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Original article

Chemical Composition of Water and Bottom Sediments in the Beysug Estuary of the Sea of Azov (Based on Field Studies, 2018)

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Abstract
Purpose. The purpose of the study is to present the geochemical characteristics of the Beysug Estuary (the Sea of Azov) based on the data obtained during field studies of the chemical composition of water and bottom sediments in spring, summer and autumn of 2018.
Methods and Results. Water and bottom sediments were sampled in the western part of the estuary under calm weather conditions. The chemical composition of water was assessed using the following parameters: major ions (chlorides, sulfates, bicarbonates, magnesium, calcium, sodium, and potassium), nutrients (total nitrogen and its mineral forms, total phosphorus and phosphate phosphorus), petroleum products, organic matter, metal compounds (iron, copper, zinc, lead, cadmium, nickel, arsenic, chromium, mercury), phenols, benzo(a)pyrene, and synthetic surfactants. The grain-size composition of bottom sediments, as well as the mass fractions of sulfate ions, phosphate ions, petroleum products and phenols in the sediments, was determined. The obtained results indicate that, during the field research period, the ionic composition of the water in the studied area of the estuary (salinity ranged from 16.0 to 18.1) was stable. The concentrations of the studied forms of nitrogen and phosphorus exhibited pronounced seasonal variability (except for nitrite nitrogen). A similar trend was characteristic of petroleum products and organic matter. Slight exceedances of the maximum permissible concentrations were noted for readily oxidizable organic matter (BOD_5) (by 1.5–1.6 times), iron compounds (by 1.3–5.2 times), petroleum products (by 1.5–1.8 times) and ammonium ions (by 1.6 times). In most cases, trace element concentrations in water were below the detection limits of the applied analytical methods. The grain-size composition of bottom sediments showed a predominance (> 60%) of the aleurite-pelitic fraction (0.01–0.05 mm). The concentrations of petroleum products and phenols in the bottom sediments exhibited variability, while those of sulfate ions and phosphate ions remained relatively stable.
Conclusions. The geochemical parameters of water and bottom sediments in the Beysug Estuary are mainly determined by the prevailing hydrometeorological conditions, which govern the patterns of pollutant migration and accumulation.

Keywords: pollution, wetlands, chemical composition, heavy metals, nutrients, bottom sediments, eastern Azov region

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Introduction

In 2025, the Government of the Russian Federation approved the Strategy for Sustainable Development of the Azov Region up to 2040 and an action plan for its implementation [1]. As stated in the document, environmental monitoring is one of the tasks aimed at achieving the goal set out in this strategy.

In the context of hydrological and anthropogenic transformations in the eastern Azov region over recent decades, the accumulation of *in situ* data and the study of the chemical composition of water and bottom sediments in the region's water bodies are of particular relevance. The Beysug Estuary is the largest lagoon in the Sea of Azov (272 km²). Its functioning is determined by a complex balance of seawater inflow, freshwater input from the catchment area, and evaporation under shallow-water conditions [1]. The Beysug River, which provides almost the entire volume of freshwater inflow to the estuary, is significantly regulated by artificial ponds, which disrupt the natural water-salt balance of the water body and affect its biogeochemical cycles, ecosystem productivity, and the habitat conditions of aquatic organisms [2, 3].

The Beysug Estuary plays an important ecological role in maintaining the biodiversity of wetlands of both regional and international importance, serving as an area for the conservation and natural reproduction of birds, fish, and plants, including rare species [2] [4]. Elevated levels of pollutants in water and bottom sediments can have a negative impact on the food resources of fish and avifauna through changes in the state of planktonic and benthic communities. This can also create risks for the spawning grounds of valuable commercial fish species and negatively affect the stability of the food web.

The purpose of the study was to investigate the chemical composition of water and bottom sediments in the Beysug Estuary based on field data collected in 2018.

Materials and methods

Field studies were carried out in the western part of the Beysug Estuary (on the eastern side of the Yasenskaya Spit) at three observation stations (Fig. 1). Sampling was performed under calm weather conditions, which prevented the resuspension of bottom sediments, during summer (June 5 and August 8) and autumn (October 1) 2018.

