ST. NAUM SPRINGS AS ONE OF THE HYDROLOGICAL CONNECTIONS BETWEEN LAKES OHRID AND PRESPA

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Abstract

Lake Ohrid and Lake Prespa are one of the oldest lakes on earth. They are situated in southeastern Europe and the largest parts belong to R. Macedonia. Although the upstream Lake Prespa has no surface outflow its waters reach the 160 m lower Lake Ohrid by underground hydrological connection. Several studies have been performed on the hydraulic connection between the two lakes using stable isotopes and St. Naum Springs, the largest spring area, is one of their connections.

The goal of this investigation was to compare the water trophic state of St. Naum Springs with the water trophic state of Lakes Ohrid and Prespa. The investigative period of this study took place over the years 2001 and 2002.

According to the results obtained during these investigations it was determined that in the spring water at St. Naum there was not a presence of phytoplankton and measurable chlorophyll *a* content. Total nitrogen concentration was significantly higher in spring water than in Lake Ohrid and lower than in Lake Prespa. Average total phosphorus concentration in the spring water was 13,73 μg l^{-1} in 2001 and 13,62 μg l^{-1} in 2002. It was 2.5 times higher than in Lake Ohrid and 2.5 times lower than in Lake Prespa, This represents approximately 40% of the average concentration of TP in Lake Prespa. This percentage is almost identical to data of all the previous investigations for determination the percentage of water in St. Naum Springs that originate from Lake Prespa.

Key words: Lake Ohrid, Lake Prespa, St. Naum Springs, trophic state

ИЗВОРИТЕ СВЕТИ НАУМ КАКО ЕДНА ОД ХИДРОЛОШКИТЕ ВРСКИ ПОМЕЃУ ОХРИДСКОТО И ПРЕСПАНСКОТО ЕЗЕРО

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Апстракт

Охридското и Преспанското Езеро се едни од најстарите езера на Земјата. Тие се сместени во југоисточна Европа и со најголем дел припаѓаат на Република Македонија. И покрај тоа што Преспанското Езеро нема површински истек неговите води достигнуваат во 160 м пониското Охридско Езеро со подземна хидролошка врска.

Неколку студии ја прикажале хидрауличната врска помеѓу двете езера користејќи стабилни изотопи, а изворите кај Свети Наум, најголемата изворска област, се една од тие врски.

Целта на овие истражувања беше компарација на трофичкиот статус на водата во изворите кај Свети Наум со трофичкиот статус на водата во Охридското и Преспанското Езеро. Периодот на истражување на овие проучувања се одвиваше во тек на 2001 и 2002 година.

Според резултатите добиени во текот на овие истражувања беше утврдено дека во водите на изворите кај Свети Наум нема присуство на фитопланктон и мерлива содржина на хлорофил *a*. Концентрацијата на вкупен азот беше значително повисока во изворската вода отколку во Охридското Езеро и пониска отколку во Преспанското Езеро. Просечната концентрација на вкупен фосфор во изворската вода беше 13,73 μg l^{-1} во 2001 и 13,62 μg l^{-1} во 2002 година. Тоа е 2,5 пати повисока вредност од таа во Охридското Езеро и 2,5 пати пониска отколку во Преспанското Езеро. Тоа претставува приближно 40% од просечната концентација на вкупен фосфор во Преспанското Езеро. Овој процент е скоро идентичен со податоците на сите претходни истражувања за одредување на процентот на водите од изворите кај Свети Наум кои потекнуваат од Преспанското Езеро.

Клучни зборови: Охридско Езеро, Преспанско Езеро, извори Свети Наум, трофички статус

Introduction

Several different studies have been performed on the hydrological connection between Lakes Ohrid and Prespa (Anovski et al., 1980; Anovski et al., 1992; Eftimi and Zoto, 1997; Eftimi et al., 2001; Zoto et al., 2004).

According to the investigations of Anovski et al. (1980), 56% from the water of the St. Naum Springs originates from Lake Prespa.

