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Original article

Major Ion Composition of Waters in the Kerch Strait and the Adjacent Areas

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Abstract
Purpose. The work is purposed at studying the influence of water exchange processes between the Black and Azov seas upon the characteristics of major ion composition (MIC) and other hydrochemical indicators of the Kerch Strait waters, as well as the impact of changes in the relative content of major ions of water salt composition upon the accuracy in determining salinity values. The MIC transformation during mixing of the sea surface waters and the Taman Bay ones in the Kerch Strait is investigated. The errors in calculating salinity by the standard methods are assessed for the Kerch Strait, the northeastern Black Sea and the Taman Bay waters.
Methods and Results. The concentrations of major ions determining MIC in the Kerch Strait, Black Sea and Taman Bay surface waters in 2019–2023 were defined by the potentiometric titration method. The water salinity values were obtained in four different ways.
Conclusions. It was established that the salinity value ~18.66 calculated by a sum of the major ions corresponds to the surface waters in the northeastern part of the Black Sea, that conforms to the practical salinity value ~18.10 calculated using the *CTD* probe data. On the average, MIC of these waters is characterized by the following relative content of major ions: Cl^- = 54.1%, SO_4^{2-}= 8.2%, HCO_3^- = 1%, Na^+ = 30.8%, K^+ = 1.3%, Ca^{2+} = 1.3% and Mg^{2+} = 3.4%. It is shown that the Kerch Strait waters, even in case of their similar salinity, can have different ratios of the major ions characterized by high spatial and temporal variability which, in its turn, is subjected to a significant impact of the waters inflowing from the shallow Taman Bay. The largest differences were between the sum of major ions and the practical salinity. For the Kerch Strait waters, the differences averaged ~2.5%. The ionic variations contributed to underestimating the practical salinity values calculated for all the waters under study. In calculating salinity using the chlorine coefficient, the deviations from the sum of ions constituted ~2%, whereas those obtained using the TEOS-10 equations – ~1%.

Keywords: Kerch Strait, Black Sea, Taman Bay, Sea of Azov, determination of salinity, salinity, major ion composition, major ions, water exchange

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Introduction

The Kerch Strait is a part of the Sea of Azov connecting it with the Black Sea. The western coast of the strait is the Kerch Peninsula of Crimea, the eastern one is the Taman Peninsula. The width of the strait is 4.5–15 km, the greatest depth is 18 m. The strait plays an important role in formation of the hydrological and hydrochemical regime of the Azov-Black Sea basin. It is one of the main fishing areas and an important shipping route [1]. The main factors influencing salt composition of the Kerch Strait waters are seasonality of the continental runoff and precipitation inflow, water inflow from the estuaries and lagoons surrounding the sea bays, as well as water exchange with the Black Sea and the Sea of Azov. Complex water formation processes in the Kerch Strait result in the salinity values that vary within a fairly wide range of 9.5–19 and ionic variations lead to errors (up to 3%) in its determination [2, 3].

The scientific stage of studying the hydrochemical characteristics of the Black Sea waters started in 1890, of the Sea of Azov – in 1873 [1, 4], and their comprehensive study in our country began in the 1920s. Basic knowledge of hydrochemistry of the Black Sea and the Sea of Azov is presented in the works [1, 2, 3]. In the 1970s and 1980s, the processes of hydrogen sulfide production and oxidation, organic carbon production and consumption, etc., were intensively studied. In the literature, as a rule, one can find the results of studies of individual elements of the major ion composition (MIC) of the Black Sea waters [1] [1, 5, 6] and the Sea of Azov waters [4]. To date, the carbonate system of the Black Sea has been well studied; a number of works [1, 7–11] are devoted to describing the research results. Some hydrochemical characteristics of the Sea of Azov waters are given in the works [4, 5] [12–15]. Unfortunately, the authors were unable to find any published data on the main ion concentrations in the chemical composition of the Sea of Azov, Kerch Strait and Taman Bay waters.

The changes in hydrochemical properties of the Sea of Azov and the Black Sea are inevitable in the era of global climate change expressed in an increase in the maximum monthly average summer temperatures and minimum winter temperatures, a decrease in ice concentration in the Sea of Azov, as well as an anthropogenic load increase on its basin water resources. These changes lead to a decrease in the incoming part of the freshwater balance and an increase in salinity, water pollution, changes in their biocenoses – the species composition of hydrobionts and productivity of individual components of hydroecosystems [16–20].

The Sea of Azov water balance is regulated by the river flow (~ 50% of the balance), the inflow of the Black Sea waters through the Kerch Strait, water exchange with Lake Sivash, precipitation and evaporation [4]. Due to a large supply of fresh water mainly from the Don and Kuban rivers and a limited water exchange

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[1] Skopintsev, B.A., 1975. [*Formation of the Modern Chemical Composition of the Black Sea Waters*]. Leningrad: Gidrometeoizdat, 336 p. (in Russian).

[2] Knipovich, N.M., 1932. [Hydrological Research in the Sea of Azov]. In: *Proceedings of the Azov and Black Sea Scientific and Fishery Expedition*. Zagorsk, iss. 5, pp. 3-97 (in Russian).

[3] Knipovich, N.M. and Bregman, G.R., eds., 1936. *[Hydrological Directory of the Seas of the USSR]. Vol. 3: The Sea of Azov*. Leningrad; Moscow. Iss. 1, 222 p. (in Russian).

[4] Bronfman, A.M., Dubinina, V.G. and Makarova, G.D., 1979. [*Hydrological and Hydrochemical Foundations of the Productivity of the Sea of Azov*]. Moscow: Pischevaya Promyshlennost, 288 p. (in Russian).

[5] Matishov, G., Matishov, D., Gargopa, G., Dashkevich, L., Berdnikov, S., Kulygin, V., Arkhipova, O., Chikin, A., Shabas, I. [et al.], 2008. *Climatic Atlas of the Sea of Azov 2008*. Washington: United States Government Publishing Office, 148 p. Available at: https://repository.library.noaa.gov/view/noaa/1135 [Accessed: 17 January 2024].

with the Black Sea, the hydrochemical properties of individual parts of the Sea of Azov vary significantly. Early studies showed that salinity in the main part of the sea during 1952–2007 varied in the range of 10–12, in the central part– in the range of 11–12.5, in the Taganrog Bay – in the range of 1–9 [21, 22]. Historically, the Kerch Strait waters have a large variability in salinity – from 9.5 to 19 [4] [2, 4, 23].

The development of agriculture, especially irrigation farming, causes the flow of large amounts of chlorine salts, sulfates, metals, biogenic and organic substances into the rivers and, consequently, into the Sea of Azov with return waters. This, along with a river flow reduction, affects the increase in the overall mineralization of river and sea waters, which determines the sea ecosystem and human economic activity in the water area. The increase in salinity leads to water stratification with oxygen deficiency, which increases the risk of death of aquatic organisms, reduces the level of primary production of organic matter and also decreases the sea water self-purification rate [4, 6] [12, 14, 18, 21, 24, 25]. The increasing runoff of sulfates from year to year creates preconditions for hydrogen sulfide pollution of sea waters [4] [4, 15, 16]. For the resent years of the Don low-water period, the Sea of Azov salinity reached the values of > 14 [25]. Although its salinity has been studied since the end of the 19th century, the study of the dynamics and the forecast of changes in its regime are still relevant.

The Kerch Strait waters are transformed Azov-Black Sea water masses; some historical hydrochemical characteristics of them (before 1981) are given in [4]. The principal factors influencing MIC formation of the Kerch Strait waters are seasonality of continental runoff and precipitation inflow, water inflow from the bays, as well as water exchange with the Black and Azov seas. Complex processes of MIC formation of Kerch waters lead to the hydrochemical compositional anomalies causing errors (up to 3%) when determining salinity with standard methods (calculations based on electrical conductivity and chlorinity). Kerch waters differ from ocean waters in a lower content of chlorides and a higher content of sulfates and hydrocarbonates [3].

