant in the rivers, with a maximum value attained in the summer period, in the samples collected from the rivers Velgoshka (150,000 CFU·ml⁻¹) and Cherava (148,000 CFU·ml⁻¹). Maximum values of the heterotrophic bacteria in the same area, and relatively higher values nearby the river inflows were also reported in the previous study in Lake Ohrid and its tributaries (LOKOSKA 2000).

According to the classification of KAVKA et al. (2008), the water from the studied localities in the littoral of the lake was assessed as: class I for Velidab and St. Naum in spring and winter, class III for Grashnica, and class II for the other localities. The water from the rivers Sateska and Koselska was classified under class II, and this from the rivers Velgoshka and Cherava were classified under class IV in summer and class III in the other periods. Therefore, according to the sanitary indicators, the water from the littoral of Lake Ohrid at Velidab and St. Naum was the purest/ unpolluted, i.e. there were no indicators of faecal pollution, on the contrary to the water from the coastal areas nearby the river inflows.

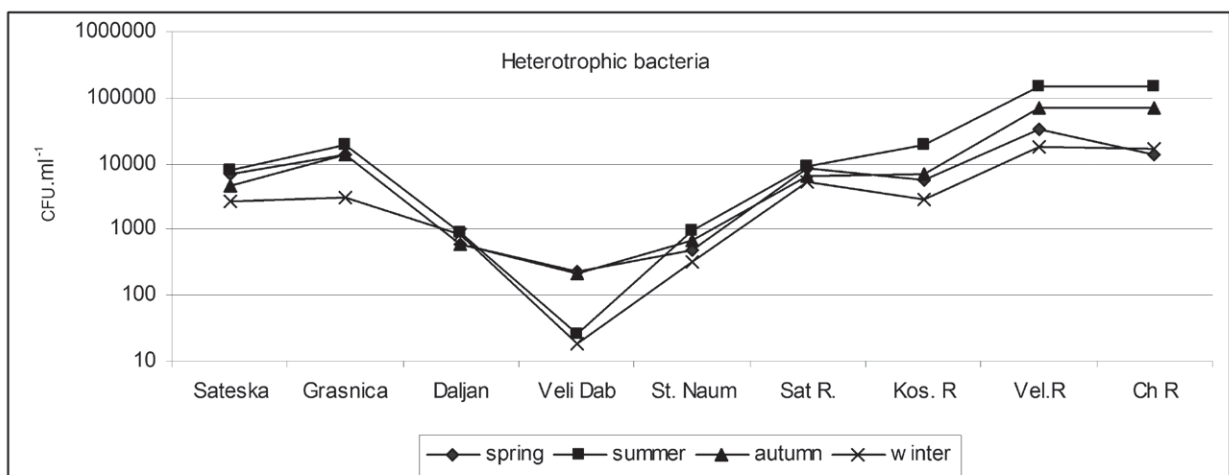


Fig. 1. Heterotrophic bacteria (colony forming units [CFU]·ml⁻¹) in the water of Lake Ohrid and its tributaries, in 2014