Eftimi and Zoto (1997) found similar numbers for St. Naum Springs and a slightly increased share of Lake Prespa water in the Tushemisht spring area (Albania). In total, the two areas contribute about 4.5 m^3 s^{-1} of Lake Prespa water to Lake Ohrid. This corresponds to 58% of the total underground outflow from Lake Prespa.

The last investigations by isotopes of Zoto et al. (2004) indicated that 37.3% from the water of St. Naum Springs and 54.4% from the Tushemisht Springs originate from Lake Prespa.

The newest investigation for argumentation of this connection from Matzinger et al. (2006), were carried out in the period 2001-2003, which coincided with our investigations period. The results from this investigation implies that 43 ± 5% of the spring water at St. Naum is fed from Lake Prespa and 57 ± 5% from local precipitation.

Materials and methods

Water samples were collected during 2001 and 2002 from the pelagic zone of Lake Prespa on four depths (0, 5, 10 and 15 m) and from the pelagic zone of Lake Ohrid on nine depths (0, 10, 20, 30, 40, 50, 75, 100 and 150 m) by Niskin bottles, seasonally and with a

monthly frequency of sampling in the summer period. Also, the material was collected from the St. Naum Springs with a monthly frequency of sampling.
The physic-chemical parameters were carried out by standard limnological methods. The Phytoplankton identification was carried out in sedimentation chamber under an inverted microscope (Utermöhl 1958).
The determination of chlorophyll *a* content was carried out spectrophotometrically after extraction in 90% ethanol (ISO 10260, 1992; Meyns et al., 1994).

Results and discussion

During the investigated period in the spring water at St. Naum there was not a presence of phytoplankton and measurable chlorophyll *a* content.

Tab. 1. Values of the investigated physic-chemical parameters in the spring water of St. Naum during 2001

	Jan´01	Feb´01	Mar'01	May'01	Jun'01	Jul'01	Aug'01	Sep'01	Oct'01	Nov'01
t °C	11,3	11,5	11,4	11,5	11,6	11,6	11,6	11,6	11,5	11,2
O_2 - mg l^{-1}	6,60	6,57	7,01	7,17	6,82	6,93	6,47	7,14	6,67	7,05
O_2 %	67,82	67,87	72,32	74,05	70,55	71,78	69,95	74,05	68,94	72,38
TP - µg l^{-1}	8,87	6,67	7,25	23,90	25,11	39,00	3,41	9,64	9,95	3,53
NO_2 - µg l^{-1}	1,316	0	0	4,38	2,17	4,30	4,70	0	0	0
NO_3 - µg l^{-1}	188,17	175,49	353,82	385,68	409,26	875,93	338,66	316,14	329,30	357,81
N-org. µg l^{-1}	213,36	1387,99	529,34	616,28	356,61	266,53	1061,76	175,50	456,74	397,85
TN - µg l^{-1}	402,85	1563,48	883,16	1006,34	768,04	1146,76	1405,12	491,64	786,04	755,66

Tab. 2. Values of the investigated physic-chemical parameters in the spring water of St. Naum during 2002 and 2003

	Feb'02	Mar'02	May'02	Jun'02	Jul'02	Aug'02	Sep'02	Feb'03	May'03	Jun'03
t °C	11,5	11,2	11,6	11,6	12,8	11,6	11,5	11,4	11,50	11,5
O_2 - mg l^{-1}	7,06	7,18	7,26	6,85	7,48	6,79	7,37	7,02	7,91	7,73
O_2 %	72,94	13,70	75,12	70,94	79,63	70,31	76,18	72,41	80,80	79,01
TP - µg l^{-1}	7,44	3,875	5,89	22,32	30,38	15,81	9,61	3.72	19.53	16.43
NO_2 - µg l^{-1}	0	0	1,82	1,82	2,52	0,41	3,78	3,22	16,52	0
NO_3 - µg l^{-1}	233,52	247,52	256,90	589,19	363,93	216,51	361,76	449,40	278,88	440,97
N-org. µg l^{-1}	425,88	327,66	646,80	354,48	134,12	512,12	485,24	202,44	518,28	579,60
TN - µg l^{-1}	659,40	575,18	905,52	945,49	500,57	729,04	850,78	655,06	813,68	1020,57

The high concentration of dissolved oxygen and high oxygen saturation in the spring water (Tab. 1, 2) indicated that during the underground transport come at oxidative mineralization of the organic matter.