The Taman Bay is a separate part of the Kerch Strait. It is located on its eastern shore between the Chushka and Tuzla spits and protrudes into the mainland for 16 km. It has an average depth of 5 m and a width at the entrance to the sea of 8 km [7]. Some hydrochemical characteristics of the Taman Bay waters are given in [16]. The bay is adjacent directly to the Kerch Strait and its influence on the Kerch water properties can be significant.

The Black Sea is a meromictic water body with a clearly defined two-layer water column structure with oxygen and anaerobic layers [26]. The hydrochemical and thermohaline properties of the upper layer depend on river runoff (~ 1000 rivers) and interaction with the atmosphere on various time scales. The properties of the lower layer depend on the influence of the Marmara (Mediterranean) waters coming with the Lower Bosporus current, as well as on vertical exchange processes.

[6] Dobrovolsky, A.D. and Zalogin, B.S., 1982. *Seas of the USSR*. Moscow: Moscow State University, 192 p. (in Russian).

[7] Lotyshev, I.P., 2006. [*Geography of Kuban: Encyclopedic Dictionary*]. Maykop: Afisha, 527 p. (in Russian).

In the coastal zone and in the Kerch Strait, the surface water layer is characterized by lower salinity compared to deeper layers with increased horizontal salinity gradients. The salinity of surface waters in the central Black Sea is assumed to be 17.85−18.40 and on the northwestern shelf 14–16 (up to 17.90) (based on calculations using electrical conductivity [22]) [27].

Numerous studies of the complex hydrochemical structures of the Black Sea and the Sea of Azov attest to their significant differences from similar World Ocean structures. The most important physical characteristics, such as salinity and density, as well as their determination accuracy by indirect methods, depend on ionic variations. A possibility of accurate salinity calculation from electrical conductivity is determined by the constancy of the relative ion-salt composition of sea water and its violation leads to errors [27−29]. It was previously noted that ionic composition variations, even at the same chlorinity values, can cause differences in electrical conductivity values [4]. In 1970s, these differences in the Black and Azov waters served as the basis for the development of relationships for a more accurate calculation of salinity using the chlorine coefficient [4, 6].

Knowledge of the content and distribution of MIC components in the water mixing area will expand understanding of the processes of their formation and transport in the Kerch Strait. The need for comprehensive analysis of the characteristics of sea waters and the monitoring system development is especially relevant today in the context of climate change and increasing anthropogenic load on water resources. The knowledge gained can help in finding optimal solutions for their operation, developing technologies for hydrochemical process and water dynamics simulation in the strait. The present paper is aimed at studying MIC of the Kerch Strait waters and adjacent waters of the Black Sea and the Sea of Azov and the Taman Bay and their water exchange, as well as at estimating the influence of ionic variations in salt composition on the accuracy of determining water salinity in the areas under consideration.

Materials and methods

Location of stations. The sampling from the surface water layer was carried out on board R/V *Ashamba* and during coastal expeditions to the Kerch Strait, the Taman Bay, the northeastern part of the Black Sea and the southern part of the Azov Sea.

The water samples from the Kerch Strait were obtained on board R/V *Ashamba* in 2019–2023, from the Black Sea – along the route from the Blue Bay (Gelendzhik) to the Kerch Strait at a distance of up to 10 km from the coast on 21 September 2022 (2022 BSA stage).

During coastal expeditions, water samples were obtained in the following areas: in the Kerch Strait on 15–16 December 2021 (from Kerch to Yakovenkovo village) (published in [3]); in April, July and November 2021 – in the coastal area near the Chushka Spit (Port Kavkaz area) and in different areas of the Taman Bay, including the lagoon adjacent to the bay; in the Black Sea on 29 September 2022 (from Anapa to Sochi, Lazarevskoe microdistrict and near Sevastopol (2022 BSC stage)); in the Temryuk Gulf of the Sea of Azov on 10 October 2020 (in the area of Golubitskaya village).

T a b l e 1

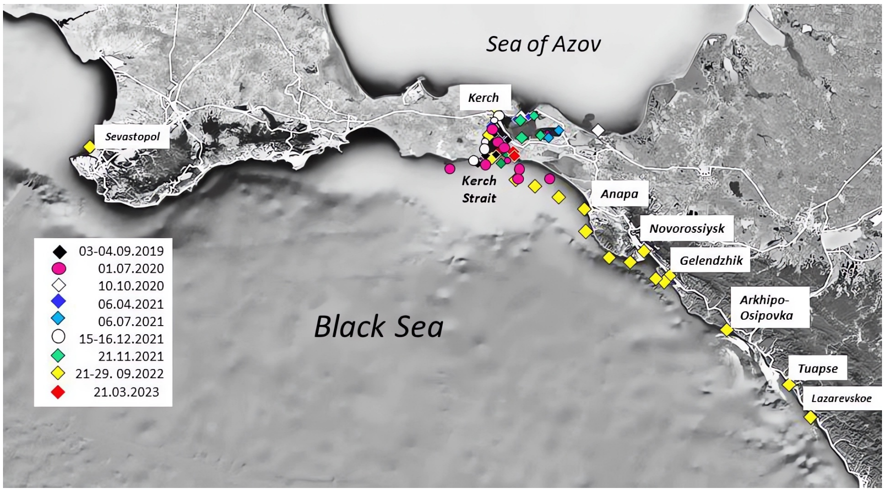
Characteristics of stations and dates of water sampling

Date of sampling	Water area	Station (location of sampling)	Station coordinates	
			°N	°E
01 May 2019	Kerch Strait – Feodosia Bay	*0*	45.089490	35.520194
		1a	44.987528	35.835800
		6	45.012694	36.209528
		24	45.291056	36.461444
		31	45.183333	36.592972
03–04 September 2019	Kerch Strait	*12*	45.071708	36.461732
		17	45.103928	36.482090
		20	45.119100	36.555908
		23	45.135783	36.623403
		24	45.288658	36.457697
		28	45.223365	36.535535
		31	45.182142	36.589330
01 July 2020		*6*	45.016460	36.215190
		1b	45.100560	36.468800
		23	45.132810	36.623840
		24	45.291690	36.460600
		30	45.193770	36.567890
		31	45.178270	36.583490
		32	45.034790	36.740890
		36	45.099130	36.741730
		41	45.066560	36.998340
15–16 December 2021		*1*	45.349800	36.476900
		2	45.301800	36.460700
		3	45.271700	36.437500
		4	45.244200	36.421200
		5	45.219800	36.405700
		6	45.229700	36.413600
		7	45.178100	36.405900
		8	45.166400	36.410700
		9	45.059200	36.327143
29 September 2022		*1N*	45.349607	36.47619
		4N	45.1572039	36.554363
		9N	45.128749	36.546070
		10N	45.1240664	36.638590
21 March 2023		*10*	45.1240664	36.638590
		10N	45.07516	36.625380
10 October 2020		*PK* (Chushka Spit, near Port Kavkaz)	45.34686	36.683314
06 April 2021			45.352445	36.696216
21 November 2021			45.347494	36.682850
10 October 2020	Temryuk Bay of the Sea of Azov	*GV* (Golubitskaya village)	45.323314	37.27490
06 April 2021	Taman Bay of the Kerch Strait	(Chushka Spit, near Dinskoy Bay)	45.351600	36.699305
21 November 2021			45.353811	36.702750
06 April 2021		*P* (Primorskiy)	45.270794	36.912798
06 July 2021			45.270998	36.916198
21 November 2021			45.269542	36.909351
06 July 2021		*S* (Sennoy)	45.279813	36.976939
21 November 2021		*T* (Taman)	45.221259	36.700954
06 July 2021		*LP* (Lagoon in the Primorskiy)	45.25393	36.898338
21 November 2021			45.253797	36.896663

