CHARACTERIZATION OF WATERS AND SEDIMENTS FROM LACUSTRINE COMPLEX ADUNAȚII OF GEORMANE

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Abstract. The purpose of this paper is to evaluate the quality of water and sediment in Lacustrine Complex Adunaţii of Georgmane under the influence of anthropogenic factors in order to understand the complex processes taking place in these habitats, in order to develop strategies for rehabilitation and conservation of the affected aquatic ecosystems. Seasonal samples of water and sediment were taken from various points of the lacustrine complex represented by Victoria Lake and Marica Pond, respectively the shore areas (the head and tail of the lacustrine ecosystems) and the central ones. A number of physicochemical and enzymatic analyses were made. Thus, the pH of the water of Victoria Lake was 8.24 to 8.54 units, fixed residue 322.7 g/l and chloride 87.2 g/l. The hardness of Victoria and Marica lakes varies between 10.66 degrees Ge and 18.74 degrees Ge. The eutrophic Victoria Lake has *a chlorophyll* content 8 to 25 μg/l. These are intended to highlight the functional diversity of the microbiota involved in biogeochemical cycles in these media (water, sediment). Enzymatic activity records large variations, depending on the nature of the studied enzyme, sampling point, environment, season, main pollutants of the lake, and physico-chemical characteristics of the water. Dehydrogenase activity of sediments shows relatively low seasonal fluctuations; the minimum value was 0.23 μg formazan / 1 g sludge (dry matter) and phosphatase activity is moderate in Marica pond, the minimum phosphatase being 73.5 μg phenol / g sludge. Victoria Lake has an intense catalase activity of 2.30 mg H_2O_2 / g sludge. The knowledge of the intensity of the enzymatic activity represents a new method of research within the framework of water protection programs, which allows the characterization of the impurity degree of an aquatic ecosystem and offers the possibility to forecast the evolution in time, respectively quality maintaining.

Keywords: lacustrine ecosystems, sediments, physico-chemical analyses, enzymes.

Rezumat. Caracterizarea apelor şi sedimentelor din Complexul Lacustru Adunaţii de Georgmane. Scopul lucrării de faţă îl constituie evaluarea calităţii apei si sedimentului din Complexul Lacustru Adunaţii de Georgmane sub influenţa factorilor antropici în vederea înţelegerii proceselor complexe care au loc în aceste habitate, în scopul elaborării unor strategii de reabilitare şi conservare a ecosistemelor acvatice afectate. Au fost prelevate sezonier probele de apă şi sediment din diferite puncte ale coplexului lacustru reprezentat de lacul Victoria şi balta Marica, respectiv zonele litorale (capul şi coada ecosistemelor lacustre) şi centrale. Au fost determinate o serie de analize fizico-chimice si enzimatice. Astfel, pH-ul în apa lacului Victoria a fost de 8,24 - 8,54 unităţi, reziduu fix 322,7 g/l şi clorurile 87,2 g/l. Duritatea în cazul lacurilor Victoria şi Marica variază între 10,66 grade Ge şi 18,74 grade Ge. Lacul eutrof Victoria are un conţinut de *clorofilă a* cuprins între 8 – 25 μg/l. Acestea au rolul de a evidenţia diversitatea funcţională a microbiotei implicate în ciclurile biogeochimice din aceste medii (apă, sediment). Activitatea enzimatică înregistrează variaţii mari, dependente de natura enzimei studiate, de punctul de prelevare a probelor, de mediu, de anotimp, de principalii poluanţi ai lacului, cât şi de caracteristicile fizico-chimice ale apei. Activitatea dehidrogenazică a sedimentelor prezintă fluctuaţii sezoniere relativ scăzute, valoarea minimă înregistrată a fost de 0,23 μg formazan / 1 g nămol (substanţă uscată), iar activitatea fosfatazică este moderată în balta Marica, valoarea minimă a fosfatazei fiind de 73,5 μg fenol / g nămol. Lacul Victoria prezintă o activitate catalazică intensă de 2,30 mg H_2O_2 / g nămol. Cunoaşterea intensităţii activităţii enzimatice reprezintă o nouă metodă de cercetare în cadrul programelor de protecţie a apelor, acestea permiţând caracterizarea gradului de impuritate al unui ecosistem acvatic şi posibilitatea de a prognoza evoluţia în timp, respectiv menţinerea calităţii.

