Modern innovative and information technologies in the development of society

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1.4. Innovative technologies for ensuring ecological safety of maritime recreation

Coastal territories of Ukraine are characterized by the uniqueness of natural resources, high recreation and tourism potential. The territories are also marked by high urbanization (population density here is 33,0% higher than the general Ukrainian density (ONISCHENKO, 2010). They are intensively used for industrial and agricultural production. The strengthening of production component of use has a negative influence on natural resources and attractiveness of coastal areas used for the organization of recreation and health improvement of the population. In comparison with European countries where recreation and tourism industry generate 7,0-9,0% of GDP, and 9,0-14,0% of all sectors of economy, in Ukraine the same industry generates 0,6% and 1,0% respectively. Thus, a strategic task is creation of a new approach to determination of a role of coastal areas in the country's economics in accordance with their multifunctional opportunities. There is an obvious need for more attention to tourism and recreation industry. At the same time reorientation towards intensive recreation and tourism activities leads to growing importance of ecological monitoring of the quality state of the natural environment of the coastal areas. Excessive and unregulated recreational activities can cause degradation of natural ecosystems. Both discharge of industrial and communal wastewaters and polluting substances flows from fields, livestock breeding complexes, industrial sites etc. have the highest negative impact on coastal waters. As a result, environmental safety of marine waters in coastal areas is one of the main objectives and requires search and development of innovation technologies for the assessment of seawater quality.

Algae are used worldwide for the assessment of anthropogenic changes in marine ecosystems (MOCENNI and VICINO, 2006; GHARIB and DORGHAM, 2006; GHARIB et al., 2011; RAVEH et al., 2015; WELLS et al., 2015; ARROYO and BONSDORFF, 2016). Potential of algae used as indicators is much greater than that of physical-chemical methods. For this reason, their use is obligatory according to the requirements of Water Framework Directive (WFD), Marine Strategy Framework Directive (MSFD) (EUROPEAN COMMISSION, 2008).

In the result of anthropogenic influence both species composition and quantity of algae change. Cases of mass algae development, that is algae bloom, are widely known. Algae bloom has a range of negative consequences – fish kill, accumulation of decay products in seawater, its organoleptic deterioration etc. Special attention is payed to the problem of toxic algae bloom (TERENKO and TERENKO, 2012), invasion of alien algae caused by both natural factors and anthropogenic activities such as introduction, shipping traffic, ballast water discharge etc. (HOFFMAN, 2014; RAVEH et al., 2015; VINOGRADOVA and BRYANTSEVA, 2017). It is concluded that it could negatively affect fish productivity and be dangerous for recreation (FLEWELLING et al., 2005; SHARMA and RAI, 2006; CASABIANCA et al., 2013). Human pressure can cause the deepest restructuring of maritime ecosystems and endanger the biodiversity.

The issues of safe seawater recreation use while its blooming are brought up increasingly (CASABIANCA et al., 2013; QUILLIAM et al. 2014; MOKIENKO, 2016). The scientists emphasise that both bathing in blooming water and inhalation exposure to marine aerosol can be dangerous (CASABIANCA et al., 2013).

The Sea of Azov is socially and economically important for Ukraine. It provides the development of fishing, transportation, recreation and other industries. The Sea of Azov is a part of the Mediterranean basin and is the most continental sea in the world. In general, the ecological situation of the Sea of Azov corresponds to the global tendencies of anthropogenic transformation of marine ecosystems. At the same time, it is characterized by its own peculiarities such as shallowness, continentality, significant inflow of river waters, and poor connection with the Black Sea. The Sea of Azov is connected through channels with all Mediterranean ecosystems. That is why the general patterns of systemic feedbacks on

anthropogenic pollutions, migration of algae species in the result of both natural processes and anthropogenic activities also apply to it.

Thus, the study of algae is an integral part of the research focused on assessment and safety of biodiversity of marine ecosystems and quality of seawater in terms of creation of safe conditions for recreation and health improvement of people.

The aim of the study is to analyze algae species composition and their macroscopic proliferation during the marine bloom in coastal waters of the Sea of Azov, native and foreign experience of using algae as indicators for evaluation of environmental safety of marine waters in coastal areas.

Materials and methods of research. The research region includes the coastal area from Berdiansk spit to Biriuchyi Island. The peculiarities of the coastal area are a well-developed economic infrastructure, community concentration, where there are the recreation and tourism centers. There are also nature reserves in the area (Pryazovskyi National Nature Park, Azov-Syvashskyi National Nature Park).