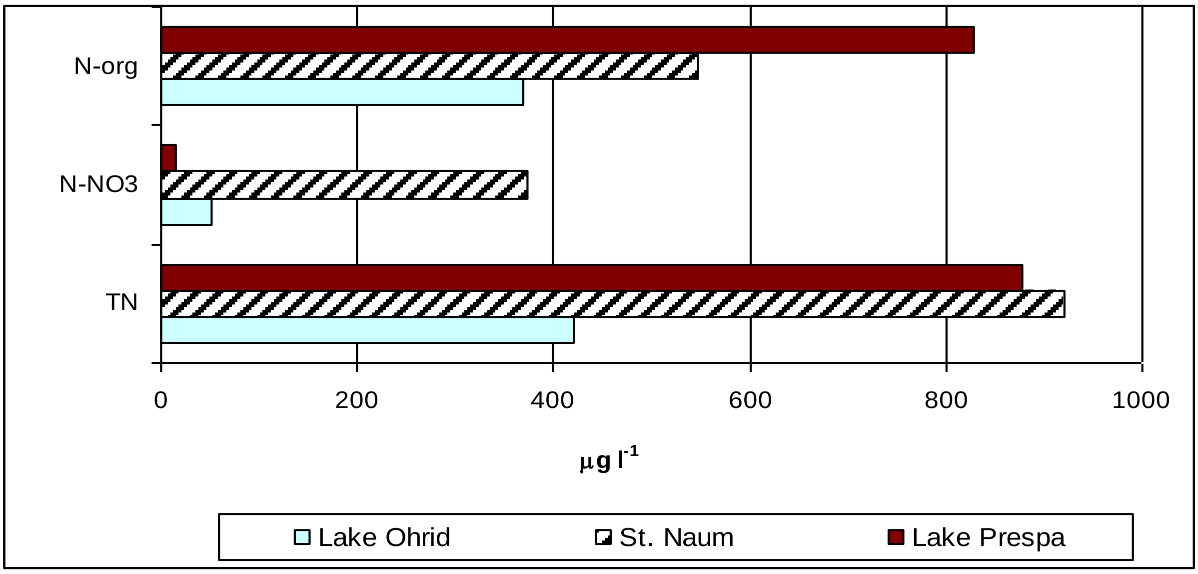

Fig. 1. Graphic review of the annual average values of nitrate, organic and total nitrogen comparatively in Lake Prespa, spring water at St. Naum and Lake Ohrid during 2001

Nitrate nitrogen concentration was considerably higher in the spring water than in the lake water of Lake Ohrid and Lake Prespa. The mean concentration in 2001 was 373.03 µg l^{-1} (Fig. 1) and 382.85 µg l^{-1} in 2002 (Fig. 2).

