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EFFECT OF SPRING FLOOD AND HYPOXIA ON MICROBIOLOGICAL AND HYDROCHEMICAL STRUCTURE OF THE NORTH-WESTERN PART OF THE BLACK SEA

Some data are given on distribution of nutrients and variations of the microbiological regime in the north-western part of the Black Sea under the influence of spring flood and autumn hypoxia. It is shown, that high phosphorus concentrations and bacteria number typical for surface waters in spring flood were habitual for bottom waters during hypoxia too. The obtained results testify that among the factors causing eutrophication of the north-western shelf the role of the secondary pollution released from bottom sediments with the development of wide hypoxia areas is comparable with the river flood influence.

Key words: bacteria, phosphate, hypoxia, shelf of the Black Sea.

Microbiological and hydrochemical regime of the north-western part of the Black Sea (NWBS) in connection with development of cultural eutrophication processes suffered considerable changes in the last decades. The particular role in alteration of the ecosystem parameters was played by the river run-off. A sharp increase of nutrients content in the river waters caused changes in functioning of biota. The concentration of nitrogen and phosphorus salts in photic layer of the northwester region according to different published information [1, 12] increased 2—5 times in 1977—1989. The increase of nutrients amount promoted the growth of phytoplankton. Its biomass grew 31 times in comparison with 1954—1974 [7]. In this connection the accumulation of autochthonous and allochthonous organic matter took place in the bottom layer of the sea. Intensive microbiological mineralization of organic matter with firm density stratification lead to the development of hypoxia in bottom waters. Those areas have changed from 3000—12 000 km^2 in 1973—1995 to 12 000—40 000 km^2 in 1988—1990 [6]. At those conditions the extreme factors affecting the ecosystem are spring flood and autumn hypoxia. These phenomena are important cause-effect links of euthrophication. It is known that those maximum concentration values of nutrients are connected with the period of bigger entering of the fresh water to the NWBS [1] and the biggest bacteria number are connected with mouth area [2]. At the same time, there is very limited information about influence of hypoxia on distribution of nutrient and variations in microbiological regime.

The objective of the present report is to make a comparative analysis of distribution of nutrients and microbiological processes in surface and bottom waters of the north-western part of the Black Sea during spring flood and autumn hypoxia.

Materials and Methods

The experimental material was selected in the NWBS during research expeditions of the Ukrainian Scientific Center of the Ecology of Sea and of the State Geological Enterprise "Odesmorgeologia". The cruises were carried out in May 1995; in September 1990; in October 1994 and in September 1997. The hydrochemical parameters were studied in accordance with the manual [5]. the total bacterial number was estimated by means of direct count with the help of microscope [9], using membrane filter with cell size 0,2 μk. Carbon dioxide dark assimilation rate was determined radiocarbon method [11].

Results and Discussions

Salinity of the surface water during investigation of near-Dnieper and near-Danube sea regions in May 1995 averaged to 9,4‰ and 9,29‰ correspondingly that showed intensive freshwater discharge from the rivers to the sea. At this time the total phosphorus content in the surface waters of the Dnieper region averaged to 51 μg/l, and its average concentration in the Danube region increased to 177,8 μg/l. In spring the total phosphorus content in bottom waters was 1,3—1,5 times less then in the surface waters (Table 1). Such vertical distribution of nutrients was the consequence of the river discharge, which kept the high concentrations of nutrients, and it spread along the sea surface with a thin layer. Total phosphorus concentrations in the Dnieper region

Table 1

Characteristics of the NW Black Sea Surface (I) and Bottom (II) Waters in Spring Flood Period (May 1994)

Parameters		Dnieper region		Danube region	
		I	II	I	II
Salinity, ‰	Maximum Average Minimum	10,63 9,40 7,86	19,49 17,80 15,86	14,33 9,29 3,87	17,93 17,39 16,18
Oxygen, mg/l	Maximum Average Minimum	12,44 11,51 11,07	12,44 9,65 8,74	15,60 13,00 10,81	8,44 7,21 5,76
Oxygen saturation, %	Maximum Average Minimum	145 134 128	115 95 80	176 138 111	76 67 54
Total phosphorus, μg/l	Maximum Average Minimum	66,0 51,0 31,0	46,0 33,6 20,0	672,0 177,8 37,0	518,0 131,6 18,0
Total bacteria number, $\times 10^6$ cells /ml	Maximum Average Minimum	2,55 2,26 2,11	3,00 1,89 1,14	4,06 3,39 2,38	3,71 1,20 0,62
Carbon dioxide dark assimilation, $mgC/m^3/day$	Maximum Average Minimum	28,52 21,95 17,39	25,39 8,40 1,22	49,54 40,00 31,32	41,26 16,21 2,16

coincided with its average content in NWBS in 1985—1989 [1]. At the same time, the extremely high concentrations of the total phosphorus (518—672,0 μg/l) registered in the Danube region exceeded the average content in 1985—1989 by an order of magnitude.

