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Distribution and Composition Patterns of Snow Cover within the Landscapes of Chashnikovo

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Abstract—The depth and reserves of snow cover, as well as chemical composition of the snow, have been investigated in the landscape of the upper reaches of the Klyazma River (Solnechnogorsk raion, Moscow oblast). Determination of the component composition of the snow cover was based on the geochemical taxonomy of chemical elements according to characteristics of their water migration ability and abundance. Data from 23 snow sampling points have been interpolated in SAGA GIS using the inverse distance weighting (IDW) method. On this basis, zones differing in the chemical composition of snow have been identified. One of the zones is confined to the Moscow—St. Petersburg M-10 highway, while the second borders on populated areas. The highway-adjacent area is characterized by increased levels of calcium, sodium, aluminum, and chloride ions in the snow cover. The second zone, which is adjacent to populated areas, is characterized by a high content of calcium, copper, and manganese in the snow. The third zone is characterized by low concentrations of components in the snow, which is typical for a superaquatic landscape due to the distance from sources of pollution.

According to their composition, the studied snow waters belong to the bicarbonate—sodium—calcium—chloride class. It has been shown that the depth and reserves of snow cover are partially controlled by two factors: the type of elementary landscape and the type of ecosystem. The spatial distribution of elements and anions in snow is predominantly controlled by the anthropogenic factor.

Keywords: hydrochemical characteristics, natural landscapes, map diagram, highway, pollution

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INTRODUCTION

The role of snow cover was shown in the classical works of A.I. Voeikov (1889). An outstanding figure in Russian soil science, S.S. Neustruev (1931, p. 27), wrote, "many phenomena of soil diversity may be explained by the uneven distribution of snow cover resulted from the wind activity." Today, in the studies of the snow cover in connection to environmental monitoring, close attention is paid to the patterns of spatial distribution of snow and its chemical composition. Noteworthy are the patterns of the snow cover distribution in different areas. In particular, it was shown that, in the landscapes of Smolensk oblast (including forest, floodplain, and wetland ones), the differences in snow depth often depend on the age and type of forest plantings (Osipova, 2014).

Other works emphasize the differences in snow cover, which are determined by the climatic characteristics of the frosty period. In floodplain landscapes, the role of vegetation is also significant and determines high snow reserves (Shkalikov and Osipova, 2014). In the taiga zone, forest ecosystems contribute to more intensive accumulation of a number of elements than the open areas. In forest ecosystems, proximity to pollution sources results in increased concentrations of the most important macroelements in the snow cover (Pristova and Vasilevich, 2011). Under pollution, variations in the content of essential microelements in snow increase due to increase in technophilicity (Bordon, 1996). Additionally, in residential areas, snowmelt waters are exposed not only to increased total mineralization, but also to alkalization (Moskovchenko et al., 2021). The difference in the depths of the snow cover in arable and forest areas was shown to be associated with the degree of forest cover, microrelief, and nature and exposure of the slopes (Evseeva et al., 2017). Studies of the nature of snow water in agricultural landscapes revealed that, for some areas of Moscow oblast, the values of hydrochemical indicators can be close to natural, while acidification of atmospheric precipitation was observed for other areas. At the same time, increased mineralization of snow water (with a low content of heavy metals) is considered as a reclamation factor for soils in agricultural landscapes (Ermakov et al., 2014a).

Other areas of snow-cover research concern its spatial distribution, which is studied by a combination of land and satellite observations with subsequent processing using geographic information technology (GIS) technologies (Romasko, 2019). Such a study was conducted for the Western Alps (Colombo et al., 2022) and Alaska (Macander et al., 2015).

Consideration of environmental issues is widely associated with the use of GIS technologies for constructing pollution maps (Kopylov, 2013; Krotkov, 2015; Mustafin et al., 2017; Chupikova, 2017; Yadav et al., 2020) and subsequent comparison of the resulting material with results of field snow surveys (Dvornikov et al., 2015). Mapping of the content of individual elements or groups of components in snow cover are quite common: for example, mapping of the mercury content (Siudek et al., 2014) or the content of sulfates, nickel, and copper in the local pollution zone of the Kola Peninsula (Ratkin et al., 2001).

Long-term 50-year observations of snow cover were carried out in Croatia (Perčec et al., 2015). Recognizing the enormous role of snow cover as a factor influencing regional and global water and energy cycles, optical remote sensing methods based on medium-resolution imaging spectroradiometer are widely used in the arsenal of modern snow cover mapping methods (Jiang and Shi, 2018).