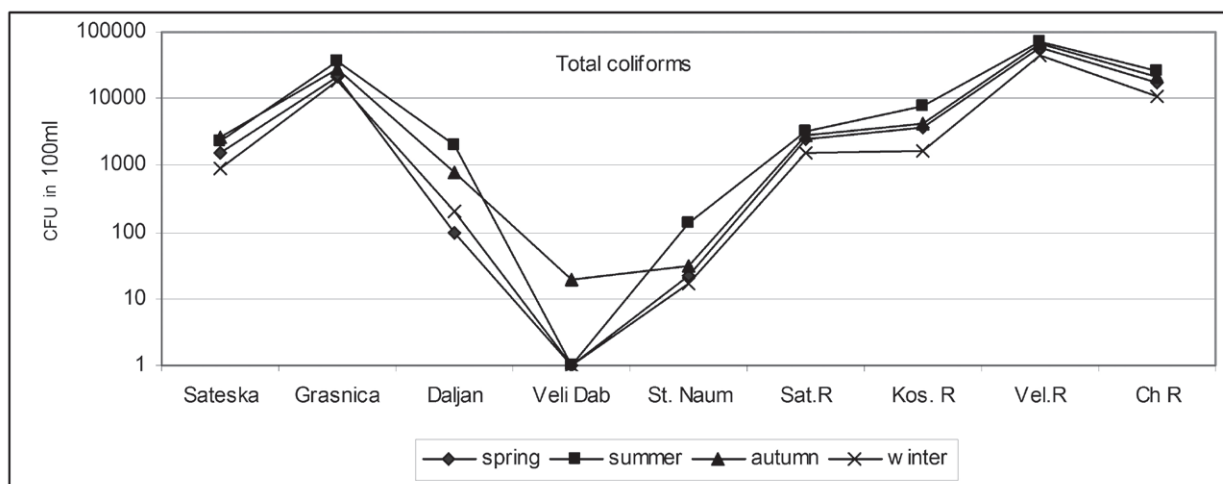


Fig. 2. Total coliform bacteria (colony forming units [CFU] in 100 ml) in the water of Lake Ohrid and its tributaries, in 2014

Total coliforms are not specific indicators of faecal pollution (ASHBOLT et al. 2001), but can provide basic information on the source water quality. In the lake, values for the total number of coliform bacteria were the highest in the region of Grashnica, where a maximum value of 37,600 CFU in 100 ml was registered in summer (Fig. 2). During the same period, the highest abundance of coliforms (73,400 CFU in 100 ml) was recorded in the Velgoshka River, which inflows in the surrounding areas. The high abundance of these bacteria may be provided by the tourist activities and the high temperatures of the water. In addition, the coliform bacteria are correlated with the external factors, such as rainfalls, location, as well as with the internal factors of the environment. Usually, rainstorms not only introduce faecal materials from contamination sources to surface waters through runoff or storm water discharge, but also greatly increase water flow (MEDEMA et al. 2003). HONG et al. (2010) reported that total coliforms in the reservoirs are closely related with water physical-chemical properties, while faecal coliforms are more associated with external input brought in by seasonal runoff. Under rapid water flow, self-purification mechanisms that may remove pathogens in water, such as sedimentation, dilution, sunlight inactivation, predation and starvation, become much less significant as compared to those under slower water flow (MEDEMA et al. 2003).

The enterococci were presented at all localities during all studied seasons, with substantial variability in the values (Fig. 3). Generally, these bacteria were more abundant at all localities in summer, except for the locality of Grashnica, where a maximum of 12,900 CFU in 100 ml was recorded in autumn, and in the Velgoshka River (25,600 CFU in 100 ml, in autumn),

which has a significant negative effect on this part of the lake. With similar seasonal and spatial dynamics was characterised *Escherichia coli*, an indicator of fresh faecal pollution. It had a maximum of 16,800 CFU in 100 ml in the region of Grashnica and 182,000 CFU in 100 ml in the Velgoshka River (Fig. 4).

The obtained results for the chemical parameters of the water from Lake Ohrid and its tributaries were in correlation with the results from the microbiological analyses. The oxygen required to oxidise organic matter in water measured as chemical oxygen demand (COD) by KMnO_4 was the highest at Grashnica locality in the lake ($16 \text{ mg}\cdot\text{L}^{-1}$, in summer) and in the Velgoshka River, which inflows in this region ($45 \text{ mg}\cdot\text{L}^{-1}$, in summer) (Fig. 5). Besides the Velgoshka River, relatively high quantities of organic matter were found in the Cherava River, while lower quantities of organic matter were recorded in the rivers Sateska and Koselska. In the latter two rivers, the heterotrophic bacteria were much more abundant, indicating organic pollution.

