Water Quality and Self-purification Capacity Assessment of Snagov Lake

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The aim of this paper is to identify the spatial and temporal distribution of chemical and physical parameters that characterize the water quality, the trophic state and the self-purification capacity assessment of Snagov Lake. The Snagov Lake is a natural lake located at 25-30 km North from Romania's capital, Bucharest. The study was conducted during a five years period, from April 2010 until October 2014. The measurements used (temperature, pH, dissolved oxygen, transparency, chlorophyll-a, total phosphorus, TN/TP ratio) are presented in the form of spatial and temporal evolutions. For self-purification identification the aerobic mineralization degree, biological depuration factor and TN/TP ratio were used. The trophic stage of Snagov Lake in the range and in all the points of sampling is eutrophic–hipereutrophic for all the parameters used for assessment, excepting several short periods of time (fall of 2010, spring and fall of 2011) when the lake was in mesotrophic state.

Keywords: Snagov Lake, trophic status, aerobic mineralization degree, biological depuration, TSI

Eutrophication is a biological response to a lake's excess nutrient input that causes degradation of lentic aquatic systems [1, 2]. The increase of nutrients concentration (nitrogen, phosphorus, sulfur etc.) in lakes increases the primary production (dense algal blooms) causing high turbidity and increasing anoxia in the deeper parts, increasing the acidy and modifying the aquatic ecosystems [3, 4], is slow in natural conditions when the input of nutrients is smaller and accelerated when the nutrients are in high concentrations, when provided from anthropogenic sources [5].

The Snagov Lake is a natural lake located at 25-30 km North from Bucharest, in the Ilfov County of Romania. It is an important natural lagoon on the inferior Ialomia river course with its 5.75 km² surface, 16 km length and 9 m maximum depth, it is included in national patrimony as natural reservation (fig. 1). Lake represents the most important agreement resort situated around Bucharest and includes also a residential zone. The Lake's water sources are the underground waters and in small part the snow and rain waters. Consequently, the water level is relatively constant through the year, except for winter and autumn [6].

Biological activity into lakes water are influenced of many parameters. Temperature influences the biological, chemical and physical processes, gas solubility decreases with the increase of temperature, while the biochemical activity doubles every 10°C of temperature increase [7, 8]. The toxicity of un-ionized ammonia is also related to warmer temperatures. The optimal temperature for phytoplankton cultures (blue-green algae) is generally between 20 and 24°C, the most commonly cultured species of micro-algae tolerate temperatures between 16 and 27°C [9-10].

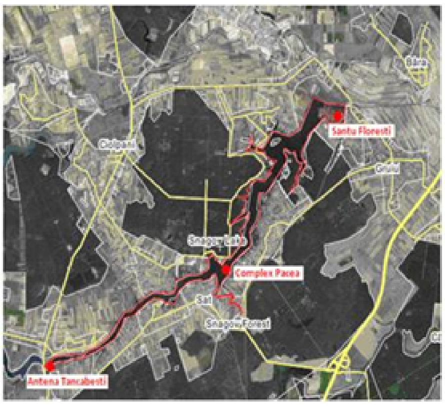

Fig. 1. Sampling sites to Snagov Lake: input-Antena Tancabesti, middle–Complex Pacea and output-Santu Floresti

The *p*H variation in water lakes is determined either by the algal and macrophytes photosynthesis which increase the lake's pH either by the organic matter decomposition which reduces the *p*H. The presence of a high alkalinity (>100 mg/L) represents a considerable buffering capacity and reduces the large fluctuations in *p*H [9]. Usually, the pH range for most cultured algal species is situated between 7 and 9, with an optimum range between 8.2 and 8.7 [10]. Oxygen in water provide by dissolved oxygen from air and the primary production (photosynthesis process). The consumption of oxygen in the lake is made by the oxidative processes, the biochemical processes like decomposition and respiration (animals, plants and microbes) and by the oxide-reducing chemical processes. The latter include the oxidation of the dissolved organic

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matter and the take up of oxygen by purely chemical oxidation or photochemical oxidation by UV light. At turnover (both spring and fall in a dimictic system) the O_2 value in water is situated at nearly 100% saturation (12 to 13 mg/L at 4°C at sea level pressure) [11].