Keywords: ecosisteme lacustre, sedimente, analize fizico-chimice, enzime.

INTRODUCTION

The protected area of national interest Lacustrine Complex Adunaţii of Georgmane (code: 2393) is located in a plain area within the hydrographical basin of the Jiu River and it extends to the territory of Bratovoeşti and Teasc settlements, being part of the wetland category. This zone is characterized by the presence of lake ecosystems, such as Marica Pond and Victoria Lake, which have adjacent wetlands.

Victoria Lake is located on the upper left terrace of the Jiu, called Rojiştea terrace, at about 25 km south of Craiova, in Oltenia Plain. This lake forms an isolated biological unit linked to the Jiu through a canal for the surplus water discharge through Marica Pond (MARX, 1982) (Fig. 1).

The soils in this Protected Natural Area of National Interest are sandy, with a low humus content, which makes them vulnerable to erosion caused by surface water. In order to prevent or reduce erosion effect of the shores, it is recommended to plant native tree species to maintain their integrity.

The clogging of Marica Pond and Victoria Lake is closely related to erosion and natural eutrophication. Thus, by their combined actions, they can contribute to the increase of the sediment load of the lakes; they can favor the excessive development of the vegetation and can lead to the reduction of the surface of the water. Natural eutrophication occurs as a result of their organic load and is particularly evident during summer, when high nutrient concentrations in water also increase. The accumulation of organic mass, increased amounts of nutrients such as nitrogen and phosphorus, lead to the abundant development of various microorganisms, which consume large amounts of oxygen in the water.

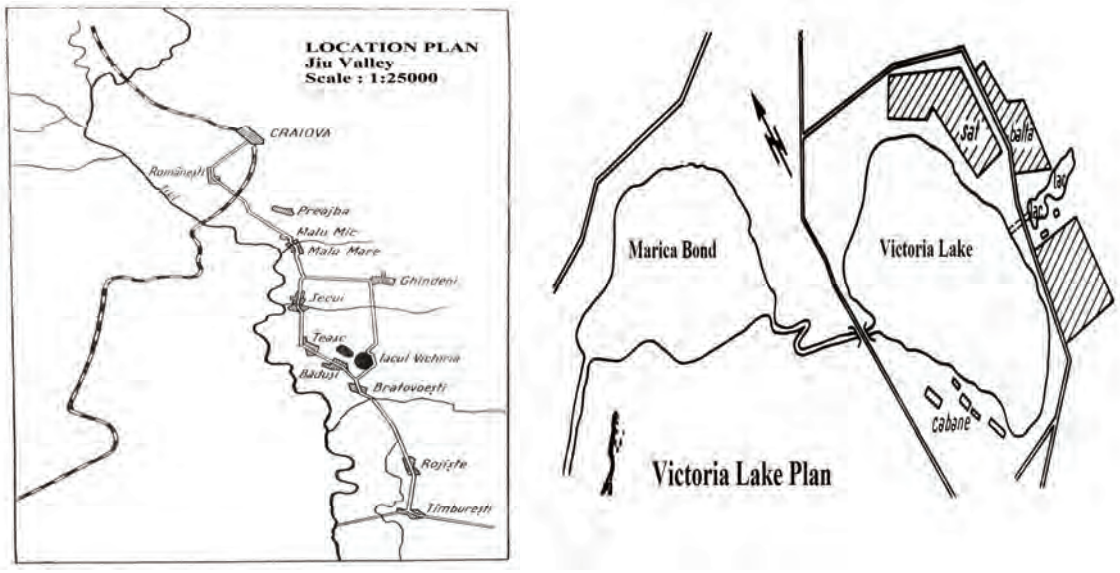

Figure 1. Victoria Lake and Marica Pond in the lacustrine complex (after MARX, 1982).

The human settlements in the vicinity of the protected natural area do not have a proper wastewater collection and treatment system; thus, wastewater can end up through the percolation process or surface drainage in Victoria Lake, contributing to the decrease of the water quality. In order to minimize the effects of this pressure, it is necessary to implement projects aimed at the provision of localities with a unitary collection system for household wastewaters, as well as adequate treatment. This form of the impact was considered as a pressure on the protected natural area as a result of the observations made on the site: the localities and the configuration of adjacent lands. The diffuse pollution is caused by agricultural and forestry activities.