Continuation of the Table 1

Date of sampling	Water area	Station (location of sampling)	Station coordinates	
			°N	°E
21 September 2022	Black Sea, the BSA stage (Blue Bay – Kerch Strait)	*1*	44.57105	37.966255
		2	44.622805	37.773119
		3	44.660862	37.578031
		4	44.739155	37.393548
		5	44.854028	37,309866
		6	44.908118	37.309154
		7	44.940812	37.13572
		8	44.964315	36.950363
		9	44.997965	36.750853
		10	45.06947	36.563719
		11	45.206595	36.463493
29 September 2022	Black Sea, the BSC stage (Anapa – Lazarevskoe)	*A* (Anapa)	44.89789	37.306041
		N (Novorossiysk)	44.73275	37.783855
		S (Sevastopol)	44.615857	33.521145
		BB (Gelendzhik, Blue Bay)	44.576505	37.977587
		G (Gelendzhik Bay)	44.576335	38.024019
		AO (Arkhipo-Osipovka)	44.357138	38.526734
		T (Tuapse)	44.0942	39.072294
		L (Sochi, Lazarevskoe)	43.909438	39.322485

In total, 36 samples from the Kerch Strait were analyzed within the period of 2019–2023, 10 – from the Taman Bay, 21 – from the Black Sea and 1 – from the Sea of Azov. The location, station numbers, their coordinates and sampling dates are given in Table. 1, the location of stations on the map is shown in Fig. 1.



F i g. 1. Location of the sampling stations in 2019–2023 on the map (taken from *Google* Earth *Pro*)

During collection, water samples were placed in sealed containers volumed 0.5 and 1 l and delivered to the laboratory within several days for subsequent analysis. After determination of total alkalinity (*AT*), total dissolved inorganic carbon (T_{CO_2})

and pH, samples were filtered through a GF/F Whatman 0.7 μm membrane filter to remove mineral and organic suspended matter, placed in 250–300 ml glass containers, stored in a refrigerator at 4 °C and removed as needed during the analytical period.

Ion-salt composition study. Concentrations of the major ions of the salt composition (Cl^-, SO_4^{2-}, HCO_3^-, Na^+, K^+, Ca^{2+}, Mg^{2+}), expressed in g/kg, total alkalinity (*AT*) (in mmol/kg) and pH of waters of the studied samples were determined in the laboratory of the Institute of Oceanology of RAS in accordance with the methods originally selected for the analysis of hypersaline waters and described in [30], but taking into account the Black Sea water salinity. Similar determinations of major ion concentrations and densities were also carried out on *IAPSO* standard seawater (SSW) samples, specially intended for instrument calibration and verification of salinity measurements [31]. Comparison of the obtained results with literature data showed good convergence. Determination of concentrations of the main ions in the composition of the studied samples made it possible to obtain the most accurate values of the surface water salinity of the Kerch Strait and its water areas, to calculate the relative content of ions in the water compositions and the sulfate-chlorine ratio (SO_4^{2-}/Cl^-) and to determine salinity using the chlorine coefficient. Salinity was calculated by the sum of the major ions. Relative contribution of ions to the total mineralization of the studied water samples is given and analyzed in the present paper.

Deionized water (electrical conductivity < 0.2 μS/cm) was used to prepare reagent solutions and dilute samples. The analyzed sample mass was measured by weighing on Ohaus AX 423 laboratory analytical balance (USA) of the first accuracy class with an error of ± 0.005 g.

Density (σ_t) determination. Water density of the studied samples was measured in the laboratory of the Institute of Oceanology of RAS, using Anton Paar DMA 5000M precision density meter (Austria) at *in situ* temperature and atmospheric pressure. The instrument was calibrated according to the instructions. The error in measuring water density was ± 10^{-5} g/cm³. The standard deviation when measuring the density of the studied samples with a density meter did not exceed 0.02 kg/m³. The density data are presented in conventional density units (kg/m³).

Salinity determination. Salinity was calculated in several ways: according to the CTD probe data (SeaBird 19plus until 2021 and CastAway since 2021), practical salinity (*SP*) was obtained based on electrical conductivity (only for the Kerch Strait waters); using the chlorine coefficient (S_{Cl}) from the ratio given in [6]; using the sum of major ions (*SS*) and density values (SA_ρ) from the TEOS-10 equation (http://www.TEOS-10.org, https://www.teos-10.org/software.htm). The results of similar studies for the Kerch Strait waters are given in [3]. The accuracy of the aforementioned methods for salinity calculation is given in the work [8]. Salinity determination depends on the equipment error degree and the following methods:

[8] Millero, F.J., 2013. *Chemical Oceanography*. Boca Raton: CRC Press, 591 p. https://doi.org/10.1201/b14753

– using density values up to ± $3 \cdot 10^{-5}$ g/cm^3, which is equivalent to a salinity error of ± $0.4 \cdot 10^{-2}$;

– using chlorinity $0.2 \cdot 10^{-2}$ g/kg;

– using electrical conductivity ± $0.1 \cdot 10^{-2}$ μS/cm;

– using a sum of major ions of $0.1 \cdot 10^{-1}$ g/kg.

Studying the SSW ion composition in the laboratory of the Institute of Oceanology of RAS and comparing the salinity obtained by the sum of ions with the reference salinity from [31], we found that the salinity exceeded our calculated one by 0.3%. For surface water samples of the Black Sea with a salinity of 18, this is equivalent to 0.05.

Practical salinity was calculated only for the Kerch Strait waters, since CTD probing was carried out only in this area.

Results

The results of hydrochemical studies of water samples from the Kerch Strait, the Taman Bay, as well as from the northeastern part of the Black Sea in 2019–2023 are given in Table 2.

T a b l e 2

Hydrochemical characteristics of water samples from the Kerch Strait and adjacent waters of the Black Sea and the Taman Bay obtained in 2019–2023