The spatial distribution of snow cover was studied for large territories (Kryuchkov, 2021), as well as for a system of conjugate elementary landscapes (Petrov et al., 2013). These studies revealed the role of macro-, meso-, and microrelief in the distribution of snow cover (Kontsevaya et al., 1989; Mustafin et al., 2017).

Thus, the presented material convincingly shows how seriously attention is paid to the study of snow cover in Russia and abroad. At the same time, issues of spatial distribution of snow cover and its composition are resolved at different levels of landscape organization.

The territory of the Chashnikovo Training and Experimental Soil Ecological Center of Moscow State University is currently proposed as a site for the operation of a carbon polygon (https://carbon.msu.ru/), which requires a detailed study of environmental conditions. In this regard, the purpose of this work is to study snow cover in the various elementary landscapes and ecosystems of the Chashnikovo Center. The objectives of the study include determining the characteristics of the spatial distribution of snow cover and its chemical composition; construction of special map diagrams in GIS, reflecting the spatial distribution of concentrations of some components of snow cover; and identification of factors influencing the characteristics of snow cover.

It is worth noting that our previous studies of snow cover on the Chashnikovo Center territory included research of the distribution patterns of snow cover only in a system of associated elementary landscapes (Bogatyrev et al., 2018). However, they did not cover general patterns of spatial distribution of snow and its composition.

MATERIALS AND METHODS

The study area is located within the upper reaches of the Klyazma River in the northwest of Moscow oblast, 43 km from Moscow and 8 km from the city of Zelenograd. The study area is located within the Central Russian Upland and predominantly covers the southern slope of the Klinsko-Dmitrovskaya ridge with absolute heights of 250–320 m. Ridges that are arms of the Klinsko–Dmitrovskaya ridge stand out within the described territory. They are elongated almost latitudinally and serve as watersheds of the Klyazma and other rivers. The Chashnikovskaya depression with the Klyazma River valley is located between the L'yalovskaya and Alabushiskaya ridges. The geomorphological conditions are characterized by soft outlines of watersheds and gentle slopes. The climate of the area is temperate continental with minimum temperatures of –40°C and maximum temperatures up to +34°C. The annual precipitation is 700–750 mm, 70% of which occurs in the warm season. Snow cover persists from mid-November to mid-April. The soil can freeze to a depth of 40–100 cm (*Pochvenno-agronomicheskaya kharakteristika*..., 1986).

Watershed areas of the territory of the Chashnikovo Center are characterized as eluvial landscapes occupied by arable and meadow lands. Adjacent landscapes are transit–eluvial and transit ones, occupied by forests, meadows, and arable lands. Floodplain territories belonging to superaquatic landscapes are occupied mainly by meadows and forests of varying degrees of hydromorphism.

According to the Classification and Diagnostics of Soils of the Soviet Union (*Klassifikatsiya*..., 1977), and ten soil types were preliminarily determined on the studied territory of the Chashnikovo Center with a total area of 338.9 ha. These soils develop in the conditions of various elementary landscapes (Kirillova, 2015). Thus, within the eluvial–transit and transit landscapes, the dominant soils are those of the podzolic series, usually developed, with a minor participation of sod–gley soils. A variety of alluvial and bog soils are common within the superaquatic landscape. Not widespread, but geochemically interesting, soils within the narrow contact zone of the transit–

