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Chemical and Physicochemical Properties of Plain Soils in the Pacific Coast of Russia

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Abstract—Chemical and physicochemical properties of the soils of the coastal plains adjacent to the Sea of Japan and the Sea of Okhotsk are described. These data are compared with data on similar soils in other parts of the world. Several groups of soils of the coastal plains are distinguished.

INTRODUCTION

The soils of relatively narrow strips along oceanic and sea coasts are formed in a unique geochemical environment under the action of a specific set of pedogenetic agents. These soils are distinguished by their specific properties and can be grouped together at a high level of soil taxonomy [3, 9, 12–15].

It was suggested that coastal soils should be considered azonal soils that develop under strong and diverse influence from the sea; they form a separate association of genetic types of soils that can be referred to as Thalassosols [16]. The association of Thalassosols includes synlithogenic soils of the littoral zone (tidal marsh soils), postlithogenic hydromorphic soils (soils of maritime swamps), and postlithogenic mesohydromorphic and mesomorphic soils (soils of maritime meadows). The impact of the sea on tidal marsh soils is very strong and diverse. These soils are subjected to regular inundation by tides with corresponding redeposition of sediments; therefore, they develop under the combined action of pedogenic and lithogenic processes and are referred to as synlithogenic soils. Postlithogenic coastal soils are also influenced by the sea via the specific ground-water regime, spraying of easily soluble salts with sea winds and tiny drops of sea water, and

the effect of the sea on all other soil-forming factors. The classification of Thalassosols down to the subtype level is presented in Table 1.

Irrespectively of the classification position of soils of coastal lowlands and marshes, many authors have described their properties. In this paper, we will discuss the literature and our own data on the chemical and physicochemical properties of coastal soils.

Coastal soils, especially hydromorphic soils, are characterized by a distinct tendency for the accumulation of decomposed plant remains (in the form of peat or muck) on the soil surface. Most hydromorphic soils have typical organomineral (humus) horizons, though the primitive mineral soils (soils of sand dunes, marshes, and offshore barriers) are also frequent. The distribution pattern of organic matter in hydromorphic coastal soils is rather irregular; the surface maximum of C_{org} is not always observed. Usually, these soils are characterized by the deep penetration of humus, which is conditioned by the high mobility of humic substances in them [6, 18, 19, 22, 24, 28].

The reaction of coastal soils may vary from strongly acid to alkaline depending on particular conditions. Regularities in the distribution of pH values can only be revealed on the basis of statistical analysis of large data

Table 1. The classification of Thalassosols

Taxonomic level	Names of soil taxa					
Group of soil types	Thalassosols					
Subgroups of soil types	Marsh soils		Maritime swampy soils		Maritime meadow soils	
Soil types	Organic marsh soils	Proper marsh soils	Maritime swampy organic soils	Maritime meadow-swampy soils	Maritime meadow organic soils	Maritime meadow soils
Soil subtypes	Mucky–peaty Peaty–mucky Mucky	Typical Alluvial marsh	Mucky–peaty Peaty–mucky Mucky	Typical Slightly peaty Peaty	Mucky–peaty Peaty–mucky Mucky	Typical Gleyed

sets. The analysis of available data shows that the reaction of most of the tidal marsh soils ranges from weakly acid to neutral. The drying of soil samples to the air-dry state leads to a drastic drop in pH (by three pH units and more). The acidification of marsh soils while drying is conditioned by the oxidation of sulfides (mainly, pyrite) accompanied by the appearance of sulfuric acid. The content of pyrite in coastal marsh soils may reach 10%; therefore, the acidification effect is very strong unless the soil contains some neutralizing substances, e.g., carbonates. The natural drying of marsh soils leads to the development of strongly acid sulfate soils with pH_{H_2O} below 4.0–3.5 [11, 20, 25, 27, 29, 31].

Reducing conditions prevail in soils of tidal marshes. Oxidizing conditions are only observed in the soils of relatively elevated positions composed of light-textured rocks with good drainage capacity and aeration. Most of the swampy marsh soils develop in anaerobic environments with low redox potential (from –150 to 400 mV). Low redox potential values favor the development of gleyzation and some other specific chemical processes in marsh soils. For instance, the accumulation of pyrite in these soils is conditioned by the reduction of sulfates. The correlation between the redox potential and the content of sulfates in marsh soils is rather definite [4, 17, 21, 29, 31].

The cation exchange capacity of marsh soils is correlated with the content of the clay fraction and the amount of organic substances in them. In sandy soils, CEC values are very low (<10 meq/100 g), whereas in clayey and peaty soils, CEC exceeds 90 meq/100 g. The base saturation degree is usually high. The composition of exchangeable cations depends on the character of a substrate; on calcareous rocks, exchangeable cations are mainly represented by calcium, whereas magnesium and sodium prevail in tidal marsh soils developed from other substrates. This is conditioned by the effect of saline seawater, which is often responsible for the development of solonetzic properties in tidal marsh soils [18, 19, 23, 26, 30].