Significant development of coastal areas and failure to meet zoning regulations have resulted in the absence of boundaries between recreation and agricultural areas and the absence of clearly formed 100-meter-wide protection zones around beaches. A high concentration of coastal settlements, industrial and agroindustrial objects leads to environmental deterioration and can cause unwanted effects in terms of adherence to environmental safety rules.

In summer 2017, the excessive growth of macrophytic algae was observed in waters of the Sea of Azov in this coastal area. It produced uncomfortable conditions for tourists and residents of the coastal area. The algae proliferated on the surface of water 10-20 meters away from the water's edge. They were thinning out further off the coast. Their samples were taken during the expeditions to 5 stations of the coastal waters of the Sea of Azov (Berdiansk spit (the end of the spit), the area of Lysiacha clough (Berdiansk district), village Botievo, Stepanivka spit, island Biriuchyi (border "Chynka")). The places where the samples were taken include a northwestern part of coastal area traditionally used by people for recreation. The object of research was macrophytic and microscopic algae from algal blooms. The material was gathered in accordance with accepted procedures in hydrobiology (TOPACHEVSKY and MASYUK, 1984). Laboratory investigation of the materials was carried out with the help of microscopic examination and culture methods. Nomenclature of representatives of divisions Chlorophyta, Phaeophyta i Rhodophyta is given in accordance with the identification guide of A. D. Zinova and A. V. Topachevskii (ZINOVA, 1967; TOPACHEVSKY and MASYUK, 1984) and the national data collection (TSARENKO et al., 2006).

Results and discussion. The Sea of Azov is a globally unique ecosystem. Its depth is not bigger than 14 meters, its salinity varies between 2-3 per mille in the eastern sea and 17,5 per mille in the southern and western sea. Hydrological regime is characterized by significant inflows of freshwater from rivers and salt water from the Black Sea.

Many countries face problems of water quality deterioration and ecological imbalance due to the intensification of anthropogenic activities (SUBRAMANIAN and VINODHINI, 2018; BHAGOWATI and AHAMAD, 2018). Water pollution is typical for both the Sea of Azov and other seas (JIANG et al, 2018; PANIZZO et al, 2018; NEVEROVA-DZIOPAK and KOWALEWSKI, 2018). The researchers emphasize that land pollution and water pollution are strongly linked to each other. The impact of agricultural intensification on ecological state of aquatic ecosystems is being often considered due to this problem. Because of lack of information and understanding of connection between land and water quality in most countries farmers more and more often use fertilizers. Nitrogen and phosphorus flows to the water bodies are constantly increasing. In Ukraine agriculture is highly developed in the southern parts of the country. Adding of mineral fertilizers

into soil is accompanied by their washing out into the waters of the Sea of Azov. It can lead to the processes of eutrophication that can influence food and water safety (REDDY, 2018). Whereas, eutrophication is one of the main threats caused by pollution. By eutrophication processes excessive richness of nutrients leads to undesirable water quality problems and degradation of the whole aquatic ecosystem (REDDY, 2018). Today it is eutrophication that poses a global threat to all types of aquatic ecosystems (NEVEROVA-DZIOPAK and KOWALEWSKI, 2018; BHAGOWATI and AHAMAD, 2018).

The most noticeable effect of eutrophication is great increase of phytoplankton that reduces water transparency and deteriorates its quality. As a result, it is impossible to provide recreational activities in a coastal area of a body of water; it is also harmful for economics and sanitary conditions of the area. Intensity of eutrophication processes depends on many factors: nutrient concentration, temperature, and pH of water. In particular, these factors influence significantly growth rate and composition of algae biomass. However, the most significant factors are water temperature, solar radiation, also accumulation of nitrogen and phosphorus. The result is excessive production of autotrophs. Excess nitrogen causes the excessive growth of eukaryotic algae and excess phosphorus causes the excessive growth of cyanoprokaryotes. The high quantity of them and intensive oxygen consumption by them lead to hypoxia and anoxia (PATHAK, 2018). There is a belief that eutrophication can be one of the factors regulating distribution and quantity of algae and cyanoprokaryotic species.

Algologists from different countries are working on problems of biodiversity and environmental safety of the aquatic systems of the Mediterranean region (MOCENNI and VICINO, 2006; GHARIB and DORGHAM, 2006; GHARIB et al., 2011; RAVEH et al., 2015). Special attention is payed to the problem of alien algae invasion (HOFFMAN, 2014; RAVEH et al., 2015; VINOGRADOVA and BRYANTSEVA, 2017), algae bloom including toxic algae bloom (TERENKO and TERENKO, 2012).

Their efforts are aimed at evaluation of changes in aquatic systems in general and at the research of coastal areas in detail. On the one hand, consequences of anthropogenic changes are more obvious in these areas. On the other hand, the coastal areas are the most important for recreation and attractive tourism.

