••• БОТАНІКА ТА ЕКОЛОГІЯ РОСЛИН •••
••• BOTANY AND PLANT ECOLOGY •••

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Макрофітобентос штучних паркових водойм міста Одеси

Ф.П.Ткаченко, М.В.Сидоренко

Комплексного еколого-флористичного дослідження водної рослинності штучних водойм паркових зон міста Одеса раніше не проводили. Тому метою цієї роботи було встановлення видового різноманіття макрофітів, їх систематичної структури та індикаторного значення в чотирьох водоймах парків міста. Всього ідентифіковано 21 вид макрофітів, з них водоростей-макрофітів 15 і водних судинних рослин 6. Основна частина виявлених видів водоростей-макрофітів належала до Chlorophyta (8), за ними йшли Charophyta (4). Cyanoprocaryota були представлені 2 видами, а Ochrophyta (Xanthophyceae) – 1. У складі вищих водних рослин було виявлено 6 широко розповсюджених видів. На склад і розподіл макрофітів у досліджуваних водоймах вирішальний вплив мав рівень їх мінералізації, евтрофування і забруднення важкими металами. Підвищена концентрація органічного вуглецю зазначена у водоймах, де поряд з водною рослинністю присутні й водоплавні птахи. Найбільше флористичне розмаїття макрофітів нами відмічено у верхній водоймі парку «Дюківський» (17 видів). Це одна з найбільших штучних водойм міста. Характерною особливістю його рослинності є наявність тут великих за площею заростей харових водоростей з монодомінантом *Chara vulgaris.* Харові, як і інші водорості, очевидно, є тут основними постачальниками органічного вуглецю у водоймі (С орг.=1,38%). На другому місці за кількістю макрофітів (10) знаходилася нижня водойма цього парку. Вміст органічного вуглецю в ньому найбільший серед досліджених нами водойм (С орг.=4,48%). Крім водної рослинності значний внесок у цей показник, очевидно, належав декоративним качкам, яких утримує береговий ресторан у відгородженій сіткою частині водойми. Мінімальна кількість видів водоростей і вищих водних рослин виявлена у водоймах парків імені Савіцького (5) і Перемоги (6). У парку імені Савіцького надлишок біогенних речовин призводить до того, що тут масово розвивається такий мезо-евтрофний вид макрофітів, як *Lemna minor,* який щільним килимом вкриває майже всю поверхню паркового озера і створює несприятливий світловий режим для розвитку водоростей. У водній товщі біли помічені лише окремі екземпляри зелених водоростей *Scenedesmus quadricauda* (Turpin) Brebisson і *Desmidium sp.* Уздовж берега розташовані переривчасті зарості *Typha angustifolia* і *Persicaria hydropiper.* Макрофіти тут є основними продуцентами органічних речовин (С орг.=1,94%). Індикаторні види водоростей і вищих водних рослин у досліджуваних водоймах представлені в основному β-мезосапробним угрупованням, що свідчить про середній рівень їх органічного забруднення.

Ключові слова: *макрофітобентос, біоіндикатори, прісноводні штучні водойми, забруднення, екологія, Одеса.*

Macrophytobenthos of artificial ponds in the parks of Odessa city

F.P.Tkachenko, M.V.Sidorenko

Complex eco-floristic investigation of water vegetation of the artificial ponds in the park zones of Odessa city has not been conducted. Thus, the purpose of this work was determination of species diversity of macrophytes, their systematic structure and indicator role in four ponds in the park of the city. In sum, 21 species of macrophytes were identified, among them 15 species of macrophyte algae and 6 species of vascular water plants. The main part of the revealed species of macrophyte algae belongs to Chlorophyta (8) and Charophyta (4). Cyanoprocaryota were presented by 2 species, and Ochrophyta (Xanthophyceae) were presented by 1 species. 6 widely distributed species were revealed among higher water plants. Composition and distribution of macrophytes in the investigated ponds were influenced primarily by the level of water mineralization, eutrophication and heavy metals contamination. Elevated concentration of organic Carbon was registered in the ponds where waterfowl birds were presented together with water plants. The biggest floristic diversity of macrophytes is registered in the upper pond of the Dyukovsky Park (17 species). It is one of the largest artificial ponds of the city. The characteristic feature of the pond's vegetation is the presence of an extensive field of Charophyta with a monodominant *Chara vulgaris*. The presence of the Charophyta is the evidence of the relative ecologic well-being of the investigated pond. Charophyta, as well as the other algae, are obviously the main providers of organic Carbon in the pond ($C_{org.}$=1.38%). By the quantity of macrophytes species (10) the lower pond of the Dyukovsky Park is on the second place. The content of organic Carbon is