The presence of considerable amounts of easily soluble salts in the soils of tidal marshes allows one to attribute these soils to the group of salt-affected soils (solonchaks). However, in some cases, the salt content in marsh soils can be relatively low. The ion composition of salts in the profile of marsh soils is characterized by the predominance of Na^+ and Mg^{2+} cations and Cl^- and SO_4^{2-} anions, i.e., the same ions that prevail in seawater. However, the proportion between these ions in marsh soils may differ from that in seawater. Some soils are dominated by chlorides, whereas other soils have a distinct maximum of sulfates. The processes of salt migration and redistribution in marsh soils are governed by the lithological composition of a substrate, the presence of organic matter, the ion composition of seawater in the zone of shallow water, the geomorphic position and hydrological regime of a soil, and the climate. Data

on the electrical conductivity of water extracts from soils can be efficiently used for the determination of the degree of soil salinization [5, 6, 17, 18, 21, 25].

MATERIALS AND METHODS

The sampling of coastal soils was performed in different parts of the coasts of the Sea of Japan and the Sea of Okhotsk in Primorskii krai and in Sakhalin and Magadan obalsts. In total, samples from 100 pits were analyzed. Usually, these pits were made along the transects stretched inland from the waterline and characterizing different successive stages of soil formation in the coastal zone.

Standard procedures were used to determine the chemical and physicochemical soil properties: the humus content was determined by the Tyurin's method; the Corg content in organic horizons, by the ignition method; pH of water and salt extracts, by potentiometers; CEC, by the Bobko–Askinazi method in modification of Grabarov and Uvarova; the redox potential, by platinized glass electrodes immediately after digging a soil pit; the sum of reduced substances, by the Starzhes method in modification by Neunylov; and mobile iron compounds, in the 0.1 N H_2SO_4 extract [1, 2]. While analyzing water extracts from soils, we used the recommendations suggested by Kostenkova *et al.* [7]. The degree of soil salinization was determined from data on the dry residues in water extracts according to criteria developed by Kovda *et al.* [10]. The specific electric conductivity of water extracts was measured by the OK-102/1 conductometer in three replicates. Water extracts from mineral and organic (peaty) substrates were prepared using the soil-to-water ratio of 1 : 5.

RESULTS AND DISCUSSION

Organic Substances of Thalassosols

The data obtained show us that the Thalassosols of the Pacific coast of Russia are very diverse with respect to the content and composition of organic matter in them. Organic substances may be represented by both half-decomposed organic remains (peat) and by humic substances. Peat layers of different thickness can be found in all types and subtypes of Thalassosols, except for typical meadow maritime soils.

The variability in the soil organic matter (SOM) content in all taxa of Thalassosols is very great. Therefore, while characterizing the SOM pools in Thalassosols, it is better to use averaged values and variation ranges. The same is true with respect to the chemical and physicochemical properties of Thalassosols. Data on the ranges of variation in SOM and pH of Thalassosols are given in Table 2. Average values are calculated to illustrate some tendencies in the behavior of organic matter in different groups of Thalassosols.

The highest pools of organic matter are observed in organic (histic) Thalassosols, especially in swampy

Table 2. The organic matter content and pH_{KCl} in Thalassosols of the Pacific coast of Russia

Soils	Organic matter content			pH_{KCl}		
	mean	variation range	mean square deviation	mean	variation range	mean square deviation
	%					
Mucky–peaty marsh soils	50.3 / 5.8	18.7–73.1 / 0.9–10.7	22.02 / 6.95	4.6 / 2.4	4.1–4.9 / 2.1–2.6	0.27 / 0.23
Typical marsh soils	15.4	0.2–78.0	19.47	4.4	2.3–7.5	1.27
Alluvial marsh soils	8.1	0.4–48.1	13.38	5.0	3.1–7.5	1.15
Swampy mucky–peaty maritime soils	62.9	51.5–82.0	10.04	4.0	3.6–4.6	0.51
Swampy peaty–mucky maritime soils	55.8	5.6–78.1	28.54	4.1	3.3–4.8	0.70
Meadow-swampy peaty maritime soils	19.9	2.6–68.1	21.73	5.0	3.1–6.8	0.88
Meadow-swampy slightly peaty maritime soils	10.5	0.7–29.0	12.24	2.7	2.3–3.0	0.37
Meadow-swampy typical maritime soils	4.9	0.6–13.9	4.02	4.9	2.4–7.7	1.57
Peaty–mucky meadow maritime soils	34.6	31.8–41.1	4.39	5.1 / 3.8	3.5–7.0 / 3.2–4.3	1.23 / 0.79
Meadow gleyed maritime soils	6.6	0.1–60.5	12.14	4.1	3.5–5.3	0.56
Typical meadow maritime soils	2.5	0.2–14.7	3.64	4.6	3.4–6.1	0.86