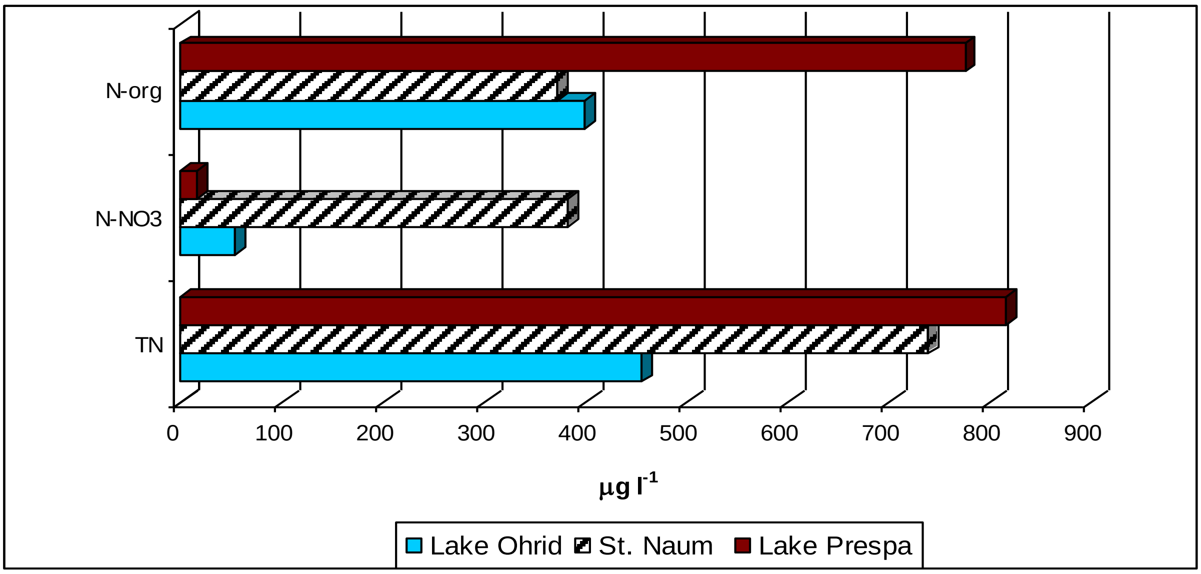

Fig. 2. Graphic review of the annual average values of nitrate, organic and total nitrogen comparatively in Lake Prespa, spring water at St. Naum and Lake Ohrid during 2002

For the spring water at St. Naum was characteristic high total nitrogen (TN) concentration, which value of 920.91 µg l^{-1} in 2001 exceed value in Lake Prespa (Fig. 1) and in 2002 was within the ace of it (738 μg l^{-1}). It contributes for the higher values of the total nitrogen in Lake Ohrid (Fig. 2).

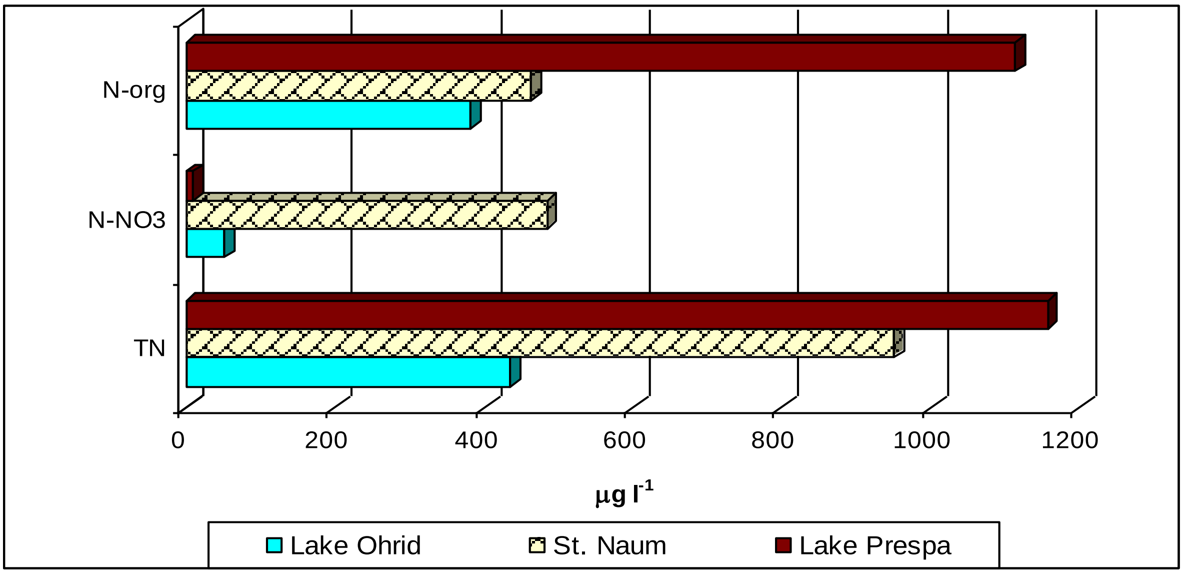

Fig. 3. Graphic review of the summer average values of nitrate, organic and total nitrogen comparatively in Lake Prespa, spring water at St. Naum and Lake Ohrid during 2001