The intensive processes of degradation of the organic matter by the bacteria were evidenced by the high concentrations of ammonia in the waters from the rivers and some parts of the lake (Fig. 6). The concentrations of the ammonia (NH_3), ionised in the water to NH_4^+ nitrogen, had seasonal and spatial variability. Besides the fact that the Velgoshka River had substantial organic matter and bacteria content, it was also rich in ammonia, with its values reaching $567.07 \text{ }\mu\text{g}\cdot\text{L}^{-1}$, in summer. The quantity of ammonia in the lake littoral was the highest in the area in front of the inflow of the Velgoshka River ($217.67 \text{ }\mu\text{g}\cdot\text{L}^{-1}$), while at the localities Velidab and St. Naum, ammonia was not registered at all. The ammonia is usually present in low quantities (lower

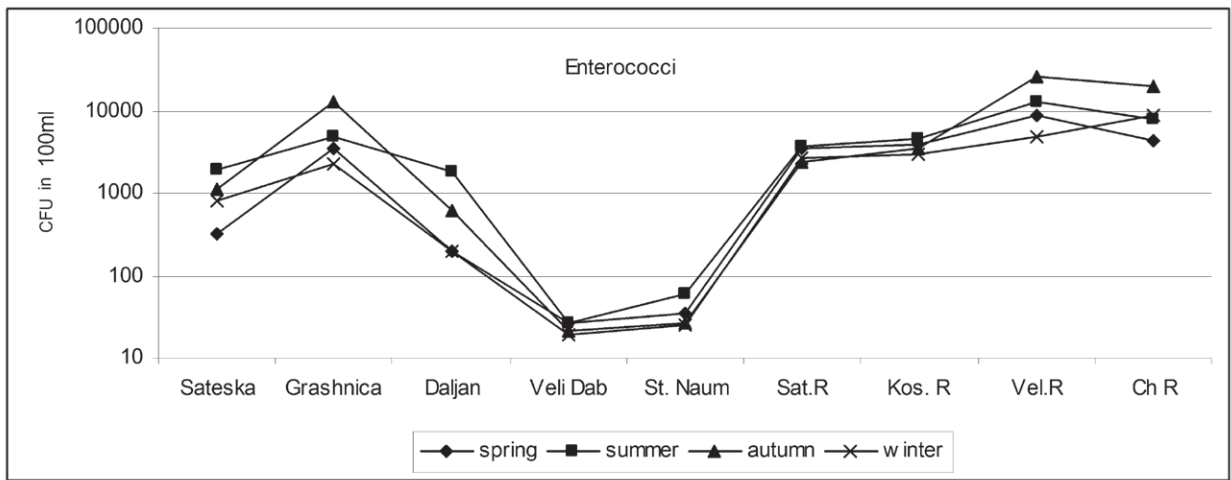


Fig. 3. Seasonal fluctuations in the abundance of enterococci (colony forming units [CFU] in 100 ml) in the water of Lake Ohrid and its tributaries, in 2014

