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RELATIONSHIP OF THE PROCESSES OF AEROBIC OXIDATION AND ANAEROBIC DESTRUCTION OF ORGANIC MATTER IN THE BOTTOM SEDIMENTS OF COASTAL WATERS OF CRIMEA (BLACK SEA)

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The relationship between water masses and bottom sediments is obvious. This primarily refers to the formation of oxygen regime and self-purification of water bodies. Stoichiometric ratios allow assessing certain parameters of energy metabolism associated with oxygen consumption. The aim of this work is to determine the possible contribution of aerobic and anaerobic processes to the destruction of organic matter in bottom sediments of various areas of the Crimean coast by interpreting the data on oxygen consumption. The total oxygen consumption rate was measured using a respirometry camera hermetically connected to an HQ40D oxygen sensor with LDO oximeter. To suppress bacterial activity and reveal the rate of oxidation of reduced anaerobiotic products, the antibiotic streptomycin was used. Vertical sounding of the bottom sediment strata in the Belbek River paleochannel showed an increase with depth of oxidative potential and a subsurface peak of anaerobic activity. Due to the limited diffusion of oxygen, the rate of hydrogen sulfide oxidation in the surface layer was comparable to the rate of its formation in the underlying sediment layer. A higher level of aerobic oxygen consumption and content of reduced compounds was observed in the bottom sediments of the Chernaya River paleochannel in contrast to its slopes. Increased concentration of hydrogen sulfide is due to the higher rate of its formation at relatively low rates of oxidation. In the Sevastopol Bay, the experimentally measured oxygen consumption by a unit of the bottom surface in the 0.6-cm sediment layer averaged 2.18 $\mu g \cdot cm^{-2} \cdot h^{-1}$. In the Kruglaya Bay, certain differences in the dynamics of reduced compounds (H_2S) were registered between the oxidized background areas and the zones of reduced bottom sediments (sulfurettes). In sulfurettes, the calculated values for concentration, oxidation rate, and formation of hydrogen sulfide were higher by 32, 29, and 57%, respectively. The maximum rate of organic matter decomposition, up to 4.05 $\mu g \cdot cm^{-3} \cdot h^{-1}$, was recorded in the Sevastopol Bay and the adjacent water areas, with the anaerobic component accounting for a larger share. The share turned out to be quite high in the Kruglaya Bay as well, but there, aerobic destruction prevailed. This is due to differences in both the targeted use of the bays and the granulometric composition of bottom sediments. In sulfurette sediments, against the backdrop of the rate of oxidation of organic substances equal to that of the background area, anaerobic utilization occurred more than 2 times more intensive. Its absolute value corresponded to the level characteristic of the open-sea coastal areas, in particular, the Belbek River paleochannel.

Keywords: bottom sediments, oxygen consumption, destruction of organic matter, Black Sea

When assessing the state of the environment, including the Black Sea bottom sediments, data are usually given on the content of both organic matter and its possible oxidizers [Gorshkova, 1974; Orekhova, 2010]. Specifically, it was reported that the share of the organic component in sediments of the Heracles Peninsula bays varied within 0.51–5.41% [Orekhova et al., 2018]. Oxygen concentration fluctuates over a wide range as well. Thus, almost complete absence of oxygen was recorded in the Sevastopol Bay sediments during the warm season: its content in the bottom water layer could drop to 30 μmol·L^{-1}, which is 10 times lower than the value characteristic for the winter period [Orekhova, Konovalov, 2018a]. Regular monitoring in the Sevastopol Bay [Ignat'eva et al., 2008; Moiseenko, Orekhova, 2011; Osadchaya et al., 2003] allows identifying certain trends, but single measurements in other water areas only make it possible to ascertain levels of the substances at a given time. However, their content often results from multidirectional processes, the intensity of which can shift the balance in one direction or another. Therefore, the study of such dynamic characteristics allows for both short-term and long-term forecasting. In this regard, a key role is played by the rate of oxygen consumption, the calculation of which in the form of certain derived parameters provides an integral picture of the processes occurring in biocenoses. On the one hand, these are the formation of environmental conditions and self-purification; on the other hand, these are the state and stability of constituent elements. Based on stoichiometric formulas, patterns for determining possible coefficients were proposed for the transition between various indicators of the biological activity of the community [Sapozhnikov, Metrevely, 2015]. By shifts in one parameter, a whole range of characteristics can be tracked. In order to study the relationship between possible rates of aerobic and anaerobic utilization of organic matter in various areas of the Crimean coast, an attempt was made to analyze the data obtained by the author on oxygen consumption by bottom sediments.

