RESEARCH PAPER

INFLUENCE OF QUARANTINE MEASURES AGAINST THE NEW CORONAVIRUS INFECTION COVID-19 ON THE STATE OF BLACK SEA COASTAL WATERS

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ABSTRACT. The Black Sea is one of the main recreational facilities in Russia subject to a high annual anthropogenic stress. Anthropogenic activity led to high coastal sea waters pollution, eutrophy, and endangered the sea's self-purification capabilities. The total quarantine introduced on the Black Sea coast of the Krasnodar territory associated with the new coronavirus infection COVID-19 pandemic led to a decrease in anthropogenic pressure on coastal ecosystems and provided a unique opportunity to trace the dynamics of the most important hydrochemical indicators of coastal waters in the Tuapse district. The study aimed to characterize the impact of quarantine measures against the coronavirus on the state of coastal waters in the eastern part of the Russian Black Sea. For this, we identified and characterized the hydrochemical indicators and determined the effect of quarantine measures on their dynamics. The study used the standardized methods. The results obtained showed that a decrease in the recreational stress led to a proportional decrease in the pollutants supply to coastal sea waters; with the recreational stress resumption the concentrations of mobile pollutants tended to increase; a proportional relationship was established between biochemical oxygen demand (BOD_5) and the ammonium nitrogen (NH_{4+}) concentration; the nitrates' (NO_3) concentration, in the seawater did not depend on the recreational stress degree. In particular, a proportional increase in NH_{4+} concentration and BOD_5 in seawater was detected: in the third quarter of 2019 the concentration of NH_{4+} and BOD_5 amounted to 3.0 mg/dm³ and 8.5 mg/dm³, and 3.8 mg/dm³ and 7.5 mg/dm³ in the fourth quarter, respectively; in the 2020 samples, a decrease in the NH_{4+} concentration to 0.8 mg/dm³ in the third and to 1.2 mg/dm³ in the fourth quarter led to a proportional decrease in BOD_5 4.5 mg/dm³ and 3.9 mg/dm³, respectively. Thus, it was shown that the quarantine measures were shown to have a positive effect on the processes of self-purification of coastal sea waters in recreational zones.

KEYWORDS: COVID-19, quarantine restrictions, sea waters' hydrochemical indicators, pollutants concentration, recreational areas, recreational stress, seawater's self-purification capabilities

INTRODUCTION

Currently, entering biological and chemical polluting components, including their derivatives, into the general circulation of substances threatens the self-purification capabilities of many water areas. This is due to an increase in the technogenic and anthropogenic recreational stress on the coast, which significantly outstrips the rate of biodestructors increase and distribution (Volkova et al. 2016; Gura et al. 2020). The greatest damage to the Black Sea is caused by pollution of rivers flowing into it. These rivers contain sewage and rainwater, petroleum products, cement dust, and chemicals' residues used in construction (Gogoberidze 2010; Matishov et al. 2015; Aleynikova et al.

2019). Nitrogen and phosphorus compounds enter the river runoff from household and industrial sources with fertilizers and detergents (Kosyan and Krylenko 2014, 2019). The coastal recreational area is polluted by accidental petroleum products spills occurring in the open part of the water area (Temirov et al. 2019; Antipceva et al. 2019).

Constant monitoring of the Black Sea water area state in the coastal zone conducted at the stations of the Federal Service for Hydrometeorology and Monitoring of the Environment State (Rosgidromet) (Chasovnikov et al. 2019) makes it possible to reveal some hydrochemical markers' indicating the role of the state of seawater and its self-purification capabilities in starting these processes and their dynamics. The stations are located in coastal areas

with a maximum anthropogenic stress. They collect and analyze operational information on the pollution sources in the sea area and river mouths and assess the dynamics of hydrochemical and other parameters both throughout the year and over a long period. The Rosgidromet stations monitor the entire Russian Federation Black Sea coastal area and the largest estuaries on the coast, where industrial and domestic wastewater flows and from where it spreads (Krylenko et al. 2010; Zavyalov et al. 2014; Kostyleva 2015). The main quality indicators of the Black Sea coastal waters include the content of phosphates, nitrates, silicon and iron compounds, ammonium nitrogen, dissolved mercury, petroleum products, and synthetic surfactants (Korshenko 2016; Sergin et al. 2018). Exceeding the maximum concentration limit (MCL) for the above products (established in accordance with the standards of the Interstate Council for Standardization, Metrology, and Certification (ISC) and International Standardization Organization(ISO)), along with changing oxygen concentration in the surface water, cause fluctuations in number of dissective organisms and their activity, intensity of the organic substances formation and decomposition processes and, as a consequence, a decrease in the seawater's self-purification capabilities (Mironov et al. 1975; Korshenko 2020).