The transparency (clarity) of water, express like Secchi depth is determined by the dissolved and colloidal organic matter [12], the inorganic particulates like humic and fulvic acids [13] and the phytoplancton [14]. These parameters will be associated with another parameters like Chlorophyll-*a* and phosphorus concentration [15]. Phosphorus is one macro-nutrient very important that limits the primary production. Phosphorus in aquatic systems occurs in three forms: inorganic phosphorus, particulate organic phosphorus and dissolved (soluble) organic phosphorus. Aquatic plants require inorganic phosphate for nutrition, namely orthophosphate ions ($PO4^{3-}$) [11, 16]. CHL is an excellent indicator used for a good agreement between planktonic primary production and algal biomass the cellular chlorophyll content depending on algal species (0.1–9.7% of fresh algal weight [17].

Nitrogen and phosphorus are two nutrients that are necessary for microorganisms to grow. The nitrogen can be present in three species: nitrate, nitrite and ammonia, highly soluble in the aquatic environment. If the nitrogen is in low concentration then the microorganisms can use the one from atmosphere [18]. The phosphorus is the most important nutrient after nitrogen, its concentration controls the plants growth [19]. The ratio nitrogen: phosphorus of 10:1 is ideal for the aquatic plant growth., a value higher than 10:1 indicates phosphorus limited systems while a ratio lower than 10:1, the nitrogen limited systems [7, 20].

The lake mineralization capacity of organic material (MD) can be used for describe the metabolic activity of microorganisms involved a considerable consumption of dissolved oxygen for biodegradation organic compounds, is the beginning of the stabilization process [21-23]. The lake organic material capacity of mineralization (MD) can be calculated using the ratio between dissolved oxygen (DO), concentration in photic zone and chemical oxygen demand (COD-Mn). These criteria can be applied especially for natural depth lakes that have a retention time of around one year.

The biological depuration factor (BD) is defined as the ratio between the biomass capacity to biodegrade the organic compounds and the concentration of organic compounds from the analyzed system, BOD_5/COD-Cr. A BD ratio in the range 0.5-1.0 indicates water with a good biological depuration factor and in the range 0.5-0.2 indicates that the bacterial populations should be adapted to the concentration and the type of organic compounds, while in the range 0.1-0.2 the water content organic compounds hardly biodegradable or the toxic compounds [24, 25].

The objective of this study was to identify the spatial and temporal distribution of chemical and physical parameters that characterize the water quality, the trophic state and self-purification capacity assessment of Snagov Lake water over a five years period, 2010 - 2014.

Experimental part

Material and methods

The lake water sampling started in May 2010 and continued until October 2014. The samples were collected during three annual campaigns: April-May, July-August and September-October. Samples duplicates were collected from three sampling sites chosen for the monitoring of the Snagov Lake, as following: Antena Tancabesti at the input, Complex Pacea in the middle and Santu Floresti at the output (fig. 1). Water samples were collected from the water column of the photic zone using the Ruttner sampler. The water samples were then filtered, preserved and packed in accordance with SR ISO 5667-2. The parameters analyzed, standard methods and apparatus used for the parameters analysis are presented in table 1. In this work are shown the spatial and temporal evolutions for the following parameters: temperature, *p*H, dissolved oxygen (DO), Secchi transparency (SD), chlorophyll-*a* (CHL), total phosphorus (TP) and TN/TP ratio. For the identification of self-purification the aerobic mineralization degree (MD), biological depuration factor (BD) and TN/TP ratio were used.