MATERIAL AND METHODS

In most of the surveyed water areas (the Dvuyakornaya Bay, the Chernaya River paleochannel, the Sevastopol Bay, and the Balaklava Bay), sampling was carried out with a Petersen grab. The material for the study was a surface 2-cm layer of bottom sediments. Containers for transportation were filled to the top to prevent air penetration. In the Kruglaya Bay, material was sampled from the same layer directly from the sulfurette and the background area by a diver using syringe tubes. In the clean coastal zone of the Cape Martyan nature reserve and in the Belbek River paleochannel, samples were taken from a 4–6-m depth with a Rumalot-type tubular sampler equipped with a transparent acrylic tube, 54 mm in diameter and 30 cm in height, with a shut-off valve at the opposite end and a weight with fastening fittings. As a rule, lifted bottom sediment cores retained an undisturbed structure, which made it possible to study them layer by layer. The coordinates of sampling points and the dates of field works are given in Table 1.

Oxygen content and redox potential were measured using sensors HQ40D and Sension 1 (Hach, the USA) with LDO oximeter. The accuracy of dissolved oxygen determination was ±0.1 mg·L^{-1} within a range of 0.1–8.0 mg·L^{-1}. To stabilize the readings of the redox potential, the sensor was immersed in a sample for 10 min; then, the result was recorded. The total oxygen consumption rate (hereinafter TOC) was determined in a 60-mL respirometry chamber filled with seawater and hermetically connected to an oxygen sensor. Initial oxygen concentration in water was about 7–8 mg·L^{-1}. A test 0.2-cm^3 sample was introduced into the chamber; there, it was distributed over an area of 20 cm^2, which corresponded to a layer of about 0.01 cm. The results were registered at 1-h intervals automatically for 20–24 h. Based on the data obtained, mean TOC was subsequently calculated.

From the bottom sediments of the Cape Martyan area, samples were taken from the horizons of 0–2 and 3–5 cm, while in the Belbek River paleochannel, from 0–2, 2–4, and 4–6 cm. For each layer, a unified scheme for TOC calculating was applied. It involved measurements under conditions of oxygen maximum availability in the 0.01-cm surface layer, followed by extrapolation to a thickness of 0.6 cm, with the features in diffusion of oxygen into bottom sediments taken into account [Chekalov, 2016].

The rate of oxygen neutralization of reduced compounds (hereinafter ONRC) was determined in a similar way, after suppressing the vital activity of bacteria. It was achieved by adding streptomycin to a measuring container at a final concentration of 0.1 $mg \cdot mL^{-1}$ and then incubating it at +8…+10 °C for the entire measurement period. This was also facilitated by lowering pH to 5 (using a 0.1N solution of sulfuric acid) in order to shift the ratio of sulfur compounds in water (S^{2-}, HS^-, H_2S) towards the prevalence of the most actively oxidized hydrogen sulfide. Oxygen content was determined every hour. Based on the data obtained, the mean rate of hydrogen sulfide oxidation was calculated, taking into account that in aqueous solutions, hydrogen sulfide is usually oxidized to sulfur and water:

$$2H_2S + O_2 \rightarrow 2H_2O + 2S \ .$$

The rate of aerobic oxygen consumption (hereinafter AOC) was obtained by subtracting ONRC values from the corresponding levels of total oxygen consumption. The data for AOC and ONRC are given as mean values with a confidence interval ($p = 0.95$).