Station	Date	pH	*AT*, mmol/kg	Salinity				Anions, %			Cations, %			
				SP	*SS*	S_{Cl}	SA_ρ	Cl^-	SO_4^{2-}	HCO_3^-	Na^+	K^+	Ca^{2+}	Mg^{2+}
Kerch Strait – Feodosia Bay														
0	01.05.2019	8.13	3.21	–	18.24	17.69	17.92	53.49	7.56	0.98	31.99	1.08	1.26	3.64
1a		8.17	2.94	17.09	17.69	17.06	17.23	53.21	7.97	0.92	31.75	1.24	1.23	3.69
6		8.08	2.99	17.43	18.01	17.44	17.43	53.41	7.67	0.93	31.84	1.22	1.26	3.67
24		8.05	2.64	14.71	15.25	14.63	15.00	52.91	8.33	0.97	31.74	1.11	1.30	3.65
31		8.11	2.91	18.05	18.62	18.01	18.16	53.37	7.84	0.87	31.93	1.10	1.30	3.59
-		**8.11**	**2.94**	**16.82**	**17.56**	**16.97**	**17.15**	**53.28**	**7.87**	**0.93**	**31.85**	**1.15**	**1.27**	**3.65**
-		***0.04***	***0.19***	***1.27***	***1.19***	***1.21***	***1.12***	***0.11***	***0.16***	***0.04***	***0.09***	***0.07***	***0.02***	***0.04***
Kerch Strait														
12	01–08.09.2019	8.25	2.69	18.30	19.04	18,46	18.50	53.47	8.51	0.93	31.10	1.27	1.24	3.49
17		8.34	2.95	18.30	19.01	18.43	18.43	53.56	8.39	0.96	31.13	1.29	1.27	3.40
20		8.42	3.07	18.25	18.84	18.46	18.32	53.88	7,98	0.97	31.05	1.26	1.27	3.58
23		8.26	3.00	18.15	18.94	18.40	18.34	53.54	8.32	0.95	31.03	1.30	1.33	3.53
24		8.17	2.86	18.15	18.76	18.39	18.27	53.62	8.26	0.96	31.05	1.26	1.29	3.56
28		8.21	2.89	18.20	18.85	18.24	17.68	53.80	8.09	0.96	31.04	1.27	1.20	3.64
31		8.21	2.3	18.15	18.90	18.39	18.23	53.40	8.55	0.94	31.07	1.27	1.24	3.54
-		**8.26**	**2.90**	**18.21**	**18.91**	**18.39**	**18.25**	**53.61**	**8.30**	**0.95**	**31.07**	**1.27**	**1.26**	**3.53**
-		***0.08***	***0.11***	***0.06***	***0.09***	***0.07***	***0.25***	***0.16***	***0.19***	***0.01***	***0.03***	***0.01***	***0.04***	***0.07***
6	20.07.2020	8.29	2.89	17.90	18.42	17.98	18.04	53.95	8.40	0.98	30.74	1.29	1.24	3.41
16		8.29	2.90	17.81	18.34	17.89	17.88	53.79	8.48	0.98	30.93	1.20	1.42	3.20
23		8.19	3.06	17.92	18.36	18.00	17.94	54.09	8.25	0.98	30.80	1.19	1.29	3.39
24		8.22	2.99	18.05	18.40	18.14	17.99	54.30	8.00	0.99	30.84	1.20	1.30	3.37
30		8.13	2.92	17.86	18.35	17.94	17.98	53.89	8.42	0.99	30.67	1.37	1.29	3.38
31		8.14	2.89	17.84	18.20	17.92	17.91	53.70	8.63	0.98	30.54	1.41	1.35	3.38
32		8.14	2.95	17.85	18.38	17.93	18.19	53.91	8.37	1.00	30.56	1.49	1.25	3.42
36		8.18	2.90	17.86	18.25	17.94	17.91	54.12	8.12	1.00	30.56	1.51	1.26	3.42
41		8.24	2.87	17.72	18.12	17.80	17.78	54.11	8.13	1.00	30.57	1.53	1.25	3.41
-		**8.20**	**2.93**	**18.31**	**17.87**	**17.95**	**17.96**	**53.99**	**8.31**	**0.99**	**30.69**	**1.36**	**1.29**	**3.38**
-		***0.06***	***0.06***	***0.10***	***0.08***	***0.09***	***0.11***	***0.18***	***0.19***	***0.01***	***0.13***	***0.13***	***0.06***	***0.06***

Continuation of the Table 2

Station	Date	pH	*AT*, mmol/kg	Salinity				Anions, %			Cations, %			
				SP	*SS*	S_{Cl}	SA_{ρ}	Cl^{-}	SO_4^{2-}	HCO_3^{-}	Na^{+}	K^{+}	Ca^{2+}	Mg^{2+}
9	15–16.12.2021	8.27	2.89	16.8	17.19	16.8	17.1	53.88	8.58	0.96	30.40	1.28	1.38	3.61
8		8,26	2.36	15.89	16.3	15.82	16.11	53.54	9.10	0.86	30.43	1.22	1.25	3.70
7		8.16	2.47	15.86	16.23	15.77	16.17	53.57	8.97	0.88	30.26	1.40	1.35	3.64
6		8.22	2.52	15.94	16.34	15.85	16.2	53.62	8.97	0.86	30.32	1.32	1.34	3.66
5		8.19	2.47	15.87	16.28	15.83	16.06	53.52	9.08	0.88	30.26	1.34	1.30	3.71
4		8.25	2.50	16.00	16.37	15.9	16.29	53.59	9.00	0.86	30.41	1.27	1.30	3.64
3		8.21	2.46	16.06	16.41	15.93	16.25	53.54	9.04	0.86	30.29	1.40	1.30	3.65
2		8.38	2.37	15.8	16.22	15.66	16.16	53.24	9.41	0.83	30.32	1.34	1.28	3.67
1		8.17	2.49	16.04	16.38	15.91	16.22	53.59	8.98	0.87	30.35	1.32	1.34	3.63
-		**8.23**	**2.5**	**16.03**	**16.41**	**15.94**	**16.28**	**53.57**	**9.01**	**0.87**	**30.34**	**1.32**	**1.32**	**3.66**
-		***0.06***	***0.14***	***0.28***	***0.28***	***0.31***	***0.3***	***0.15***	***0.20***	***0.03***	***0.06***	***0.06***	***0.04***	***0.03***
1N	29.09.2022	8.00	2.65	–	18.01	17.68	17.98	54.16	8.03	0.92	31.31	1.25	1.21	3.10
4N		8.03	3.01	18.58	18.86	18.66	18.71	54.57	7.77	0.91	30.70	1.31	1.36	3.44
9N		8.13	3.13	18.57	18.81	18.61	18.77	54.57	7.55	0.97	31.23	1.32	1.21	3.19
10N		8.06	3.21	18.53	18.98	18.7	18.88	54.34	7.77	0.98	31.36	1.26	1.20	3.16
-		**8.06**	**3**	**18.56**	**18.67**	**18.41**	**18.59**	**54.41**	**7.78**	**0.94**	**31.15**	**1.29**	**1.25**	**3.22**
-		***0.05***	***0.22***	***0.02***	***0.39***	***0.42***	***0.35***	***0.17***	***0.17***	***0.03***	***0.26***	***0.03***	***0.07***	***0.13***
10	21.03.2023	8.15	2.66	17.28	17.55	17.3	17.66	54.35	8.13	1.00	30.26	1.16	1.45	4.06
10N		8.17	2.74	16.23	17.15	16.94	17.53	54.50	8.01	1.00	30.22	1.17	1.34	3.67
-		**8.16**	**2.7**	**16.75**	**17.35**	**17.12**	**17.59**	**9.44**	**1.40**	**0.17**	**5.25**	**0.20**	**0.24**	**0.64**
-		***0.01***	***0.04***	***0.53***	***0.2***	***0.18***	***0.07***	***0.10***	***0.03***	***0.00***	***0.07***	***0.00***	***0.01***	***0.00***
PK	09.10.2020	8.12	2.71	-	18.96	18.95	19.11	55.13	7.28	0.88	30.29	1.41	1.42	3.60
	06.04.2021	7.56	3.10	-	16.80	16.17	16.55	53.08	9.17	1.23	30.02	1.60	1.29	3.61
	21.11.2021	7.63	2.50	-	13.80	13.40	13.75	53.56	8.84	1.09	30.31	1.26	1.38	3.56
Black Sea, BSA stage														
1	21.09.2022	8.31	2.89	-	18.69	18.33	18.75	54.08	8.36	1.00	30.31	1.29	1.36	3.60
2		8.30	2.98	-	18.82	18.43	18.94	54.04	8.37	0.99	30.44	1.24	1.41	3.51
3		8.29	2.91	-	18.78	18.43	18.82	54.13	8.32	1.00	30.35	1.19	1.41	3.59
4		8.32	2.95	-	18.76	18.44	18.89	54.21	8.23	0.96	30.25	1.33	1.46	3.56
5		8.27	2.94	-	18.74	18.44	18.90	54.27	8.18	0.98	30.29	1.23	1.46	3,59
6		8.28	2.87	-	18.72	18.43	18.84	54.30	8.16	1.00	30.26	1.28	1.36	3.66
7		8.31	2.90	-	18.91	18.54	18.89	54.05	8.42	0.98	30.37	1.21	1.35	3.60
8		8.31	2.93	-	18.78	18.46	18.80	54.23	8.20	0.99	30.40	1.20	1.42	3.56
9		8,27	2.90	-	18.76	18.45	18.79	54.27	8.18	1.00	30.33	1.23	1.39	3.61
10		8.28	2.85	-	18.57	18.32	18.71	54.39	8.04	0.99	30.22	1.30	1.42	3.64
11		8.28	2.85	-	18.70	18.49	18.76	54.53	7.88	0.97	30.45	1.28	1.30	3.59
-		**8.29**	**2.91**	-	**18.75**	**18.43**	**18.83**	**54.23**	**8.21**	**0.99**	**30.33**	**1.25**	**1.39**	**3.59**
-		***0.02***	***0.04***		***0.08***	***0.06***	***0.07***	***0.14***	***0.15***	***0.01***	***0.07***	***0.04***	***0.05***	***0.04***
Black Sea, BSC stage														
A	29.09.2022	8.11	3.05	-	19.00	18.67	18.87	54.21	7.95	0.93	31.40	1.26	1.20	3.06
N		7.93	3.08	-	17.70	17.32	17.62	53.98	7.98	1.08	31.44	1.34	1.23	2.95
BB		8.08	3.11	-	18.88	18.59	18.68	54.33	7.76	0.96	31.49	1.29	1.11	3.05
G		8.15	3.05	-	18.59	18.20	18.46	54.01	8.02	1.01	31.45	1.36	1.18	2.98
AO		8.01	3.07	-	18.90	18.55	18.77	54.14	7.93	0.98	31.51	1.25	1.19	2.99
L		7.97	3.11	-	18.36	18.06	18.22	54.26	7.79	1.02	31.54	1.20	1.20	3.00
T		8.03	3.07	-	18.67	18.34	18.70	54.20	7.86	0.99	31.49	1.26	1.23	2.98
S		8.10	3.08	-	18.89	18.54	18.76	54.12	7.98	1.00	31.39	1.23	1.24	3.04
-		**8.04**	**3.08**	-	**18.59**	**18.25**	**18.47**	**54.16**	**7.90**	**0.99**	**31.47**	**1.28**	**1.19**	**3.00**
-		***0.07***	***0.02***	-	***0.41***	***0.43***	***0.40***	***0.12***	***0.09***	***0.04***	***0.04***	***0.05***	***0.04***	***0.04***