Table 1
STANDARD METHODS ANA APPARATUS USED FOR ANALYZING THE QUALITY PARAMETRS OF WATER

No	Parameter	Standard method	Analysis method	Apparatus
1	pH	SR ISO 10523:1997	Electrochemical	pH, WTW Inolab 740
2	Dissolved oxygen (DO)	SR EN 25813:2000	Volumetric On situ	Winkler methods Oxi-meter Jenway 970
3	BOD_5	SR EN 1899-2:2002	Volumetric	TS1006-i WTW thermostat
4	Total Kjeldahl Nitrogen (TN)	SR EN 12260:2004	Catalytic combustion	Analytik Jena- total nitrogen analyzer Multi N/C 3100 method
5	Total phosphorus (TP)	SR EN ISO6878:2005	Molecular absorption spectrometry	SPECORD 200 Analytik Jena – molecular absorption spectrometer HACH Drell 2000
6	COD-Mn	SR EN ISO 8467:2001	Volumetric	sand bath ST 82 - LHG Germany
7	COD-Cr	SR ISO 15705:2002	Volumetric	sand bath ST 82 - LHG Germany
8	Chlorophyll-*a* (CHL)	SR ISO 10260:1996	Molecular absorption spectrometry	SPECORD 200 Analytik Jena – molecular absorption spectrometer
9	Transparency, (SD)	Secchi disc methods	Visual	Secchi disc

Table 2
ASSESSMENT CRITERIA FOR LAKE TROPHIC STATUS (SD, TP, CHL, TSI)

Parameter	Oligotophic	Mesotrophic	Eutrophic	Hipereutrophic
Transparency (SD), m	>4	2-4	2-0.5	0.5-0.25
Total phosphorus (TP), µg/L	<12	12-24	24-96	96-389
Chlorophill-*a* (CHL), µg/L	<2.6	2.6-20	20-56	56-155

In table 2 were presented the assessment criteria for lake's trophic status based on Secchi depth, chlorophyll-*a* and total phosphorus concentration [15].

Results and discussions

In figure 2a is shown the average temperature variation during the time period from 2010 until 2014 in all the three sampling points: input - Antena Tancabesti, middle - Complex Pacea and output -Santu Floresti. As can be seen, the temperatures showed seasonal variations consistent with lake's geographic location, presents a uniform distribution of temperature in all the sampling points. The temperature varied between 12 and 25°C during spring time, from 26 to 30°C during summer and from 6 to 20°C during fall. The maximum growth rate of algae in the Snagov Lake water corresponds to the temperature range 25-27°C.

The Snagov Lake's *p*H values in the photic zone lies in the weak alkaline domain, in the range from 7.4 to 8.5, with average values of approximately 8, normal values for surface water. At the output of the lake, at Santu Floresti, an exception was observed during spring of 2012 and 2014 when the pH values were higher, 9.5, (fig. 2b), this proves an intense process of phpotosynthesis of algae and macrophytes. The optimum *p*H needed for the growth rate of algae in the Snagov Lake is situated in the range 8.0 - 8.2. Several intensive processes of photosynthesis are responsible for the increase of the CHL concentration simultaneous with increase of oxygen dissolved concentration (fig. 2c). Moreover, in the Snagov Lake DO value varied between 21 mg/L in summer in 2010, and 5 mg/L in fall, higher than the saturation concentration at 20°C (9.17 mg/L), that showing an intense pollution in the lake at the input which were propagated in time in the middle. The DO concentrations into the Snagov Lake decrease in time in all the sampling points and pollution level in lake decrease. The variation of DO compared with