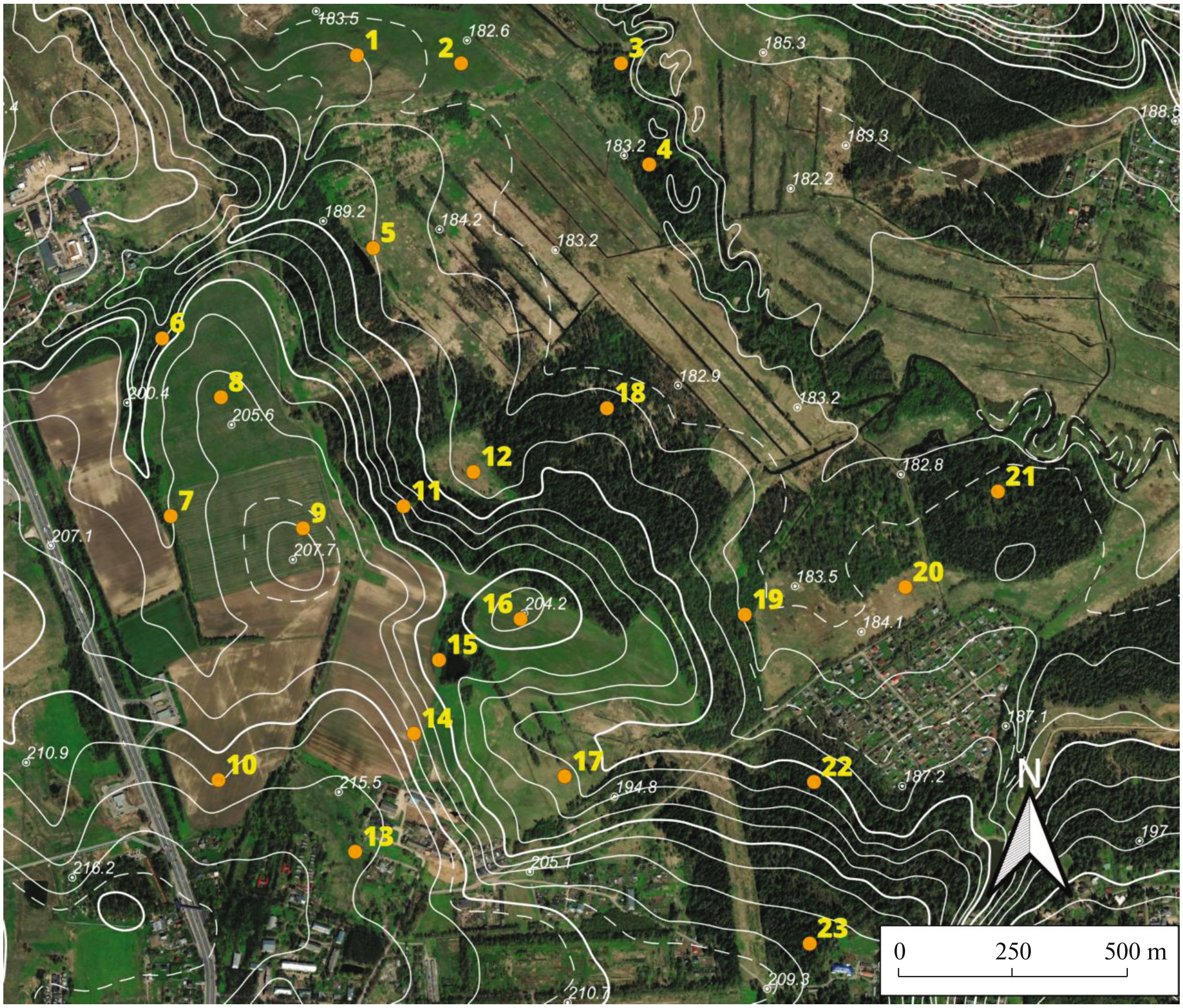

Fig. 1. Location of sampling points in the study area (the Moscow–St. Petersburg M-10 highway is located in the west; populated areas are in the southeast).

accumulative and superaquatic landscape related to meadow–bog carbonated soils are of particular interest.

The nature of the distribution and chemical composition of snow cover was studied on 23 selected sampling points, which characterize various types of elementary landscapes and lands and are located at different distances from populated areas and the M-10 Moscow–St. Petersburg highway (Table 1, Fig. 1). In this work, the background areas are understood as the areas most distantly located from the sources of pollution.

To conduct a detailed study of the relationship between the type of landscape and the natural patterns of snow cover, a detailed study of the characteristics of the vegetation cover of forest, meadow, and arable areas was carried out in the summer period within the entire territory of the Chashnikovo Center, which is located in the subzone of coniferous–deciduous forests. In upland areas not affected by agricultural activities, forests are dominated by *Picea abies* (L.) H. Karst. with an admixture of *Quercus robur* L., *Acer platanoides* L., *Betula pendula* Roth., and *Populus tremula* L. The underwood storey is represented by *Corylus avellana* L., *Rubus idaeus* L., *Padus avium* Mill., and *Lonicera xylosteum* L. The ground-cover layer is dominated mainly by nemoral species (*Galeobdolon luteum* Huds., *Asarum europaeum* L., and *Pulmonaria obscura* Dumort.) and, to a lesser extent, by boreal species (*Oxalis acetosella* L., *Luzula pilosa* (L.) Willd., and *Dryopteris carthusiana* (Vill.) H.P. Fuchs). Waterlogged intrawatershed depressions are occupied by boggy birch and aspen grass forests. The near-terrace part of the Klyazma River floodplain is covered by birch and gray alder forests, and in its central part there are grass–forb meadows. The abandoned arable lands were replaced by dry meadow plant communities dominated by meadow and weed–ruderal species

Table 1. Characteristics of the research objects in the Chashnikovo Training and Experimental Soil Ecological Center of Moscow State University

