УДК 576.8

Kovalyova N. V., PhD, Leader research assistant, **Medinets V. I.,** PhD, Director,
Gazyetov Ye. I., Post-graduate student
Odessa State University, Center of Environmental Monitoring,
Dvoryanskaya St., 2, Odessa, 65026, Ukraine

VARIATIONS IN MICROBIOLOGICAL CHARACTERISTICS OF THE NORTH-WESTERN SHELF OF THE BLACK SEA

The analysis of long-term data on seasonal dynamics of microbiological processes with taking into account abiotic factors in the north-western part of the Black Sea is presented. The annual variation of total bacteria number, aerobic oxidation rate of the organic matter and the rate of carbon dioxide assimilation by microorganisms is shown. In the surface waters annual dynamics of all microbiological parameters had synchronous type and close connection with the water temperature. In the bottom waters the variations of number and functional activity of bacteria are connected with hypoxy and anaerobic conditions.

Key words: microbiological regime, organic matter, the Black Sea

It is known that in moderate latitudes, where the Black Sea is located, seasonal variations of physical and biological properties of the upper water layer are pronounced. For the north-western part of the Black Sea (NWBS) the annual variation of hydrological and some hydrochemical parameters is described in detail [1, 12, 11], but the information on annual variability of microbiological processes has not been systematized. At the same time, for solution of eutrophication problems in the north-western shelf it is necessary to study the features of organic matter transformation, that requires the total registration of all changes in annual cycle of bacterial activity. The analysis of the rate of organic matter mineralisation by microorganisms is necessary for assessment of processes promoting occurrence of hypoxy and anaerobic conditions.

The present work purpose is obtaining of the ordered characteristics of annual dynamics of total bacteria number, oxygen consumption rate and carbon dioxide assimilation by bacteria with taking into account of hydrophysical and hydrochemical characteristics changes in water masses of the north-western part of the Black Sea.

Materials and methods

The research materials are the authors' observations in 1983—1997 carried out in coastal and open regions of the NWBS. For collecting of dynamic series more than 770 integrated observations on 7 parameters are used. The series include total bacteria number, oxygen and carbon dioxide consumption by bacteria, temperature, salinity, oxygen concentration and water saturation with oxygen.

The total bacteria number was determined by directl account method [8] by microscope with membrane filters "Synpor" № 8 (pores diameter — 0,2 mkm). The determination of organic matter aerobic oxidation rate was conducted in accordance with the oxygen concentration change in closed water volume placed in conditions as

close to the natural ones as possible, and following the technique [10]. Carbon dioxide assimilation rate by bacteria was measured by of radiocarbon method [10]. The determination of hydrochemical parameters was conducted in accordance with the manual [7].

Results and Discussions

The microbiological regime research in framework of complex ecological monitoring of marine environment [3, 4, 5, 6, 9] allowed to receive materials about long-term seasonal variability of total bacteria number, rate of organic matter oxidation and rate of carbon dioxide consumption by bacteria in the NWBS. Considering temperature, salinity and oxygen as the major factors influencing the habitability of marine organisms, variability of microbiological characteristics has been considered in close connection with changes of these factors. Taking into account two-layer structure of waters [1, 12] the analysis of annual dynamics has been conducted for the surface and bottom layers separately.

Total bacteria number. Determination of this parameter gives notion about regularities of seasonal distribution of microbial population and allows to characterize more completely the substance transformation processes with participation of microorganisms. In surface waters the range of average monthly values of bacteria number was 0.9—2.8 mln.cells/ml; in bottom waters this value was even more — 0.33—3.1 mln.cells/ml (Fig. 1). The smallest number of microorganisms in both waters was noted in January—February. During this period the average monthly concentration of bacteria did not exceed 1.05 mln.cells/ml that corresponds to mesotrophic level of marine waters. It is necessary to note that low density of bacteria in winter was combined with the maximum of water salinity (Fig. 2).