To establish the rate of enrichment (production) with reduced compounds, immediately after sampling, ONRC was determined under laboratory conditions until the curve of oxygen content change reached a plateau, *i. e.*, until the readings stabilized at approximately the same level for more than 3 measurements. Based on the volume of oxygen consumed in this case, possible hydrogen sulfide content was calculated. In parallel, a part of samples, avoiding oxygen penetration, was placed in sealed containers, which were kept under conditions close to natural. The duration of incubation was determined experimentally. Usually, incubation lasted for 30–60 days, and then ONRC was determined again. The difference between the initial value and the repeated measurement, taking into account the time interval, allowed calculating the rate of formation of reduced compounds.

The results on aerobic oxygen consumption and the dynamics of reduced compounds (H_2S) according to stoichiometric formulas [Orekhova, Konovalov, 2018a; Sapozhnikov, Metrevely, 2015] were expressed as the utilization rate of organic matter:

$$(CH_2O)_{106}(NH_3)_{16}H_3PO_4 + 138O_2 = 106CO_2 + 122H_2O + 16HNO_3 + H_3PO_4 \ ,$$

$$(CH_2O)_{106}(NH_3)_{16}H_3PO_4 + 53H_2SO_4 = 106CO_2 + 16NH_3 + H_3PO_4 + 53H_2S + 106H_2O \ .$$

Organic matter concentration in bottom sediments was determined by the gravimetric method after drying of samples at +105 °C and their further calcination at +500 °C [Gorshkova, 1974; PND F 16.2.2:2.3:3.32-02, 2002].

RESULTS AND DISCUSSION

In terms of the degree of isolation of the water areas studied, the sampling points can be united into two groups: those located within relatively closed bays and those located in the coastal zones of open sea areas. The first group includes stations in the Sevastopol, Kruglaya, and Balaklava bays, which are characterized by a large-scale influx of suspended matter into bottom sediments. Thus, in the Sevastopol Bay, the sedimentation rate was 2.4 mm·year^{-1}, while in coastal waters of Crimea, the value was only 0.35 mm·year^{-1} [Denisov, 1998]. Accordingly, in the first group, TOC obtained by us varied in the range of 2.63–4.36 μg·cm^{-3}·h^{-1}. In the second group, which included stations in the Dvuyakornaya Bay, in the Cape Martyan area, and in the Belbek River paleochannel, the values did not exceed 2.90 μg·cm^{-3}·h^{-1} (Table 1).

Table 1. Oxygen consumption and derived data on the dynamics of reduced compounds (H_2S) in the bottom sediments of coastal waters of Crimea

Coordinates of sampling points, date	Layer, cm	Redox potential, mV	O_2, μg·cm^{-3}·h^{-1}		Reduced compounds (H_2S)		
			AOC	ONRC	Concentration, μg·cm^{-3}	Oxidation, μg·cm^{-3}·h^{-1}	Production, μg·cm^{-3}·h^{-1}
Dvuyakornaya Bay, 44.990°N, 35.36°E, 07.07.2012	0–0.6	−182	2.20 ± 1.00	0.70 ± 0.20	38	1.49	0.77
Cape Martyan, 44.509°N, 34.256°E, 13.08.2014	0–0.6	14	2.40 ± 0.19	0.27 ± 0.23	574	0.57	0.17
	3–3.6	−199	3.36 ± 1.07	0.35 ± 0.28	567	0.74	0.62
Belbek River paleochannel, 44.631°N, 33.418°E, 21.05.2013	0–0.6	−193	1.27 ± 0.52	0.61 ± 0.13	609	1.30	0.34
	2–2.6	−176	2.46 ± 0.86	0.84 ± 0.60	777	1.79	0.54
	4–4.6	−184	9.43 ± 5.48	1.35 ± 0.99	1,011	2.87	0.17
Chernaya River paleochannel, 44.618°N, 33.474°E, 26.05.2013	Riverbed, 0–0.6	−68	2.41 ± 0.78	0.28 ± 0.09	1,320	0.60	1.07
	Slope, 0–0.6	−140	1.25 ± 0.43	0.43 ± 0.15	797	0.91	0.71
Sevastopol Bay, 44.615°N, 33.520°E, 12.06.2012	0–0.6	–	2.00 ± 0.59	0.63 ± 0.19	1,345	1.34	1.00
Kruglaya Bay, 44.602°N, 33.441°E, 27.07.2020	Background, 0–0.6	30	3.39 ± 0.49	0.35 ± 0.18	750	0.75	0.15
	Sulfurette, 0–0.6	−72	3.14 ± 0.25	0.50 ± 0.21	1,097	1.06	0.35
Balaklava Bay, 44.496°N, 33.595°E, 23.10.2008	0–0.6	−209	3.98 ± 0.78	0.38 ± 0.03	703	0.81	–

Note: AOC, aerobic oxygen consumption; ONRC, oxygen neutralization of reduced compounds.