A decrease in the technogenic and anthropogenic recreational stress should maintain the main MCL indicators for the Black Sea coastal part within acceptable limits and contribute to restoration and acceleration of the seawater's self-purification capabilities (Arakelov et al. 2019). The pandemic of the new coronavirus infection COVID-19, which began at the end of 2019, has become one of the most important factors on a planetary scale, which had an inhibitory effect on the numerous sectors of global economy. The infection forced the people in the whole world to change their way of life. Many countries closed their borders and enterprises, transport traffic dropped sharply, people were called on self-isolation in their homes. Such a change in people's way of life and entire states influenced all life spheres on our planet, changed the environment. Russia was no exception, including the Krasnodar territory, which closed its borders and recreational areas on the coast of the Black Sea on March 31, 2020. Since the Black Sea is one of the main recreational facilities in Russia, the pandemic and the associated restrictive measures had a particularly strong negative impact on the resort and recreational industry state in the region. But in natural and ecological terms, this decreased anthropogenic pressure on coastal ecosystems, in particular, on the Black Sea coastal water area (RuNews24.ru). The introduced total quarantine on the Black Sea coast of the Krasnodar territory lasting from April to July 15, 2020 provided a unique opportunity to trace the hydrochemical indicators dynamics of coastal waters in the Tuapse district.

The research aim was to characterize the impact of quarantine measures against the coronavirus infection on the state dynamics of coastal waters in the Russian Black Sea eastern part within the Krasnodar territory's coast (the case of coastal waters in the Tuapse district). For this, we determined the concentrations of the most important hydrochemical indicators and assessed the impact of quarantine measures on their dynamics.

MATERIALS AND METHODS

The work was performed in the analytical chemical laboratory for environmental monitoring at the Affiliated Branch of the Russian State Hydrometeorological University (RSHU). Analysis of seawater samples and hydrochemical surveys were conducted on a quarterly basis according to the Standards of the Interstate Council for Standardization, Metrology, and Certification (ISC) and International Organization for Standardization (ISO); state standards of the Russian Federation; Management Directives (MD) and Federal Environmental Regulations (FER) of the Russian Federation Ministry for Environment Protection and Natural Resources, Russian Federation State Committee for Environment Protection (Arakelov et al. 2018). Water samples were taken directly in the recreational coastal areas confined to river mouths in the study areas. Hydrochemical indicators did not exceed the maximum concentration limit (MCL) (Korshenko 2020). In 2020, the hydrochemical indicators analysis could be conducted in the Tuapse region only due to the quarantine restrictions – the other Black Sea coastal waters monitoring points did not function.

The indicators were analyzed according to ISO 31861–2012: Water. General requirements for sampling and included biological oxygen demand (BOD_5); contents of ammonium nitrogen (NH_{4+}), total iron (Fe_{3+}), suspended substances, nitrates (NO_{3-}), petroleum hydrocarbons, and synthetic surfactants (Akhsalba and Marandidi 2021).

In the work, we used the following methods: gravimetric method for determining suspended substances and total content impurities in water and gravimetric method for measuring their mass concentration (MD 52.24.468-2005), jar method for estimating biochemical oxygen demand (BOD_5) in waters (MD 52.24.420-2006) (Tserenova and Muzalevsky 2015), photometric method for measuring mass concentration of ammonium nitrogen (NH_{4+}) in sea waters (MD 52.10.772-2013) (Akhsalba and Ekba 2017), photometric method for measuring indophenol blue NO_{3-}, quantitative chemical analysis of waters (ER F 14.1:2.4-95), photometric method for measuring mass concentration of nitrate ions in natural and waste water with salicylic acid and mass concentration of total iron (Fe_{3+}) and 1.10-phenanthroline in waters (MD 52.24.358-2006), extraction-photometric method for measuring mass concentration of synthetic surfactants and anion synthetic surfactants in water (MD 52.24.368-2006), and method for detecting them (LEKI SS2107 spectrophotometer, Republic of Korea), quantitative chemical analysis of waters and fluorometric method for measuring mass concentration of petroleumproducts in natural, drinking, and waste waters (ER F 14.1:2:4.128-98), and fluorophotometric method for estimating petroleum hydrocarbons content (FLUORAT 02, LUMEX, Russia) (Akhsalba 2018).