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the highest in this pond ($C_{org.}$=4.48%). Except for the water vegetation, a considerable contribution in this parameter is obviously made by the decorative ducks which are kept in the fenced off with a net part of the pond by the bank restaurant. The minimum number of species of algae and higher water plants is registered in the Savitsky Park (5) and the Victory Park (6). In the Savitsky Park the excessive biogenic substances cause massive development of meso-eutrophic species of macrophytes – *Lemna minor* which covers almost the entire surface of the pond and creates adverse light regime for the development of algae. In the water column only sparse specimens of green algae *Scenedesmus quadricauda* (Turpin) Brebisson and *Desmidium sp.* were registered. Among the bank of the pond intermitted thicket of *Typha angustifolia* and *Persicaria hydropiper* is located. Macrophytes are the primary producers of organic substances here ($C_{org.}$=1.94%). Indicator species of algae and higher water plants in the investigated ponds were presented mostly by β-mesosaprobic group. It is the evidence of the medium level of their organic contamination.

Key words: *macrophytobenthos, bioindicators, freshwater artificial ponds, pollution, ecology, Odessa.*

Макрофитобентос искусственных парковых водоемов города Одесса

Ф.П.Ткаченко, М.В.Сидоренко

Комплексное эколого-флористическое исследование водной растительности искусственных водоемов парковых зон города Одесса ранее не проводилось. Поэтому целью этой работы было выявление видового разнообразия макрофитов, их систематической структуры и индикаторного значения в четырех водоемах парков города. Всего идентифицирован 21 вид макрофитов, из них водорослей-макрофитов 15 и водных сосудистых растений 6. Основная часть выявленных видов водорослей-макрофитов относилась к Chlorophyta (8), за ними шли Charophyta (4). Cyanoprocaryota были представлены 2 видами, а Ochrophyta (Xanthophyceae) – 1. В составе высших водных растений было выявлено 6 широко распространенных видов. На состав и распределение макрофитов в исследуемых водоемах определяющее влияние оказывал уровень их минерализации, эвтрофирования и загрязнения тяжелыми металлами. Повышенная концентрация органического углерода отмечалась в водоемах, где наряду с водной растительностью присутствовали и водоплавающие птицы. Наибольшее флористическое разнообразие макрофитов нами отмечено в верхнем водоеме парка «Дюковский» (17 видов). Это один из наиболее крупных искусственных водоемов города. Характерной особенностью его растительности является наличие здесь обширных зарослей харовых водорослей с монодоминантом *Chara vulgaris.* Харовые, наряду с другими водорослями, очевидно, являются здесь основными поставщиками органического углерода в водоем (С орг.=1,38%). На втором месте по количеству видов макрофитов (10) находился нижний водоем этого парка. Содержание органического углерода в нем наибольшее среди исследованных нами водоемов (С орг.=4,48%). Кроме водной растительности значительный вклад в этот показатель, очевидно, принадлежит декоративным уткам, которых содержит береговой ресторан в отгороженной сеткой части водоема. Минимальное число видов водорослей и высших водных растений выявлено в водоемах парков имени Савицкого (5) и Победы (6). В парке имени Савицкого избыток биогенных веществ приводит к тому, что здесь массово развивается такой мезо-эвтрофный вид макрофитов, как *Lemna minor,* который сплошным ковром покрывает почти всю поверхность паркового озера и создает неблагоприятный световой режим для развития водорослей. В водной толще были замечены лишь одиночные экземпляры зеленых водорослей *Scenedesmus quadricauda* (Turpin) Brebisson и *Desmidium sp.* Вдоль берега водоема расположены прерывистые заросли *Typha angustifolia* и *Persicaria hydropiper.* Макрофиты здесь являются основными продуцентами органических веществв (С орг.=1,94%). Индикаторные виды водорослей и высших водных растений в исследуемых водоемах были представлены в основном β-мезосапробной группировкой, что свидетельствует о среднем уровне их органического загрязнения.