Water temperature, pH, and dissolved oxygen content were determined on board the boat within a few minutes of sampling. Recent information on the composition of water and bottom sediments in the Beysug Estuary is scarce. To facilitate comparison between the results presented in this paper and those of future studies, information on the applied methods is provided below.

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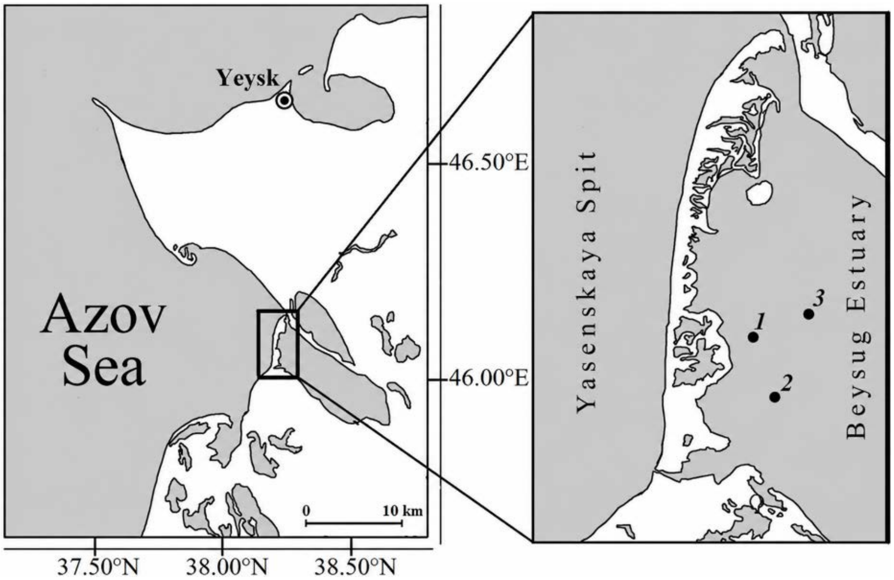
[1] Decree of the Government of the Russian Federation No. 4140-r of 29 December 2025. [*On Approval of the Strategy for Sustainable Development of the Azov Region up to 2040 and an Action Plan for Its Implementation*], 21 p. (in Russian).

[2] Zamotailov, A.S. and Lokhman, Yu.V., eds., 2017. *Red Data Book. Animals*. Krasnodar: Krasnodar Krai Administration, 720 p. (in Russian).



F i g. 1. Study area, indication of field observation points. Adapted from [5]

Water analysis was carried out using the methods specified in the following regulatory documents: salinity (RD 54.10.243-92); mineral forms of nitrogen (GOST 33045-2014); total nitrogen (RD 52.24.364-2007); total phosphorus (RD 52.24.387-2006); phosphate phosphorus (RD 52.24.382-2006); chlorides (PND F 14.1:2:3.96-97, ed. 2016 and GOST 31867-2012); sulfates (GOST 31867-2012); bicarbonates (GOST 31957-2012); magnesium, calcium, sodium, and potassium (GOST 31957-2012); suspended solids (PND F 14.1:2:3.110-97); chemical oxygen demand – COD (GOST 31859-2012); biochemical oxygen demand – BOD_5 (PND F 14.1:2:3:4.123-97); total iron (PND F 14.1:2:4.50-96); copper, lead, zinc, nickel, arsenic, total chromium, cadmium, and mercury (PND F 14.1:2.253-09); petroleum products (PND F 14.1:2:4.128-98, ed. 2012); total phenols (PND F 14.1:2:4.182-02); benzo(a)pyrene (PND F 14.1:2:4.186-02); and synthetic surfactants (PND F 14.1:2.247-07).

Since the Beysug Estuary can be classified as a water body of the highest fishery category [6], the obtained analytical results were compared with the maximum permissible concentrations (MPCs) for water bodies of fishery importance [3] to assess the degree of water pollution.

Analysis of bottom sediments was carried out using the methods specified in the following regulatory documents: petroleum products (PND F 16.1:2.21-98); volatile phenols (PND F 16.1:2.3.3.44-05); sulfate ions (PND F 16.1:2.2.2.3.53-08); and phosphate ions (PND F 16.1:2.2.2.3.52-08). The grain-size composition was determined according to GOST 12536-79.