The formation of sediments in the Chernaya River paleochannel is affected by significant anthropogenic load on the Sevastopol Bay [Orekhova et al., 2013]. Apparently, it explains the similarity of these sampling points in several parameters, which does not allow us to attribute the paleochannel area to any group. As a specific object, paleochannels in Sevastopol vicinity are analyzed in the paper [Gulin, Kovalenko, 2010]. Bottom sediments in both groups were represented by slightly silty sands and finely dispersed silts. Silty sediments were characteristic of the Sevastopol and Balaklava bays and paleochannels of the Chernaya and Belbek rivers. Other samples were represented by sands with minor traces of siltation. In most samples, negative values of the redox potential were recorded, and this evidenced for reduced environmental conditions.

Bottom sediments of the Cape Martyan (a protected area) and the Belbek River paleochannel differed in granulometric characteristics, anthropogenic load, and, accordingly, concentration of organic compounds. At the same time, vertical sounding of bottom sediment strata at these sampling points revealed an increase with depth of oxidative potential and a subsurface peak of anaerobic activity (see Table 1).

In 2008, we determined several parameters in the bottom sediments of the central Kruglaya Bay, *inter alia* TOC. Repeated studies of TOC and organic matter content, which were carried out in the course of this work, did not reveal significant changes in the values over time. TOC varied within 3.25–3.66 $\mu g \cdot cm^{-3} \cdot h^{-1}$, and organic matter concentration was about 33 $mg \cdot g^{-1}$.

The rates of formation of reduced compounds depended, among other things, on the granulometric composition of bottom sediments: in silts, those were 1.5–2 times higher than in sands. The maximum values, more than 1 $\mu g\, H_2S \cdot cm^{-3} \cdot h^{-1}$, were obtained in the silty sediments of the Sevastopol Bay. In general, a higher level of hydrogen sulfide concentration was registered in the bays, up to 1.4 $mg \cdot cm^{-3}$. In the samples from the coastal zones of open sea areas, H_2S content did not exceed 0.6 $mg \cdot cm^{-3}$ in the surface layer, and the formation rate was 0.77 $\mu g\, H_2S \cdot cm^{-3} \cdot h^{-1}$. The bottom sediments in the Chernaya River paleochannel were the exception, and this can be explained by the effect of the Sevastopol Bay. Specifically, the intensity of sulfate reduction in the surface sediment layer in the bays of Sevastopol reached 93 $\mu M \cdot dm^{-3} \cdot day^{-1}$, or 0.132 $\mu g \cdot cm^{-3} \cdot h^{-1}$ [Egorov et al., 2012]. The values of bacterial sulfate reduction in the sediments of the Black Sea northwestern shelf ranged from 28.3 to 427.0 $mg\, H_2S \cdot kg^{-1}$ of wet sediment *per* day [Karnachuk, 1989].

Hydrological features of relatively closed bays, which are associated with limited water exchange, weakened wave action, and, as a rule, significant influx of organic and biogenic substances, contribute to intensive sedimentation [Lomakin, Popov, 2014; Orekhova et al., 2013]. With sufficient aeration, this ultimately results in increased activity of biochemical processes in the surface sediment layer.