RESULTS

Fig. 1–4 show the assessment of the correspondence of the hydrochemical indicators of the seawater quality to their MCL.

A decrease in the recreational press in the research period of 2020 led to a reduction in the intake of pollutants into coastal sea waters – for all the estimated indicators, the concentrations approached the MCL values. The content of the petroleum derivates, nitrates (NO_{3-}), and suspended solids indicated a decrease in concentrations to a level below the MCL (Fig. 1–4).

Quarantine restrictions imposed on July 15, 2020 and the recreational stress resumption on the coast increased the concentrations of the most mobile pollutants in seawater: petroleum derivates and ammonium nitrogen (NH_{4+}) (Fig. 1a, 2a).
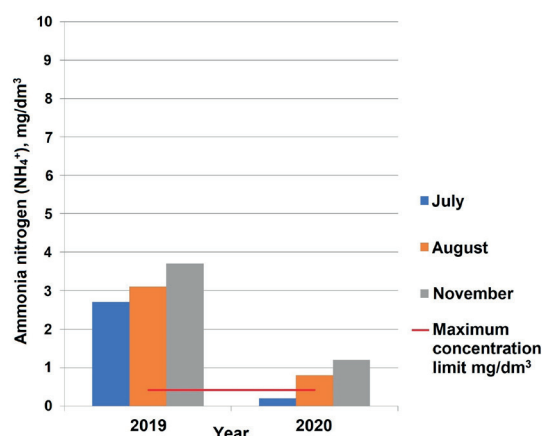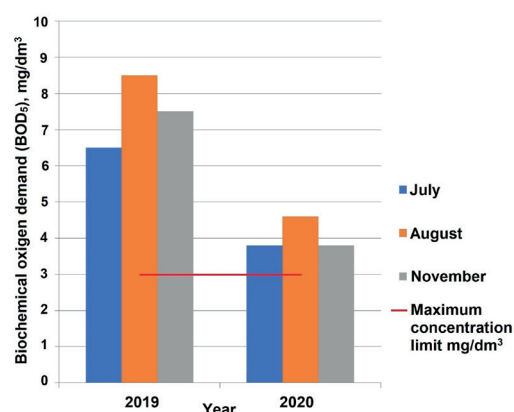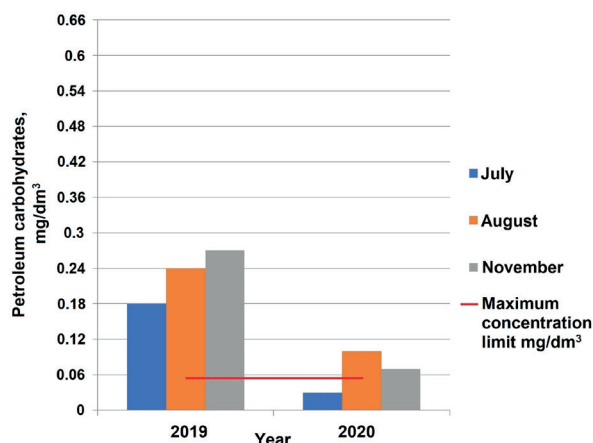
Fig. 1. Concentration dynamics of ammonium nitrogen (NH$_{4+}$) (a) and biochemical oxygen demand (BOD$_5$) (b) in seawater during periods of medium, minimum, and renewed recreational stress on the Black Sea coastal waters in the Tuapse district of the Krasnodar territory

We revealed a proportional increase in NH$_{4+}$ concentration and BOD$_5$ in seawater: in the third quarter of 2019 the concentration of ammonia nitrogen and BOD$_5$ amounted to 3.0 mg/dm^3 and 8.5 mg/dm^3, and 3.8 mg/dm^3 and 7.5 mg/dm3 in the fourth quarter, respectively; in the 2020 samples, a decrease in the NH$_{4+}$ concentration to 0.8 mg/dm^3 in the third and to 1.2 mg/dm^3 in the fourth quarter led to a proportional decrease in BOD5 up to 4.5 mg/dm^3 and 3.9 mg/dm^3, respectively (Fig. 1).