Environmental problems and problems of water quality of the Egyptian Mediterranean Coast became the basis for the research of scientists from the Institute of Oceanology of the Polish Academy of Sciences (GHARIB and DORGHAM, 2006; NIHAL et al., 2014). S. M. Gharib and his co-authors (GHARIB et al., 2011) emphasize that bloom of a potentially toxic species of diatoms *Pseudo-nitzschia* sp. coincides with eutrophication of coastal waters in time. It is worth noting that potentially toxic and nontoxic species of this genus were noticed in the Black Sea by Ukrainian (TERENKO and TERENKO, 2012), Turkish (BESIKTEPE et al., 2008), Greek and Bulgarian scientists (MONCHEVA et al., 2001). Their mass development can be observed during different seasons and is linked to trophic status of seawater. Species *Pseudo-nitzschia* sp. are also noticed in the Sea of Azov (RYABUSHKO et al., 2008). It needs to be taken into account during the diagnostics of environmental safety of coastal waters. There is also information that poisoning by toxic algae and allergic reaction can happen not only during bathing but also through inhalation exposure to marine aerosol (FLEWELLING et al., 2005; SHARMA and RAI, 2006; CASABIANCA et al., 2013).

Israeli scientists from the National Institute of Oceanography have been studying algae in the eastern Mediterranean Sea. O. Raveh and his co-authors have studied phytoplankton and heterotrophic bacteria in the coastal waters of the eastern Mediterranean Sea. They concluded that it is very important to know variability, abundance and production rates of phytoplankton in order to understand a trophic balance of the eastern Mediterranean Sea that is considered to be the most oligotrophic. This information is also important for identification of migration of such toxic species as cyanobacteria, diatoms, dinoflagellates in the marine systems. Nowadays

increasing attention is paid to the algae invasion and a study of migration corridors of algae species including toxic ones in the marine ecosystems of the Mediterranean region (HOFFMAN, 2014; RAVEH et al., 2015; VINOGRADOVA and BRYANTSEVA, 2017).

There is enough accumulated evidence on algae reaction on different anthropogenic changes in the marine ecosystems and information about the algae invasion. They provide development of standardized methods and programs for the evaluation of these processes including an impact of the excessive growth of algae and cyanoprocaryota on human health (MOCENNI and VICINO, 2006; MOKIENKO, 2016; SIDELEV, 2014; CASABIANCA et al., 2013).

According to the European Directives (Hallegraeff et al., 1995; WHO, 2000) ecological safety of bathing water shall be provided and investigations shall be taken if there is a tendency for proliferation of algae and marine phytoplankton. They shall also be evaluated according to their safety for human health.

Scientists from the University of Siena (Italy) that study connections between algae and biochemical processes including eutrophication worked out a mathematical model that represents an ecological situation in the lagoons of Italy: Orbetello, the Sacca di Goro etc. (Italy) (MOCENNI and VICINO, 2006; FACCHINI et al., 2007). The authors believe that this model could be an instrument for the quality management of water in European coastal lagoons.

Diatoms are used worldwide for the evaluation of water quality. In particular, the EU countries use Trophic Diatom Index (TDI), Diatom multimetric index, WFD Diatom Index for the evaluation of river water quality in accordance with The European Union Water Framework Directive. A high information value of these indicators allows using them as basic indicators for water monitoring on other continents. As a result, a number of specialists in the USA and the RSA also tried this method. The possibility of using diatoms as bio-indicators in marine ecosystems is being actively worked out today. Scientists search for indicators that could be further standardized and used in different countries. Despite similarity of the methods, it is difficult to use a single method for ecological monitoring. First of all, geographical and ecological factors of distribution of diatoms shall be taken into account. New indicators are being searched for in order to solve this problem. Also, the present indicators and diatom indices are adapted for the needs of marine ecology considering specifics of certain bodies of water with corresponding flora of diatoms (GONZALO, 2012; DESROSIERS et al., 2013; DALU and FRONEMAN, 2016; LAVOIE et al., 2018).

Considering the strong correlation between algae population and marine water quality, Ukrainian, Bulgarian, Greek and Romanian scientists explore the Black Sea (MONCHEVA et al., 2001; TENEVA et al., 2015). They emphasize that such researches are already recognized as an integral part of the international monitoring program. It is the response to the society's need in such strategic assessment of the environment as EU WFD, MSFD. The researches are very important for the understanding of algae invasion processes and algae biodiversity of the Sea of Azov. They are also essential for the development of the programs on protection of the sea and environmental safety.