Station	Date	pH	*AT*, mmol/kg	Salinity				Anions, %			Cations, %			
				SP	*SS*	S_{Cl}	SA_p	Cl^-	SO_4^{2-}	HCO_3^-	Na^+	K^+	Ca^{2+}	Mg^{2+}
Sea of Azov														
GV	09.10. 2020	7.03	2,16	–	14.81	14.64	14.98	54.53	7.80	0.98	30.04	1.57	1.49	3.59
Taman Bay														
D	06.04. 2021	7.65	3.68	–	18.88	18.28	18.58	53.41	8.66	1.19	29.63	2.12	1.46	3.53
P		7.44	6.97	–	22.12	21.48	22.00	53.56	7.71	2.15	30.17	1.67	1.22	3.53
P	06.07. 2021	8.31	2.87	–	18.64	18.17	18.18	53.77	8.72	0.88	30.47	1.34	1,37	3.46
S		8.38	2.95	–	18.54	18.07	18.23	53.76	8.77	0.88	30.52	1.25	1,35	3.48
D	21.11. 2021	7.53	4.21	–	19.50	18.94	19.42	53.58	8.56	1.33	30.20	1.31	1.51	3.51
T		7.1	2.49	–	16.07	15.58	15.88	53.46	9.05	0.96	30.37	1.30	1.31	3.55
P		6.68	4.4	–	16.13	15.44	15.85	52.78	8.83	1.99	29.87	1.40	1.61	3.52
LP	06.07. 2021	7.66	3.18	–	39.61	38.66	39.82	53.84	9.30	0.47	29.75	1.23	1.57	3.84
	21.11. 2021	7.42	5.09	–	26.63	25.99	26.70	53.84	8.66	1.05	29.53	1.43	1.75	3.74

Note: Bold straight font shows the average values of hydrochemical characteristics, bold italic – *sd*.

In addition to the main results for each sample, the expedition average values of the obtained indicators and the standard deviation (*sd*) between them are listed here. Large differences in *sd* indicated heterogeneity and small differences indicated the homogeneity of waters in the study area. The mean values and *sd* were not calculated for the data from the Taman Bay, Port Kavkaz and the lagoon near Primorskiy village due to large time intervals between sampling, which would inevitably lead to large deviations in these indicators. Calculating the mean values at the BSC stage, characteristics from A and *H* stations were not taken into account due to their maximum and minimum salinity, respectively.

Major ion composition of the Black Sea waters. From Table 2 it can be seen that the salinity and relative content of the major ions in the samples have similar values, and the *sd* values are very small which indicates relative homogeneity of the alongshore Black Sea water mass in the direction from Sevastopol along the Kerch Strait to Lazarevskoe. The maximum (SS_{max}) and minimum (SS_{min}) salinity values of the Black Sea waters during the 2022 expedition were recorded at the BSC stage: SS_{max} = 19.0 near Anapa, SS_{min} = 17.7 near Novorossiysk. The reduced water salinity in the Novorossiysk Bay was probably due to the sea water desalination by the Tsemes River runoff entering the bay from the northwestern direction.

On average, *AT* was 2.90 mmol/kg (AT_{max} = 3.08 mmol/kg, AT_{min} = 2.85 mmol/kg). In the Black Sea, *AT* is represented mainly by carbonate alkalinity, while the proportion of borate, phosphate, silicon and other alkalinity ions is insignificant [1]. In the coastal zone of the Black Sea (BSC stage), *AT* was on average 9% higher than in the open sea (BSA stage).

The concentrations of major ions in the water samples collected from the vessel during the BSA stage and those obtained from the shore during the BSC stage were very similar (Table 2).

The study results of the ionic composition and salinity of surface waters in the northeastern Black Sea revealed that they had a very specific MIC, where

SS = 18.66 (which corresponded to SP = 18.10), S_{Cl} = 18.29 ($sd_{SS,\ SP,\ S_{Cl}}$ = 0.3), SA = 18.44 (sd_{SA} = 0.4), and the relative content of the major ions (in %) was as follows:

Cl^- = 54.05 (*sd* = 0.3),
SO_4^{2-} = 8.16 (*sd* = 0.3),
HCO_3^- = 1 (*sd* = 0.3),
Na^+ = 30.84 (*sd* = 0.4),
K^+ = 1.29 (*sd* = 0.1),
Ca^{2+} = 1.30 (*sd* = 0.1),
Mg^{2+} = 3.30 (*sd* = 0.2).

Sulfate-chlorine ratio for the Black Sea surface waters (according to the BSA and BSC data) averaged 0.1492 (*sd* = 0.004).

Major ion composition of the Taman Bay waters. The data from Table 2 show significant seasonal fluctuations in the salinity of the Taman Bay waters and the lagoon adjacent to it. For example, samples obtained near Primorskiy village (station *P*) of the Taman Bay had a salinity of 22.12 in April, 18.64 in July and 16.13 in November. Less significant salinity fluctuations were observed on the opposite side of the Taman Bay, near the Dinskoy Bay (station *D*) (a small bay in the northwest of the Taman Peninsula, 8 km long, 2 km wide at the exit and no more than 4 m deep). This bay is a part of the Taman Bay and is separated from the Kerch Strait by the Chushka Spit [7]. The salinity at station *D* was 18.88 in April and 19.50 in November.