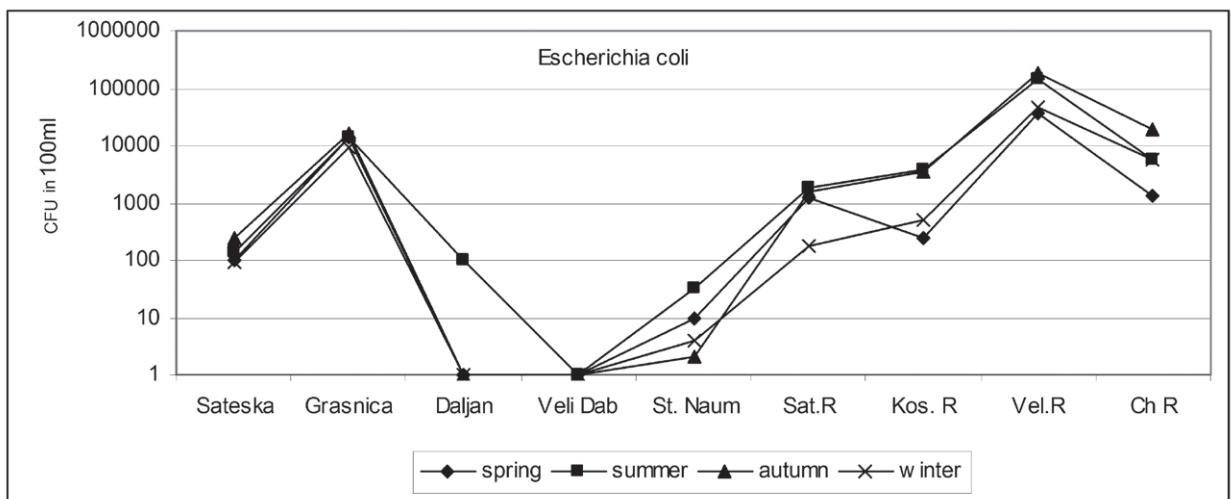


Fig. 4. Seasonal fluctuations in the abundance of *Escherichia coli* (colony forming units [CFU] in 100 ml) in the water of Lake Ohrid and its tributaries, in 2014

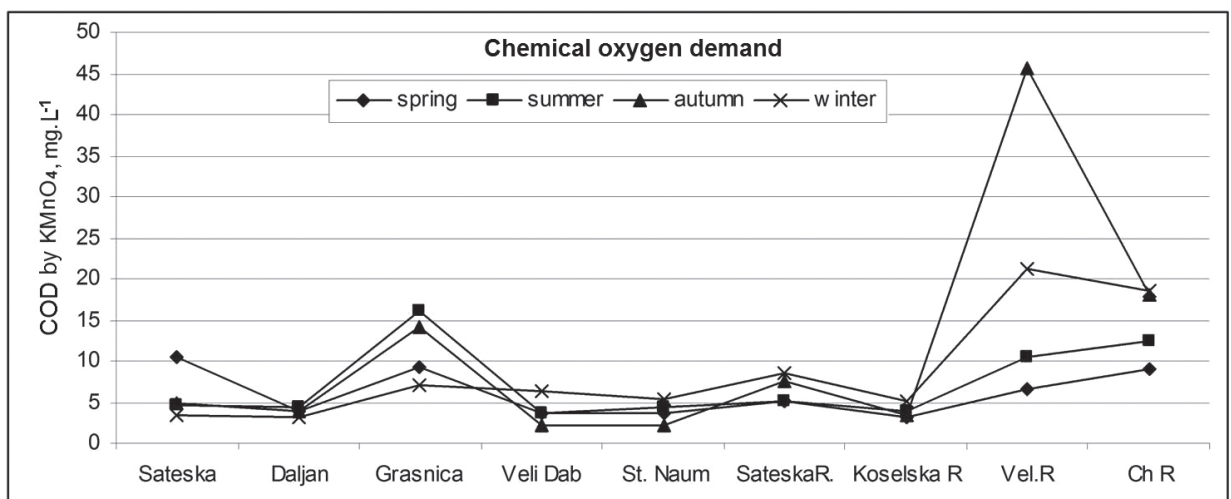


Fig. 5. Chemical oxygen demand (COD) by KMnO_4 ($\text{mg}\cdot\text{L}^{-1}$) in the water of Lake Ohrid and its tributaries, in 2014