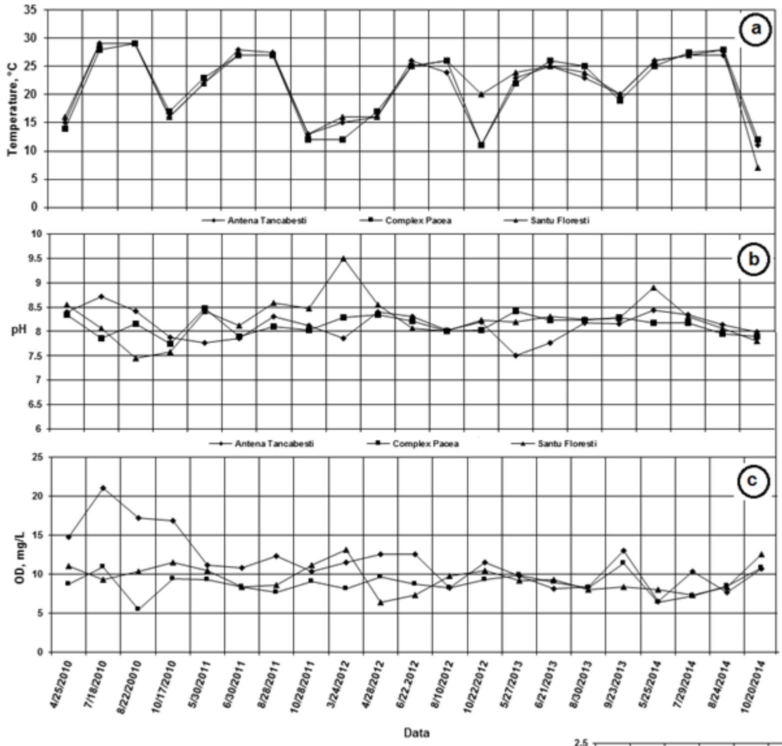

Fig.2 Variation in time of average values of T, *p*H and OD in points of sampling -♦input-Antena Tancabesti,■middle-Complex Pacea ▲output-Santu Floresti. a. Temperature (T,°C), variation in time; b. *p*H variation in time; c. Oxygen dissolved (OD, mg/L) variation in time

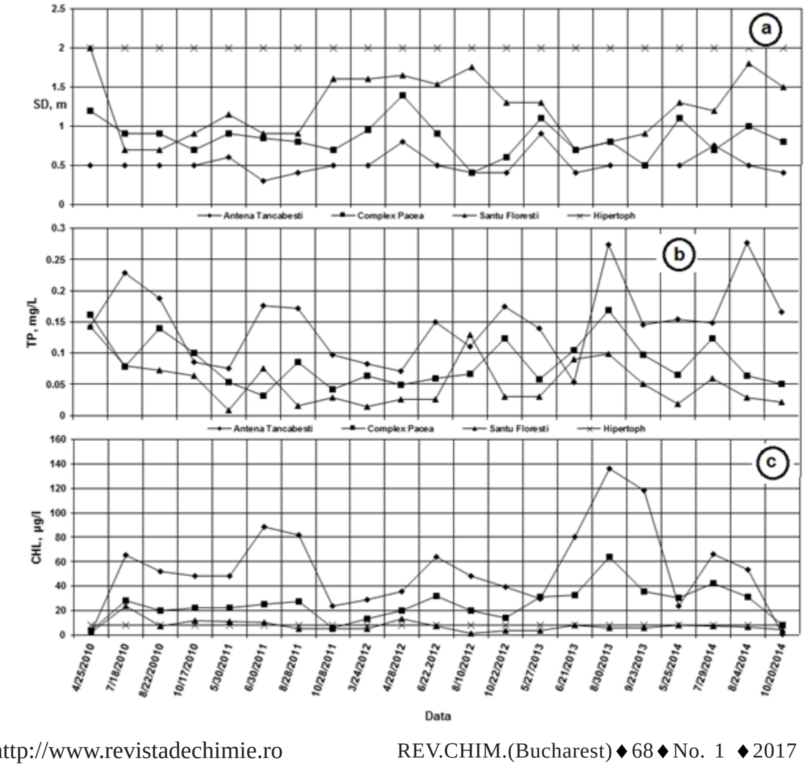

Fig.3. Variation in time of average values of SD, TP and CHL, in points of sampling -♦input-Antena Tancabesti, ■middle-Complex Pacea ▲output-Santu Floresti. a. Secchi depth, (SD, m), variation in time; b. Total phosphorus, (TP, mg/L), variation in time; c. Chlorophille ***a***, (CHLµg/L) variation in time.