Shallowness of the Sea of Azov, climatic conditions of the area, fast heating and cooling of water, complete seawater mixing formed a specific in composition and functional qualities biota. Besides, the transportation made it available for alien algae invasion and it also contributes to indigenous species migration throughout the sea and outside of it.

Research of algae in the Sea of Azov has a long history. The first information about algae of the Sea of Azov and its bay Syvash is represented in the works of K. I. Meyer and V. M. Arnoldi and is dated within the beginning of the 20th century. The works were later complemented by both native and foreign scientists (KOVALEVA, 2016).

Different parts of the Sea of Azov are explored unequally. The most researches are devoted to coastal waters. Open sea area is less explored. Many works are devoted to the research of algae biodiversity in eastern, southeastern and southern coastal areas of the Sea of Azov (Tahanroh Bay,

Temriuk Bay, Kazantyp Bay, Dynsk Bay, Beisuh Estuary and Yeisk Estuary). Besides, scientists research phytoplankton biomass for stable fish productivity (STUDENKINA, 2007), ultraphytoplankton for studying its biodiversity and its potential to be a bioindicator (GLUSCHENKO, 2012). The scientists also actively research species of benthic algae in eastern part of the Sea of Azov (BONDARENKO, 2012; RYABUSHKO and BONDARENKO, 2017), epiphyton, (BONDARENKO, 2012). A lot of attention is paid to the studying of diatoms (BONDARENKO and RYABUSHKO, 2010; RYABUSHKO and BONDARENKO, 2011) and cyanoprokaryota (SADOGURSKAYA, 2001).

H. P. Lypnytska, M. V. Borysiuk, N. M. Lialiuk, scientists from Donetsk National University, described in their works the diversity of phytoperiphyton and phytoneuston and their bioindicative features in Tahanroh Bay in the Sea of Azov in Donetsk region (BORYSIUK, 2001, 2004; LYALYUK, 2001).

The algae in the western and southwestern Sea of Azov are the least explored. The latest data go back to the beginning and the middle of the 20th century and concern Molochnyi Estuary (PROSHKINA-LAVRENKO, 1950; VLADIMIROVA, 1960a), Sivash lake (MEYER, 1915; PROSHKINA-LAVRENKO, 1940, 1962; VLADIMIROVA, 1960b; IVANOV, 1960) and Henichesk Strait (MEREZHKOWSKY, 1902).

After that, the economic life and urbanization processes have intensified. As a result, the ecosystems of this part of the Sea of Azov have fallen under anthropogenic influence. Besides, it is actively used for recreation now. Complex influence of industrial and agricultural anthropogenic pollutants and a higher number of tourists change quality indicators of the seawater. That is why, it should be evaluated from the point of view of ecological risks for both the ecosystem and tourists.

High eutrophication of coastal waters leads to the excessive growth of algae. It can have a negative effect on tourists who bathe and have a rest at the seaside. It is inadmissible to stop studying algae in coastal waters of the northwestern Sea of Azov. The lack of information about the algae bloom in coastal waters cannot be allowed for recreation safety and health improvement of the population.

In summer 2017, the excessive growth of macrophytes could be observed at the water's edge of the Sea of Azov. Tourists and local people experienced discomfort because of this. Macroscopic algae that looked like filamentous algae were not slimy to the touch, of a green color. The wet algae had a filamentous structure, while the dried ones had a felt-like structure. During the process of drying, they were turning into algal mats of dark green to light grey color.

The main producer of macroscopic proliferations on island Biriuchyi, in the area of Lysiacha clough and on Berdiansk spit was *Cladophora albida,* a green alga from an order *Siphonocladales*. On Berdiansk spit there was an accumulation of filamentous algae with higher aquatic plants (*Zostera marina* L*., Ruppia maritime* L.). On Stepanivka spit, the main producer of macroscopic proliferation was another species from a genus *Cladophora* – *Cladophora siwaschensis*. However, filaments of this species were not numerous in the area of Lysiacha clough.

The taxonomy of filamentous algae can be seen in the following Table 1.

A great number of discovered diatoms were attached to macrophytes. Only single members of division Rhodophyta were discovered among filamentous algae.

During the research 18 algae species that were a part of proliferation of macroscopic algae were found at different points. They were representatives of the following divisions: Bacillariophyta – 10 species, Chlorophyta – 6 species, Rhodophyta – 2 species. The species that proliferated the most were dominant in littoral zones of the Sea of Azov and the estuaries (ARROYO and BONSDORFF, 2016). The found species were not toxic.