Note: Here and in Tables 3 and 4, data on organic horizons are given above the line and data on mineral horizons are under the line.

maritime soils, clayey marsh soils, and meadow maritime soils subjected to some mineralization of the organic matter on their surface. Among the organomineral soils, the highest SOM pool is characteristic of peaty meadow-swampy maritime soils. The SOM content in meadow-swampy maritime soils with a thin peat horizon is twice as low. The minimal SOM pool is observed in typical meadow-swampy soils without a histic horizon. It is interesting to note that the SOM content in typical tidal marsh soils is much higher than in alluvial marsh soils. This is conditioned by the more active deposition of sediments in alluvial marsh soils that leads to an admixture of a considerable amount of mineral substances to the peaty material. The lowest SOM content is observed in typical meadow maritime soils that do not have a histic horizon on the surface, receive a lower amount of organic residues with tides, and are characterized by a somewhat coarser texture than other tidal marsh soils; in the sandy horizon of these soils, the humus content does not exceed 4%.

Distribution patterns of organic matter in the profiles of Thalassosols are very diverse (Fig. 1). As seen from Fig. 1, the maximum of the organic matter is not always confined to surface horizons. Sometimes, several maximums can be distinguished in a soil profile. The latter pattern is very typical for polycyclic Thalassosols. The high content of organic matter is traced to great depth. Swampy maritime soils are somewhat thicker than swampy soils of tidal marshes because of their greater age. Even the soils developing from similar rocks may have quite different humus distribution patterns.

The pools of organic matter reach their maximum in organic Thalassosols, especially in meadow maritime soils, in which the specific bulk density is much higher than in typical peaty and swampy soils. In general, the reserves of organic matter in meadow maritime soils may be as high as 180 kg/m^2 (for the layer of 0–100 cm). The reserves of organic matter in peaty (meadow-swampy and marshy) soils vary from 30 to 70 kg Corg/m^2. Minimal amounts of organic matter are inherent in typical and gleyed meadow maritime soils with sandy texture and in primitive sandy soils of tidal marshes (7–8 mg/kg).

The vertical distribution of organic matter in the profiles of Thalassosols is also very diverse. Though most of these soils are characterized by a distinct maximum of Corg in surface horizons of different thickness (the so-called ectomorphic soils), the profiles with several maximums of Corg are also observed (polycyclic soils), as well as the profiles with a deep maximum of Corg (endomorphic soils).

Soil Reaction

The reaction of Thalassosols (for air-dry samples) varies from strongly acid (pH_{KCl} 2.1) to alkaline (7.7). Most of the pH_{KCl} values vary within the acid range. Thus, about 78% of the samples are distinguished as moderately and strongly acid (including 50% of strongly acid samples), slightly acid and neutral samples constitute about 19% of the total number of samples, and a slightly alkaline and alkaline reaction is observed in about 3% of the samples.

It is probable that the share of acid and strongly acid soils in natural conditions is not as high as for air-dry
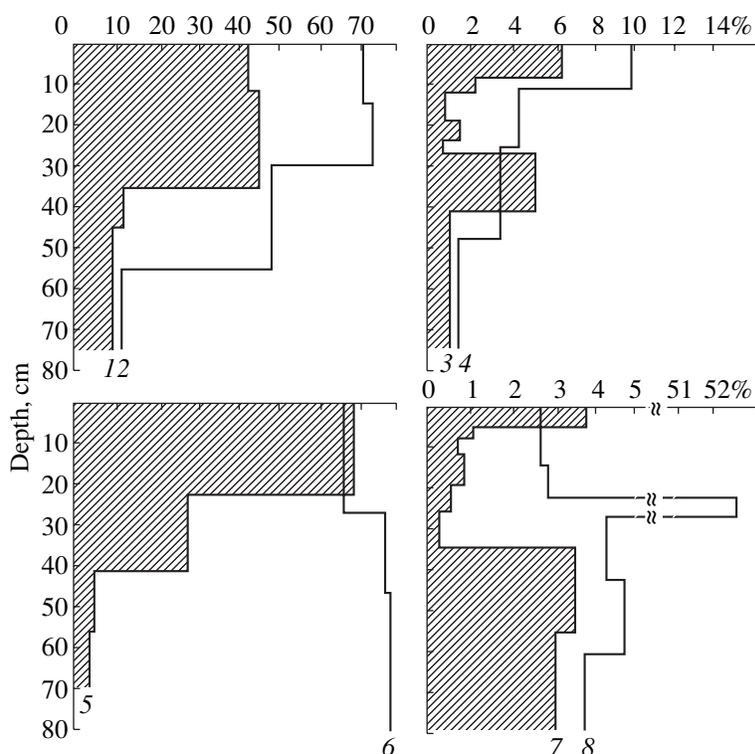
Fig. 1. Distribution patterns of organic matter in the profiles of Thalassosols. Soils: (*1*) typical peaty marsh soil (pit 1-93), (*2*) mucky–peaty marsh soil (pit 2-93), (*3*) alluvial marsh poorly developed soil (pit 2-94), (*4*) typical poorly developed marsh soil (pit 5-92), (*5*) peaty meadow-swampy maritime soil (pit 3-93), (*6*) peaty–mucky swampy maritime soil (pit 4-95), (*7*) typical shallow meadow maritime soil (pit 1-92), and (*8*) deep meadow gleyed maritime soil (pit 6-92).