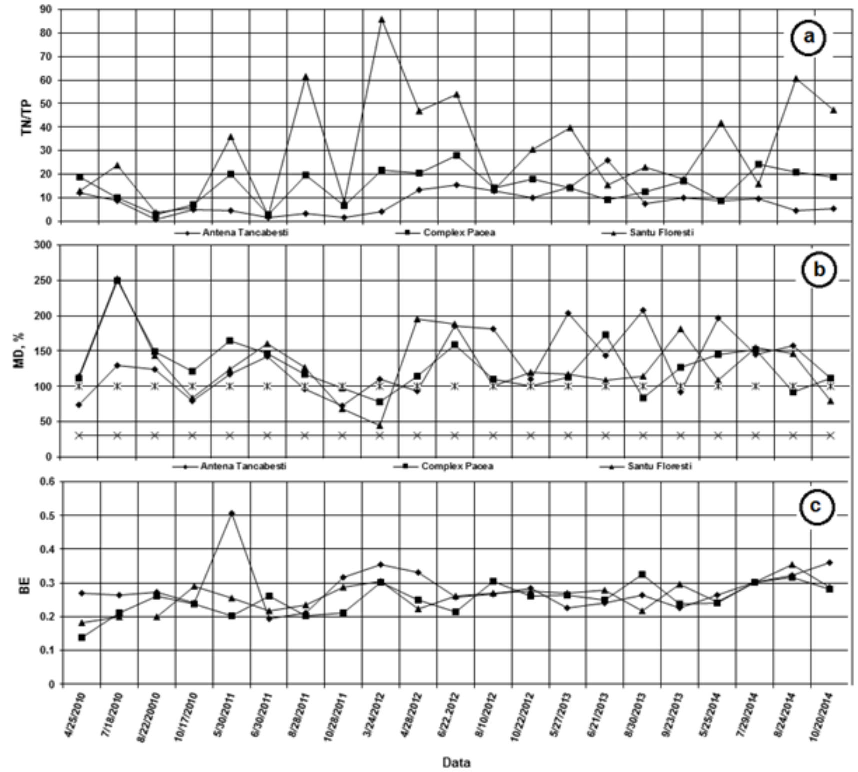

Fig.4. Variation in time of average values of TN/TP ratio, MD and, BD, in points of sampling -♦input-Antena Tancabesti, ■middle-Complex Pacea ▲output-Santu Floresti. a. Ratio total nitrogen total phosphorus (TN/TP), variation of in time; b. Mineralization degree (MD, %), variation in time; c. Biochimical depuration, BD, variation in time

the average value is smaller at the exit of the lake, on the water route degradation of organic compounds significantly and intensely and reduce toward the exit. The increase of the CHL concentration lowers the transparency of the lake's water. The average transparencies were 0.5m, 0.8m and 1.25m in all the three sampling points respectively, for the time period 2010-2014 (fig. 3a). All the values of Secchi depth indicate the eutrophic conditions. The transparency increases from input to output.

The CHL concentration was influenced by the variation of the phosphorus concentration. The maximum concentrations of phosphorus correspond to the maximum values of CHL, (fig. 3b, 3c). At the input (AntenaTancabesti) the average concentration of the total phosphorus was of 148μg/L and the values ranged between 53 μg/L and 277 μg/L, specifically to the eutrophic-hypertrophic stage. In the middle sampling point (Complex Pacea), the average concentration was 81 μg/L and the values were situated in the range 31-169 μg/L, specific for the eutrophic lakes. Finally, at the output (Santu Floresti), the average concentration decreases to 52 μg/L, with the values being situated in the interval 8-98 μg/L, specific mesotrophic - eutrophic stage. The major sources of phosphorus are the underground waters that feed the lake. The total phosphorus concentration was generally highest when the lake's temperature was higher. This was observed especially during summer when the solubility of the phosphorus salts from sediments increased.