The microbiological process changes conformed to the alteration of nutrients during spring flood. The most bacterial number (2,11—4,06 · 10^6 cells /ml) and carbon dioxide dark assimilation rate (17,39—49,54 mgC/m^3/day) were determined in the surface waters. In this layer, the highest bacteria density and the rate of bacteriological processes were habitual to the Danubian region of the northwestern shelf. The absolute maximum of the bacterial number (4060 · 10^3 cells /ml) and the bacterial activity (49,54 mgC/m^3/day) coincided with the positive extreme value of the total phosphorus too.

In the bottom waters bacteria quantity appeared to be 1,2—1,7 times lower then at the surface and carbon dioxide assimilation rate was 2,5 times less then at the surface. Thus, research of the northwestern shelf in spring flood period showed that the highest nutrient contents and the high rate of the microbiological regeneration of nutrients took place in the surface layer of the sea. At these conditions intensive phytoplankton development [3] caused oversaturation with oxygen of the surface waters which reached in average 110% and 176% for near-Dnieper and near-Danube regions accordingly. Microbiological and hydrochemical indices showed the intensity of euthrophication, which diffused from surface waters to bottom waters in spring. Conforming to the laws of nature, the result of these processes was development of anaerobic conditions at the bottom.

The oxygen concentrations 0—3,87 mg/l were fixed in the bottom waters of the chosen sections of the NWBS in September—October 1990—1997. It was the evidence of hypoxia development in the bottom layer of the shelf (Table 2).

Table 2

Characteristics of the NW Black Sea Surface (I) and Bottom (II) Waters During Hypoxia

Parameters		09.1990		10.1994		09.1997	
		I	II	I	II	I	II
Oxygen, mg/l	Maximum	9,16	0,0	7,60	0,36	10,76	3,97
	Average	8,38	0,0	7,44	0,10	9,88	3,40
	Minimum	7,81	0,0	7,19	0,00	8,17	2,47
Oxygen saturation, %	Maximum	105	0,0	95	3	127	39
	Average	98	0,0	92	1	95	36
	Minimum	91	0,0	88	0	110	25
Total phosphorus, μg/l	Maximum	35,3	126,6	82,0	220,0	—	—
	Average	23,8	124,1	57,2	162,2	—	—
	Minimum	17,2	118,0	41,0	102,0	—	—
Phosphate, μg/l	Maximum	16,8	111,0	23,0	217,0	38,1	222,0
	Average	12,6	98,5	12,6	145,0	23,8	151,2
	Minimum	8,0	86,0	7,2	84,0	19,0	92,0
Total bacteria number, × 10^6 cells /ml	Maximum	1,89	2,81	2,30	3,16	—	—
	Average	1,86	2,58	1,83	2,50	—	—
	Minimum	1,26	2,19	1,33	1,68	—	—
Carbon dioxide dark assimilation mgC/m^3/day	Maximum	48,60	383,0	25,87	172,8	33,20	16,38
	Average	32,97	191,7	21,06	108,4	20,39	11,15
	Minimum	7,80	56,8	10,00	47,9	8,24	6,56

At these conditions the distribution of phosphorus concentrations between surface and bottom waters became diametrically opposite in comparison with the spring observations. Concentrations of the total phosphorus in the bottom waters appeared to be 3—5 times as much as in the surface waters. In that situation the increase of phosphorus content at the bottom took place at the expense of phosphate, which made 80—85% of the total phosphorus. The phosphate quantity in the surface layer was not exceeding 22—50% of the total phosphorus. The phosphate concentration in the bottom layer exceeded that in the surface 7—10 times.

Intensity of the microbiological processes in the bottom waters in autumn was much higher than in surface water too. When oxygen concentrations lowered to 0—0,36 mg/l carbon dioxide dark assimilation averaged to 108,41—191,75 mgC/m^3/day, that was 5 times as much as on the surface (Table 2). However, it is necessary to take into account that chemobacterial evolution takes place in anaerobic conditions, which consume more carbon dioxide then heterotrophic bacteria [10]. At the same time the increase of the total bacteria number was noted in the anaerobic conditions of the bottom layer. The bacteria density averaged to $2{,}5 \cdot 10^6$ cells /ml and it was 1,4 times as much as in upper layers. The increase of bacteria quantity in anaerobic conditions in comparison with aerobic conditions was fixed in the laboratory experiments by A. Rayabov et all. [7]. These authors noted also a sharp increase of bacterial number when saturation degree of the water with oxygen reduced to 50% and lower. This phenomenon received confirmation in our researches of the annual variations of the total bacteria number and oxygen concentration in bottom layer NWBS [4]. Vertical distribution of the observed parameters showed that the maximum values of the phosphate concentrations, bacteria number and carbon dioxide assimilation rate were typical for the lowest water layer where reductive conditions were formed (Table 3).