Oxygen supply to the reduced sediment layer also initiates oxidative processes, the intensity of which can be even higher than for the surface sediment layer. Thus, in the sediment core from the Belbek River paleochannel, AOC rose from 1.27 $\mu g\, O_2 \cdot cm^{-3} \cdot h^{-1}$ at the surface to 9.43 $\mu g\, O_2 \cdot cm^{-3} \cdot h^{-1}$ at a 4-cm depth. Apparently, a subsurface peak of activity of reduced compounds, mentioned above, is related to the activation of sulfate reduction. Compared to the surface horizon, it increases by 1.5–3.5 times. At the same time, the oxidation of anaerobiosis products in the sediments of the paleochannel due to insufficient diffusion of oxygen into the silts is limited by the surface layer alone. Therefore, the layer-by-layer sum of the rates of H_2S formation and its oxidation rate in the surface layer turn out to be quite comparable. In the Cape Martyan area, in more aerated sandy sediments, the layer of oxidation of reduced compounds is slightly thicker; in general, the scale of this process prevails over the scale of their production, which determines positive values of the redox potential.

As already mentioned, the formation of the bottom sediments in the Chernaya River paleochannel is affected by the proximity of the Sevastopol Bay mouth [Orekhova et al., 2013]. Directly in the mouth, the sediments differed from those on the slope by a higher maximum level of aerobic oxygen consumption, as well as by the content of reduced compounds, which can be explained by a higher rate of their formation at relatively low rates of oxidation.

In the 0.01-cm sediment layer of the Sevastopol Bay, experimentally measured TOC averaged 0.96 $\mu g \cdot cm^{-2} \cdot h^{-1}$ [Chekalov, 2016]. Considering the assumed depth of oxygen penetration (0.6 cm), this corresponds to 2.18 $\mu g \cdot cm^{-2} \cdot h^{-1}$. As reported earlier [Orekhova, Konovalov, 2018a], the value of the oxygen flux through the surface of the bottom sediments in the bay, calculated according to Fick's first law, varied insignificantly during the cold season, averaging 2 $mol \cdot m^{-2} \cdot year^{-1}$. This value corresponds to 0.73 $\mu g \cdot cm^{-2} \cdot h^{-1}$, which is slightly lower than that obtained by us. However, the authors point out that several geophysical factors and the high rate of biochemical processes were not taken into account. In another paper [Orekhova, Konovalov, 2018b], the values of the oxygen flux calculated for the Crimean shelf increased from 2.85 $M \cdot m^{-2} \cdot year^{-1}$ in the western area to 3.55 $M \cdot m^{-2} \cdot year^{-1}$ on the southern coast and to 4.26 $M \cdot m^{-2} \cdot year^{-1}$ in the eastern water area, which corresponds to 1.05, 1.31, and 1.56 $\mu g\ O_2 \cdot cm^{-2} \cdot h^{-1}$.

The agreement between the given and previously obtained values of the total oxygen consumption by bottom sediments in the Kruglaya Bay allows us to assume a balanced state of this system. Despite rather intensive recreational use of the bay, the key role seems to be played by the hydrochemical regime and loose composition of sandy sediments, which ensure free oxygen penetration into their core. In general, unlike water masses, bottom sediments are a more conservative environment, and its inertness is smoothed by both seasonal and interannual fluctuations in hydrochemical parameters. In the bay, zones of reduced sediments with negative values of the redox potential (sulfurettes) were revealed. We recorded certain differences in the dynamics of reduced compounds (H_2S) between sediments of sulfurettes and adjacent oxidized areas. In sulfurettes, the calculated data on concentration, rate of oxidation, and formation of hydrogen sulfide were higher by 32, 29, and 57%, respectively.

Based on the experimentally obtained data on TOC, including that during oxidation of reduced compounds, we calculated possible rates of destruction of organic matter (Table 2). The sum of aerobic and anaerobic utilization of organic compounds turned out to be maximum, up to 4.05 $\mu g \cdot cm^{-3} \cdot h^{-1}$, in the Sevastopol Bay and the adjacent water area, with the anaerobic component accounting for a larger share. The share turned out to be quite high in the Kruglaya Bay as well, but there, aerobic destruction prevailed. This is due to differences in both the targeted use of the bays and the granulometric composition of bottom sediments. Loose sediments are usually more aerated, which determines the prevalence of the oxidative metabolism. Even in sulfurettes of sandy sediments in the Kruglaya Bay, the level of aerobic oxidation turned out to be as high as in the background point. At the same time, the intensity of anaerobic utilization of organic matter differed twofold, although its absolute values remained closer to the level characteristic of the coastal zones of open sea areas, in particular, the Belbek River paleochannel.