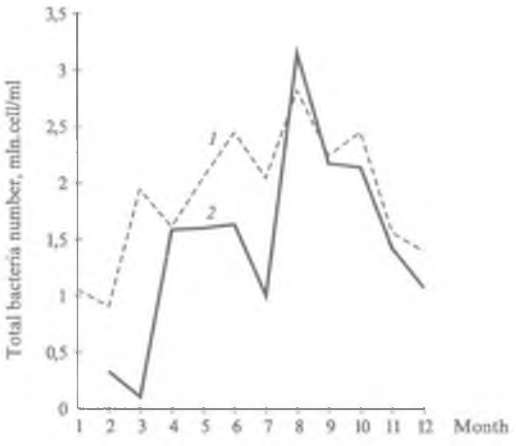

Fig. 1. Average monthly values of total bacteria number in the surface (*1*) and bottom (*2*) waters of the NWBS

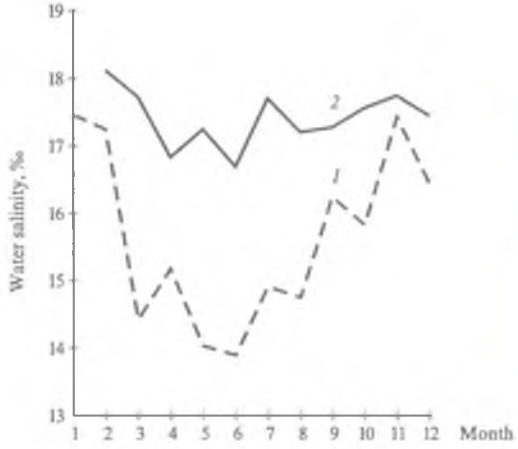

Fig. 2. Average monthly values of salinity in the surface (*1*) and bottom (*2*) waters of the NWBS

An analysis of correlation between these parameters in the surface layer has shown a close statistical dependence (correlation coefficient — 0,7). In March bacteria number

in surface waters sharply increased (up to 1,94 mln.cells/ml) and corresponded to the eutrophic level of marine waters. These changes of bacteria number corresponded to sharp reduction of salinity. Obviously, that the main reason for these changes was the river inflow. There was observed periodic decreases and increases of bacteria number well correlated with salinity changes. In June bacteria number reached 2,45 mln.cells/ml, that correlated with the minimum of average monthly salinity and, consequently, with the greatest influence of fresh waters. In July a small recession of bacteria density was observed, and in August bacteria number reached the maximum average monthly values (2,82 mln.cells/ml). Unlike spring period, when the increase of bacteria quantity is connected with inflow of river waters, in summer and autumn big density of microorganisms was caused, probably, by a surplus of organic matter collected in ecosystem.

In the bottom layer bacteria concentration during January — June was smaller than on the surface. But, in August an extremely big burst of the number was observed: it exceeded the average monthly maximum in surface waters. It is noted that exactly in August in the bottom waters the minimum concentration of dissolved oxygen was observed (Fig. 3).

The conducted analysis of the average monthly values of oxygen and bacteria number concentration has shown that the correlation coefficient between these parameters was –0,82 (statistically reliable with importance level — 99%). It is possible to consider an increase of bacteria number in bottom waters in hypoxy state as one of the factors causing deterioration of water sanitary condition in summer.

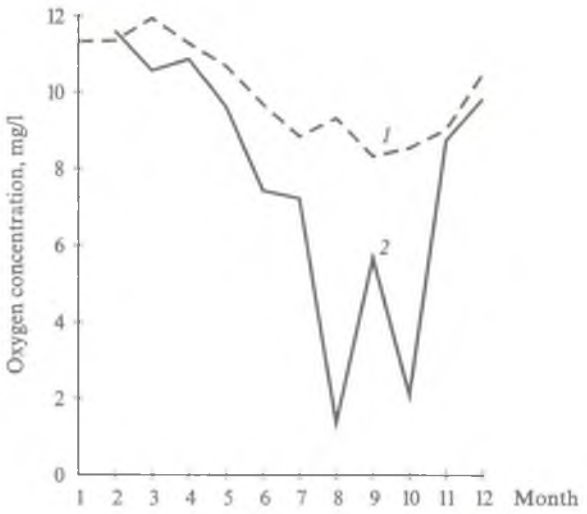

Fig. 3. Average monthly values of dissolved oxygen inthesurface (*1*) and bottom (*2*) waters of the NWBS