This lacustrine complex is located in a region where the main activity of the locals is represented by agriculture. As a result of the use of fertilizers and pesticides in agriculture, through percolation or drainage, they can reach the water of Victoria Lake and Marica Pond, contributing to the decrease of water quality. The decrease of the water quality will impact on all fauna species, directly on fish, amphibians or turtles, as well as indirectly by reducing food resources or the degradation of feeding and resting habitats of mammalian species. These lakes are occupied with paludous macrophytes: *Phragmites communis, Typha angustifolia, Scirpus lacustris, Carex riparia* and aquatic: *Lemna minor, Polygonium amphibium, Salvinia natans, Ceratophyllum submersum, Myriophyllum spicatum*. Zoocoenoses, both planktonic and benthic, are typically stagnant.

GIANFREDA & BOLLAG (1996) considers that sediments contain three major components: detritus material derived as a result of erosion, biogenic material formed by biological productivity and autogenous material formed *in situ*. The final character of the sediment is given by the relative proportion of these components.

The sediments are extremely heterogeneous systems where the various phases (solid, liquid and gaseous), biotic components (many microorganisms), small organisms (enzymes) and abiotic components (minerals, humus, organo-mineral aggregates) are involved in physical, chemical and biological processes in these environments. All biochemical transformations at sediment level depend on the presence of enzymes.

The action of microorganisms on the substrate in the environment is done enzymatically and is accomplished by the processes of oxidation and hydrolysis, respectively, as a result of the action of some end products of microbial metabolism. In this sense, the determination of enzymatic activity yields suggestive results in much shorter time on processes occurring in sediment or other natural habitats than microbiological analyses. Sediments are environments where different factors participate in complex functions. These factors are considered to be the major mineral matrix, texture, amount of organic carbon, position and geographic conditions.

MATERIALS AND METHODS

The Lacustrine Complex Adunații of Geormane has a surface of 102 hectares (the considered surface was extended to 111.25 ha, considering important both Victoria and Marica lakes and the canal connecting the two lakes). The shape of the lakes is alluvial Plain of the almost oval, with low, sandy shores and very few trees. Thus, the protected natural area is located within the Jiu - Jieț (Fig. 2).

