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Characteristics of bottom sediments (Aquasoils) of the Baklan and Boisman bays of Peter the Great Bay

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Abstract: The allocation of aquatic soils, their revision, and the collection of new data are urgent tasks in light of global challenges related to assessing the distribution and reserves of organic carbon and nutrients in the oceans, as well as managing blue carbon. This article presents the results of an assessment of the main biogeochemical parameters of the surface-active layer of bottom sediments (aquasoils) in the Baklan and Boisman bays of Peter the Great Bay in the Sea of Japan. Samples for the study were taken from the upper 5 centimeters of bottom sediments. These aquasoil samples were obtained during an expedition conducted by the scientific research vessel "Professor Gagarinsky" using geological coring techniques. The studies revealed that the content of key elements constituting the organic carbon in the bottom sediments—such as carbon, nitrogen, and phosphorus—is correlated with the silty fraction. Additionally, freshwater inflow into the bays influences the acid-base properties and geochemical composition of the bottom sediments at depths reaching up to 60 meters.
Keywords: *Aquasoils, Bottom sediments, Geochemical composition, Organic matter, Sea of Japan.*

1. Introduction

Assessment of the current ecological state of bottom sediments (aquasoils) is an extremely urgent task for developing a strategy for the rational use of coastal territories. The active development of ocean resources and the creation of mariculture farms requires annual environmental monitoring to assess the safety of marine products. Offshore coastal territories are actively influenced by terrigenous runoffs. Coastal bottom sediments inherit their biogeochemical composition from terrestrial soils and, like classical soils, are formed under the influence of soil formation factors, which allows them to be classified as aquatic soils. According to Ivlev and Nesterova [1] «aquasoils» are formed at the bottom of reservoirs under the influence of soil—forming processes, as a result of which an organomineral complex is formed [1]. The use of the same research methods for land soils and marine sediments makes it possible to make a comparative assessment between the available published materials on land soils and bottom sediments (aquasoils).

The current state of the marine ecosystem is characterized by the upper 5-10 cm layer of bottom sediments, since it contains the largest amount of organic carbon and nutrients, and it also interacts most actively with the aquatic environment, aquatic plants and animals and actively participates in the carbon cycle and other elements [2].

The allocation of aquatic soils, their revision and the collection of new data is an urgent task from the point of view of global tasks of assessing the distribution and reserves of organic carbon and nutrients in the oceans and managing blue carbon [2].

The purpose of the study was to compare the basic biogeochemical conditions of formation of the surface-active layer (pH, organic carbon, phosphorus, potassium, nitrogen, and geochemical composition) of bottom sediments (aquasoils) of the Baklan and Boisman bays of Peter the Great Bay of the Sea of Japan.

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2. Materials and Methods

The objects of the study are bottom sediments (aquasoils) selected during the marine expedition of the scientific research vessel "Professor Gagarinsky" (flight No. 84) using geological columns from depths from 18.2 m to 51.1 m (depth, excluding the draft of the vessel 4.25 m). The selection of bottom sediments (aquasoils) was carried out in the shelf zone of the Baklan and Boisman bays, located in Peter the Great Bay (Sea of Japan). The upper mixed sample of the geological column from 0 to 5 cm was used for the analysis. The sampling diagram is shown in the Figure 1.