Ключевые слова: *макрофитобентос, биоиндикаторы, пресноводные искусственные водоемы, загрязнение, экология, Одесса.*

Introduction

Odessa is one of the most ecologically adverse cities of Ukraine. Industrial enterprises, port complexes, motorways, railway lines and their service centres are sources of pollution, including heavy metals contamination (Shikhaleeva et al., 2009). Pollutants are engaged into biogeochemical cycles: they are accumulated in soils and water, circulate with precipitations and air flows in the atmosphere (Otmakhov, 2003). In ponds they are accumulated in bottom sediments. One of efficient methods of environmental control is biomonitoring (Orlova et al., 2010). Such hydrobiological indicators as biodiversity of hydrobionts, saprobity, microbiological parameters characterize the quality of water as the habitat of living organisms. High sensitivity to the quality of the environment is characteristic of

phytobenthos, and it determines the efficiency of using it in bioindication and estimating the condition of water ecosystems (Oksiyuk et al., 2010).

It is determined that structural and functional characteristics of algae (taxonomic and floristic diversity, ecological spectrum etc.) can be used for the estimation of ecological condition of antropogenically modified reservoirs (Sherbak, Semenyuk, 2011).

Investigation of macrophytobenthos of artificial ponds as components of recreational park zone of Odessa city has not been conducted before. Thus, the purpose of our work was conducting their floristic inventory and ecological estimation taking into consideration hydrochemical features of the ponds and indicator role of macrophytes.

Objects and methods of research

Samples of macrophyte algae and higher water plants collected during summer period of 2018 in 4 artificial ponds in the parks of Odessa (Victory Park, Dyukovsky, and Park of Savitsky) served as material for the article. Algae were collected according to the common method (Algae..., 1989).

In the Victory Park the cascade pond was investigated. The length of the pond is 500 m and the width is 50–100 m. The pond is made of concrete with the bottom bedding of gravel and sand. Its depth is up to 1.5 m. The coordinates of the pond: 46º44’47” N × 30º70’75” E.

In the Dyukovsky Park the lower pond has rounded shape and its diameter is around 70 m. The edging of the bank is made of concrete and the bottom is silty. Its coordinates: 46º48’10” N × 30º70’68” E. The upper pond of this park has a similar construction but its size is larger (100 × 150 m). The maximum depths are up to 2 m. The coordinates of the pond: 46º48’34” N × 30º70’75” E.

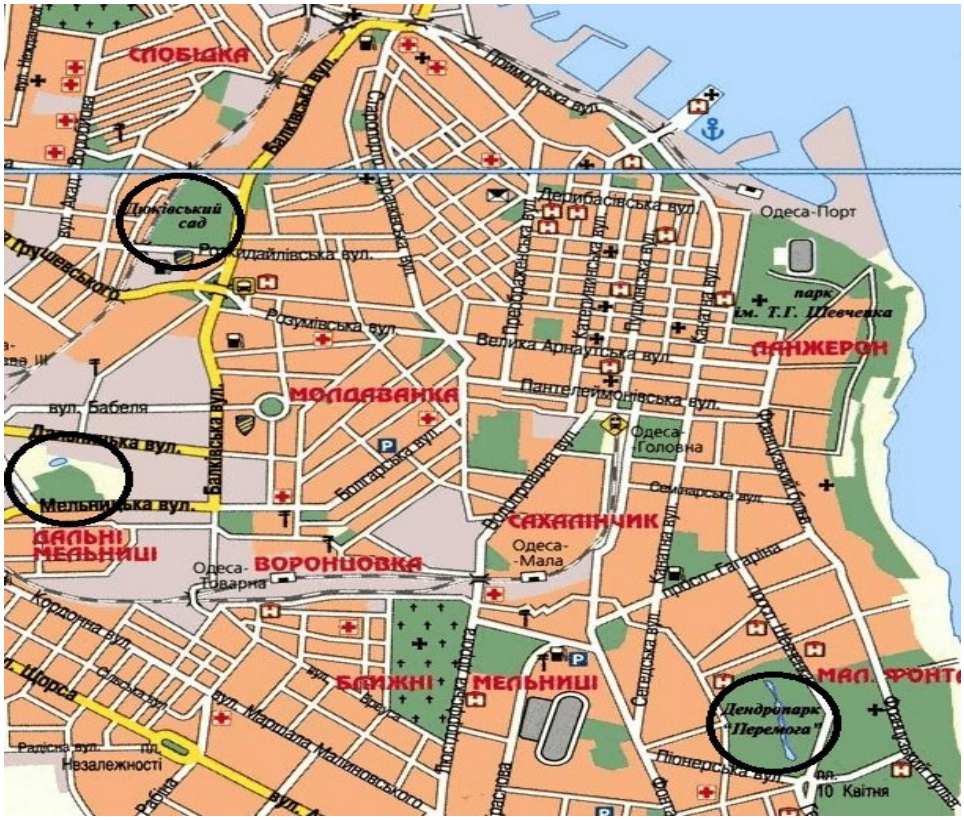

Figure 1. Schematic map of Odessa city with an indication (circle) of the investigated park zones