At the beginning of autumn in both water layers a big number of bacteria (2,14—2,45 mln.cells/ml) is observed that correspond to the eutrophic level of marine waters. Only in November—December there is a gradual decrease of bacteria quantity simultaneously with increasing of salinity and concentration of dissolved oxygen. This tendency is characteristic for both surface and bottom waters.

Bacteria density increase in eutrophication conditions sometimes accompanies with the decrease of bacteria specific activity, especially the breathing intensity [2]. It, in turn, results that the rate of organic matter oxidation by bacteria is not proportional to the increase of their number. Therefore, bacteria quantity gives only rough notion about the rate of microbiological processes. A better assessment of organic matter oxidation processes is made by the breathing intensity or oxygen consumption by microorganisms.

Aerobic oxidation rates of organic matter (OM). Bacteria, first of all, are responsible for destruction OM collected in ecosystem, and, therefore, microorganisms' activity determines an intensity of self-purification processes. The average monthly rate of the

OM oxidation in surface waters of the NWBS varied from 0,14 mgO_2/l/day in February up to 1.0 mgO_2/l/day in July and August. The lowest activity of oxidation processes was observed in winter (Fig. 4), during the minimum of temperature (Fig. 5) and bacteria density. In March and April the most intensive increase of oxygen consumption rate was noted. It was growing 2—2.5 times per month and was 0.41 and 0.71 mgO_2/l/day accordingly. The next month's intensity of the processes continued to increase but significantly slower than early spring.

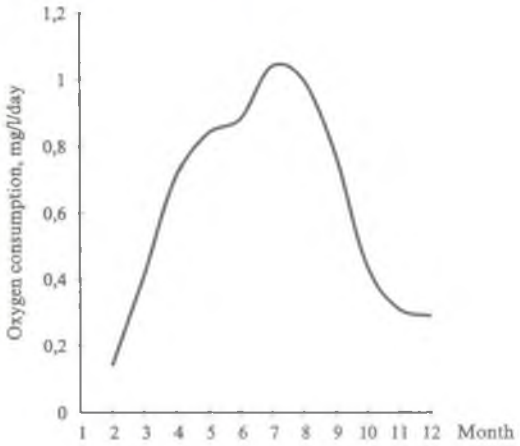

Fig. 4. Average monthly values of oxygen consumption in the surface waters of the NWBS

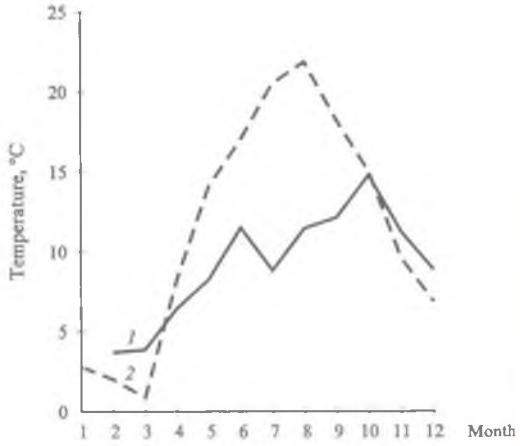

Fig. 5. Average monthly values of temperature in the surface (*1*) and bottom (*2*) waters of the NWBS

The maximum rate of the OM oxidation was registered in July-August when the biggest values were reached for: water temperature (Fig. 5), saturation degree of water with oxygen (Fig. 6) and microorganisms' quantity. The average monthly maximum of the OM oxidation rate was 1,04 mgO_2/l/day (as for eutrophic waters). Since September the OM aerobic oxidation rate was gradually reducing. The sharpest reduction of this process intensity was noted in October. During November and December the OM oxidation rate was reducing and was already 3 times less than the summer maximum. The amplitude between the maximum and minimum values registered in February was almost an order of magnitude. It is interesting that the annual variation of average monthly values of the OM oxidation rate was rather a smooth line whereas the number of microorganisms changed spasmodically. At the same time, a rather close statistical relation was noted between these parameters (correlation coefficient is 0,7, with probability degree — 98%). The seasonal variation of oxygen