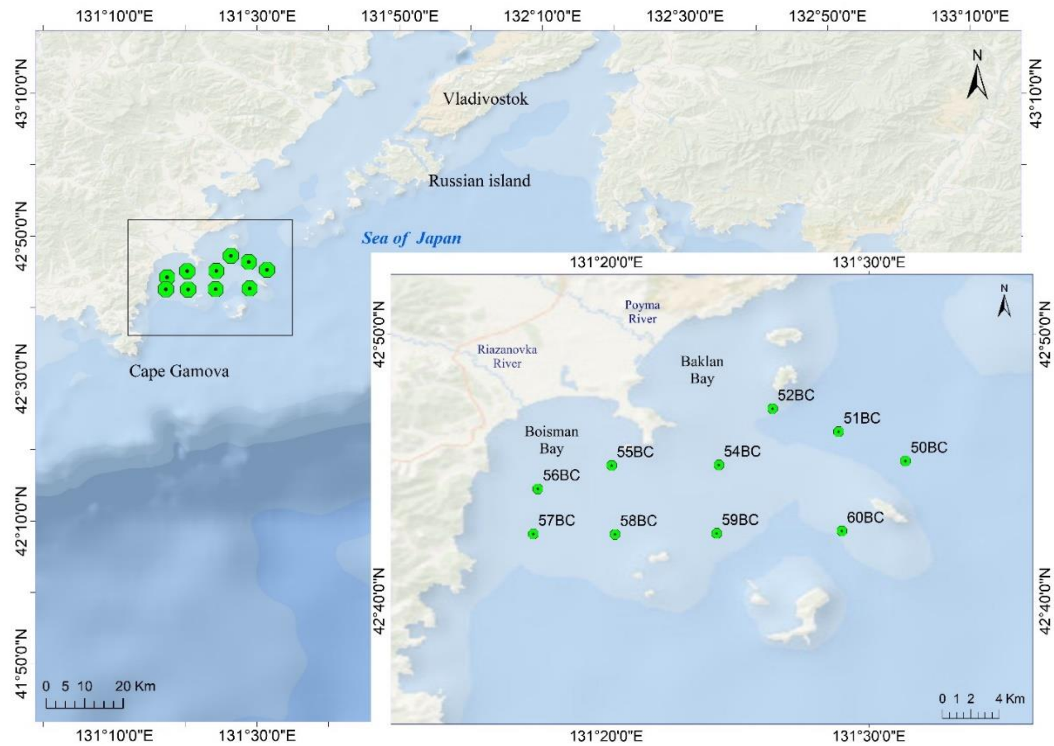

Figure 1.
Bottom sediment sampling map.

Standard soil analyses were used to determine the parameters, such as soil pH was analyzed potentiometrically (Five Easy Plus FP20, Mettler Toledo, Russia) in suspension with 1 mol dm-3 KCl solution ratio 1:2.5 [3]. Soil organic carbon (Corg) content was measured using the wet combustion method—oxidation of soil organic matter (SOM) by a mixture of 0.07 mol dm-3 H_2SO_4 and $K_2Cr_2O_7$ with titration using Mohr's salt [4, 5]. The granulometric composition was determined by the sieve-pipette method [6].

The granulometric composition of bottom sediments (aquasoils) was determined by the standard method [6] the total nitrogen content was determined by the standard method [7].

The content of available phosphates was determined by the spectrophotometric method [8]; potassium was determined by the flame photometric method [8].

The geochemical composition of the sediments was determined using a Handheld XRF Analyzers X-550 X-ray fluorescence analyzer.

3. Results and Discussion

The basic parameters affecting the global cycles of elements in marine and terrestrial ecosystems include granulometric composition, organic carbon (Corg), acid-base properties (pH), total nitrogen content (N), available phosphorus (P_2O_5), exchangeable potassium (K_2O), and geochemical composition, i.e. those properties that are related not only to the ecological state of bottom sediments, but also with the accumulation of organic matter.

The two studied territories border each other and are influenced by terrigenous runoff and freshwater outflow, however, samples from the Baklkan Bay were taken at great depths (31-51 m) compared with the samples from Boisman Bay (18-26 m).

The two studied territories border each other and are influenced by terrigenous runoff and freshwater outflow, however, samples from the Baklkan Bay were taken deeper (31-51m) compared with the samples from Boisman Bay (18-26 m).

The acid-base properties of aquasoils reflect the intensity of redox processes, the rate of decomposition of organic matter, microbial activity, as well as the properties of the mineral skeleton [9, 10].