[3] Order of the Federal Agency for Fishery (Rosrybolovstvo) No. 296 of 26 May 2025. [*On Approval of Water Quality Standards for Water Bodies of Fishery Importance, Including Standards for Maximum Permissible Concentrations of Pollutants in Waters of Water Bodies of Fishery Importance*], 120 p. (in Russian).

Results and discussion

Chemical composition of water

The chemical composition of water in the Beysug Estuary exhibited pronounced seasonal variability in several parameters (Table 1).

Table 1

Ranges and mean values of water quality parameters in the Beysug Estuary based on field observations in 2018

Parameter	June 5	August 30	October 1
pH	7.9–7.9/7.9	7.9–8.2/8.1	7.9–8.3/8.1
Transparency, cm	38.6–41.6/40.0	14.0–16.0/15.3	19.9–20.3/20.1
Suspended matter, mg/L	49–54/51	42–44/43	262–302/278
Salinity, ‰	16.0–16.0/16.0	17.8–17.8/17.8	17.6–18.5/18.1
O_2, mg/L	7.0–7.0/7.0	7.9–9.1/8.5	6.0–6.6/6.3
O_2, %	85–91/89	91–107/98	85–92/88
Total dissolved solids, g/L	15.8–15.9/15.8	17.8–17.8/17.8	17.6–18.5/18.0
Cl^-, g/L	> 5.00	> 5.00	8.68–9.11/8.89
SO_4^{2-}, g/L	1.37–1.37/1.37	1.37–1.62/1.54	1.41–1.57/1.48
HCO_3^-, mg/L	171–171/171	183–207/191	207–220/211
Na^+, g/L	> 5.00	4.73–4.86/4.80	4.40–> 5.00
Mg^{2+}, mg/L	564–566/565	598–644/621	538–652/605
Ca^{2+}, mg/L	204–204/204	209–226/218	212–219/214
K^+, mg/L	172–177/175	145–154/149	175–242/202
N_{total}, mg/L	13.7–14.0/13.8	12.8–13.1/13.0	8.80–10.4/9.60
NO_3^-, mg/L	13.4–13.7/13.5	12.6–12.9/12.8	8.70–10.3/9.5
NH_4^+, mg/L	0.28–0.28/0.28	0.19–0.71/0.43	0.78–0.78/0.78
NO_2^-, mg/L	0.006–0.008/0.007	< 0.005	< 0.005
P_{total}, mg/L	0.038–0.043/0.040	0.036–0.045/0.040	0.028–0.029/0.028
PO_4, mg/L	0.031–0.037/0.035	0.030–0.040/0.034	0.022–0.025/0.024
Petroleum products, mg/L	0.026–0.033/0.029	0.077–0.090/0.084	0.027–0.039/0.035
COD, mgO_2/L	26–27/26	15.0–15.2/15.1	> 80
BOD_5, mg/L	4.4–4.7/4.6	2.5–2.7/2.6	2.9–3.3/3.2
Fe, mg/L	0.10–0.11/0.10	0.15–0.24/0.20	0.46–0.69/0.56
Cu, mg/L	< 0.0010	< 0.0010–0.0032	< 0.003–0.0031
Pb, mcg/L	< 2.0	< 2.0–4.9	< 2.0–2.8
Cd, mcg/L	< 0.20	< 0.20–0.50	0.20–0.60/0.40

Water temperature varied seasonally, reaching 16 °C in June and a maximum of 23 °C in August. In October, the temperature dropped to 16 °C. Water transparency in June ranged from 38 to 41 cm, whereas a noticeable decrease was recorded in August and October owing to the active growth of phytoplankton in the water column. The water remained slightly alkaline (pH = 7.9–8.3) throughout the field observation period; this range complies with the standard for water bodies of fishery importance (pH = 6.5–8.5). The concentration of dissolved oxygen in the water ranged from 6.0 to 9.1 mg/L (with a minimum standard of 6 mg/L). As a result of photosynthetic supersaturation, oxygen saturation reached a maximum in summer (up to 107%).