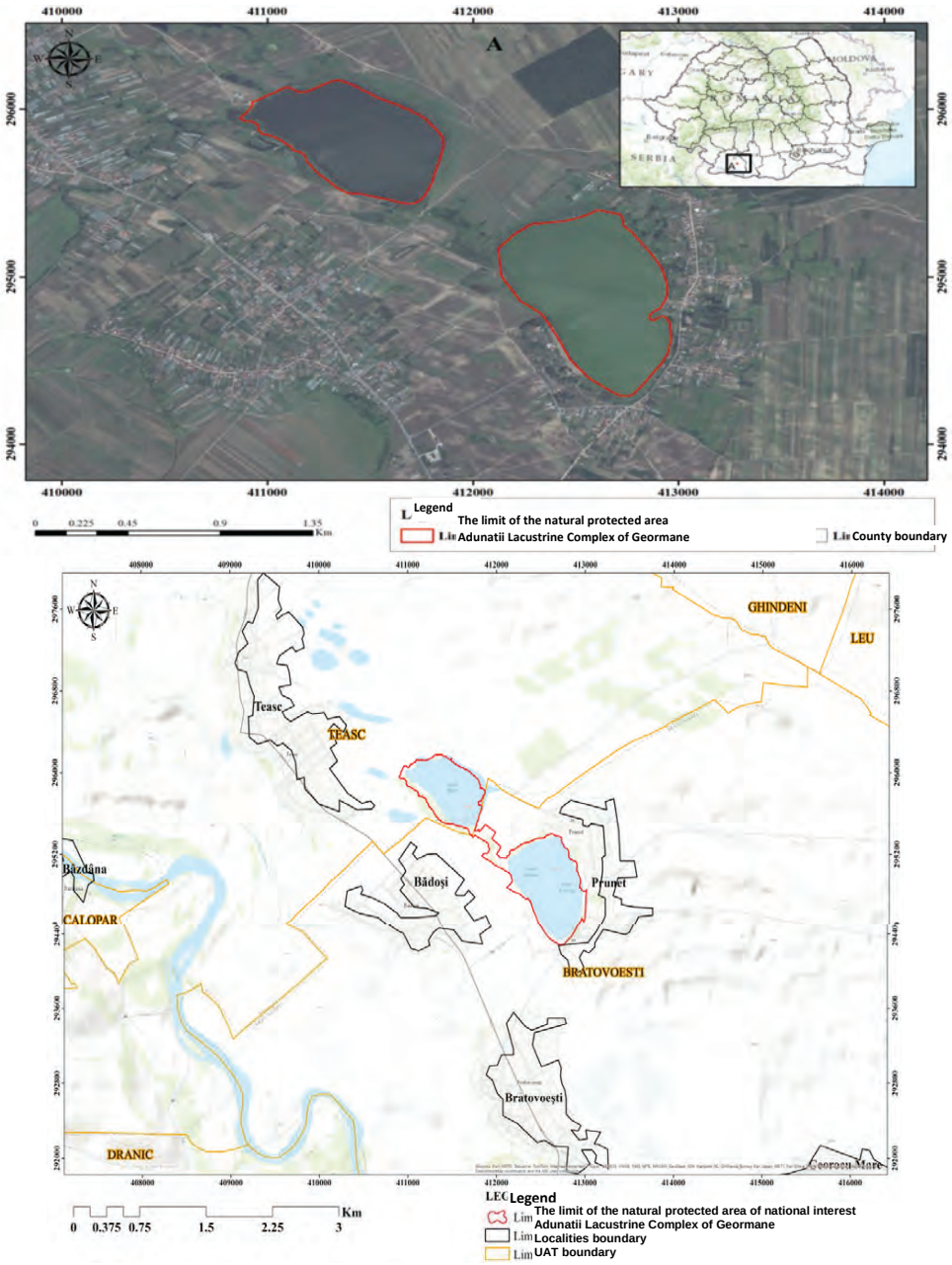

Figure 2. Sketch of Adunatii Lacustrine Complex of Geormane in the lower sector of the Jiu (Google Earth, accessed: February 18, 2017).

The physico-chemical and enzymological studies on water and sediments have been made over the years 2016, 2017. In order to establish the influence of abiotic environmental factors on the density and composition of the studied microbial communities, there were determined the following physico-chemical parameters: pH with Hanna pH meter, electrical conductivity with Hach conductivity meter, dry fixed residue 105^0C, dissolved oxygen (O_2), organic matter quantity determined by CCO-Mn, nitrates, nitrites, ammonium, sulphates, total phosphorus (total P), sulphates with spectrophotometer DR2010 and chlorophyll.

Enzymatic studies consisted in determining quantitative enzymatic activity as follows: phosphatase activity (AF) - Kramer and Erdei method (PUSKÁS et al., 2005), catalase (AC) - Kappen method based on H_2O_2 decomposition processes and current dehydrogenase activity (ADA) - Caside method by reducing 2.3.5-triphenyltetrazolium chloride - TTC in the absence of glucose, respectively, potential dehydrogenase activity (ADP) - in the presence of glucose. As different sediment categories may have a different content in water, the degree of moisture of each sample was determined, which may influence the expression of microbial load and the enzymatic activity relative to dry sediment grams (CUŞA, 1996).

RESULTS AND DISCUSSIONS

The climate is continental characteristic to plain areas. The area is exposed to very cold continental air invasions (-10 … -20^{0}C) and very hot summer invasions (30 - 35^{0}C), thus being characterized by an increased temperature amplitude during the year. The climate is continental temperate with Mediterranean influence, with hot and dry summers, relatively cold winters, short springs and long autumns. The multiannual average temperature is 10.8^{0}C. Precipitation has a multi-annual average of 509 mm, with a maximum of rainfall in the warm (June) period. The winds with the highest intensity and frequency are those from the eastern sector (24.6% with 4.3m/s).

Hydrological characteristics. The hydrographic network is influenced by the lithological structure of the soil and by the climate, being represented by two valleys: Prunet and Giorocul Mare. The surface waters are represented by a series of lakes, the largest one being Victoria Lake, which has about 70-80 ha and is arranged for recreation, with a flow rate of 20-25 l/s; this area is also crossed by the Gioroc stream. The lake is fed by groundwater and three streams that do not dry out in summer and do not freeze in winter (BREZEANU et al., 2011).