In figure 3c is given the variation of chlorophyll-a (CHL), into the Snagov Lake. The average concentrations of CHL decreased from input to output. The values were 54.6 μg/L at the input, 26.0 μg/L in the middle and 9.0 μg/L at the output, which was in accordance to the phosphorus concentration variation. At the input of Snagov Lake the ratio TN/TP was frequently below 10 and this might be due to the nitrogen which limits the growth of biomass (fig. 4a). However, from figure 3c it can be seen that the concentration of CHL at the input is the highest compared to the other monitoring points. Moreover, the phosphorus presents a maximum concentration. Therefore, the water's nitrogen deficiency is due to the atmospheric nitrogen. Also, the dissolution rate limited the nitrogen use. In the middle of the lake, the TN/TP ratio varied between 10 and 20 and biomass increased greatly. However, its increase was limited by the phosphorus concentration. At the lake's output, the TN/TP ratio varied between 25 and 60 and the biomass increase was low, while the phosphorus limited the algal development.

The mineralization capacity of Snagov Lake presented a seasonal variation. Thus, during summer it decreased at values higher that 67.7% and increased around an average value of 100% during spring and fall (fig. 4b). At the input the mineralization degree was higher than the mineralization capacity in the middle and at the output of the lake. The amount of oxygen necessary for organic compounds biodegradation was higher than the concentration of oxygen dissolved in the lake water. The increase of temperature during summer decreased the mineralization capacity. Moreover, the degradation capacity of organically compounds decreased also and the organic compounds were accumulated in the lake. The mineralization capacity of the organic compounds decreased in time during the analyzed period. For the complete mineralization of the organic compounds it would be required an additional quantity of oxygen, by aeration.

The biological depuration factor, BD, varied between 0.2 and 0.35. The average values of the three sampling points were 0.28, 0.26 and 0.26 respectively (fig 4c). These values included also the lake water's lower limit of the middle depuration factor field. The microorganisms present in the lake weren't capable to degrade all the organic compounds due on the one hand, to the limited oxygen concentration, and the other hand, the toxic organic compounds that are difficult to be biodegraded, (pesticides, drugs, etc). Thus, the organic compounds that were difficult to be biodegraded were accumulated in the lake and their biodegradation improved the developing of specific microorganisms.

Conclusions

In the Sangov Lake's water the maximum growth rate of algae corresponds to the temperature range 25-27° C. Generally, the pH values for Snagov Lake ranged from 7.4

up to 9.5, corresponding to neutral and slow alkaline media, the optimum *p*H needed for the growth rate of algae is in the range 8.0 - 8.2. The transparency increases from the input to the output of the lake. All the transparence values indicate the eutrophic conditions. The main sources of nutrients (N, P) are the waters that feed the lake. The increase of algae biomass (chlorophyll-*a* concentration) is limited by the nitrogen concentration at the input and by the phosphorus concentration at the output. The dissolved oxygen (DO) concentration in water is not enough to determine the mineralization of all organic compounds. Thus, the organic compounds that are difficult to be biodegraded are accumulated into the lake improving its biodegradation by the development of specific microorganisms. Based on analyze of studied parameter Snagov Lake is classified generally, to the eutrophic and hypertrophic stage.