The ionic composition of the water remained stable over time, with no significant variation observed. The sum of ions (mineralisation) varied from 15.8 g/L in June to 17.6–17.8 g/L in August and decreased to its initial level in October. The increase in mineralisation in summer was attributed to the evaporative concentration of salts under conditions of seasonally reduced water exchange at high temperatures [7, 8].

Despite the inflow of freshwater runoff from the catchment, the salinity and ionic composition of the estuary water are similar to those of the Sea of Azov, regardless of the sampling season [9, 10]. In summer, the concentrations of chloride and sodium periodically exceeded the upper detection limits of the methods used (> 5.00 g/L). Therefore, in October, chloride was analysed using a different method (GOST 31867-2012), which enabled its concentration in the water to be determined. In most cases, the concentrations of major ions complied with the standard established for water bodies with a salinity of 12–18‰ [3].

The seasonal variation in the nitrogen concentrations in the water is noteworthy. *Total nitrogen* concentration decreased from June to August by 70–80% and then increased significantly in October relative to the values recorded in August. The *nitrate ion* concentration in the water decreased from June to October (by 30%), indicating its significant consumption or transformation. The *ammonium ion* concentration, on the contrary, increased from June to October by a factor of 2.3, which may reflect the intensification of organic matter mineralisation processes. The *nitrite ion* concentration remained relatively low, indicating its active involvement in redox transformations. The nitrate and nitrite ion concentrations in the water did not exceed the MPCs of 40 and 0.08 mg/L, respectively, throughout the entire observation period. At the same time, the mean ammonium ion concentration across the observation stations exceeded the MPC (0.50 mg/L) in autumn. The *total phosphorus* concentration was relatively stable in summer but decreased by 30% in October. A similar pattern was observed for *phosphate phosphorus*, which may be associated with its consumption by aquatic organisms and migration into bottom sediments. The *phosphate phosphorus* concentration in the water slightly exceeded the MPC of 0.20 mg/L established for eutrophic water bodies, but a comprehensive study of the trophic status of the Beysug Estuary is required for a more objective assessment.

Petroleum product contamination of the water exhibited significant seasonal variability. The degree of contamination of the estuary water was comparable to that in the waters of the Sea of Azov during the same period [11]. The concentration of petroleum products increased on average by a factor of 2.9 from June to August, after which it decreased in October relative to the August values, while remaining somewhat above the initial level. The *chemical oxygen demand* decreased by more than 40% in August, but increased several-fold by October, indicating a sharp increase in the concentration of organic matter. *Biochemical oxygen demand* decreased by more than 40% from June to August and then increased by 20–30% in October. The mean *total iron* concentration across the observation stations gradually increased relative to the initial level. The concentrations of *copper*, *lead*, and *cadmium* in the water showed little variation over time. No MPCs exceedances were detected.

In some cases, the maximum permissible concentrations were exceeded for readily oxidizable organic matter (as indicated by BOD_5), total iron, and petroleum products by factors of 1.5–1.6, 1.3–5.2, and 1.5–1.8, respectively.

The concentrations of other pollutants analysed in all samples were below the detection limits of the applied methods and did not exceed the MPCs: zinc, nickel, and arsenic (< 0.0050 mg/L); synthetic surfactants (< 0.10 mg/L); total chromium (0.0025 mg/L); mercury (< 0.010 μg/L); phenols (< 0.0005 mg/L); and benzo(a)pyrene (< 0.0005 μg/L).

Bottom sediments

Bottom sediments are capable of accumulating dissolved and suspended substances, reflecting both the background state of the environment and its anthropogenic disturbance. Owing to the highly variable water-salt and oxygen regimes in shallow wetlands, secondary pollution of the aquatic environment may occur [12, 13].

The sediments of the Beysug Estuary are mainly represented by pelitomorphic limestones with inclusions of shell limestone. The *grain-size composition* of bottom sediments in the Beysug Estuary was characterised by a predominance of the aleurite-pelitic fraction and relative seasonal stability (Table 2).