Water chemistry. The analysis of the main physico-chemical indicators reveals the formation conditions of the chemical composition of the water and the mineralization stage of these lacustrine ecosystems. The chemical composition of the water is characteristic to eutrophic ecosystems. According to the ionic balance and the anion and cation content, the water of the lakes belongs to the bicarbonate-sulphato-calcic-magnesium category, characteristic to the mixed mineralization stage. From the point of view of quality conditions for surface waters, the lakes fall into category II and can be used for fish farming (Tables 1; 2).

Table 1. Physical and chemical composition of the water in Victoria Lake.

Indicators analyzed	Victoria Lake	Method of analysis
Conc. Hydrogen ions, unit. pH	7.5	STAS 6325-75 Hanna pH-meter
Electrical conductivity max.	390	STAS 7722-84 Hach conductivity meter
Dissolved Oxygen, mg / dm^3, min.	8.6	STAS 6536-87
Subst.org. Oxidab. CCOCr mg O_2 / dm3, max	11.7	STAS 3002-85
Total hardness, German grades, max	12.7	STAS 3026-76
Fixed residue, mg / dm^3, min, / max	195	STAS 3638-76
Ammonia, mg / dm3, max	0.270	STAS 6328-85 Spectrophotometer DR2010
Calcium, mg / dm^3, max	59	STAS 3662-62
Magnesium, mg / dm^3, max	19	STAS 6674-77
Nitrites, mg / dm3, max	0.058	STAS 3048-90 Spectrophotometer DR2010
Nitrates, mg / dm, max	9.7	STAS 3048- 77 Spectrophotometer DR2010
Chlorides , mg / dm3, max	21	STAS 3049- 86
Phosphates, mg / dm3, max	0.05	STAS 3265-66 Spectrophotometer DR2010
Sulfates, mg / dm3, max	13	STAS 3002-87 Spectrophotometer DR2010
A chlorophyll μg / l-16 μg	11.8	Spectrophotometer DR2010

The pH values are between 7.5 and 8.4 (slightly alkaline) in accordance with the content of bicarbonate elements. The content of biogenic elements is a particular feature of the lakes. The amount of nitrates and nitrates 0.058 and 9.7 mg/dm^3 is due to the supply of nutrients as a result of the administration of mineral and organic fertilizers on the neighbouring agricultural lands.

The presence of nitrates (NO_3^-), which represents the most advanced oxidation degree in the natural nitrogen cycle, is also the result of a bacterial oxidation activity of abundant organic matter in the water and the substrate. The same explanation can be given to the presence of phosphate ions (PO_4^{3-}) the concentration of which reaches 0.05 mg/dm^3. Among the cations, we firstly mention calcium (Ca^{2+}), his origin of which is considered to be the sedimentary rocks of the lakes, but also the amendments applied to agricultural land.

The ions of calcium and magnesium (Ca^{2+} and Mg^{2+}) together with carbonates, bicarbonates and sulphates present in the water of the lakes, are the cause of relatively high values of temporary and total water hardness. What needs to be emphasized is that, as a whole, water chemistry is more or less similar to that characteristic to all lakes. There are also some differences between the concentrations of the various components related to the peculiarities of the station the samples were taken from. It is the case of sulphate (SO_4^{2-}), which has a concentration of 13 mg/dm^3 (POSTOLACHE, 2006; BUCUREȘTEANU et al., 2007; CIOBOIU, 2011; CIOBOIU & CISMAȘIU, 2016).

Table 2. Physico-chemical composition of the water of Marica pond.

Indicators analyzed	Marica Pond	Method of analysis
Conc. Hydrogen ions, unit. pH	8,4	STAS 6325-75 Hanna pH-meter
Ammonia, mg / dm3, max	SLD	STAS 6328-85 Spectrophotometer DR2010
Nitrites, mg / dm3, max	0,01	STAS 3048-90 Spectrophotometer DR2010
Nitrates, mg / dm, max	3,61	STAS 3048- 77 Spectrophotometer DR2010
Chlorides, mg / dm3, max	14,18	STAS 3049- 86
Phosphates, mg / dm3, max	0,033	STAS 3265-66 Spectrophotometer DR2010
A chlorophyll µg / l-16 µg	15,8	Spectrophotometer DR2010

A chlorophyll represents alongside phosphorus and nitrogen in all its forms, an important quality indicator used to assess the degree of eutrophication of lakes. Using the chlorophyll concentration values as a quality indicator, the eutrophication level of water according to Order 161/2006 was estimated, the lakes being eutrophic - with a chlorophyll content ranging from 8 to 25 µg/l – Victoria lake and 10 µg/l-16 µg/l – Marica pond (SANDU et al., 2004; FAUR & GEORGESCU, 2009; OBASOHAN et al., 2010; CISMAŞIU, 2012a, b; PĂCEŞILĂ, 2012).