The amount of petroleum derivates and suspended substances entering the seawater depended on the recreational stress onto the coast – imposition of quarantine measures coincided with a sharp decrease in the concentrations of the both indicators below the MCL: to 0.03 mg/dm^3 in July 2020 for petroleum derivates and 4 mg/dm^3 in August 2020 for suspended substances (Fig. 2).

A similar trend was noted in the total iron (Fe$_{3+}$) and synthetic surfactants concentrations' dynamics: with a decrease in the recreational stress on the coast due to imposing quarantine measures, the above substances concentrations decreased by 2–5 and 2–9 times, respectively (Fig. 3).
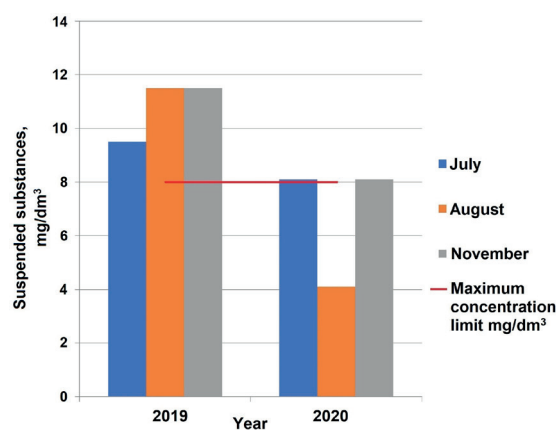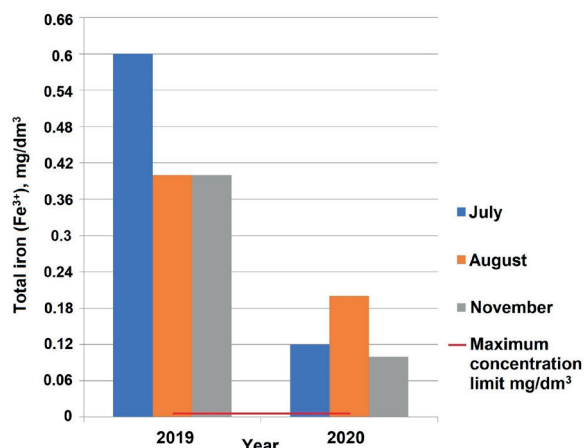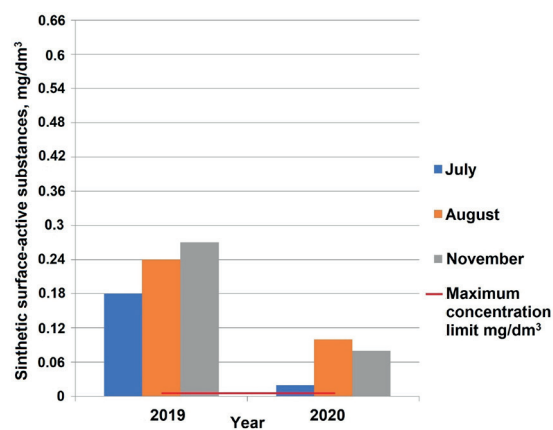

Fig. 2. Concentrations dynamics of petroleum products (a) and suspended solids (b) in seawater during periods of medium, minimum, and renewed recreational stress on the Black Sea coastal waters in the Tuapse district of the Krasnodar territory

Fig. 3. Concentrations dynamics of total iron (Fe$_{3+}$) (a) and synthetic surfactants (b) in seawater during periods of medium, minimum, and renewed recreational stress on the Black Sea coastal waters in the Tuapse district of the Krasnodar territory