The 0.01–0.05 mm fraction prevailed (62.8–66.3%) during all sampling periods and showed minimal variability, indicating the stability of the lithological structure of the sediments. At the same time, the proportion of the coarser fraction (0.05–0.1 mm) was characterised by greater variability: in April and August, it ranged from 5.6 to 10.1%, with a maximum at station *2*, while in October it decreased to 1.3–4.4%. This indicates sediment redistribution under the influence of hydrodynamic factors, primarily owing to intensive wind-induced mixing of the water and the upper layer of bottom sediments [14].

The mass fraction of *petroleum products* was characterised by pronounced variability: in spring, it varied widely, with the maximum recorded at station *1*, which may indicate a localised input of hydrocarbons or their accumulation under conditions of weak water exchange. In August, the mass fraction of *petroleum products* showed less variability. In October, the range of values widened again. The mass fraction of *phenols* remained generally low but showed a pattern similar to that of petroleum products. This suggests that the input and transformation of aromatic organic compounds were uneven.

T a b l e 2

Ranges and mean values of bottom sediment parameters in the Beysug Estuary based on field observations in 2018

Parameter	April 14	August 30	October 1
Grain-size composition			
Fraction < 0.01 mm, %	27.1–29.3/28.5	27.1–29.3/28.5	29.3–33.7/32.1
Fraction 0.01–0.05 mm, %	62.8–65.1/64.0	62.8–65.1/64.0	64.7–66.3/65.3
Fraction 0.05–0.1 mm, %	5.6–10.1/7.5	5.6–10.1/7.5	1.3–4.4/2.6
Chemical composition			
Petroleum products, mg/kg	6.08–19.83/14.33	9.08–11.15/10.20	9.51–20.98/15.52
Phenols, mg/kg	< 0.05–0.066	0.030–0.037/0.034	0.032–0.070/0.052
Sulfates, mg/kg	53.2–60.7/56.5	49.6–57.4/53.0	54.3–61.2/56.8
Phosphates, mg/kg	51.0–58.1/54.2	47.4–55.3/52.1	49.7–55.3/51.2

The mass fraction of *sulfate ions* in the bottom sediments exhibited moderate seasonal variability. In April, an elevated value was recorded at station *3* (60.7 mg/kg). The absence of pronounced variation was associated with stable redox conditions and sulfate-reduction processes. No significant changes in the mass fraction of *phosphate ions* were observed either, indicating stable accumulation of this component.

Conclusions

The presented data on the chemical composition of water and bottom sediments in the Beysug Estuary, Sea of Azov, obtained during field studies in 2018, characterise the geochemical features and pollution level of the estuary.

The oxygen regime of the water was periodically at the permissible limit. MPC exceedances among the analysed substances occurred only occasionally. The parameters for which exceedances were recorded included readily oxidisable organic matter (as indicated by BOD_5), total iron, and petroleum products.

Considering the shallow depth of the water body and the geochemical parameters of its water and bottom sediments, the pollution level of the Beysug Estuary can be considered to depend not only on possible anthropogenic factors but also on the prevailing hydrometeorological conditions, which can significantly influence the migration and accumulation of pollutants.