Since the Ryazanovka and Poima rivers flow into both bays (Fig. 1), the pH values of the studied aquasoils range from slightly acidic to close to neutral (Table 1), which is consistent with other research studies on pH conditions in the Sea of Japan [9, 10]. Our research has shown that there is a slight variation in pH values (5.64 - 6.61) of the acid-base properties.

Table 1.
Basic parameters in the upper 5 cm of bottom sediments of Baklan Bay and Boisman Bay.

No.	Depth	pH	Corg	N	P_2O_5.	K_2O.	C/N	Granulometric composition
	m		%		мг/100 г			
				Baklan Bay				
50	51	5.64±0.01	0.76±0.11	0.31±0.01	24.60±1.20	21.30±1.10	2.45±0.07	Desiccated loam
51	43	6.22±0.01	1.09±0.09	0.34±0.01	21.50±0.90	25.30±1.30	3.23±0.02	Desiccated loam
52	31	5.71±0.01	0.80±0.12	0.27±0.01	16.50±1.30	20.60±1.10	2.94±0.01	Loamy sand
54	23	6.25 ±0.01	0.79±0.06	0.09±0.01	6.90±0.30	13.80±0.90	8.87±1.20	Loamy sand
60	39	6.41±0.01	0.83±0.08	0.23±0.01	3.90±0.90	9.10±0.80	3.65±0.01	Loamy sand
				Boisman Bay				
55	18	6.09±0.01	0.81±0.03	0.06±0.00	8.10±0.21	16.70±1.10	13.06±0.14	Loamy sand
56	19	6.17±0.01	0.41±0.01	0.03±0.00	7.10±0.20	12.40±1.20	13.22±0.14	Sand
57	26	5.91±0.01	0.52±0.03	0.02±0.00	10.10±0.80	14.50±1.40	32.50±0.15	Sand
58	22	6.61±0.01	0.37±0.01	н/о	6.70±0.14	10.60±1.10	-	Sand
59	26	6.57±0.01	0.26±0.01	н/о	6.70±0.21	9.20±0.90	-	Sand

Studies of the organic carbon content in the aquasoils of the Baklan and Boisman bays play an important role in developing a model of carbon circulation in the system of bottom and bottom ecosystems, which in turn reveals the features of carbon deposition in these waters. Organic matter in bottom sediments is formed mainly under the influence of the vital activity of microorganisms. The decomposition of organic matter is influenced by air, moisture, and the chemical composition of rocks. When there is a lack of air and an excess of moisture in the sediments, conditions are created for an anaerobic microbiological decomposition process. Also, in addition to the activity of microorganisms, the accumulation of organic matter in bottom sediments is influenced by acid-base properties and granulometric composition, which further affect the indicator of their ecological status.

The organic carbon content in all studied bottom sediments does not exceed 1.09% (Table 1). If we compare the bottom sediments of Cormorant Bay and Boisman Bay, then in the samples from Cormorant Bay we see higher values of organic carbon, probably due to a higher content of macrobenthos, as evidenced by the abundant annual storm emissions of *Ahnfeltia*. Nitrogen is a basic and essential element for all living organisms. It participates in an intensive biogeochemical cycle and is closely related to organic carbon. The nitrogen cycle is very complex, and in the marine environment, its organic and inorganic compounds, including gaseous ones, are assimilated [11]. Also, when the organic matter is fully mineralized, nitrogen turns into ammonium salts, which, thanks to the work of

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bacteria, oxidize it into nitrate and nitrite forms. The total nitrogen content (N total, %) varies from 0.0016 to 0.337%, which corresponds to the studies of the Sea of Japan and the Pacific Ocean according to Romankevich, et al. [11]. The degree of enrichment of organic carbon with nitrogen (C/N ratio) was calculated for bottom sediments. According to the ratio of C/N, it is possible to judge the rate of decomposition of these elements as they are sedimented and re-incorporated into biological and geological cycles. The C/N data range from 2.45 to 32.5, which is typical for soils that are very poor in organic matter [12].