samples. The acidification of soils while drying can be explained by pyrite oxidation with the simultaneous formation of sulfuric acid. This hypothesis is supported by data on the negative correlation between soil pH and the content of sulfate ions. For example, the coefficient of correlation for two marsh soils (the organic soil and the typical marsh soil) developed near the Tsaplich'ya Lagoon (Khasan district) reaches –0.97. Therefore, we have good reason to conclude that most of the Thalassosols in the Pacific coast of Russia should be referred to as potentially acid sulfate soils.

Taking into account data on soil reaction in different groups of Thalassosols (Table 2), we can see that the soils of all subtypes may have acid reaction, while neutral and alkaline reaction is only observed in about half of the subtypes. Marsh and maritime swampy soils always have a strongly to moderately acid reaction; the soil acidity in these groups of soils increases in mineral horizons in the lower part of soil profiles. Thus, the soil reaction in the lower part of the organic layer of maritime meadow soils may reach alkaline values, but it drops to strongly acid values in the underlying mineral horizons.

The wide range of pH variation in the profiles of meadow-swampy maritime soils is conditioned by the differences in composition of the upper (organic) and lower (mineral) parts of these soils. If peat layers are taken separately, the range of pH variation in them is much narrower (from 4.8 to 5.8). The maximum variability in pH values is inherent in typical meadow-swampy maritime soils, which may be conditioned by their relatively young age and low buffer capacity.

In meadow maritime soils, pH conditions are more uniform. Gleyic meadow maritime soils fall into the category of strongly and moderately acid soils with some increase in pH of their bottom mineral horizons. Typical meadow maritime soils formed on the seaward sides of barrier beaches are marked by a wide range of pH values (from strongly acid to neutral ones). The most acid reaction is usually observed in bottom horizons of these soils. The soils of the same group, but located farther from the sea, always have a strongly acid reaction.

As far as the soils of tidal marshes are concerned, a strongly acid reaction can be found in all their varieties, whereas alkaline conditions are only characteristic of primitive sandy soils. In general, the acidity of these soils increases from primitive soils to peaty soils. The latter are always strongly acid, with moderately acid conditions in separate soil horizons. The lower limit of pH variations in alluvial–marsh soils is somewhat higher than that in typical marsh soils, which may be explained by the higher content of carbonates in the soils near the estuaries of rivers.
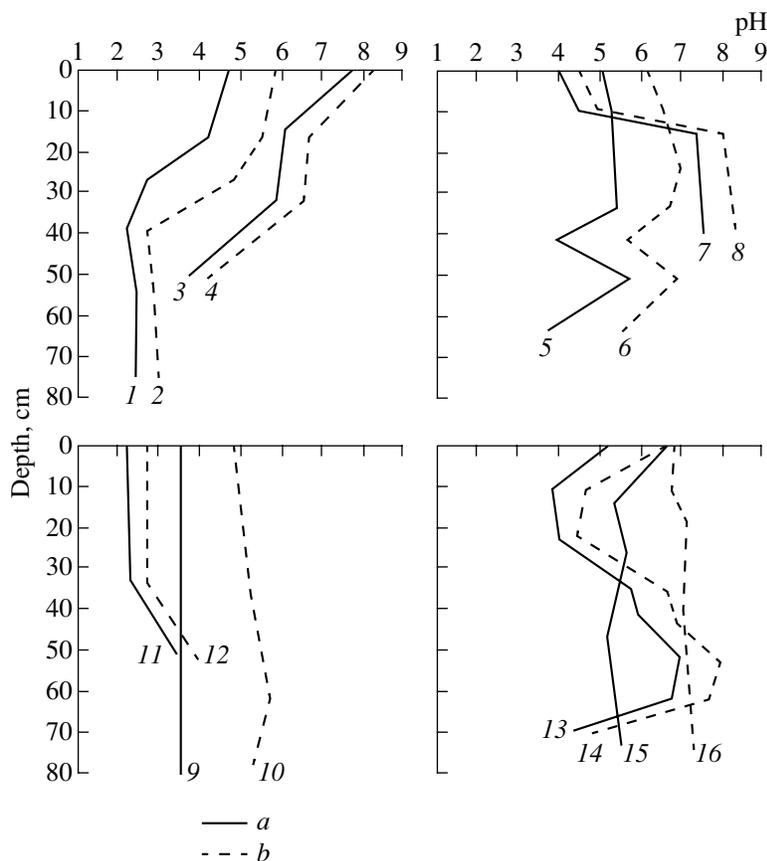
Fig. 2. Distribution patterns of soil reaction in the profiles of Thalassosols: (*a*) pH_{H_2O} and (*b*) pH_{KCl}. Soils: (*1*, *2*) typical peaty marsh soil (pit 1-93); (*3*, *4*) typical primitive marsh soil (pit 43-96); (*5*, *6*) mucky–peaty alluvial marsh soil (pit 11-95); (*7*, *8*) primitive alluvial marsh soil (pit 9-95); (*9*, *10*) mucky–peaty swampy maritime soil (pit 2-95); (*11*, *12*) typical medium-deep meadow-swampy maritime soil (pit 14-96); (*13*, *14*) peaty–mucky meadow maritime soil; and (*15*, *16*) typical shallow meadow maritime soil (pit 1-95).