Enzyme monitoring in sediments. The activity of phosphatase was detected in all analyzed samples, with a rather high numerical fluctuation. The highest values were observed during the warm season, indicating that sediments are the main phosphorus reservoir (COJOCARU, 2005; GAVRILESCU, 2011). Phosphatase, being an accumulated enzyme, better keeps its activity for a long time. This is less influenced by external factors (temperature and pollution), which are immediately visible on the activity of microorganisms.

Victoria Lake has an intense phosphatase activity; the mean value is 229.1 mg of phenol / g dry substances in the middle of the lake, while the minimum amount is 14 mg of phenol phosphatase / g dry substance, in February. The highest values are in September, 199 mg of phenol / g wet substance, in sediments, also in the middle of the lake. The annual mean phosphatase activity of the sediment for this lake is around 100 µg phenol / g s.u. (COJOCARU et al., 2007; GAVRILESCU & POPESCU, 2012).

The sediments of Marica Pond have an annual average of the phosphatase of 178.9 µg phenol / g s.u. Sediment in the middle area and the seasonal fluctuations ranged between 28.5 and 196.7 µg phenol / g s.u. Sediment, with an average value of 131.2 µg phenol / g s.u. (Fig. 3).

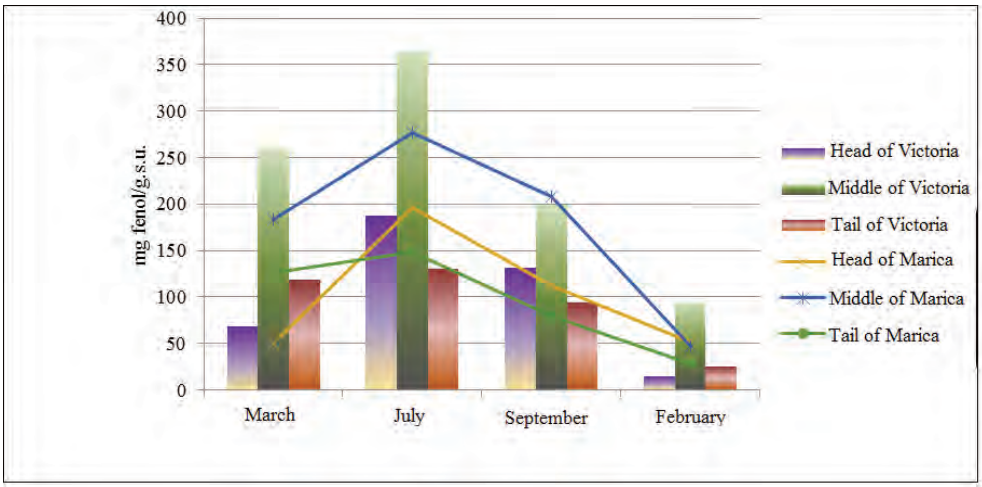

Figure 3. The activity of phosphatase in the sediments of the studied lakes.

The catalases are found in almost all animal cells and in smaller quantities in higher plants. In the case of microorganisms, the catalases are found only in aerobic ones (cyanobacteria). The catalase has long been attributed to the decomposition of hydrogen peroxide in order to keep the living cell from its damaging action. Lately, it has been demonstrated that they participate in xenobiotic degradation in the organic matter of the soil and sediment (GIANFREDA & BOLLAG, 1996).

Victoria Lake has a catalase activity comprised between 20.1 mg H_2O_2 / g s.u. at the head of the lake and 22.6 mg H_2O_2 / g s.u. in the middle of the lake. The most intense activity is in March and July, respectively 29.7 mg and 21.5 mg H_2O_2 / g s.u., the mean value being 19 mg H_2O_2 / g s u.

Marica Pond had a catalase activity of 16.8 mg H_2O_2 / g s.u. in March; the maximum value of 25.90 mg H_2O_2 / g s.u. was determined for the sediment in July, with an annual average of 18 mg H_2O_2 / g s.u. (Fig. 4).