The granulometric composition is inherited from the soil-forming rocks and determines the basic properties of both terrestrial and aquatic soils, namely: physical, physico-chemical and chemical. The ratio of the fractions of sand and clay explains the mechanisms of fixation of organic matter in the surface layer of aquatic soils. As a rule, aquapoils, in which the sand fraction (2-0.05 mm) prevails, have a low content of organic matter [11].

Studies have shown that the granulometric composition of bottom sediments is represented by desalinated loam, loamy sand and sand. The sand fraction (2-0.05 mm) prevails in all the studied samples, where its content varies from 76% to 93% (Figure 2).

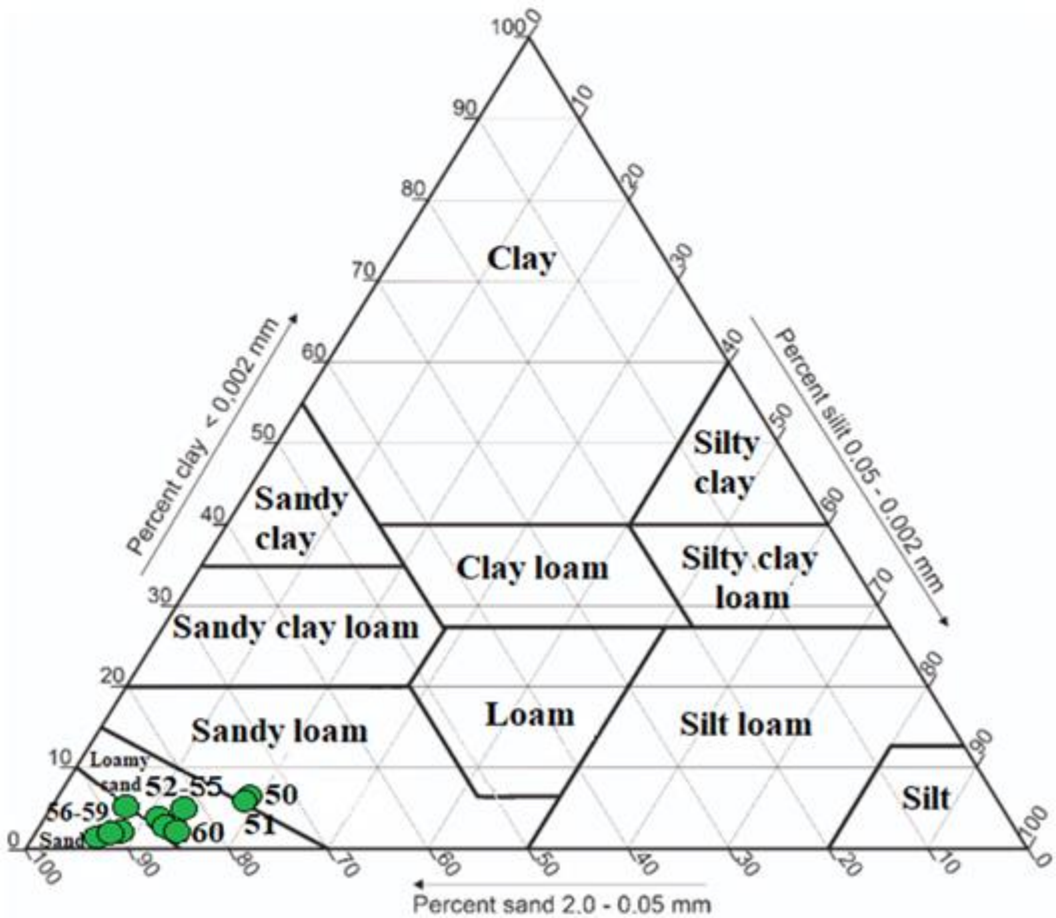

Figure 2.
Classification of bottom sediments, showing the percentage of sand, silt and clay.
Source: Bashour and Sayegh [8].