Table 3

Vertical Distribution of Microbiological and Hydrological Parameters in the North-Western Part of the Black Sea during Hypoxia

Date	Horizon, m	Oxygen, mg/l	Total phosphorus, μg/l	Phosphate, μg/l	Bacteria Number, $\times 10^6$ cells/ml	Carbon dioxide dark assimilation, mgC/m^3/day
5.10.1994	0,5	7,57	51,0	7,7	1,91	25,87
	10	7,49	60,0	7,7	1,68	22,70
	20	2,80	68,0	29,0	1,68	20,86
	27	0,00	204,0	169,0	1,74	172,78
6.10.1994	0,5	7.30	82,0	23,0	2,14	22,37
	10	7,19	68,0	23,0	2,32	25,01
	20	2,90	151,0	126,0	2,46	25,01
	25	0,36	220,0	217,0	3,16	140,50

However, abnormally high phosphate concentrations were found also at the distance of 5—7 m from the bottom where oxygen content was higher than 2,0 mg/l. On this occasion, one can assume that phosphates were at a distance from the place where the processes of enrichment of the bottom waters by nutrients occurred. As it is known [13], the bacterial production can accelerate the transport of phosphorus from bottom sediments to water increasing its concentration in the bottom layer. At the same time bacteria consuming oxygen reduce its concentration to zero and form the reductive conditions. In that situation phosphorus connected with bottom sediments become soluble and enter the bottom waters. Therefore, the high phosphate concentrations fixed in the bottom waters by us, in all probability, was a result of the microbiological processes and of the chemical reactions releasing phosphate from the bottom sediments. Conformity of the maximum values of phosphorus concentrations and of carbon dioxide assimilation rate by bacteria allows to define the areas of phosphate release from the bottom sediments with the help of the microbiological index.

Thus, the highest phosphorus concentrations in the shelf bottom waters during hypoxia period coincide with its maximum quantity in the surface water in spring flood. At the same time the total bacteria number increase in the bottom water that can negatively influence the hygiene and sanitary condition of the coastal waters. In this connection, we believe, among the factors causing eutrophication of the north-western shelf the role of the secondary pollution released from bottom sediments with development of the wide hypoxia areas can be compared with river flood influence.

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ВПЛИВ ПОВЕНІ ТА ГІПОКСІЇ НА МІКРОБІОЛОГІЧНУ ТА ГІДРОХІМІЧНУ СТРУКТУРУ ВОД ПІВНІЧНО-ЗАХІДНОЇ ЧАСТИНИ ЧОРНОГО МОРЯ

Резюме
Наведено дані про розподіл біогенних речовин та мінливість мікробіологічного режиму у водах північно-західної частини Чорного моря під впливом весняної повені та осінньої гіпоксії. Показано, що високі концентрації фосфору та чисельності бактерій, властиві поверхневим водам у період повені спостерігаються також у придонних водах під час гіпоксії. Одержані результати свідчать, що поміж факторів, які породжують евтрофікацію північно-західного шельфу, роль вторинного забруднення, що надходить із донних відкладів за розвитку значних зон гіпоксії, може порівнюватися з впливом річкового стоку.

Ключові слова: бактерії, фосфат, гіпоксія, шельф Чорного моря.

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ВЛИЯНИЕ ПОЛОВОДЬЯ И ГИПОКСИИ НА МИКРОБИОЛОГИЧЕСКУЮ И ГИДРОХИМИЧЕСКУЮ СТРУКТУРУ ВОД СЕВЕРО-ЗАПАДНОЙ ЧАСТИ ЧЕРНОГО МОРЯ

Резюме
Представлены данные о распределении биогенных веществ и изменчивости микробиологического режима в водах северо-западной части Черного моря при воздействии весеннего паводка и осенней гипоксии. Показано, что высокие концентрации фосфора и численности бактерий, характерные для поверхностных вод в период половодья, также присущи придонным водам во время осенней гипоксии. Полученные результаты свидетельствуют о том, что среди факторов, вызывающих эвтрофикацию северо-западного шельфа, роль вторичного загрязнения, поступающего из донных отложений при развитии обширных зон гипоксии, сопоставима с воздействием речного стока.

Ключевые слова: бактерии, фосфат, гипоксия, шельф Черного моря.