During vertical sounding of the sediment strata in the Cape Martyan area and in the Belbek River paleochannel, a rise was recorded in the ability to both aerobic and anaerobic destruction with depth, which naturally repeated the oxygen profile. Thus, in the Cape Martyan area, the values increased in the 0–3-cm layer from 1.93 to 2.70 and from 0.34 to 1.22 $\mu g \cdot cm^{-3} \cdot h^{-1}$, respectively. Absolute values of the oxidation rates of organic matter in the sediments of the Belbek River paleochannel were slightly lower, 1.02–1.98 $\mu g \cdot cm^{-3} \cdot h^{-1}$. Decomposition of organic matter due to sulfate reduction in the surface horizon turned out to be twice higher there; the value, forming a peak of 1.06 $\mu g \cdot cm^{-3} \cdot h^{-1}$ at a depth of 2 cm, dropped to 0.34 $\mu g \cdot cm^{-3} \cdot h^{-1}$. In the bottom sediments of the Sevastopol Bay, already in the surface layer, the rates of anaerobic destruction exceeded aerobic utilization of organic matter, reaching 1.97 *vs.* 1.61 $\mu g \cdot cm^{-3} \cdot h^{-1}$. So, larger variability is characteristic of the anaerobic component.

Oxygen penetration into the sediment layer deeper than 1 cm is usually very insignificant; in particular, in the Sevastopol Bay, the value is no more than 0.5 cm [Orekhova et al., 2013]. In this case, in the lack of oxygen, aerobic destruction of organic matter, in contrast to anaerobic one, almost stops in underlying sediment layers. Therefore, taking into account the intensity of anaerobic processes in the sediment core, we obtain an approximately equal, and sometimes even higher contribution of anaerobiosis to total destruction of organic matter. Sulfate reduction was found to contribute up to 50% of organic carbon mineralization in marine sediments [Jørgensen, 1982]. At the same time, it decomposes up to 99% of organic carbon consumed for sulfate reduction and methanogenesis [Karnachuk, 1989]. All this evidences the significance of the participation of sulfate reducers both in the global sulfur cycle and the carbon cycle.

Table 2. Content of organic matter and calculated rates of its aerobic and anaerobic destruction in the bottom sediments of coastal waters of Crimea

Sampling point	T, °C	Layer, cm	Organic matter, mg·cm^{-3}	Destruction of organic matter, μg·cm^{-3}·h^{-1}	
				aerobic	anaerobic
Dvuyakornaya Bay	+24	0–0.6	25	1.77	1.52
Cape Martyan	+24	0–0.6	17	1.93	0.34
		3–3.6	24	2.70	1.22
Belbek River paleochannel	+21	0–0.6	45	1.02	0.67
		2–2.6	54	1.98	1.06
		4–4.6	46	7.58	0.34
Chernaya River paleochannel	+20	Riverbed, 0–0.6	68	1.94	2.11
		Slope, 0–0.6	51	1.01	1.40
Sevastopol Bay	+21	0–0.6	60	1.61	1.97
Kruglaya Bay	+25	Background, 0–0.6	41	2.73	0.30
		Sulfurette, 0–0.6	34	2.52	0.69
Balaklava Bay	+19	0–0.6	61	3.18	–