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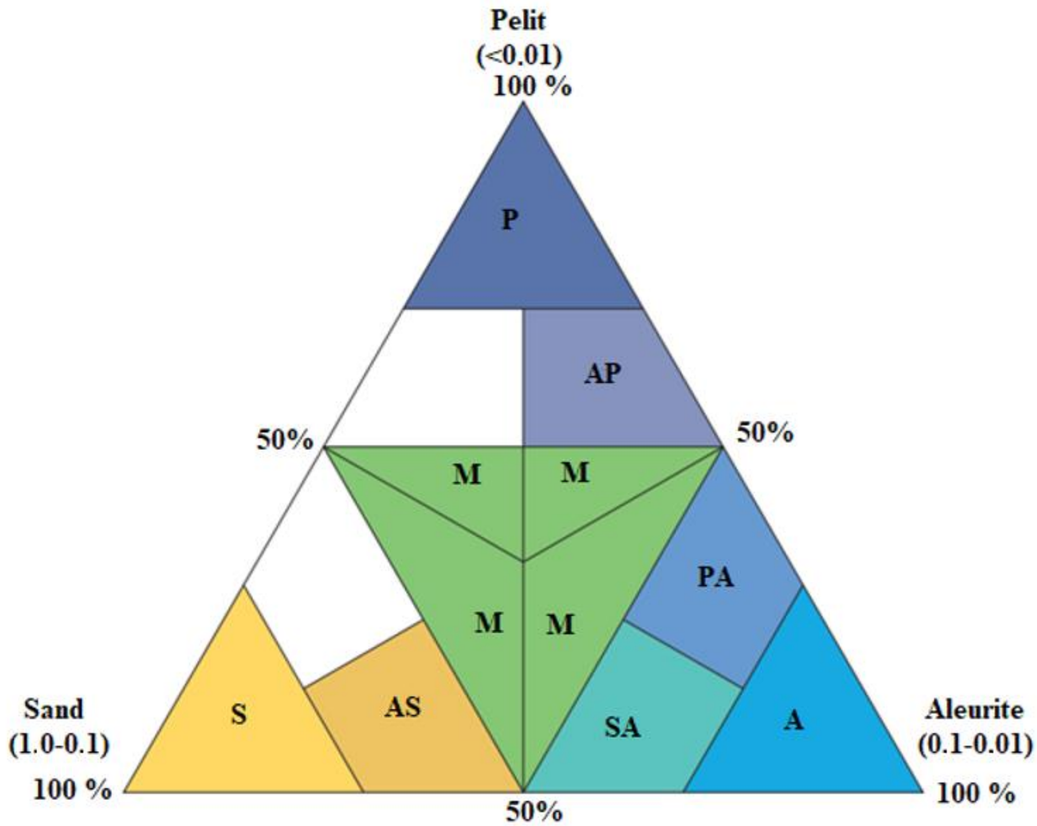

Figure 3.
Classification triangle, fraction sizes in mm.
Source: S – Sand; P – Pelit; A – Aleurite; SA – Sand aleurite; PA – Pelit aleurite; AS – Aleurite sans; AP – Aleurite pelit; M – Mictites sand-aleurite-pelit.
Bondarenko, et al. [13].

This distribution is also confirmed by the geological map of the lithological surface of the seabed (Fig. 3), which shows that according to the classification of granulometric fractions, all the studied samples belong to sand (diameter particles 1.0-0.1 mm) [13].

The granulometric composition and organic matter(s) are closely interrelated, since different fractions of the former fix and allow the accumulation of the latter with varying degrees of intensity. Smaller soil fractions are the most "active", which, in turn, with their predominant presence in the soil, can affect various physical and chemical processes occurring in the soil [14]. The decomposition of organic matter is influenced by air, moisture, and the chemical composition of rocks. When there is a lack of air and an excess of moisture in the sediments, conditions are created for an anaerobic microbiological decomposition process, which also depends on the granulometric composition and organic matter of the aquatic soils. In this regard, it is necessary to consider the content of organic matter and granulometric composition in bottom sediments (aquapoils) of the Sea of Japan and coastal soils for further assessment of the ecological state of coastal marine ecosystems [14].