Let us consider the changes in distribution of pH values by vertical profiles of Thalassosols. In typical marsh soils and in poorly developed alluvial marsh soils, pH conditions are mainly governed by the acidity of soil-forming rocks. All kinds of pH distribution patterns can be found in these soils (Fig. 2). Very often, sharp contrasts between pH values in neighboring horizons are observed. In peaty marsh and alluvial–marsh soils, a general tendency for an increase in acidity down the soil profile is quite distinct, so that bottom mineral horizons of these soils have a more acid reaction than their organic horizons. The difference in pH values between topsoil and bottom horizons can exceed 2.5 pH units.

The soil reaction in peaty horizons of swampy maritime soils is rather stable. In the soils with thick peat horizons, the acidity increases down the soil profile and reaches its maximum in the mineral bottom horizons. In typical meadow-swampy soils without a distinct accumulation of peat on the soil surface, the variation in pH is not so definite; often, the mineral horizons of such soils have even higher pH values in comparison

with the organic horizons, which is conditioned by the peculiarities of soil-forming rocks.

The rocks underlying organic meadow maritime soils and swampy marsh soils usually have a strongly acid reaction. The reaction in peaty horizons of these soils ranges from strongly acid to alkaline with a tendency for a rise in pH down the soil profile. Such a distribution pattern of soil reaction distinguishes peat soils of coastal marshes from typical synorganogenic peat soils. Gleyed meadow maritime soils have an acid and strongly acid reaction. Considerable changes in pH are only observed in the soils with sharp lithological changes in their profiles. A tendency for a decrease in acidity down the soil profile is not very distinct. Sometimes, the profile distribution of pH values is characterized by a complex pattern with the maximum in the middle part of the profile. Typical meadow maritime soils are characterized by a relatively uniform distribution of pH values, except for the topmost horizon, which is distinguished from the underlying horizons by generally lower pH values. As a rule, the distribution pattern of pH values in meadow maritime soils depends on the nature of coastal sediments; a general tendency

Table 3. The characteristics of the exchange complex of Thalassosols in the Pacific coast of Russia

Soils	Cation exchange capacity			Base saturation		
	mean	variation range	mean square deviation	mean	variation range	mean square deviation
	meq/100 g soil			%		
Organic marsh soils*	71.5 / 28.2	40.8–107.4 / 11.3–45.2	24.56 / 24.00	69.6 / 44.1	55.6–80.0 / 31.2–57.0	9.56 / 18.23
Typical marsh soils	36.3	12.1–92.3	22.45	68.7	21.0–90.8	18.44
Alluvial marsh soils	23.7	8.1–67.7	14.53	82.9	51.0–97.1	14.43
Swampy maritime soils	65.2	33.4–75.0	14.75	56.3	49.7–61.8	4.24
Meadow-swampy maritime soils	49.2	25.5–142.8	32.58	56.3	18.8–88.9	22.88
Meadow maritime soils	29.7	7.5–77.2	19.47	70.4	38.5–92.7	11.91

towards an increase in pH down the soil profile is often observed.

The values of pH_{KCl} and pH_{H_2O} are well correlated, though their vertical distribution patterns do not correspond to one another. In general, pH_{H_2O} values exceed pH_{KCl} values by 0.4–2.1 pH units; the difference between the pH of salt and water extracts is relatively stable for every particular soil profile (Fig. 2).