AT values in the Primorskiy village area had large seasonal variations between an extremely high value of 6.97 mmol/kg in April (at pH = 7.44), a lower value of 2.87 mmol/kg in July (pH = 8.31) (corresponding to the Black Sea waters) and an intermediate value of 4.4 mmol/kg in November (pH = 6.68). Changes in the pH of surface waters of natural water bodies are significantly affected by phytoplankton activity accompanied by the processes of organic matter oxidation, photosynthesis and respiration, which leads to changes in the carbonic acid content. An increase in pH is usually influenced by river runoff enriched in bicarbonates and calcium [1]. With a decrease in the mean annual runoff of the Don and the salinity of the Sea of Azov waters, there has been a persistence of high intensity of biological productivity of phytoplankton and a change in its taxonomic groups [12]. The sulfate-chlorine ratio in the Taman Bay waters fluctuated in the range of 0.1320–0.1727 and in most cases decreased with increasing salinity.

The hydrochemical parameters of the Taman Bay waters are affected by water exchange with the lagoon waters (station *LP*) located near Primorskiy village and connected to the bay by a channel. Its characteristics are given in Table 2. It can be seen that the lagoon has high salinity (39.1 in July, 26.63 in November) and a composition different from other parts of the Taman Bay. There were more chlorides and magnesium ions in the lagoon and less bicarbonates and sodium ions than in other samples of the bay. In general, the waters of the lagoon represented the Taman Bay waters transformed, probably, due to evaporation and biological processes. The relative concentrations of chlorides were the lowest and sulfates –

the highest of any area in the bay. The sulfate-chlorine ratio was 0.1728 at *SS* = 39.61 in July and 0.1608 at *SS* = 26.63 in November.

Analyzing the results obtained, it can be assumed that the Kerch Strait waters entering the Taman Bay under certain conditions (for example, under the influence of the southwest wind) fill the bay and the adjacent lagoon. Due to insufficient horizontal circulation and the shallow waters of the Taman Bay, Kerch waters, entering the lagoon, stay here, partially evaporate and undergo biological processes changing their composition. Under the northeast wind (and/or other conditions) influence, these waters with increased salinity as a result of evaporation and a transformed composition flow back into the Kerch Strait along with less saline waters from the central part of the Sea of Azov. Thus, the Taman Bay plays an important role in the salt balance of the Kerch Strait waters.

The Kerch Strait. According to Table 2, the values of salinity and relative content of the major ions in the Kerch Strait water samples (excluding the Taman Bay waters) in September 2019 and 2022, July 2020 and December 2021 are very close, which demonstrates homogeneity of the waters, but at the same time these values have significant seasonal differences. The lowest salinity values were observed in May 2019, November (station *PK*) and December 2021 and were 15.25, 13.80 and 16.22, respectively. The lower salinity in these months compared to other seasons is associated with the inflow of both less saline (~ 14) waters of the Sea of Azov into the strait, which is facilitated by the northeast wind [22, 32] and salty waters of the Taman Bay. The major composition of the Kerch Strait waters at low salinity was different from the composition of the Black Sea waters (BSA and BSC stages) with a lower content of chlorides and a higher content of sulfates, characteristic of the central Sea of Azov waters. The highest salinity (18.01–19.04) and *AT* were observed in September 2019 and 2022. High salinity and the nature of MIC at this time of year indicate the distribution of Black Sea waters in the strait and the absence of inflow of Sea of Azov waters. The maximum thickness of the evaporation layer from the Sea of Azov surface in the Kerch Strait area is observed in late summer and autumn as a result of the entry of warmer Black Sea waters through the strait, increasing the temperature of the Sea of Azov waters [1]. The similar relative contents of the MIC components here and in the Black Sea waters (BSA stage) should be noted. In July 2020, the sum of ions in the strait waters had an intermediate value between the minimum and maximum and amounted to ~ 18.31.

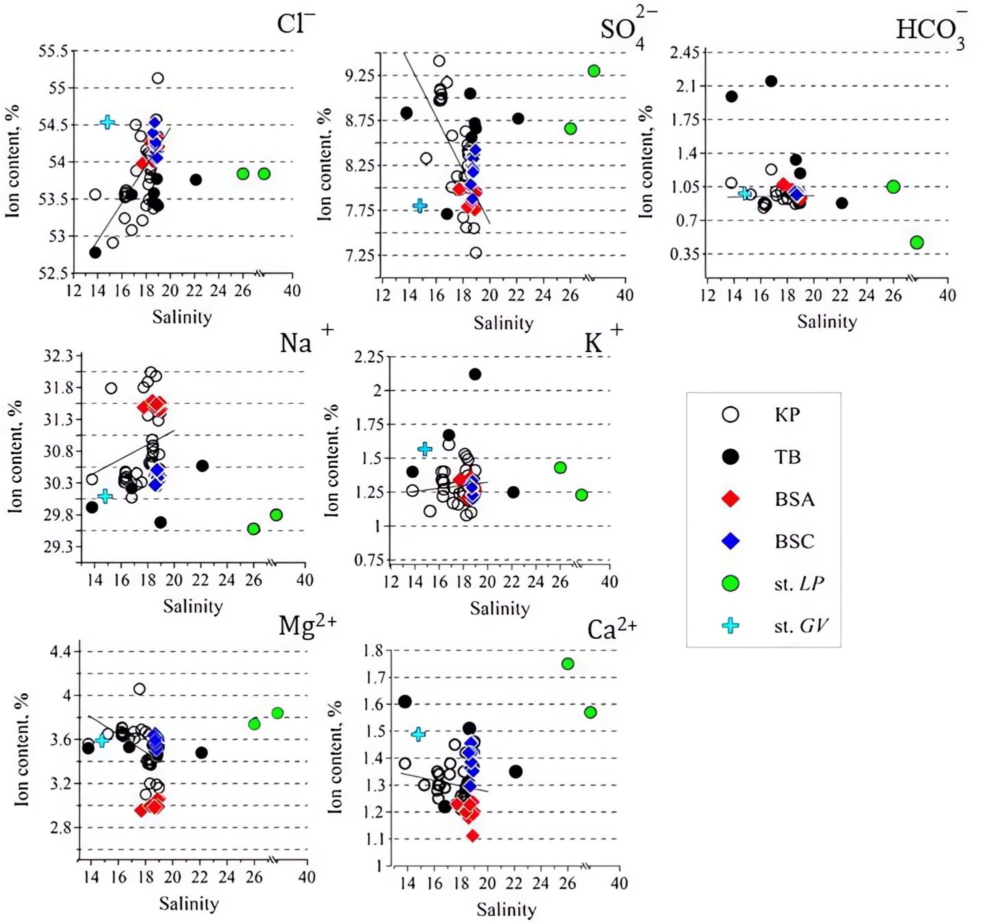
The pH values in the Kerch Strait for the entire observation period were 8–8.42, which indicates a slightly alkaline reaction of the aquatic environment. In the central Black Sea waters, the most common previously recorded pH values were 8.31–8.33 (maximum 8.45 in April–May, minimum 8.25 in late summer and winter) [1]. In the Kerch Strait in the summer of 2008, pH values reached 8.65 after the tanker disaster in 2007 [16].