The pond in the Park of Savitsky formed in a gully with an earthy dam and low earthy banks. The length of the pond is around 250 m and the width is around 100 m, the depth is up to 1.5 m. The coordinates of the pond: 46º46’39” N × 30º69’34” E.

In total, 30 samples of macrophytes were collected and processed in the investigated ponds. The identification of algae and higher water plants was conducted using appropriate keys (Kondrat'eva, 1968; Gollerbakh, Palamar-Mordvintseva, 1991; Vinogradova et al., 1980; The key..., 1987; Rundina, 1988; Junger, Moshkova, 1993; Diel, 1975). Taxonomy of the algae is accorded with the base AlgaeBase (Guiry, Guiry, 2018). Indicator role of macrophytes was estimated using (Algae..., 1989; Dubyna et al., 1993).

The chemical analysis of water (ion composition) is conducted on the automatic analyser Metrohm, organic Carbon – on the device LECO CS 744, pH – on the pH meter Hydrus 400, electrical conductivity – on the conduct meter Mettler MC 226. The content of heavy metals was defined with the use of atomic adsorption method on the device ZEENIT 600.

Results

As remarked above, development of algae and higher water plants and their species diversity depend on trophity and heavy metals contamination level in ponds. For the evaluation of the background of water plants development in the investigated ponds, we conducted the analysis of physical parameters and the content of ions in water (table 1).

Table 1.

Hydrochemical parameters of water samples of artificial ponds in Odessa city

№	Parameters of water, units of measurement	Investigated ponds			
		Dyukovsky (upper)	Dyukovsky (lower)	Victory	Savitsky
1.	pH	7.81	7.48	6.84	7.28
2.	Electrical conductivity, mS/cm	5.84	5.91	1.25	0.94
3.	SO_4^{2-}, mg/dm^3	2140.67	1892.97	342.77	29.37
4.	Cl^-, mg/dm^3	518.98	554.23	88.43	120.50
5.	NO_2^-, mg/dm^3	0	0	0	0
6.	NO_3^-, mg/dm^3	82.07	75.54	0.22	1.25
7.	NH_4^+, mg/dm^3	0.19	0.22	0.04	5.64
8.	Ca^{2+}, mg/dm^3	179.67	198.64	30.09	29.03
9.	Mg^{2+}, mg/dm^3	154.51	145.27	27.02	7.12
10.	Na^+, mg/dm^3	440.85	427.34	68.27	48.50
11.	K^+, mg/dm^3	3.44	5.99	4.51	5.95
12.	Li^+, mg/dm^3	0.01	0.05	0.03	0.004
13.	Sr^+, mg/dm^3	3.16	3.92	0.84	0.22
14.	Br^-, mg/dm^3	0	0	0.95	0.01
15.	F^-, mg/dm^3	0.56	0.50	0.12	0.08
16.	PO_4^{3-}, mg/dm^3	0	0	0.059	2.27

According to the obtained results, the most mineralized water is found in the ponds of Dyukovsky park (3004.67–3524.11 mg/dm^3). It is caused by the mineralized underground sources supplying the ponds.

The pond in the Victory Park is filled with tap water from the Dniester. With the purpose of avoidance of stagnation, the water in it is constantly pumped over, replenished and aerated in virtue of the cascade construction of the pond's concrete bedding. General mineralization of water in the pond is 563.28 mg/dm^3.

In the pond of the Savitsky Park the level regime is maintained by the supply of rain and snow water from the city's streets, thus mineralization of water is minimal (249.95 mg/ dm^3). With the street flushes, excess biogenic substances get into the pond. Particularly, the content of ammonium Nitrogen there was more than 20 times higher than in the other investigated artificial ponds in the city parks. The content of phosphates in this pond also was 40 times higher, than, for example, in the pond of the Victory Park. Certainly, such hydrochemical features of the ponds influence the floristic composition and distribution of their algae and macrophytes components.

Heavy metals contamination level of the investigated ponds was also examined (table 2).