Redox Conditions

Most of the marsh soils are characterized by the predominance of reducing conditions, except for their topmost horizons, in which the alternation of reducing and oxidation conditions takes place. The range of Eh values is rather wide (from 190 to 400 mV); averaged values for separate horizons range from 226 to 348 mV. The sum of reduced substances (the oxidation index) varies from trace amounts to 28 mg O_2 per 100 g soil. The most considerable variations in the oxidation index are observed in the topmost soil horizons. The accumulation of ferrous iron may reach 30 mg/100 g soil.

The average Eh value reaches its minimum in swampy maritime soils, though particular values do not fall below 200 mV. These soils are also distinguished by the highest amounts of reduced substances (up to 60 mg O_2 per 100 g soil) and ferrous iron compounds (up to 85 mg/100 g soil).

The oxidation–reduction regime of meadow maritime soils varies from weakly reducing to moderately oxidative. Averaged Eh values calculated for separate soil horizons range from 207 to 640 mV. The most considerable changes in Eh take place in topsoil horizons. In these soils, oxidized iron compounds prevail over ferrous iron compounds. The sum of reduced substances varies from trace amounts to 42 mg O_2 per 100 g soil.

Exchange Complex of Thalassosols

The cation exchange capacity of Thalassosols is characterized by a high variability. In the soils studied, it varies from 8 to 143 meq/100 g soil. Minimal values are typical for low-humus sandy soils; maximum values (>40 meq/100 g) are observed in the peaty soils of swamps. In most of the organomineral and mineral horizons of Thalassosols, CEC values are below 50 meq/100 g.

Data on variations in the cation exchange capacity are given in Table 3. As seen from this table, the variations in CEC for separate taxonomic groups of Thalassosols are also very significant. As a rule, CEC values decrease down the soil profile; the maximum values are observed in the middle part of organic horizons.

The base saturation of Thalassosols has been studied by comparing data on the cation exchange capacity and the hydrolytic (total) acidity. The total acidity values are rather significant in all the horizons. They vary from 0.6 to 108 meq/100 g soil, reaching their maximum in the soils with a high cation exchange capacity, i.e., in organic horizons.

The frequency distribution of the base saturation shows that in 20% of the samples the values of base saturation are below 55%; these soils can be attributed to the group of strongly unsaturated soils [8]. In 39% of the samples, the base saturation varies from 55 to 75%. High base saturation (>90%) is observed in 12% of the samples.

Low base saturation is typical for most Thalassosols, except for the organic marsh soils, in which low base saturation is only observed in underlying rocks. However, even in these soils, the base saturation is just a little higher than 55%. Therefore, we can assume that strongly unsaturated soils can be encountered among swampy marsh soils. The variation in the base saturation index in organic horizons is somewhat lower than that in organomineral horizons, which is conditioned by a high buffer capacity of peat. The highest values of

base saturation are typical for alluvial–marsh soils; the lowest values are observed in swampy maritime soils.

The regularities of distribution of base saturation values along the profiles of Thalassosols are rather indistinct. Often, Thalassosols have very sharp contrasts in the degree of base saturation within a soil profile. The maximum difference in the degree of base saturation registered in different horizons of a soil profile reaches 61%; the difference between neighboring horizons is also very significant (up to 54%).

The Salinity of Thalassosols

The Thalassosols of the Pacific coast of Russia can be separated into several groups (from nonsaline to strongly saline soils) with respect to their salinity. The dry residue of water extracts from these soils varies from 0.03 to 5.65%; however, in 70% of the samples, it does not exceed 1%. The occurrence of saline soils in the humid climate of the Far East coastal region is only possible due to the continuous spraying (impulverization) of salts from the sea, regular tidal floods, and the presence of salts in the groundwater. Therefore, the qualitative composition of ions in salts extracted from Thalassosols is similar to that in the seawater. However, the proportions between these ions change under the impact of pedogenesis. Topsoil horizons have a chloride or sulfate–chloride type of salinization, whereas in bottom horizons, the prevalence of sulfate ions is observed. Magnesium and sodium prevail among the cations; in some soils, the sodium ion is the dominant one. The association of magnesium and calcium can be also found; in the horizons composed of seashells, calcium ions predominate over magnesium ions.

The intrusion of sea salts into the profiles of Thalassosols is accompanied by periodic leaching of these soils by rainwater. Such a combination of oppositely directed processes supports the pulsating regime of salts in the profiles of Thalassosols and explains the diversity of types of the vertical distribution of salts in these soils. The vertical heterogeneity of soil-forming rocks composed of different lithological strata with different capacities to retain salty seawater also contributes to the complexity of salt distribution patterns. It should be noted that the regularities governing the redistribution of salts in the profiles of arid soils are quite different from those that are observed in Thalassosols. Therefore, the grouping of Thalassosols with respect to their salt content should be based on principles different from those that are accepted for salt-affected soils of arid regions [9, 10]. We suggest that the salinity classes of Thalassosols should be taken into account at the family (genus) level of their classification [16].