Comparative analysis of MIC waters of the Kerch Strait and adjacent water areas. The data in Table 2 show significant differences in the relative content of major ions in the Kerch Strait and adjacent water areas. According to the data obtained and the materials from [31], the content of major ions in the Kerch Strait and in SSW differs significantly. In all the studied samples, there was less chloride than in SSW (55.2%): in the Kerch Strait waters by 1−2%, in the Taman Bay – up to 2%, in the Black Sea waters – by ~ 1%. The similar differences in the Kerch Strait waters were observed earlier [3]. In most of the samples studied, the relative content of SO_4^{2-} was generally higher than in SSW, where it was 7.8% or lower. For all samples from the northeastern Black Sea (BSA and BSC stages), the SO_4^{2-} content was on the verge of determination error. For the Kerch Strait and the Taman Bay waters, these deviations were up to 1%. In all cases, there was significantly more HCO_3^- than in SSW (0.35%): in the waters of the Kerch Strait, the Black Sea (BSA and BSC stages) – 3 times, in the Taman Bay waters – up to 6 times. The relative Na^+ content in the Kerch Strait waters and in SSW (30.8%) was generally very similar and in some cases in the Kerch Strait and in all Black Sea samples of the BSA stage it was less by 0.5%. Only in May 2019, Na^+ was 3% higher in the Kerch Strait than in SSW. The Na^+ content in the Taman Bay waters was on average 1% less, in the waters at the BSC stage it was more by 1%. The relative K^+ content in the water samples from the BSA and BSC stages was ~ 1.3%, which is close to the content in SSW (1.2%). The K^+ concentration in the Kerch Strait was slightly different (less by ~ 0.2%) from the content in the SSW and in the Taman Bay it almost coincided with the SSW, but sometimes the excess was up to 1% (station *D*). The Ca^{2+} content in the studied samples was almost everywhere higher than in SSW: in the Kerch Strait and the Black Sea – by ~ 0.3%, in the Taman Bay waters – by ~ 0.6%. The Mg^{2+} content in the samples of the Taman Bay and the BSA stage was close to SSW (3.5%), in the Kerch Strait – 0.2% less, in the BSC stage waters – by 0.6%.

Fig. 2 shows the distribution of the relative content of MIC components of waters (at the corresponding salinity) in the studied samples. It can be seen that for the Black Sea waters, both coastal (blue diamonds) and outlying at a distance of ~ 10 km (red diamonds), the relative content of the major ions of MIC within *sd* had good convergence. This indicates that the surface water mass of the Black Sea is generally homogeneous over a distance of ~ 500 km.

The Kerch Strait waters differ from the Black Sea ones in greater heterogeneity and seasonal variability of MIC (Fig. 2). It is shown that when the sum of ions is greater or less than 18.66 (*sd* = 0.3), their relative content changes. A relationship between the content of Na^+ and Mg^{2+} is observed both in the Kerch Strait waters and at the BSA and BSC stages, which is associated with ion exchange processes at geochemical barriers when terrigenous suspended matter enters the sea with river runoff. Within each stage of the expedition, the Na^+ and Mg^{2+} contents were close. In the Kerch Strait waters, K^+ was sometimes slightly less than in the Black Sea waters; the deviation of its values was ±0.5%. The Ca^{2+} content in the Kerch Strait and Black Sea waters was almost the same.

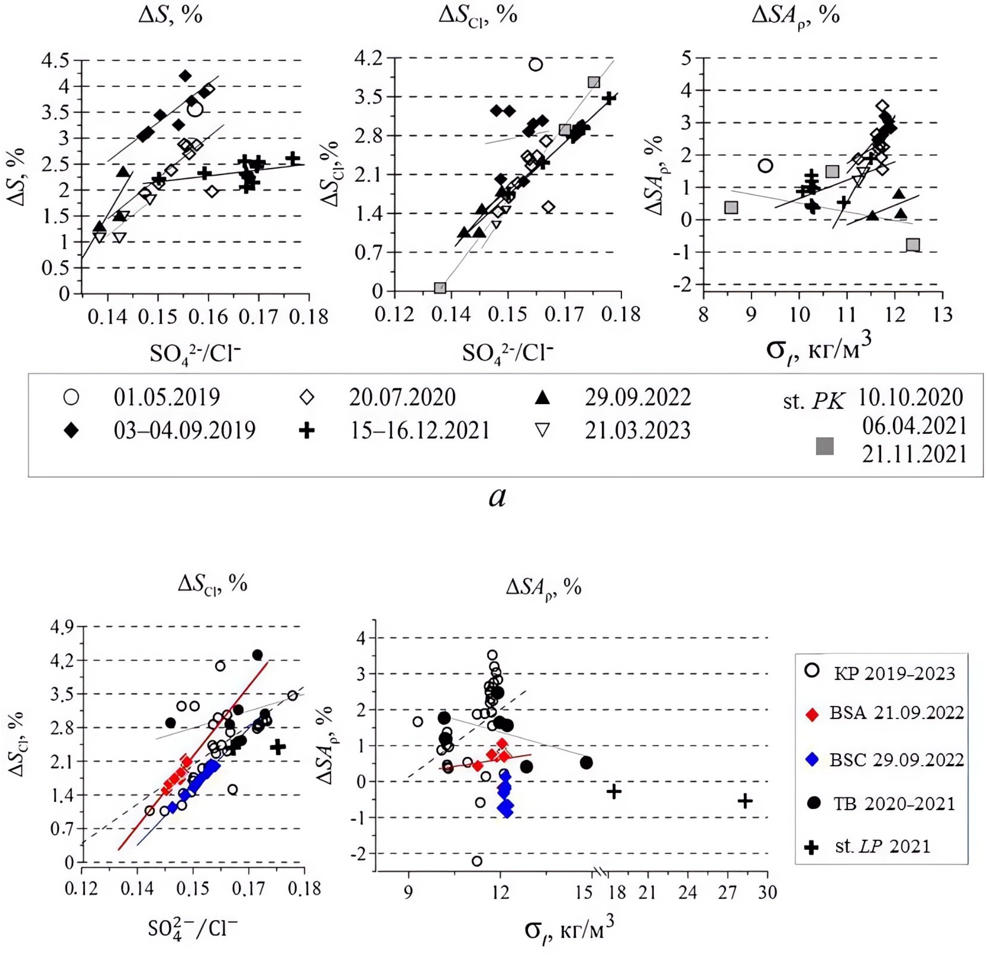
The studies showed that SS_{max} in the Kerch Strait waters was 19.04 in September 2019. In the salinity range of 15–19, as shown by the trend line in Fig. 2, the content of chlorides and sodium ions in the composition of Kerch waters increases, and the content of sulfates, magnesium and calcium decreases. There are fluctuations in the relative content of potassium and bicarbonates, but no noticeable trend towards change is observed. The highest salinity and greatest variability in composition were observed in the Taman Bay, where metamorphism of the Kerch waters occurred while they were in the adjacent lagoon. At the same time, the relative content of chlorides, bicarbonates and sodium ions in the lagoon water composition decreased, and the content of sulfates, magnesium and calcium increased. The potassium content did not change significantly. Under the influence of the northwestern wind, which facilitated the inflow of the Sea of Azov waters into the Kerch Strait [32, 33], the lagoon water masses were probably mixed successively with the Taman Bay and Kerch Strait waters. For this reason, the content of the major ions in the Kerch Strait waters has a wide variety – both seasonal and within the same expedition (Table 2, Fig. 2).



F i g. 2. Relative content of MIC components in the waters of the Kerch Strait (KS), the Taman Bay (TB), the northeastern Black Sea (stages BSA and BSC), lagoon in the Taman Bay (station *LP*) and in the Temryuk Gulf waters of the Sea of Azov (station *GV*). The trend line shows how the element content changes with increasing salinity in the Kerch Strait

Analysis of the relationship between MIC and salinity of all studied samples enables to distinguish the Black Sea waters in the Kerch Strait from the transformed the Sea of Azov waters and Taman Bay waters and to discover that the Kerch Strait waters can have different ratios of major ions with the same salinity.