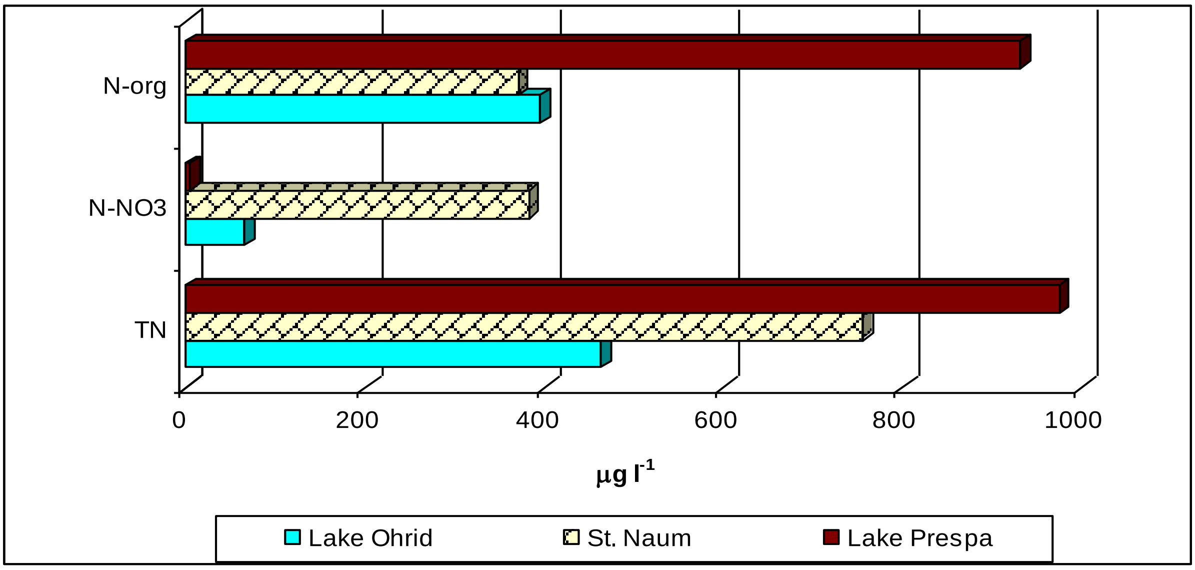

Fig. 4. Graphic review of the summer average values of nitrate, organic and total nitrogen comparatively in Lake Prespa, spring water at St. Naum and Lake Ohrid during 2002

The graphic review of the average summer values of the nitrogen forms, comparatively in Lake Prespa, St. Naum Springs and Lake Ohrid is similar to the graphic review of the average annual values. The average total nitrogen concentration in the summer period 2001 was 952.89 μg l^{-1} (Fig. 3) and in 2002 was 756.47 μg l^{-1} (Fig. 4).

Average annual total phosphorus concentration in the spring water at St. Naum was relatively constant in the both years which values were 13.73 μg l^{-1} in 2001 (Fig. 5) and 13.62

μg l^{-1} in 2002 (Fig. 6). It was 2.5 times higher than in Lake Ohrid and 2.5 times lower than in Lake Prespa,

This value represents approximately 40% of the average concentration of TP in Lake Prespa. This percentage is almost identical to data of all the previous investigations for determination the percentage of water in St. Naum Springs that originate from Lake Prespa.

Matzinger et al (2006) concluded that 65% of the total phosphorus (TP) leaving Lake Prespa (average 31 μg l^{-1}) entering into the karst underground is retained. They assumed this ratio to be constant for higher phosphorus concentration as well.