Conclusion. Certain differences were registered between relatively closed bays and open sea areas in terms of the rate of oxygen consumption and, accordingly, the utilization of organic matter in bottom sediments. First of all, this results from the features in hydrology, sedimentation, and intensity of anthropogenic use of water areas. Specifically, depending on the level of anthropogenic load and the composition of bottom sediments, either aerobic destruction of organic matter prevails (as in the Kruglaya Bay), or anaerobic destruction (this is typical for the sediments of the Sevastopol Bay). In the Chernaya River paleochannel, a higher level of aerobic oxygen consumption and content of reduced compounds was revealed in contrast to its slopes. This can be explained by the prevalence of the processes of their formation over oxidation. Differences were recorded in the dynamics of reduced compounds (H_2S) between areas of reduced sediments (sulfurettes) and oxidized background ones. The calculated data on concentration, oxidation rate, and formation of hydrogen sulfide in sulfurette were higher by 32, 29, and 57%, respectively. In sulfurette, anaerobic destruction of organic matter is more than twice as intense, while there are no differences in the rate of oxidation. In the sediment core in the Cape Martyan area and in the Belbek River paleochannel, an increase with depth in the oxidative potential and a subsurface peak of anaerobic activity were established. At the same time, due to the limited diffusion of oxygen, the rate of hydrogen sulfide oxidation in the surface horizon and the layer-by-layer sum of the rates of its formation for the sediment core turned out to be comparable. For the same reason, the contribution of anaerobiosis processes to the destruction of organic matter is often equal to, and sometimes higher than the contribution of the aerobic pathway.

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СООТНОШЕНИЕ ПРОЦЕССОВ АЭРОБНОЙ И АНАЭРОБНОЙ ДЕСТРУКЦИИ ОРГАНИЧЕСКОГО ВЕЩЕСТВА В ДОННЫХ ОТЛОЖЕНИЯХ ПРИБРЕЖНЫХ АКВАТОРИЙ КРЫМА (ЧЁРНОЕ МОРЕ)

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Взаимосвязь водных масс с донными отложениями является очевидной, в первую очередь в вопросах формирования кислородного режима и, как следствие, самоочищения водоёмов. Зная скорость потребления кислорода, с помощью стехиометрических соотношений можно оценить ряд сопряжённых параметров энергетического обмена. Цель настоящей работы — посредством интерпретации данных кислородного потребления рассчитать возможный вклад аэробных и анаэробных процессов в деструкцию органических веществ в донных осадках различных районов крымского прибрежья Чёрного моря. Измерение суммарной скорости потребления кислорода проводили с помощью респирометрической камеры, герметично соединённой с кислородным датчиком LDO-оксиметра HQ40D. Для подавления бактериальной активности и выявления темпов окисления восстановленных продуктов анаэробиоза использовали антибиотик стрептомицин. Вертикальное зондирование толщи грунта в палеорусле реки Бельбек показало рост с глубиной окислительного потенциала и подповерхностный пик анаэробной активности. Вследствие ограниченной диффузии кислорода, скорость окисления сероводорода в поверхностном слое была сопоставима с темпами его образования в нижележащей толще грунта. Непосредственно на участке палеорусла реки Чёрная, прилегающем к устью Севастопольской бухты, донные отложения отличались от грунтов на склоне бóльшим уровнем аэробного потребления кислорода, а также содержанием восстановленных соединений, которое обусловлено более высокой скоростью их образования при относительно низких темпах окисления.

Поглощение кислорода единицей донной поверхности в 0,6-см слое осадков Севастопольской бухты в среднем составляло 2,18 мкг·см$^{-2}$·ч$^{-1}$. В бухте Круглая наблюдали различия по динамике восстановленных соединений (H_2S) между окисленными фоновыми участками и зонами восстановленных грунтов (сульфурет). В сульфуретах расчётные данные концентрации, темпов окисления и образования сероводорода выше на 32, 29 и 57 % соответственно. Максимальной, до 4,05 мкг·см$^{-3}$·ч$^{-1}$, скорость утилизации органического вещества была в Севастопольской бухте и в прилегающей к ней акватории. Бо́льшая доля приходилась на анаэробную составляющую. Достаточно высокой она оказалась и в бухте Круглая, но здесь преобладала аэробная деструкция. Это связано с различиями как в целевом использовании бухт, так и в гранулометрическом составе донных осадков. В грунтах сульфуреты при скорости окисления органических веществ, равной таковой фонового участка, анаэробная утилизация протекала более чем в 2 раза интенсивнее. Её абсолютное значение было ближе к уровню, характерному для прибрежных участков открытого моря, в частности для палеорусла реки Бельбек.

Ключевые слова: донные отложения, потребление кислорода, деструкция органического вещества, Чёрное море