As it was expected, the lower pond of the Dyukovsky Park is the most subject to heavy metals contamination. Its parameters are 2–3 times higher than in the other park ponds of the city. It is explained by one of the busiest highways of the city passing along the pond's bank, and the main railway tracks of freight and passenger traffic are located up the slope. Emissions of the vehicles of these highways are obviously the main sources of the contamination of the pond. By lead content the bottom sediments of the pond are close to the ecological standard but do not exceed it, and by zinc content they exceed the allowable rate 1.5 times.

Table 2.

The content of heavy metals in the bottom sediments of the ponds in the parks of Odessa

Metals	Units of measurement	Investigated ponds				ES*
		Dyukovsky (lower)	Dyukovsky (upper)	Savitsky	Victory	
Pb^{2+}	mg/kg	78.3	27.8	30.4	26.1	85
Cd^{2+}	mg/kg	0.349	0.136	0.232	0.229	0.8
Hg^{2+}	mg/kg	0.105	0.154	0.088	0.051	0.3
Zn^{2+}	mg/kg	219.0	67.1	110.0	76.5	140

ES – ecological standard for bottom sediments.*

Conducted earlier bioindication of the bottom sediments in the investigated ponds (Sidorenko, Tkachenko, 2018) showed their medium toxicity in the Savitsky Park and high toxicity in the lower pond of the Dyukovsky Park. Thus, contamination of the bottom sediments in the investigated ponds causes negative influence on development of the phytobenthos.

Investigation of macrophytobenthos of the park ponds of Odessa city demonstrated their relative floristic poverty (table 3), caused by present ecological conditions.

Thus, the water flora of the artificial ponds in the parks of Odessa is presented by 21 species of macrophytes, among them there are 15 species of macrophyte algae and 6 species of vascular water plants.

The biggest floristic diversity of macrophytes is registered in the upper pond of the Dyukovsky Park (17 species). It is one of the largest artificial ponds of the city. The characteristic feature of the pond's vegetation is the presence of an extensive field of Charophyta with a monodominant *Chara vulgaris*. The presence of the Charophyta is the evidence of the relative ecologic well-being of the investigated pond. Charophyta, as well as the other algae, are obviously the main providers of organic Carbon in the pond ($C_{org.}$=1.38%).

By the quantity of macrophytes species (10) the lower pond of the Dyukovsky Park is on the second place. The content of organic Carbon is the highest in this pond ($C_{org.}$=4.48%). Except for the water vegetation, a considerable contribution in this parameter is obviously made by the decorative ducks which are kept in the fenced off with a net part of the pond by the bank restaurant.

The minimum number of species of algae and higher water plants is registered in the Savitsky Park (5) and the Victory Park (6). In the Savitsky Park the excessive biogenic substances cause massive development of meso-eutrophic species of macrophytes – *Lemna minor* (Dubyna et al., 1993) which covers almost the entire surface of the pond (figure 2) and creates adverse light regime for the development of algae. In the water column only sparse specimens of green algae *Scenedesmus quadricauda* (Turpin) Brebisson and *Desmidium sp.* were registered. Among the bank of the pond intermitted thicket of *Typha angustifolia* and *Persicaria hydropiper* is located. The excess of dead plant organic remains ($C_{org.}$=1.94%) causes their decomposition, thus the smell of hydrogen sulphide is distinctively perceptible near the bank.

The situation is not the same in the pond in the Victory Park. In 2016–2017 years it was dried and cleaned from the bottom sediments and the reconstruction of it was conducted. A new bedding of gravel and sand and large lumps of limestone were put into the pond. Thus, in 2018 formation of a new algocenose was continuing. The current favourable ecological situation in this pond will lead to the formation of a rather rich autotrophic component. This summer the rapid development (till bloom) of microscopic algae was observed. Water temperature during the bloom was 25–27°C.

Table 3.