No.	Coordinates	Location	Soil type (*Klassifikatsiya*..., 2004)	Land-use characteristics
		Eluvial–transit landscape		
7	56.043808 N 37.162757 E	edge of the ravine	agro-soddy–podzolic regraded	aspen–birch ruderal–tallgrass forest
7	56.043808 N 37.162757 E	edge of the ravine	agro-soddy–podzolic regraded	aspen–birch ruderal–tallgrass forest
23	56.035442 N 37.185137 E	top of the watershed	soddy–podzolic	spruce forest with *Galeobdolon* and *Impatiens*
23	56.035442 N 37.185137 E	top of the watershed	soddy–podzolic	spruce forest with *Galeobdolon* and *Impatiens*
		Transit landscape		
6	56.047284 N 37.162457 E	ravine slope	dark humus gley	tall-grass aspen forest
6	56.047284 N 37.162457 E	ravine slope	dark humus gley	tall-grass aspen forest
8	56.046133 N 37.164516 E	watershed slope	agro-soddy–podzolic regraded	dry grass-and-forb meadow
8	56.046133 N 37.164516 E	watershed slope	agro-soddy–podzolic regraded	dry grass-and-forb meadow
9	56.043569 N 37.167392 E	watershed slope	agro-soddy-podzolic	arable land with *Bromus* and *Trifolium* plantings
9	56.043569 N 37.167392 E	watershed slope	agro-soddy-podzolic	arable land with *Bromus* and *Trifolium* plantings
10	56.038642 N 37.164431 E	watershed slope	agro-soddy–podzolic regraded	short-grass fallow meadow
10	56.038642 N 37.164431 E	watershed slope	agro-soddy–podzolic regraded	short-grass fallow meadow
11	56.044 N 37.170911 E	terrace slope	agro-soddy–podzolic	spruce forest with *Oxalis* and *Galeobdolon*
11	56.044 N 37.170911 E	terrace slope	agro-soddy–podzolic	spruce forest with *Oxalis* and *Galeobdolon*
12	56.044671 N 37.173357 E	terrace slope	soddy–podzolic gleyic	dry grass-and-forb meadow
12	56.044671 N 37.173357 E	terrace slope	soddy–podzolic gleyic	dry grass-and-forb meadow
13	56.03724 N 37.169216 E	watershed slope	agro-soddy–podzolic	arable land, fallow
13	56.03724 N 37.169216 E	watershed slope	agro-soddy–podzolic	arable land, fallow
14	56.039553 N 37.171276 E	watershed slope	agro-soddy–podzolic	arable land, potato plantings
14	56.039553 N 37.171276 E	watershed slope	agro-soddy–podzolic	arable land, potato plantings
22	56.038606 N 37.185287 E	watershed slope	soddy–podzolic gleyic	birch–spruce forest with *Galeobdolon* and *Oxalis*
22	56.038606 N 37.185287 E	watershed slope	soddy–podzolic gleyic	birch–spruce forest with *Galeobdolon* and *Oxalis*

Table 1. (Contd.)