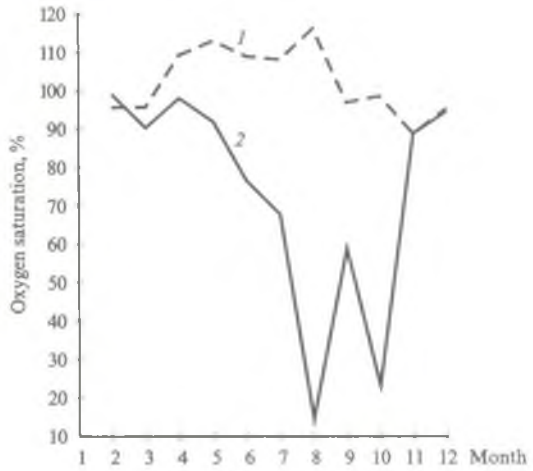

Fig. 6. Average monthly values of oxygen saturation in the surface (*1*) and bottom (*2*) waters of the NWBS

consumption rate had a synchronous type with temperature changes. The correlation coefficient between these parameters was 0,77 (probability degree is 99%). The correlation coefficient was received also between the OM oxidation rate and saturation degree of water with oxygen (r = 0,87). During all period March — August, when the surface waters were oversaturated with oxygen, the OM aerobic oxidation was the most intensive. Statistical analysis conducted confirms that the OM oxidation process depends on the temperature, saturation of water with oxygen and density of microorganisms. Due to the fact that oxygen concentration in the bottom layer of the NWBS frequently was reduced to the minimum (Fig. 3), its consumption was close to zero. Therefore, an analysis of the annual dynamics of the OM aerobic oxidation in the bottom waters has not been conducted.

Carbon dioxide dark assimilation. The rate of carbon dioxide assimilation by microorganisms characterizes the intensity of bacterial biomass production and destruction of organic matter taking place in aerobic and anaerobic conditions. However, it is necessary to take into account, that carbon dioxide quantity consumed by bacteria considerably grows with absence of oxygen [10]. Thus, the rate of carbon dioxide assimilation by bacteria is an indicator of anaerobic conditions m ecosystem. In the surface layer the average monthly rate of carbon dioxide assimilation varied from 2,51 up to 22.2 mgC/m^3/day (Fig. 7).

The minimum rate of this process was observed in period since January till March and was in accordance with the smallest water temperature. Since April an intensive increase of dark assimilation processes was observed. It was simultaneously with an increase of the temperature, bacteria number and oxygen consumption rate. The maximum intensity of carbon dioxide bacterial assimilation in the surface layer was characteristic for July—September. During this period the average rate was 19,97—22,20 mgC/m^3/day, that is on order of magnitude higher than the winter average monthly values.

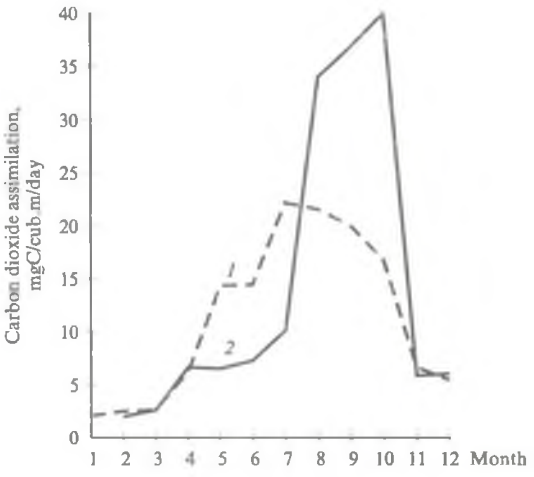

Fig. 7. Average monthly values of carbon dioxide assimilation by bacteria in the surface (*1*) and bottom (*2*) waters of the NWBS