REFERENCES

1. Matishov, G.G., ed., 2011. *Ecological Atlas of the Sea of Azov*. Rostov-on-Don: SSC RAS Publishers, 328 p. (in Russian).
2. Grigorenko, K.S. and Matishov, G.G., 2025. Mineralization of Small Watercourses of the Eastern Cis-Azov Region in Modern Low-Water Conditions. *Meteorologiya i Gidrologiya*, (11), pp. 124-131. https://doi.org/10.52002/0130-2906-2025-11-124-131 (in Russian).
3. Pogorelov, A.V., Lipilin, D.A. and Kuzyakina, M.V., 2024. On Technogenic Degradation of River Systems in the Eastern Azov Region: Hydrographic Aspect. *Geology and Geophysics of Russian South*, 14(3), pp. 243-259. https://doi.org/10.46698/i4469-5379-6925-p (in Russian).
4. Krylenko, M., Kosyan, R. and Krylenko, V., 2016. Lagoons of the Smallest Russian Sea. In: R. Kosyan, ed., 2016. *The Diversity of Russian Estuaries and Lagoons Exposed to Human Influence.* Estuaries of the World. Cham: Springer International Publishing, pp. 111-148. https://doi.org/10.1007/978-3-319-43392-9_5
5. Grechushkina, N.A., Demina, O.N., Sorokin, A.N. and Golub, V.B., 2011. Plant Communities of the Association Artemisio Santonicae-Elytrigietum Elongatae Dubyna, Neuhäuslová et Shelyag-Sosonko in Dubyna, Neuhäuslová 2000 (Class Scorzonero-Juncetea Gerardii Golub et al. 2001) in Yasenskaya Spit in the Azov Sea Coast of Russia. *Izvestia of Samara Scientific Center of the Russian Academy of Sciences*, 13(1), pp. 91-95 (in Russian).
6. Denisenko, O.S., 2022. Determination of the Parameters of the Negative Impact on the Aquatic Bioresources of the Beisug Estuary of the Work on the Liquidation of Wells and the Flyover of the Field Gas Collection Point at the Beisug Gas Field. *Scientific Review. Biological Sciences*, (4), pp. 74-82. https://doi.org/10.17513/srbs.1297 (in Russian).
7. Mohamed, Y.A., Bastiaanssen, W.G.M., Savenije, H.H.G., Van Den Hurk, B.J.J.M. and Finlayson, C.M., 2012. Wetland Versus Open Water Evaporation: An Analysis and Literature Review. *Physics and Chemistry of the Earth, Parts A/B/C*, 47–48, pp. 114-121. https://doi.org/10.1016/j.pce.2011.08.005

8. Tong, Y., Feng, L., Wang, X., Pi, X., Xu, W. and Woolway, R.I., 2023. Global Lakes are Warming Slower than Surface Air Temperature due to Accelerated Evaporation. *Nature Water*, 1(11), pp. 929-940. https://doi.org/10.1038/s44221-023-00148-8
9. Matishov, G.G., Grigorenko, K.S., Bulysheva, N.I. and Moskovets, A.Yu., 2021. New Data about the Function of Underground and Black Sea Waters in the Azov-Don Basin during the Lack of Water Period. *Science in the South of Russia*, 17(2), pp. 34-48. https://doi.org/10.7868/S25000640210204 (in Russian).
10. Berdnikov, S.V., Dashkevich, L.V. and Kulygin, V.V., 2022. A New State in the Hydrological Regime of the Sea of Azov in the 21th Century. *Doklady Earth Sciences*, 503(1), pp. 123-128. https://doi.org/10.1134/S1028334X22030059
11. Korablina, I.V., Pavlenko, L.F., Klimenko, T.L., Anokhina, N.S., Ekilik, V.S., Savchuk, I.A. and Ryzhkova, V.V., 2021. Characterization of Oil Pollution of the Azov Sea in 2016-2020. *Aquatic Bioresources and Environment*, 4(1), pp. 19-27. https://doi.org/10.47921/2619-1024_2021_4_1_19 (in Russian).
12. Reshetnyak, O.S. and Zakrutkin, V.E., 2016. Bottom Sediments as a Source of Secondary Water Pollution by Metals (According to the Laboratory Experiment). *Bulletin of Higher Educational Institutions. North Caucasus Region. Natural Sciences*, (4), pp. 102-109. https://doi.org/10.18522/0321-3005-2016-4-102-109 (in Russian).
13. Zhezherya, V.A., Zhezherya, T.P., Linnik, P.M. and Osipenko, V.P., 2023. Experimental Simulation of the Influence of Temperature on the Migration of Substances from Bottom Sediments. *Hydrobiological Journal*, 59(6), pp. 83-98. https://doi.org/10.1615/HydrobJ.v59.i6.70
14. Gurov, K.I. and Fomin, V.V., 2021. Mathematical Modeling the Dynamics of the Bottom Sediments Granulometric Composition in the Balaklava Bay Affected by the Wind Waves. *Physical Oceanography*, 28(1), pp. 78-89. https://doi.org/10.22449/1573-160X-2021-1-78-89

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