The MIC influence on the salinity determination accuracy of the waters of the Kerch Strait and adjacent waters. The difference in the ionic composition of the waters of the Black Sea and the Sea of Azov and the Kerch Strait from the World Ocean waters leads to errors when measuring salinity and density using hydrophysical equipment and other methods [1, 3, 4 and 31]. The results of a study of the influence of variations in ionic composition on the accuracy of determining salinity in the surface waters of the Kerch Strait, the Black Sea and the Taman Bay are shown in Fig. 3.



F i g. 3. ΔS, ΔS_{Cl}, ΔSA_{ρ} and their relationship with the ionic composition and density in the Kerch Strait (KS) waters (separately for 5 expeditions) (*a*); in the waters of the Kerch Strait (5 expeditions together), as well as the Black Sea (stages BSA and BSC), the Taman Bay (TB) and the lagoon (station *LP*) (*b*)

The largest deviations were observed between the *SS* and *SP* (ΔS) values, the smallest – between *SS* and SA_{ρ} (ΔSA_{ρ}). It can be noted that ΔS and ΔS_{Cl} depend on the ionic composition and grow with increasing SO_4^{2-}/Cl^-, and ΔSA_{ρ} depends on the water density and salinity and grows with their increase. These processes are observed both in the Kerch Strait and in the Taman Bay. It is noticeable that ΔSA_{ρ} in all samples generally increases to 12 kg/m^3 (at a temperature of 20–21 °C and salinity

~ 19), and then with increasing density, as can be seen in the example of water at station *LP*, ΔSA_ρ decreases under the influence of a significantly changed composition.

In the Kerch Strait, ΔS was 1–4%, on average 2.5% (*SS* = 0.5), i.e., the sum of ions was on average 2.5% greater than *SP*. CTD measurements in the Taman Bay and the Black Sea were not carried out, so ΔS was not calculated.

In the Kerch Strait, ΔS_{Cl} was 1−3%, on average 2.3% (*SS* = 0.4), i.e., the salinity calculated from chlorine was less than the sum of ions on average by 2.3%. In the Taman Bay, S_{Cl} was 0−3% less and in the Black Sea, it was on average 1.8% less (*SS* = 0.3) than *SS*.

The calculation of ΔSA_ρ showed that SA_ρ was generally less than the sum of ions, but in some samples with *SS* > 18.66 (i.e., greater than the average salinity of the Black Sea waters and therefore with a different ion composition) it was greater. Thus, in the Kerch Strait SA_ρ was generally less than *SS* by 2–3%, but at station *PK* in October 2020 (with a high *SS* value = 18.96) it was 0.8% higher. The SA_ρ value in the Taman Bay was lower than *SS* by 0.4–2.5%, but in the lagoon (with increased *SS*), on the contrary, the SA_ρ value was higher on average by 0.4%. In the Black Sea, in water samples of the BSA stage SA_ρ was 0.1–0.8% less than the sum of ions, and in water samples of the BSC stage it was ~ 1% higher, i.e., ΔSA_ρ for the Black Sea waters was on average ± 0.1 g/kg and thus the difference between ΔSA_ρ and *SS* was not significant. It follows from the foregoing that the calculation according to TEOS-10 for the Black Sea waters shows the closest (~ 1%) result to the sum of ions, if the salinity and ion ratio correspond to the composition of the Black Sea waters.

The hydrochemical MIC anomalies affect the accuracy of salinity calculations from electrical conductivity measured by a CTD probe, which leads to significant errors (up to 3%) [3]. Despite the fact that CTD probing was not carried out in the Black Sea waters of the BSA and BSC stages in 2022, some samples from the Kerch Strait with a sum of ions equal to ~ 18.8 have an ionic composition similar to the Black Sea waters and therefore ΔS component ~ 2.5% may also be typical for these waters. Due to the ΔS_{Cl} dependence on variations in salt composition, when determining salinity using the chlorine coefficient, it is necessary to take into account the ΔS_{Cl} correction equal to ~ 2% for the surface waters of the Black Sea and the Kerch Strait.

The SA_ρ value has the smallest deviation from the sum of ions in almost all the studied samples. Salinity calculations using the TEOS-10 equation are simpler than calculations using the sum of ions, but require laboratory conditions and special equipment (high-precision density meter), so this method cannot be called an alternative to CTD studies, but can be used to clarify the obtained SP data.

Conclusions

In the course of the research, new hydrochemical data were obtained on the waters of the Kerch Strait and the adjacent water areas of the northeastern Black Sea, the Taman Bay and the Sea of Azov, which significantly expands the understanding of water exchange through the Kerch Strait.

It was found that the studied Black Sea waters, including those moving through the strait, have a very definite content of major ions in MIC: Cl^- = 54.2%, SO_4^{2-} = 7.9%, HCO_3^- = 1%, Na^+ = 30.8%, K^+ = 1.3%, Ca^{2+} = 1.3% and Mg^{2+} = 3.3–3.6%. These waters correspond to a sum of ions equal to 18.66 (sd = 0.3, which amounts to 1.5%). These Black Sea waters differ from the Taman Bay waters in a ratio of MIC ions, even with the same salinity.

The Taman Bay waters are characterized by higher salinity, and the ion-salt composition is formed by water exchange between the Black Sea, the central part of the Sea of Azov and the lagoon, where the water transformation occurs. It was revealed that the waters of the lagoon in the Taman Bay had a salinity of 39 in July and 26 in November and contained Cl^- and Na^+ on average 0.2 and 0.5% less than the Black Sea waters. In the waters of the lagoon, SO_4^{2-} was 1% more and Ca^{2+} and Mg^{2+} 0.4% more than in the Black Sea waters. The Taman Bay plays an important role in the salt balance of the Kerch Strait waters supplying transformed waters of the Sea of Azov and Black Sea with the increased salinity (up to 19) calculated by the sum of ions. The processes of water exchange with the salty lagoon partly explain great variability in the composition of the Taman Bay and the Kerch Strait waters.

Comparing the waters of the studied water areas and the SSW, it was found that the MIC of the Kerch Strait and the adjacent waters differed from the ocean one in the increased content of sulfates – on average up to 1%, the increased content of bicarbonates – 3–6 times, and the decreased content of chlorides – up to 2%. These differences were more pronounced when a larger proportion in the sample belonged to the freshwater continental runoff or the transformed waters of the Taman Bay, where, for example, the sulfate-chlorine ratio was higher than in the Black Sea and the Kerch Strait. The ionic variations contributed to underestimation of salinity values when calculated from the CTD probing data in all waters under study. For the samples from the Kerch Strait and, probably, the Black Sea, this underestimation averaged 2.5%, which corresponds to a sum of ions ~ 0.5. When calculating salinity using the chlorine coefficient, deviations were found: in the Kerch Strait they were ~ 2.3%, in the Taman Bay ~ 2% and in the Black Sea ~ 2.5%.

The conducted studies showed that the Kerch Strait waters of various origins, even with the same salinity values, can differ in the content of the components of the major ion-salt composition.

In oceanological practice, it is necessary to take into account the errors in determining salinity associated with variations in the ion-salt composition in the waters of the Black Sea and the Sea of Azov and their water areas, especially pronounced in areas influenced by continental runoff and water exchange with other water bodies.

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Ivan B. Zavialov – setting the goals and objectives of the research, graphic material preparation, field measurements and sampling in the Black Sea and the Kerch Strait

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