In the bottom layer the oscillations of average monthly values of carbon dioxide bacterial assimilation were considerably higher than on the surface (2.01—40.00 mgC/m^3/day). It is remarkable, that during November-April the intensity of this process in the surface and bottom waters was practically identical. The pronounced differences were revealed in the period since May till October. In this way, in May-July the rate of carbon dioxide dark assimilation in the bottom layer was 2 times smaller than on the surface, and during August—October, on the contrary, it was in 1,5—2 times higher than on the surface (34.2—40.0 mgC/m^3/day). Thus, the maximum of bacterial activity in surface waters was in summer and in the bottom layer in autumn. The maximum values of the rate of carbon

dioxide assimilation by bacteria in the bottom waters coincided with the sharp oxygen depression, when the average monthly concentration of oxygen was reduced to 1.36—2.09 mg/l. A negative correlation was determined between these parameters: $r = -0.87$.

The analysis of correlation between average monthly values of carbon dioxide assimilation rate and other parameters of surface waters has shown close statistical connection with the temperature ($r = 0.97$), bacteria number ($r = 0.79$) and oxygen consumption rate ($r = 0.78$). These results have showed synchronous type of annual dynamics of all investigated microbiological parameters and their close relation, first of all, with the temperature. In the bottom layer the most significant coefficients of correlation were calculated during analysis of interrelation between microbiological characteristics and the oxygen concentration.

Thus, the conducted analysis has allowed to receive the pronounced annual variation of microbiological characteristics of the surface and bottom waters of the north-western shelf, which is closely connected with changes of hydrological and hydrochemical parameters of the environment. The regularities of microbiological parameters changes in the surface and bottom layers had the following features:

1. In the surface waters the period of the most intensive functioning of micro-organisms is since April till October, and the maximum number and activity of bacteria was observed in July — August. In the bottom waters the biggest number and functional activity of bacteria was in August—October and coincided with the period of strong oxygen depression.

2. The biggest average monthly values in the surface layer were: for total bacteria number — 2.5 mln.cell/ml; aerobic oxidation rate of the organic matter — 1.04 $mgO_2/l/day$; rate of carbon dioxide assimilation by bacteria — 22.2 $mgC/m^3/day$. The amplitude between the maximum and minimum average monthly values for the last two parameters was an order of magnitude and total bacteria number changed in 3 times. The average monthly maximum of total bacteria number in the bottom layer was 3.1 mln.cell/ml and was almost an order of magnitude higher than the average monthly minimum. The sharp increase of bacteria number in hypoxy conditions can result in the decrease of recreational value of the coastal waters in summer.

References

1. *Bolshakov V. S., Rozengurt M. SH., Balinskaja N. S., Tolmazin D. M.* Characteristics of the North-Western Part of the Black Sea Water Mass // Nauk. zapisky Odeskoy biol. stantsiy. — Kiev, 1964. — № 5. — P. 98—110.
2. *Drabkova V., Strashkrabova V. R.* The respiration rate and bacterioplankton increase in basins of the different type // Hydrobiological processes in basins. — Leningrad, 1983. — P. 26—44.
3. *Ivanitsa V. A., Medinets V. I., Kovalyova N. V., Khudchenko G. V., Panchenko N. N.* The current state of the Black Sea microbe cenosis // Diagnosis of the State of Marine Environment of the Azov — Black Sea Basin. — International conference, Sevastopol, Crimea, September 6—11. — 1993. — P. 55—60.
4. *Kovalyova N. V., Serman A. A.* The Studing of the Present State of the Bacterioplancton of the Black Sea // Research into the ecosystem of the Black Sea / Ed. V. I. Medinets. — Odessa: Iren-Press, 1994. — P. 134—140.
5. *Kovalyova N. V., Medinets V. I.* Analysis of the Black Sea Bacterioplankton Dynamics as an Element of the Marine Environment Ecological Monitoring // Black Sea Regional Conferebce on Environment Protection Technologies for Coastal Areas. Varna, Bulgaria, 13—15 June 1995. Conference Preprints, Union of Scientists in Bulgaria. — 1995. —P. 71—78.
6. *Kovalyova N. V., Medinets V. I., Ivanitsa V. A.* Microbiological Processes of Organic Matter Destruction