The distribution pattern of salts in Thalassosols does not depend on the presence or absence of tidal floods. Salt-containing horizons may occur both in the bottom and upper parts of soil profiles. Nonsaline Thalassosols are confined to sandy substrates, river estuaries, and lagoons with slightly saline water. It is interesting to note that the soils of the tidal zone often have a lower salt content in comparison with meadow-swampy maritime soils that are not affected by tidal floods. Thus, we can conclude that regular tides do not favor the accumulation of considerable amounts of salts in the soil profile. The concentration of salts in water extracts from the soils of tidal zones does not exceed their concentration in seawater. The salinity of surface horizons of typical maritime meadow soils of heavy texture can be explained by the impulverization of salts from the sea. This is the main factor of salt accumulation in all types of maritime soils.

The electrical conductivity of water extracts from Thalassosols is well correlated with the salt content in these extracts measured after their evaporation (the coefficient of correlation exceeds 0.95). It is known that the electrical conductivity of salt solutions depends upon the concentration and nature of ions in the solution and temperature conditions; in our experiments, all measurements were made at a standard temperature of 15°C. The correlation between the electrical conductivity and the content of salts in the dry residue from soil solutes enables us to devise the following scale of soil salinity: the specific conductivity of <0.45 mS/cm corresponds to nonsaline soils; 0.45–0.85 mS/cm, to slightly saline soils; 0.86–1.65 mS/cm, to moderately saline soils; 1.66–2.50 mS/cm, to strongly saline soils; and >2.50 mS/cm, to very strongly saline soils. These intervals virtually do not depend on the chemical nature of salts. Though the molar conductivity of sulfate ions is somewhat lower than that of chloride ions, this difference is compensated for by a higher requirement for the dry residue content in the case of sulfate salinization. Thus, strongly saline soils are distinguished when the dry residue composed of chlorides reaches 0.5–0.8%; for the sulfate type of salinization, this value should be no less than 1–2% [10].

The concentration and distribution of salts in different types of Thalassosols can be judged from the data shown in Table 4. It should be noted that determinations of electrical conductivity were performed in samples from 220 soil horizons of 43 soil pits; these measurements are more representative than our data on the dry residue content. As seen from the table, all groups of Thalassosols may contain nonsaline soil profiles or, at least, nonsaline soil horizons. The swampy soils of marshes and the maritime zone are most strongly affected by salts. The minimal content of salts in the soils of this group is observed for swampy alluvial–marsh soils, which is conditioned by the freshening effect of river water. The salinity of meadow maritime soils is somewhat lower. Gleyed meadow maritime soils are slightly and moderately saline (the strong salinity was registered in just one soil pit with the maximum accumulation of salts in the buried peat horizon). Most typical meadow maritime soils are nonsaline or contain small amounts of salts in separate horizons.

Table 4. The salt content in Thalassosols of the Pacific coast of Russia

Soils	Dry residue after evaporation of water extracts			Electrical conductivity of water extracts		
	mean	variation range	mean square deviation	mean	variation range	mean square deviation
	%			mS/cm		
Organic marsh soils	2.47 / 2.15	0.18–5.65 / 0.35–4.97	2.24 / 2.48	3.164 / 2.898	0.405–8.258 / 0.521–5.986	3.128 / 2.801
Typical marsh soils	1.47	0.07–4.86	1.49	1.868	0.020–6.880	2.124
Alluvial marsh soils	0.60	0.18–1.36	0.31	0.734	0.126–2.161	0.529
Swampy maritime soils	2.40	1.94–3.02	0.56	1.206	0.157–5.911	1.806
Meadow-swampy maritime soils	1.30	0.03–4.45	1.27	2.930	0.083–10.664	2.928
Meadow maritime soils	0.52	0.06–0.89	0.34	1.325 / 1.300	0.293–2.973 / 1.224–1.377	0.949 / 0.108
Gleyed meadow maritime soils	0.31	0.01–1.33	0.31	0.309	0.038–2.131	0.425
Typical meadow maritime soils	0.09	0.03–0.18	0.05	0.181	0.038–0.661	0.138