According to the Pearson correlation coefficient, the content of the sand fraction in all samples significantly negatively correlated with the content of organic carbon ($r - 0.88$; $p < 0.002$). The clay content significantly positively correlated with the organic carbon content ($r\ 0.88$; $p < 0.002$). The organic carbon content was significantly independent of the sampling depth ($r\ 0.54$; $p\ 0.112$). Active terrigenous runoff associated with river outflow was noted in the study area. Fluctuations in the intensity of terrigenous runoff probably cause an uneven content of organic carbon depending on the depth of sampling.

Phosphorus exists in the sea in the form of mineral and organic compounds in various forms, is an important biogenic element [15] and is part of the organic matter of bottom sediments. The mineral and organic forms of this element are important biogenic compounds that are transformed as a result of their vital activity. Phosphorus is also in close interaction with nitrogen and protein compounds and is their companion. The mobile forms of aluminum inhibit the formation of phosphatides and nucleoproteins. Phosphorus binds aluminum to the soil, fixing it, which improves carbohydrate, nitrogen and phosphorus metabolism. The coastal soils of the seacoast of the Sea of Japan are enriched with iron and aluminum, and these chemical elements enrich the terrigenous runoff [16]. Research has shown the content of available phosphates in bottom sediments varies from 3.9 to 24.6 mg/100 g. This distribution of available phosphorus in bottom sediments may be related to the specifics of the chemical composition of macrobenthos in the studied area, its abundance and distribution areas. In the bottom sediments of Cormorant Bay, the content of organic phosphorus is higher, as well as other organic elements, which is related to the composition and number of living organisms living in this bay.

Potassium is the most important nutrient component along with nitrogen and phosphorus and is considered one of the three basic elements of nutrition. According to the content of exchangeable potassium (Table 1), the indicators in bottom sediments vary from 9.1 to 25.3 mg/100 g, which is primarily due to the granulometric composition, namely, its weighting (the fine fraction increases (<0.002) at points 50-52).

The geochemical composition of bottom sediments, as a rule, is inherited from the minerals composing the sedimentary column, or in the case of active terrigenous runoff, this composition may have similarities with terrestrial soils. The studied bottom sediments in the mineral skeleton have mostly the same composition as the land soils, with a predominance of silicon, aluminum and iron (Table. 2), which may indicate the terrigenous origin of the sedimentary material forming the studied bottom sediments [14].

Table 2.
The content of chemical elements in the upper 5 cm in the bottom sediments of Baklan Bay and Boisman Bay, %.