References

1. ANDERSON, D.M, GLIBERT, P.M., BURKHOLDER, J.M., Estuaries, **25**, 2002, p. 704
2. BISHOP, M.J., POWERS, S.P., PORTER, H.J., PETERSON, C.H., Estuarine, Coastal and Shelf Science, **70**, no 3, 2006, p. 415
3. CARPENTER, S.R., Proceedings of National Academy of Sciences, **102,** no 29, 2005, p. 10002.
4. PIETERSE, N.M., BLEUTEN, W., JORGENSEN, S.E., Journal of Hydrology, **271**, 2003, p. 213.
5. ROMANESCU, G., IOSUB, M., SANDU, I., MINEA, I., ENEA, A., DASCALITA, D., HAPCIUC, O.E, Rev. Chim.(Bucharest), **67**, no.1, 2016, p.42.
6. REPA, Reports regarding the state of the environmental factors for the 8th Region – Bucharest Ilfov. 2010-2014,http://arpmbuc.anpm.ro/Mediu/raport_privind_starea_mediului_in_romania-15.
7. BACCARIN, A.E., MONTEIRO-CAMARGO A.F., Brazilian Archives of Biology and Technology**, 48**, no 1, 2005, p.81
8. RAVEN, J., GEIDER, R.J., New Phytology, **110,** no 4, 1988, p.441.
9. STEFAN D.S., STEFAN M., Water Stress Induced by Enrichment of Nutrient and Climate Change Factors, Chapter 2, in Water Stress in Plants, Edited by Rahman Mofizur I. Md., Begum, Z. A. and Hasegawa H., 2016, DOI: 10.5772/64665.
10. CIRTINA,D.,CAPATINA, C.,SIMONESCU,C.M.,Rev. Chim.(Bucharest), **66**, no 8, 2015, p. 1184.
11.WETZEL, R.G., Limnology: Lake and River Ecosystems, Elsevier Academic Press, 2001, p. 153.
12. SCHINDLER, D.W., Journal of the Fisheries Research Board of Canada, 28, 1971, p. 157.
13. ZETTLER E.R., CARTER, J.C.H., Canadian Journal of Fisheries and Aquatic Sciences**, 43**, 1986, p. 665-673.
14. OSTROFSKY, M.L., RIGLER F.H., Canadian Journal of Fisheries and Aquatic Sciences, **44**, 1987, p. 775-781.
15. CARLSON, R.E., Limnology and Oceanography. **22,** no 2, 1977, p. 361.
16. RADU, V.M., DIACU, E., IONESCU, P., DEAK, Gy., Rev. Chim., 6**6,** no. 5, 2015, p. 601.
17. BOYER, J.N., KELBLE, C.R., ORTNER, P.B., RUDNICK, D.T., Ecological Indicators, **9s**, 2009, p. s56.
18. SCHINDLER, D.W., HECKY, R.E., FINDLAY, D.L., STAINTON, M.P., PARKER, B.R., PATERSON, M.J., BEATY, K.G., LYNG, M., KASIAN, S.E.M., Proceedings of the National Academy of Sciences USA, **105,** no 32, p 11254.
19. REYNOLDS, C., Ecology and Phytoplankton, Cambridge University Press, 2006, p. 47.
20. GUILDFORD, S., HECKY, R.E., Limnology and Oceanography, **45,** 2000, p. 1213.
21. FARJALLA, V.F., MARINHO, C.C., ESTEVES, F.A., Acta Limnologica Brasiliensia, **11,** no 2, 1999, p. 185.
22. BRUM, P.R., FARJALLA, V.F., GONCALVES, JR. J.F., SANTOS, A.M., PÔRTO, M.T., VIEIRA, E.D.R., FERREIRA, F.M., BIANCHINI, JR. I., Brazilian Archives of Biology and Technology, **42,** no. 4, 1999, p.433.
23. ALEXANDER, M., Science, **211**, no 9, 1991, p 132.
24. ROBESCU D., ROBESCU D., BARAN G., Waste water treatment, Ed. BREN, Bucharest, 1999, p. 32.
25. SYMONS, J.M., MCKINNEY, R.E., HASSIS H.H., Journal Water Pollution Control Federation, **32**, no 8, 1960, p. 841.

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