in Coactel Waters of the North-Western Part of the Black Sea // Proceedings of the EUCC international symposium on Management and Conservation of the Northen-Western Black Sea Coast. Odessa, Ukraine, 1996. — Odessa, 1998. — P. 83—89.
7. *Manual* on Metods of Hydrochemical Analysis of Marine Water / Ed. S. Oradovskiy. — Leningrad: Gidrometeoizdat, 1977. — 118 p.
8. *Razumov A. S.* The Direct Method of Bacteria Count in Water. Its Comparison with Method of Koh // Microbiology. — 1932. — V. 1—2. — P. 131—146.
9. *Research* of the Black Sea Ecosystem / Ed. V. I. Medinets. — Iren-Polygraf, 1994. — 158 p.
10. *Romanenko V. I.*, *Kuznetsov S. I.* Ecology of Microorganisms of Frash Basins. Laboratory manual. — Leningrad: Nauka, 1974. — 194 p.
11. *Selin P. Yu.*, *Mikhajlov N. N.*, *Volkov N. V.* Variations in Hydrochemical Characteristics of the North-Western Shelf of the Black Sea // Ecology of the Black Sea Coastal Areas. — Moscow: VNIRO, 1991. — P. 59—100.
12. *Vinogradov A. K.*, *Rozengurt M. Sh.*, *Tolmazin D. M.* Atlas of the Hydrological Characteristics of the North-Western Part of the Black Sea. — Kiev: Naukova Dumka, 1966. — 94 c.

Ковальова Н. В., Медінець В. І., Газєтов Є. І.
Одеський державний університет, Центр моніторингу навколишнього середовища, вул. Дворянська, 2, Одеса, 65026, Україна

МІНЛИВІСТЬ МІКРОБІОЛОГІЧНОГО РЕЖИМУ ВОД ПІВНІЧНО-ЗАХІДНОГО ШЕЛЬФУ ЧОРНОГО МОРЯ

Резюме

Наведено аналіз багаторічних даних щодо сезонної динаміки мікробіологічних процесів на фоні зміни абіотичних чинників середовища у водах північно-західної частини Чорного моря. З'ясовано річну мінливість загальної кількості бактерій, швидкості аеробного окислення органічної речовини та швидкості асиміляції вуглекислоти мікроорганізмами. В поверхневих водах річна динаміка всіх досліджуваних параметрів була синхронною і залежною від температури. В придонних водах зміни кількості та функціональної активності бактерій зв'язані з гіпоксійно-анаеробними умовами.

Ключові слова: мікробіологічний режим, органічна речовина, Чорне море.

Ковалева Н. В., Мединец В. И., Газетов Е. И.
Одесский государственный университет, Центр мониторинга окружающей среды, ул. Дворянская, 2, Одесса, 65026, Украина

ИЗМЕНЧИВОСТЬ МИКРОБИОЛОГИЧЕСКОГО РЕЖИМА ВОД СЕВЕРО-ЗАПАДНОГО ШЕЛЬФА ЧЕРНОГО МОРЯ

Резюме

Представлен анализ многолетних данных о сезонной динамике микробиологических процессов на фоне изменения абиотических факторов в водах северо-западной части Черного моря. Показана годовая изменчивость общей численности бактерий, скорости аэробного окисления органического вещества и скорости ассимиляции углекислоты микроорганизмами. В поверхностных водах годовая динамика всех исследованных параметров была синхронной и зависимой от температуры. В придонных водах изменения численности и функциональной активности бактерий связаны с гипоксийно-анаэробными условиями.

Ключевые слова: микробиологический режим, органическое вещество, Черное море.