Fig. 4. Concentrations dynamics of nitrates (NO$_{3-}$) in seawater during periods of medium, minimum, and renewed recreational stress on the Black Sea coastal waters in the Tuapse district of the Krasnodar territory
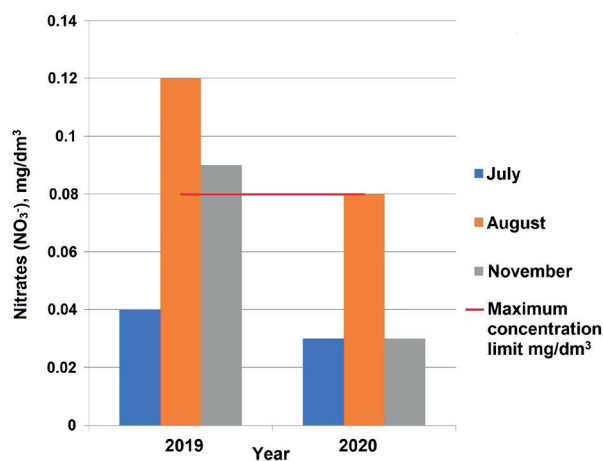
In contrast to the abovementioned hydrochemical indicators, the quarantine measures did not have such a significant impact to the nitrates (NO$_{3-}$), although there is a tendency to decrease it (Fig. 4).

DISCUSSION

The seawater's self-purification capabilities is an important indicator of its state sustainability. Identifying the factors that determine such a state and its dynamics makes it possible to assess the Black Sea coastal water area self-purification capabilities (Ostroumova 2008; Baskakova et al. 2012). The hydrochemical indicators investigated during the periods of maximum, minimum, and renewed recreational stress of the Black Sea coastal waters in the Tuapse district of the Krasnodar territory revealed tendencies in the biodegradants development from eutrophy (BOD$_5$ = 3 MCL) to restoring seawater's self-purification capabilities (BOD$_5$ = MCL). Establishing a proportional relationship between biochemical oxygen demand (BOD$_5$) and the ammonium nitrogen (NH$_{4+}$) mobile forms concentration revealed the indicator function of these jointly considered parameters in assessing the possibilities of seawater's self-purification capabilities and the risks of developing its eutrophy (Dolgova-Shkhalakhova et al. 2020). We established a positive effect of quarantine measures on the sea coast state, since compared to the hydrochemical indicators of the most unfavourable 2019 year, the ecological state of the Black Sea coastal waters in the Tuapse region has improved (Gitsba and Ekba 2019; Dolgova-Shkhalakhova et al. 2020;). We established that

the coastal recreational stress contributes to the seawater pollution with petroleum products. Despite the fact that the petroleum refineries in the Tuapse city worked at full capacity during periods of medium, maximum, minimum, and renewed recreational stress, imposition of the quarantine measures coincided with a sharp drop in the petroleum derivates concentration in the test samples. When the quarantine measures were cancelled, the petroleum derivates began to increase (Temirov et al. 2019; Arakelov et al. 2020).

CONCLUSIONS

Based on the results of the hydrochemical analysis conducted in 2020 and their comparison with the results of 2019, it was established that:
1. a decrease in the recreational stress led to a proportional decrease in the pollutants supply to coastal sea waters, which concentration reached the MCL level and below;
2. with the recreational stress resumption on the coast, the concentrations of the most mobile polluting components in seawater (petroleum derivates and ammonium nitrogen) tended to increase;
3. a proportional relationship has been established between biochemical oxygen demand (BOD$_5$) and the ammonium nitrogen (NH$_{4+}$) mobile forms concentration;
4. the amount of petroleum derivates and suspended solids entering the seawater is proportional to the recreational stress on the coast;
5. the nitrates' (NO$_{3-}$) concentration in seawater does not depend on the recreational stress on the coast. ■

REFERENCES

Akhsalba A.K. (2018). Chemical composition of atmospheric precipitation in Sukhum, Republic of Abkhazia, Bulletin of the Luhansk National University named after Vladimir Dal, 5 (11), 175-179 (in Russian with English summary).