The examples of changes in the electrical conductivity along the vertical profiles of Thalassosols are shown in Fig. 3. No definite trends in the vertical distribution of salts can be seen in soils of tidal marshes. The variations in the electrical conductivity are connected with peculiarities of the lithological composition of soil horizons rather than with particular trends in the migration of salts. In swampy maritime soils, a decrease in the salt content down the soil profile is observed. Easily soluble salts tend to accumulate in surface horizons,
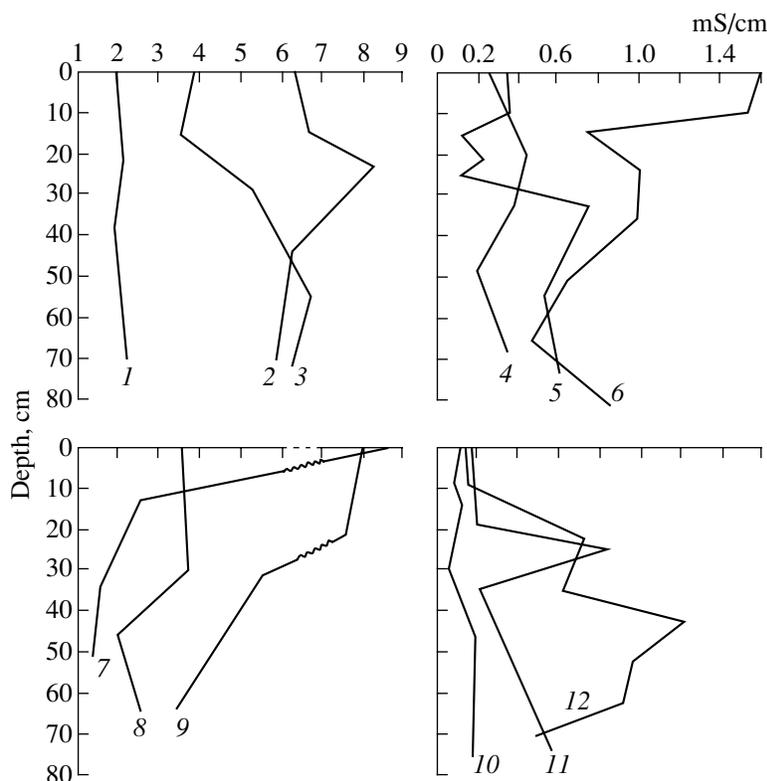
Fig. 3. Distribution pattern of electrical conductivity in water extracts from Thalassosols. Soils: (*1*) typical primitive maritime soil (pit 7-95), (*2*) mucky–peaty shallow marsh soil (pit 2-93), (*3*) typical peaty marsh soil (pit 1-93), (*4*) peaty alluvial marsh soil (pit 4-94), (*5*) poorly developed alluvial marsh soil (pit 2-94), (*6*) poorly developed alluvial marsh soil (pit 3-94), (*7*) typical moderately deep meadow-swampy maritime soil (pit 14-96), (*8*) typical deep meadow-swampy maritime soil (pit 6-95), (*9*) peaty meadow-swampy maritime soil (pit 3-93), (*10*) typical shallow meadow maritime soil (pit 1-92), (*11*) deep gleyed meadow maritime soil (pit 6-92), and (*12*) peaty–mucky meadow maritime soil (pit 42-96).

where they form a typical solonchakous profile, sometimes with a thin salt crust on the soil surface (Fig. 3, pit 14-96). The ascending migration of salts is also observed in those soils of the marsh zone, which are not subjected to regular tidal floods. Thus, the alluvial–marsh soil located 10 m from the river (Fig. 3, pit 3-94) has a higher concentration of easily soluble salts in the surface horizon as compared to lower-lying horizons. The soil of similar genesis but located closer to the river (pit 2-94) and subjected to more regular floods has a distinct minimum of salts in the surface horizon.

As a rule, salt-containing horizons of maritime meadow and meadow gleyed soils are observed in their bottom parts, at the contact with saline groundwater. The ascending migration of salts in these soils does not reach the soil surface; the maximum accumulation of salts takes place in the middle part of soil profiles. Typical meadow maritime soils developing from coarse-textured rocks in conditions of a deep groundwater level are virtually nonsaline. This is confirmed by very low and rather uniform values of the electrical conductivity in water extracts from these soils. It is obvious that the distribution of easily soluble salts along the profiles of Thalassosols is subjected to considerable seasonal changes. However, the amount of available data is insufficient to predict the seasonal dynamics of salts in Thalassosols of the Pacific coast of Russia. Further investigations are required.

CONCLUSIONS

(1) The soils of coastal marshes and lowlands in the Pacific region of Russia can be grouped together under the name of Thalassosols; the chemical and physico-chemical properties of these soils differ from those of typical inland soils and, at the same time, have may similarities with coastal and tidal marsh soils in other parts of the world.

(2) The chemical and physicochemical properties of different taxa of Thalassosols are characterized by very wide variations that are dictated by the instability of soil regimes of Thalassosols, their low buffer capacity, and considerable heterogeneity in the conditions of pedogenesis. At the same time, separate types and subtypes of Thalassosols have quite definite statistical regularities in the character of the main chemical and physicochemical properties.

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