Floristic composition of macrophytobenthos of the park ponds of Odessa city

	Taxon	Ponds				Saprobity
		Dyukovsky Park (lower)	Dyukovsky Park (upper)	Savitsky Park	Victory Park	
	Cyanoprocaryota					
1.	*Calothrix sp.*	+	+	+	–	–
2.	*Oscillatoria. tenuis* C. Agardh ex Gomont	–	+	–	+	α
	Ochrophyta (Xanthophyceae)					
3.	*Vaucheria dichotoma* (L.) C. Martius	–	+	–	–	–
	Chlorophyta					
4.	*Cladophora conglomerata* Pilger	+	–	–	+	β
5.	*Cl. globulina* (Kűtz.) Kűtz.	+	+	–	–	β
6.	*Microspora stagnorum* (Kűtz.) Lagerh.	–	+	–	+	–
7.	*Oedogonium sp.*	–	+	–	+	–
8.	*Rhizoclonium hieroglyphicum* (C. Agardh) Kűtz.	+	+	–	+	o-β
9.	*U. flexuosa* Wulfen	–	+	–	–	–
10.	*Ulva intestinalis* L.	–	+	–	–	α-β
	Charophyta					
11.	*Chara vulgaris* L.	+	+	–	–	–
12.	*Spirogyra decimina f. communis* (Nassalli) Petlovany	+	+	–	+	β-α
13.	*S. dubia* Kűtz.	–	+	–	–	–
14.	*S. hassalii* (Jenner) Petit	+	–	–	–	–
15.	*Spirogyra sp.*	–	+	–	–	–
	Magnoliophyta					
16.	*Lemna minor* L.	+	+	+	–	β
17.	*Myriophyllum spicatum* L.	+	+	–	–	β
18.	*Phragmites australis* (Cav.) Trin. ex Steud.	+	+	+	–	β
19.	*Persicaria hydropiper* (L.) Spach	–	–	+	–	β
20.	*Potamogeton crispus* L.	–	+	–	–	β
21.	*Typha angustifolia* L.	–	–	+	–	β
	Total	10	17	5	6	

According to Gerasimyuk et al. (2012), in this pond 54 species of microscopic algae were registered with dominating diatom (31 species), green algae (14) and cyanobacteria (7). 2 species of Charophyta were also registered. By the attitude towards organic contamination meso-saprobic group of algae dominated.

According to our data, the content of organic Carbon in the investigated pond is high ($C_{org.}$=2.51%). Algae, waterfowl birds and swamp turtles constantly fed by visitors of park contribute to the level of organic Carbon.

To sum up, by the level of saprobity and judging from the indicator species of macrophytes, the investigated ponds can be evaluated as medium polluted with dominating of β-meso-saprobic group of algae and higher water plants.

Figure 2. The surface of the pond in the Savitsky Park entirely covered with *Lemna minor*

Summary

In general, 21 species of macrophytes were registered in the artificial ponds in the parks of Odessa city: 7 species of Chlorophyta, 5 of Charophyta, 2 of Cyanoprocaryota, 1 of Ochrophyta and 6 of higher water plants. The minimum number of species is characteristic of the ponds in the Savitsky Park with the high level of eutrophity and of the Victory Park with algocenose re-forming after the reconstruction. The medium level of this parameter (10 species) is presented by the lower pond in the Dyukovsky Park which is contaminated with heavy metals. The highest diversity of macrophytes (17 species) is registered in the upper pond of this park.

By the attitude towards saprobity the investigated ponds can be evaluated as medium polluted with dominating of β-meso-saprobic group of algae and higher water plants.

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About the authors: F.P.Tkachenko – Odessa I.I.Mechnikov National University, Dvoryanskaya Str., 2, Odessa, Ukraine, 65082, tvf@ukr.net, https://orcid.org/0000-0001-5769-5120
M.V.Sidorenko – Odessa I.I.Mechnikov National University, Dvoryanskaya Str., 2, Odessa, Ukraine, 65082, m.v.sidorenko2000@gmail.com, https://orcid.org/0000-0001-7349-9613

Про авторів: Ф.П.Ткаченко – Одеський національний університет імені І.І.Мечникова, вул. Дворянська, 2, Одеса, Україна, 65082, tvf@ukr.net, https://orcid.org/0000-0001-5769-5120
М.В.Сидоренко – Одеський національний університет імені І.І.Мечникова, вул. Дворянська, 2, Одеса, Україна, 65082, m.v.sidorenko2000@gmail.com, https://orcid.org/0000-0001-7349-9613

Об авторах: Ф.П.Ткаченко – Одесский национальный университет имени И.И.Мечникова, ул. Дворянская, 2, Одесса, Украина, 65082, tvf@ukr.net, https://orcid.org/0000-0001-5769-5120
М.В.Сидоренко – Одесский национальный университет имени И.И.Мечникова, ул. Дворянская, 2, Одесса, Украина, 65082, m.v.sidorenko2000@gmail.com, https://orcid.org/0000-0001-7349-9613