Element	**50**	**51**	**52**	**54**	**55**	**56**	**57**	**58**	**59**	**60**
Si	39.15±0.16	37.91±0.17	35.37±0.17	36.31±0.17	42.91±0.17	43.70±0.16	34.60±0.16	47.60±0.16	44.91±0.16	35.52±0.16
Al	6.76±0.10	7.22±0.11	6.50±0.11	5.45±0.11	6.12±0.11	6.27±0.11	5.10±0.11	5.47±0.11	5.69±0.11	6.14±0.11
K	2.42±0.03	2.21±0.03	2.29±0.03	1.83±0.03	2.78±0.03	2.78±0.03	1.65±0.03	2.18±0.03	2.49±0.03	2.09±0.03
Fe	1.51±0.01	2.06±0.01	1.47±0.01	1.47±0.01	1.29±0.01	1.00±0.01	1.14±0.01	0.60±0.01	0.78±0.01	1.56 ±0.01
Ca	1.11±0.01	1.01±0.01	1.11±0.01	1.16±0.01	1.01±0.01	0.90±0.01	1.06±0.01	0.89±0.01	1.16±0.01	0.94±0.01
P	0.496±0.01	0.799±0.01	0.476±0.01	0.424±0.01	0.484±0.01	0.418±0.01	0.463±0.01	0.479±0.01	0.439±0.01	0.443±0.01
S	0.252±0.01	0.373±0.03	0.513±0.03	0.731±0.03	0.237±0.03	0.170±0.03	0.773±0.03	0.161±0.03	0.206±0.03	0.586±0.03
Ti	0.162±0.002	0.268±0.03	0.194±0.03	0.133±0.03	0.167±0.03	0.091±0.001	0.235±0.001	0.107±0.001	0.107±0.001	0.335±0.001
Co	0.121±0.002	0.121±0.03	0.125±0.03	0.074±0.002	0.098±0.002	0.075±0.002	0.088±0.002	0.044±0.002	0.056±0.002	0.132±0.002
As	0.0540±0.001	0.071±0.001	0.0601±0.001	0.0446±0.001	0.029±0.001	0.017±0.001	0.038±0.001	0.013±0.001	0.011±0.001	0.110±0.001
Mn	0.024±0.002	0.034±0.002	0.026±0.002	0.017±0.002	0.020±0.002	0.017±0.002	0.026±0.002	0.013±0.002	0.017±0.002	0.035±0.002
Pr	0.022±0.003	0.022±0.003	0.018±0.003	0.023±0.003	0.020±0.003	0.026±0.003	0.022±0.003	0.023±0.003	0.018±0.003	0.027±0.003
Cr	0.0093±0.0004	0.0083±0.0004	0.015±0.0004	0.0083±0.0004	0.0081±0.0004	0.0084±0.0004	0.0096±0.0004	0.0062±0.0004	0.0071±0.0004	0.0079±0.0004
Th	0.0074±0.0002	0.0073±0.0002	0.0068±0.0002	0.0060±0.0002	0.0067±0.0002	0.0069±0.0002	0.0062±0.0002	0.0057±0.0002	0.0053±0.0002	0.0077±0.0002
Cu	0.0037±0.0005	0.0038±0.0005	0.0037±0.0005	0.0038±0.0005	0.0030±0.0005	0.0038±0.0005	0.0037±0.0005	0.0039±0.0005	0.0029±0.0005	0.0036±0.0005
Sr	0.0037±0.0001	0.0040±0.0001	0.0036±0.0001	0.0036±0.0001	0.0029±0.0001	0.0032±0.0001	0.0037±0.0001	0.0028±0.0001	0.0027±0.0001	0.0032±0.0001
V	0.0027±0.0002	0.0031±0.0002	0.0026±0.0002	0.0015±0.0002	0.0021±0.0002	0.0021±0.0002	0.0020±0.0002	0.0015±0.0002	0.0021±0.0002	0.0023±0.0002
Mo	0.0015±0.0001	0.0030±0.0001	0.0020±0.0001	0.0011±0.0001	0.0015±0.0001	0.0012±0.0001	0.0019±0.0001	0.0007±0.0001	0.0007±0.0001	0.00029±0.0001
Pb	0.0011±0.0001	0.0013±0.0001	0.0011±0.0001	0.0009±0.0001	0.0011±0.0001	0.0009±0.0001	0.0009±0.0001	0.0016±0.0001	0.0007±0.0001	0.0011±0.0001

There is no fundamental difference between the content of chemical elements in the studied bays, which indicates a similar genesis of the mineral material that forms the basis of bottom sediments.

4. Conclusion

In general, our research has shown that the content of the basic elements that make up the organic carbon of the bottom sediments of the studied territories, such as carbon, nitrogen and phosphorus, is related to the content of the silty fraction. The influence of fresh waters flowing into the bays affects the acid-base properties and geochemical composition of bottom sediments at depths up to 60 m, which is confirmed by a number of researchers in the waters of the Sea of Japan [9, 16]. Slightly higher concentrations of organic matter and its constituent carbon and nitrogen are noted for Baklan Bay, which is most likely due to the great depths, accumulation of silty fraction and composition of bottom and bottom biocenoses.

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Transparency:
The authors confirm that the manuscript is an honest, accurate, and transparent account of the study; that no vital features of the study have been omitted; and that any discrepancies from the study as planned have been explained. This study followed all ethical practices during writing.

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