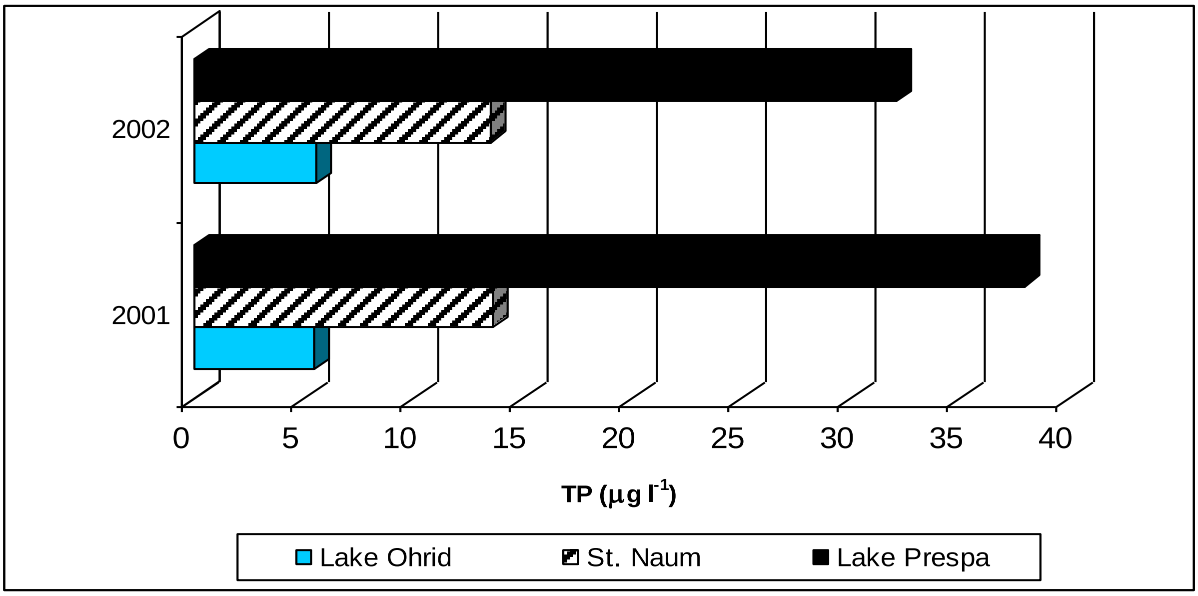

Fig. 5. Graphic review of the annual average values of total phosphorus comparatively in Lake Prespa, spring water at St. Naum and Lake Ohrid during 2001 and 2002