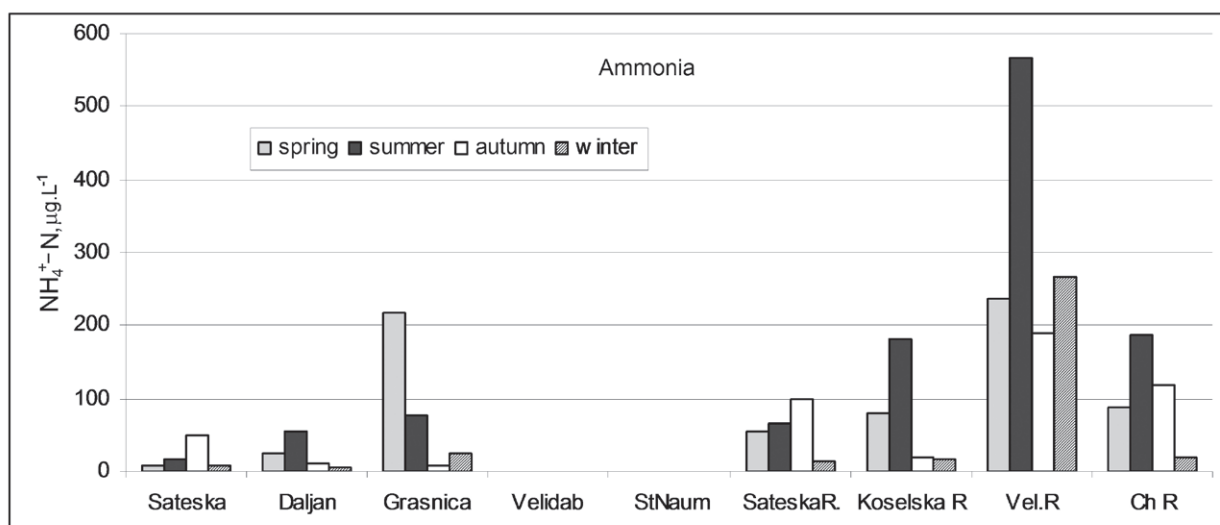


Fig. 6. Concentration of ammonia (NH_3 ionised to $\text{NH}_4^+\text{-N}$, $\mu\text{g}\cdot\text{L}^{-1}$) in the water of Lake Ohrid and its tributaries, in 2014

than $10 \mu\text{g}\cdot\text{L}^{-1}$) in unpolluted, oxygen-rich waters, and increases in water with high pH and temperature, but it can attain quantities of $5\text{--}10 \text{ mg}\cdot\text{L}^{-1}$ in the anaerobic hypolimnion of eutrophic lakes (LIND 1985).

Based on the obtained results and the bacteriological standard parameters for faecal pollution, the lake water at the localities Velidab and St. Naum was classified as unpolluted. The water at the localities Daljan and Sateska was low to moderately faecally polluted (classes I and II) according to *E. coli*, and critically polluted (class III) according to the enterococci. At Grashnica locality, the water was critically and strongly polluted (classes III and IV). The rivers Sateska and Koselska were mainly classified under class III, the Cherava River was under classes III and IV, while the Velgoshka River was most polluted (classes IV and V).

The tributaries of the lake (rivers Sateska, Koselska and Velgoshka) affect the presence and abundance of bacteria in the littoral parts, in front of their inflows (regions of Sateska, Daljan, and Grashnica, respectively). Especially notable is the faecal pollution. During our study, most abundant were the bacteria at Grashnica locality, in front of the inflow of the Velgoshka River, which is the most polluted tributary, and which inflows to the lake the majority of waste communal and industrial waters rich with pollutants, organic matter and bacteria. Similar results were reported by the previous studies as well (LOKOSKA 2000, 2011, 2013, 2015).

Conclusions

The results from the microbiological and chemical study of the water quality of Lake Ohrid and its

tributaries showed spatial and seasonal fluctuations in the studied parameters. The parts of Lake Ohrid, which are away from the settlements and river inflows, were classified as pure (unpolluted) waters. The worse water quality was observed in the area of Grashnica, where relatively high, critical organic and faecal pollution was recorded. This part of the lake is under pressure of communal and industrial waste waters rich with pollutants and nutrients, which originate in the Velgoshka River. This river was the most polluted, with excessive faecal pollution. Similar conditions were registered in the Cherava River, while the rivers Koselska and Sateska were less polluted. In order to prevent further worsening of the ecological status of Lake Ohrid certain preventive measures, mainly rehabilitation of the communal waste waters and regular monitoring of the water and sediments, are recommended.

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