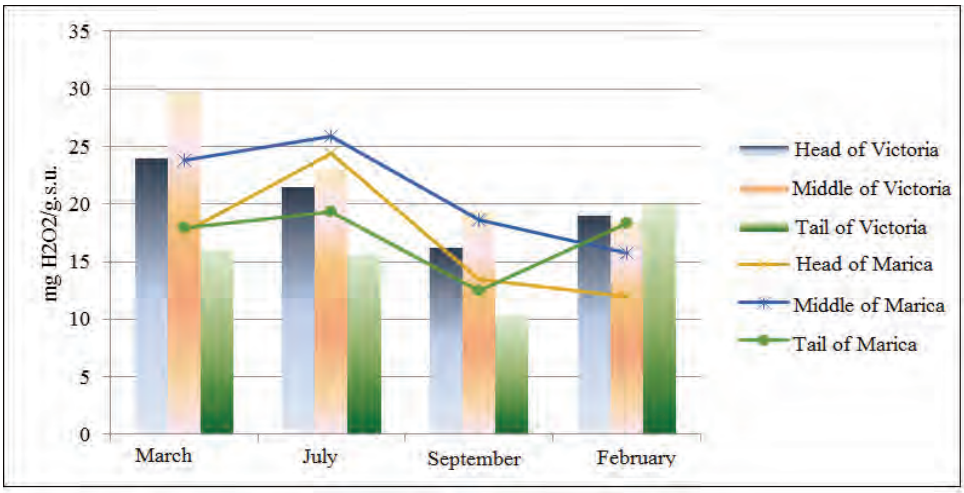

Figure 4. The catalase activity in the sediment of studied lakes.

The dehydrogenase activity can be considered as an important biological indicator of sediment microorganisms but has also been used as an ecotoxicological test to evaluate the effect of pollutants on soil microbes or sediments. The current dehydrogenase and potential dehydrogenase activity were found in all analyzed samples (Figs. 5; 6).

The current dehydrogenase activity is much more intense than the potential dehydrogenase activity, which may be due to the stimulating action of carbon assimilation by microorganisms in the enzymatic synthesis process. The highest values for the dehydrogenase activity were observed in autumn, when plant material of organic nature favours the development of microorganisms and enhances their enzymatic activity. The activity of current dehydrogenases is intensified especially in summer, when the microbial activity in the sediment level increases as a result of the accumulation of organic substances deposited at the end of the vegetation period.

Victoria Lake, depending on the current sediment of the dehydrogenase activity, shows significant seasonal fluctuations; the minimum value was 0.09 µg formazan / 1 g s.u. in September, the maximum was 19.9 µg formazan / 1 g s.u., with intense activity in June and September. Marica Pond shows high seasonal fluctuations in the current dehydrogenase activity, this being between 0.8 µg formazan / 1 g s.u. and 14.9 µg formazan / 1 g s.u. The mean value recorded during the monitored period was approximately 8.15 µg formazan / 1 g s.u. (Fig. 5).