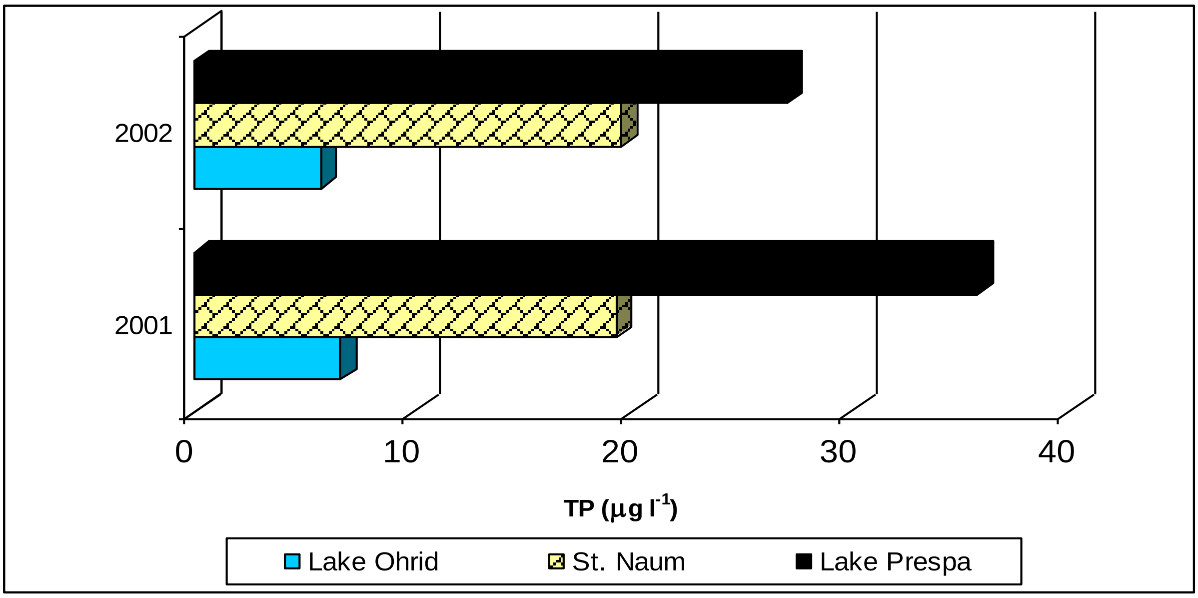

Fig. 6. Graphic review of the summer average values of total phosphorus comparatively in Lake Prespa, spring water at St. Naum and Lake Ohrid during 2001 and 2002

In October 2002 with SeaBird 19 CTD profajler was carried out measurement of the conductivity in the lake water in the whole water column on the depths, from the inflow of the spring water at St. Naum in Lake Ohrid to 1800 meters distance from the inflow. Conductivity reflects the quantity of the total soluble salts and ions in the water.

From the Figure 7 is clearly that the spring water which inflow in the lake has much higher conductivity (210 µS cm^{-1}) than lake water (204 µS cm^{-1}). This water layer with higher conductivity than lake water which originates from the St. Naum Springs, from the beginning of the flow to 700 m distance of the inflow falls to 15 m depth, and from 700 m distance further be situated in the layer of 20 m depth and this water layer is clearly separate from the surrounding lake water. This is a clear review of the spring water movement which is with different composition and quality in the water of Lake Ohrid. Surely, it has clearly correlation with the maximal average phytoplankton density and the maximal average TP concentration on the same depth in the water column. The graphic review of the vertical array of these parameters from the surface to 40 m depth is practically identical with the previous review (Patceva, 2005).