Table 1. The full list of discovered algae species according to their divisions

Taxon		Island Biriuchyi – cordon "Chynka" – 1 June 2017	Stepanivka spit – 11 July 2017	The area near Lysiacha Balka – 18 July 2017	The end of Berdiansk spit – 20 July 2017	Village Botievo – 30 November 2017
Phylum Bacillariophyta						
Class Bacillariophyceae Haeckel						
Order Cymbellales D.G. Mann						
Family Rhoicospheniaceae J. Chen & H. Zhu						
Genus *Rhoicosphaenia* Grunow						
1	*Rhoicosphaenia abbreviata* (C.Agardh) Lange-Bertalot			+		
Order Achnanthales P.C. Silva						
Family Achnanthaceae *Kütz.*						
Genus *Achnanthes* Bory						
2	*Achnanthes brevipes* C. Agardh		+	+	+	
Family Cocconeidaceae *Kütz.*						
Genus *Cocconeis* Ehrenb.						
3	*Cocconeis disculus* (Schumann) Cleve	+	+	+	+	
4	*Cocconeis scutellum* Ehrenb.			+		
Order Thalassiphysales D.G. Mann						
Family Catenulaceae Mer.						
Genus *Amphora* Ehrenb.						
5	*Amphora ovalis Kütz.*	+				
6	*Amphora coffeaeformis* (C. Agardh) *Kütz.*				+	
Class Fragillariophyceae Round						
Order Fragillariales P.C. Silva						
Family Fragillariaceae Grev.						
Genus *Fragillaria* Lyngb.						
7	*Fragillaria capucina* Desm.			+		
8	*Fragillaria crotonensis* Kitton		+			
9	*Fragillaria sp.*					
Order Licmophorales Round						
Family Licmophoraceae *Kütz.*						
Genus *Licmophora* C. Agardh						
10	*Licmophora abbreviata* C. Agardh	+		+	+	
Phylum Chlorophyta						
Class Ulvophyceae (J.V. Lamour.) Stewart et Mattox						
Order Siphonocladales (Blackman emend. Tansley) Oltm.						
Family Cladophoraceae Wille in Warm.						
Genus *Chaetomorpha Kütz.*						
11	*Chaetomorpha linum* (O. Müll.) *Kütz.*		+			
Genus *Cladophora Kütz.*						
12	*Cladophora albida* (Nees) *Kütz.*	+		+	+	+
13	*Cladophora sericea* (Huds.) *Kütz.*				+	+
14	*Cladophora siwaschensis* K.I.Meyer		+	+		
Order Ulotrichales Borzi						
Family Ulvaceae J.V.Lamour. ex Dumort.						
Genus *Ulva* L. emend. Thur.						
15	*Ulva intestinalis f. intestinalis* L.	+			+	
16	*Ulva linza* L.	+			+	
Phylum Rhodophyta						
Class Florideophyceae Cronquist						
Order Ceramiales Gray						
Family Ceramiaceae Gray						
Genus *Ceramium* Roth						
17	*Ceramium diaphanum* (Lightf.) Roth		+			
Family Rhodomelaceae Aresch.						
Genus *Polysiphonia* Grev.						
18	*Polysiphonia opaca* (C. Agardh) Moris & De Notaris	+				+

Thus, information about different algae characteristics is an integral part of understanding and predicting changes in marine ecosystems. It is valuable for both current assessment of ecosystems and long-term monitoring programs. Today scientists are working out various models based on traditional and innovative information and biological methods. They allow evaluating condition of marine ecosystems and making prognoses as within the specific region so for the reveal of long-term tendencies and space differences between different water areas. Information about composition and quantity of marine algae is an integral part of models used to evaluate environmental conditions of marine waters, especially in coastal areas. In Europe and other regions people have a great experience in solving issues of environmental safety of coastal waters. Unfortunately, in Ukraine the algae of the coastal waters, particularly in the northwestern part of the sea, were not explored for a long time. It makes impossible the use of the data on algae in seawater management in general and in coastal recreation areas. It makes the management less effective and prevents from following systemic approach standards that are used in other European countries and other regions and is foreseen by Water Framework Directive (WFD), Marine Strategy Framework Directive (MSFD) (EUROPEAN COMMISSION, 2008).

Environmental conditions of the Sea of Azov as of a constituent of the Mediterranean region have a direct connection with biological potential safety and environmental safety of European marine ecosystems in general. As a result, it is very important to continue the research of the algae in the Sea of Azov. It is important to solve the issues of eutrophication of the coastal waters and create information systems for the assessment and prediction of water quality. This information can be used for the achievement of strategic purposes in monitoring of the environmental conditions, for providing environmental safety, biological productivity conservation of the Sea of Azov and the development of recreational industry.

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