Akhsalba A.K., Ekba Ya.A. (2017). Statistical analysis of the chemical composition of atmospheric precipitation in Sukhum, Republic of Abkhazia. Bulletin of the Krasnodar regional branch of the Russian Geographical Society, Krasnodar regional branch of the All-Russian public organization «Russian Geographical Society». Krasnodar: Platonov Igor, 54-59 (in Russian).

Akhsalba A.K., Marandidi S.I. (2021). Dynamics of carbon dioxide and oxygen content in the coastal waters of the Black Sea. Fundamental and applied aspects of geology, geophysics, and geoecology using modern information technologies, Proceedings of the VI International Scientific and Practical Conference, 31-38 (in Russian).

Aleynikova A.M., Lipka O.N., Krylenko M.V. (2019). Landscape structure of coastal cliffs of the Black Sea coast of the Caucasus, Bulletin of the Peoples' Friendship University of Russia. Series: Ecology and life safety, 27, 4, 298–306 (in Russian), DOI: 10.22363/2313-2310-2019-27-4-298-306.

Antipceva J., Volkova T., Lipilin D., Yarotskaya E. (2019). Tourist potential of specially protected areas of the Black Sea coast. 14th MEDCOAST Congress on Coastal and Marine Sciences, Engineering, Management, and Conservation, MEDCOAST 2019, 1, 233-240.

Arakelov M.S., Akhsalba A.K., Dolgova-Shkhalakhova A.V., Lipilin D.A., Yayli E.A. (2020). Hydrochemical indicators of waters in recreational zones of the Black Sea coast of Krasnodar territory and the Republic of Abkhazia, Advances in current natural sciences, 3, 50–56 (in Russian with English summary), DOI: 10.17513/use.37345.

Arakelov M.S., Akhsalba A.K., Gogoberidze G.G., Dolgova-Shkhalakhova A.V., Giba R.Yu., Yaili E.A. (2018). Analysis of geomorphological and geo-ecological condition and natural and anthropogenic risks reducing the resilience of coastal systems in the Eastern part of the Black Sea, Advances in current natural sciences, 12-2, 333-338 (in Russian with English summary).

Arakelov M.S., Dolgova-Shkhalakhova A.V., Merzakanov S.A., Akhsalba A.K. (2019). Assessing natural and anthropogenic risks of reducing the stability of coastal systems in the eastern part of the Black Sea in the context of recreational coastal management, Resorts. Service. Tourism, 1(42), 88-94 (in Russian with English summary).

Baskakova T.E., Aleksandrova Z.V., Belousova E.F., Dmitrienko V.M., Shevtsova E.A. (2012). Interannual and seasonal variability of hydrochemical indicators of the water in the north-eastern part of the Black Sea, The main problems of fisheries and the protection of fisheries reservoirs of the Azov-Black Sea basin. Collection of scientific papers (2010–2011), Rostov-on-Don: Azov Scientific Research Institute of Fisheries, 41-53 (in Russian with English summary).

Chasovnikov V.K., Zhu V.P., Chasovnikova L.A. (2019). Coastal-marine studies of the hydrochemical structure of waters in the monitoring section in the north-eastern part of the Black Sea, Modern problems of hydrometeorology and sustainable development of the Russian Federation, Collection of abstracts of the All-Russian scientific and practical conference, Saint Petersburg: RSHU, 428-429 (in Russian).

Dolgova-Shkhalakhova A.V., Arakelov M.S., Akhsalba A.K., Marandidi S.I. (2020). Hydrochemical indicators of the Black Sea waters in the Tuapse district from July to November 2020, Proc. of II Russian-Abkhaz Int. Res Pract. Seminar «the Black Sea coast: ecological guidelines in the present environmental trends – sustainable development in the future», Tuapse, 43-45 (in Russian).

Gitsba Ya.V., Ekba Ya.A. (2019). Hydrophysical processes in the Abkhaz Black Sea, Reports of Russian scientific and technical society of radio engineering, electronics, and communication named after A. S. Popov, Proceedings of the International Symposium. Ser. «Scientific International symposia. Engineering ecology», Moscow, 237-242 (in Russian with English summary).

Gogoberidze G.G. (2010). Methodology and methods for assessing the marine potential of coastal territories. Doctoral thesis in Economics. Moscow, 553 (in Russian).