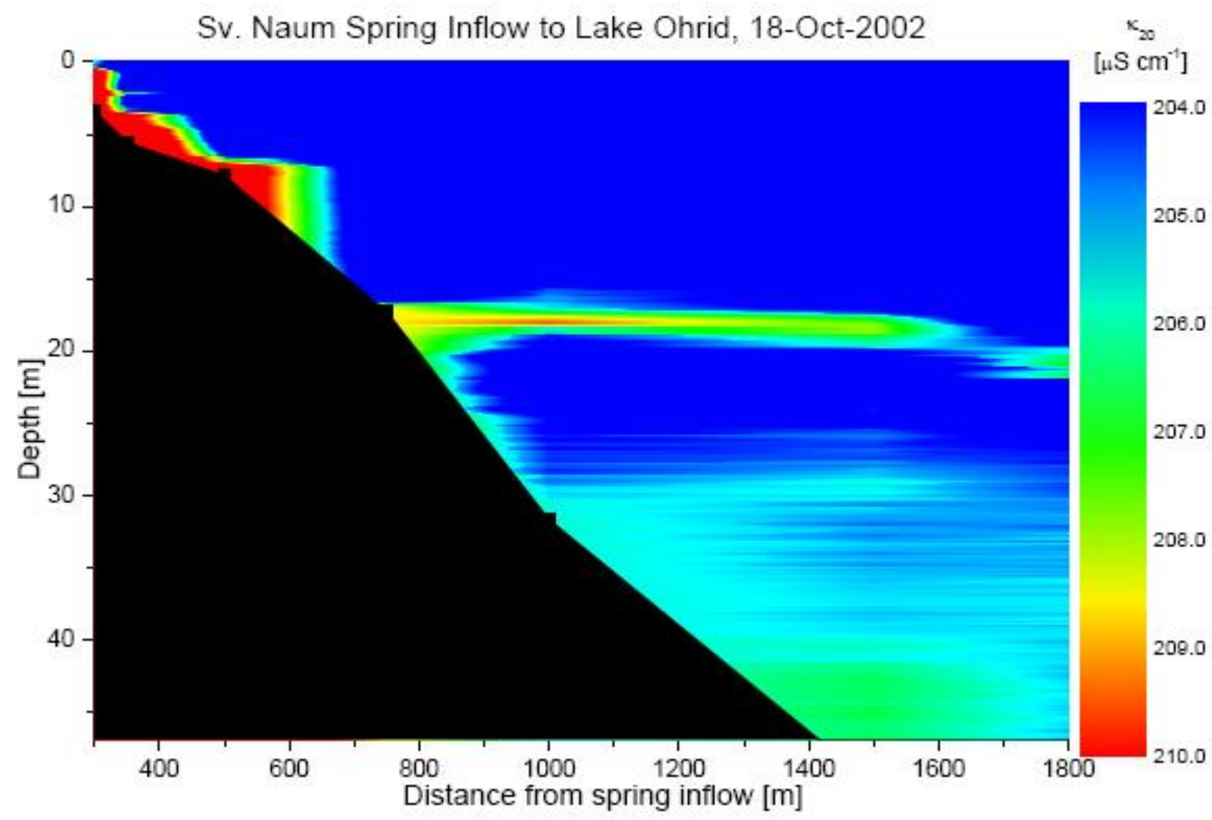

Fig. 7: Review of the conductivity values on different depths in the water column of Lake Ohrid from the beginning of the spring water at St Naum inflow in the lake to 1800 m distance from the inflow (measurements were carried out from A. Matzinger, Z. Spirkovski and B. Cakaloski)

With the proven connection between Lake Ohrid and Lake Prespa and due to water level decrease, worsened trophic state and eutrophication of Lake Prespa, come into question what will be its influence on the water level and trophic state of Lake Ohrid.

Last years not be seen more significant decrease of the water level of Lake Ohrid, and results from the triennial investigation indicated that there isn't more significant increase of the water trophic state of Lake Ohrid and also more significant changes of the phytoplankton community as the most sensitive indicator of the water quality changes. There were observed small changes in the percentage participation of the existing phytoplankton species but there were not observed changes in the phytoplankton density and its production.

Matzinger et al. (2006) found that about 20% of the Lake Ohrid water inflow and 7% of the TP load originate from Lake Prespa. Hence, the water level drop most likely is reducing the underground flow. Such a decrease has no influence on the water level of Lake Ohrid. However, its outflow is reduced, and consequently the hydraulic residence time of Lake Ohrid increases.

In the same investigations Matzinger et al. (2006) found that increase in the phosphorus load from Lake Prespa will augment the TP concentration of Lake Ohrid by merely 0.1 $\mu g\ l^{-1}$. They assumed that if the phosphorus load from Lake Prespa increase four times, the total increase of the TP concentration in Lake Ohrid would still be below 1 $\mu g\ l^{-1}$. Still, the eutrophication potential of the underground connection between Lake Prespa and Lake Ohrid seems limited, thanks to the puryfying effect of the underground.

Conclusions

During the investigated period in the spring water at St. Naum there was not a presence of phytoplankton and measurable chlorophyll *a* content.

Nitrate nitrogen, organic nitrogen and total nitrogen concentration were significantly higher in spring water at St. Naum than in Lake Ohrid and lower than in Lake Prespa, except for nitrate nitrogen which was with the highest concentration in the spring water.

Total phosphorus concentration in the spring water was 2.5 times higher than in Lake Ohrid and 2.5 times lower than in Lake Prespa, This represents approximately 40% of the average concentration of TP in Lake Prespa.

With the exception of small changes in the phytoplankton composition, in Lake Ohrid were not observed significant difference in the trophic state values. Although, for the sake of their connection there is negative influence of Lake Prespa to Lake Ohrid, however this influence is considerable limited.

From all of these investigations originates the conclusion that Lake Prespa necessarily must be protect in order to prevent process of eutrophication, primarily for the sake of its own protection as one of the oldest and more significant lakes in the world and for protection of its rich living world and its originality, and than for the sake of Lake Ohrid protection.

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