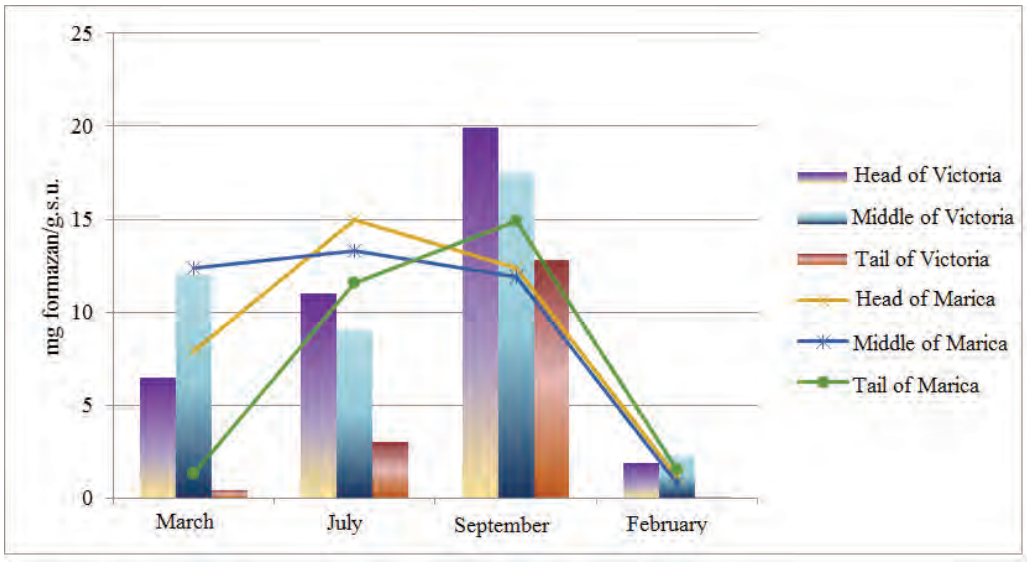

Figure 5. Activity of dehydrogenase in the sediments of studied lakes.

The potential dehydrogenase activity is maximum in both lakes in July and September (7.1 - 8.1 µg formazan / 1 g s.u.), with significant values in the middle sections of the lake. In March and February, potential dehydrogenase values are lower (Fig. 6).

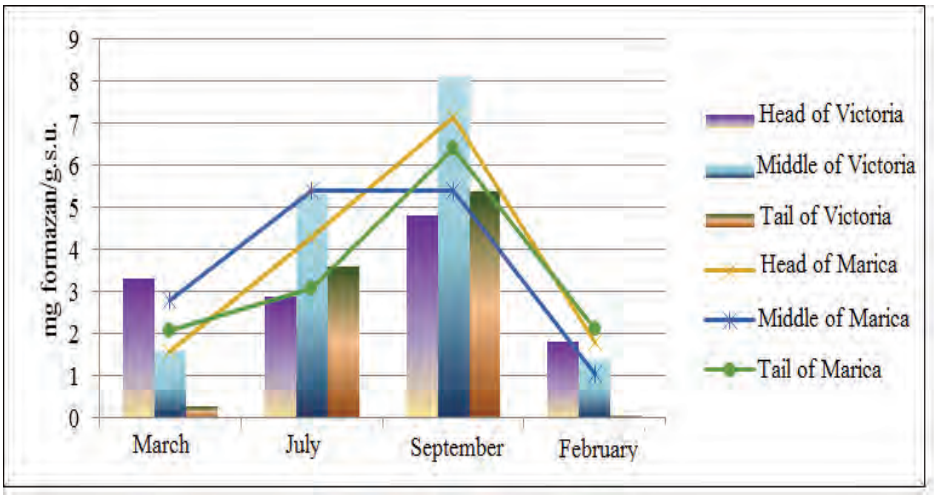

Figure 6. The activity of potential dehydrogenase in the sediment of the studied lakes.

CONCLUSIONS

The present study was carried out within Adunatii Lacustrine Complex of Geormane between 2016 and 2017. According to the physico-chemical and enzymatic analyses performed on water and sediment samples, it was found that the pH is between 7.5-8.4 units, fixed residue 195 mg/dm^3, chlorides 21 g/l, and hardness ranges between 10.66 and 12.7 degrees Ge. The eutrophic Victoria Lake has a chlorophyll content of 8 - 25 µg/l and Marica Pond has a chlorophyll content > 25 µg/l being a hypertrophic lake. Victoria Lake, with an intense phosphatase activity, has an annual average of the phosphatase value of 299.1 µg phenol / g s.u., and seasonally, the highest values are recorded in September. Marica Pond shows an average catalase activity of 18 mg H_2O_2 / g s.u. and Victoria Lake has an intense catalase activity of 29.7 mg H_2O_2 / g s.u. in March. Also, depending on the dehydrogenase activity of sediments, the lacustrine ecosystems show relatively low seasonal fluctuations; the minimal value was 0.09 µg formazan / g s.u. in February and the maximum 19.9 µg formazan / g s.u. in September.

The potential of the dehydrogenase activity is maximal in both lakes in July and September (7.1 - 8.1 µg formazan / 1 g s.u.), with significant values in the middle sections of the lake. In March and February, potential dehydrogenase levels are lower. The determination of the enzyme activity produces suggestive and more rapid results on the processes occurring in sediments or other natural habitats compared to microbiological analyses. The clogging of the lakes can contribute to increase of the sediment load of lakes, favours the excessive growth of the vegetation (algae blossoming) and reduces the water surface. The obtained results highlight the current state of the water of the two lakes under the influence of the anthropogenic factors, which act cumulatively by modifying the water quality.

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