Gura D.A., Gura A.Y., Volkova T.A., Lipilin DA (2020). Recreational space as a factor of sustainable development of coastal geosystems of the Krasnodar region. IOP Conference Series: Earth and Environmental Science, 579(1), 012007, DOI: 10.1088/1755-1315/579/1/012007.

Korshenko A.N. (2016). Quality of sea waters according to hydrochemical indicators. Annual 2015, Moscow: Nauka (in Russian).

Korshenko A.N. (2020). Quality of sea waters according to hydrochemical indicators. Annual 2019, Moscow: Nauka (in Russian).

Kostyleva A.V. (2015). Distribution of dissolved organic carbon in river mouth areas of the Greater Sochi region (north-eastern part of the Black Sea), Oceanology, 55, 2, 200-206 (in Russian), DOI: 10.7868/S0030157415020082.

Kosyan R.D., Krylenko M.V. (2019). Modern state and dynamics of the Sea of Azov coasts. Estuarine, Coastal and Shelf Science, 224, 314-323. DOI: 10.1016/j.ecss.2019.05.008.

Kosyan R.D., Krylenko V.V. (2014). Modern state of the marine accumulative coasts of the Krasnodar territory and the use of them. Moscow: Scientific world, 256 (in Russian).

Krylenko M.V., Isupova M.V., Dzaganiya E.V. (2010). Modern morpholithodynamics of estuarine seaside of the river Mzymta (Black Sea coast of Russia), Proceedings of the XXIII international coastal conference «the Doctrine of the development of sea shores: age-old traditions and ideas of modernity». Saint-Petersburg: RSHU, 222-224 (in Russian).

Matishov G.G., Stepanyan O.V., Grigorenko K.S., Kharkiv V.M., Povazhny V.V., Soyfer V.G. (2015). Features of the hydro-hydrochemical regime of the Azov and Black seas in 2013, Bulletin of the Southern Scientific Center of the Russian Academy of Sciences, 11, 2, 36-44 (in Russian with English summary).

Mironov O.G., Kiryukhina L.N., Kucherenko M.I., Tarkhova E.P. (1975). Self-cleaning in the coastal waters of the Black Sea, Kiev, 143 (in Russian).

Ostroumov S.A. (2008). Hydrobionts in the self-purification of waters and biogenic migration of elements. Moscow: MAKS Press, 197 (in Russian).

RuNews24.ru, (2020). Environmental impact of the COVID-19 pandemic, [online] The official site of the information agency «RuNews24. ru». Available at: https://runews24.ru/society/08/04/2020/71eb28sb6ad15457bfb5840e2779036a [Accessed July 25, 2021].

Sergin S.Ya., Tsai S.N., Magulyan A.O., Zemtsov R.V. (2018). Moderate and subtropical climate types of the Azov-black sea basin, Scientific notes of the Russian state Hydrometeorological University, 51, 58-62 (in Russian with English summary).

Temirov D.S., Ibragimov K.Kh., Konstantinidi Kh.A. (2019). Tourist and recreational sphere potential in the context of new goals of the state policy for the region socio-economic development. Krasnodar: Publishing House – South (in Russian).

Tserenova M.P., Muzalevsky A.A. (2015). Complex geo-ecological assessment of urbanized territory in the coastal zone. Ecological and economic aspects, Scientific notes of the Russian state Hydrometeorological University, 38, 189-200 (in Russian with English summary).

Volkova T.A., Filobok A.A., Belikov M.Yu., Pinchuk D.S., Kalustova I.S. (2016). Sustainable development and vulnerability of coastal geosystems of the Azov-Black Sea coast of the Krasnodar territory, Proc. of the VI Int. Res. and Pract. Conf. «Ecology and nature management: applied aspects», Ufa, 82-89 (in Russian with English summary).

Zavyalov P.O., Makkaveev P.N., Konovalov B.V., Osadchiev A.A., Khlebopashev P.V., Pelevin V.V., Grabovsky A.B., Izhitsky A.S., Goncharenko I.V., Soloviev D. M., Polukhin A. A. (2014). Hydrophysical and hydrochemical characteristics of marine waters near the mouths of small rivers of the Russian Black Sea coast, Oceanology, 54(3), 293 (in Russian), DOI: 10.1134/S0001437014030151.