No.	Coordinates	Location	Soil type (*Klassifikatsiya*..., 2004)	Land-use characteristics
		Transit-accumulative landscape		
15	56.040992 N 37.172155 E	bottom of the watershed slope	agro-soddy–podzolic regraded	ruderal–tallgrass fallow meadow
15	56.040992 N 37.172155 E	bottom of the watershed slope	agro-soddy–podzolic regraded	ruderal–tallgrass fallow meadow
16	56.041795 N 37.175009 E	bottom of the watershed slope	agro-soddy–podzolic	arable land, fallow
16	56.041795 N 37.175009 E	bottom of the watershed slope	agro-soddy–podzolic	arable land, fallow
17	56.038714 N 37.176554 E	bottom of the watershed slope	agro-soddy–podzolic regraded	dry grass-and-forb meadow
17	56.038714 N 37.176554 E	bottom of the watershed slope	agro-soddy–podzolic regraded	dry grass-and-forb meadow
		Superaquatic landscape		
1	56.05282 N 37.16928 E	central floodplain	alluvial grey–humus gley	floodplain grass–forb meadow
1	56.05282 N 37.16928 E	central floodplain	alluvial grey–humus gley	floodplain grass–forb meadow
2	56.052664 N 37.172928 E	central floodplain	alluvial grey–humus gley	floodplain forb meadow
2	56.052664 N 37.172928 E	central floodplain	alluvial grey–humus gley	floodplain forb meadow
3	56.052664 N 37.178528 E	levee	alluvial grey-humus	floodplain grass–forb meadow
3	56.052664 N 37.178528 E	levee	alluvial grey-humus	floodplain grass–forb meadow
4	56.050687 N 37.179515 E	riverbed part of the floodplain	alluvial sod acidic podzolic	spruce forest with *Oxalis*
4	56.050687 N 37.179515 E	riverbed part of the floodplain	alluvial sod acidic podzolic	spruce forest with *Oxalis*
5	56.049052 N 37.169849 E	central part of the floodplain	alluvial grey–humus gley	floodplain grass meadow
5	56.049052 N 37.169849 E	central part of the floodplain	alluvial grey–humus gley	floodplain grass meadow
18	56.045918 N 37.178035 E	near-terrace floodplain	alluvial humus–gley	spruce-birch tallgrass forest
18	56.045918 N 37.178035 E	ne8ar-terrace floodplain	alluvial humus–gley	spruce–birch tallgrass forest
19	56.041879 N 37.182863 E	near-terrace floodplain	alluvial grey–humus gley	alder tallgrass forest
19	56.041879 N 37.182863 E	near-terrace floodplain	alluvial grey–humus gley	alder tallgrass forest
20	56.042418 N 37.188485 E	near-terrace floodplain	alluvial grey–humus gley	floodplain ruderal–tallgrass meadow
20	56.042418 N 37.188485 E	near-terrace floodplain	alluvial grey–humus gley	floodplain ruderal–tallgrass meadow
21	56.044288 N 37.191725 E	near-terrace floodplain	alluvial humus–gley	Spruce forest with *Stellaria* and *Oxalis*
21	56.044288 N 37.191725 E	near-terrace floodplain	alluvial humus–gley	Spruce forest with *Stellaria* and *Oxalis*

Table 2. Geochemical systematics of elements according to the characteristics of their water migration abilities and abundance (Kasimov et al., 2019)

Group of elements		Elements
Cationogenic		Na, K, Ca, Sr, Ba, Mg
Complexing elements		V, Ti, Cu, Zn, Al
Transitional		Fe, Mn
Anionogenic	subgroup 1	C, N, P, Si, S
	subgroup 2	F^-, Cl^-, NO^{3-}, SO_4^{2-}, HCO_3^-

(*Alopecurus pratensis* L., *Dactylis glomerata* L., *Phleum pratense* L., *Lathyrus pratensis* L., *Cirsium arvense* (L.) Scop., *Taraxacum officinale* F.H. Wigg., and *Heracleum sosnowskyi* Manden.).

Note that the arable lands at the time of description were in a different states. Some of them were represented by fallow, others were under potato plantings, and others were under grass plantings. The classification of soils within each sample plot is done according to the classification of soils of Russia in 2004 (*Klassifikatsiya*..., 2004). GPS coordinates were recorded for each sample point characterizing a certain type of land-use (Table 1, Fig. 1). In the subsequent winter period, the snow-cover depth was measured at these points in 12 repetitions. Then, the snow density and total snow reserves were calculated, and two samples were selected to determine the component composition.

In the lab, snow was melted at room temperature and filtered through an ash-free blue ribbon filter. The pH values were determined using a Hanna pH-213 pH meter, and electrical conductivity was determined using a Hanna DIST 3 conductivity meter. Concentrations of the main elements were determined by mass spectrometry on a contrAA 300 Analytik Jena spectrometer, and anions, on an Agilent ICPMS 7500a inductively coupled plasma spectrometer (ICPMS..., 2005). Anions were separated carried on an ion exchange column with their subsequent detection using a conductometric detector (Shpigun, Zolotov, 1990). The concentrations of water-soluble forms of organic C and total N were determined using a Shimadzu TOC-V(CPN) total carbon and nitrogen analyzer. Analytical studies were carried out on the basis of the collective laboratory of the Department of Soil Science of Moscow State University.

Consideration of the results obtained was carried out in accordance with the concept of paragenetic associations of elements according to N.S. Kasimov (Kasimov et al., 2019). This methodological approach was developed at the Department of Geochemistry of Landscapes and Soil Geography (Department of Geography, Moscow State University).

In accordance with this concept, we identified four groups of elements and one group of anions (Table 2).

Data on the chemical composition of snow cover with coordinate references were imported into the SAGA GIS program. Point data were interpolated using the inverse distance weighted (IDW) method. It should be noted that this method has been successfully used previously by other authors (Shikhov, 2013; Khomushku et al., 2016). The initial cartographic material for constructing maps of snow-cover reserves and snow chemical composition was a raster image of the topographic base of the territory of the Chashnikovo Center at a scale of 1 : 10000 with geographic references.

The nomenclature of elementary landscapes and water classes is given in accordance to the classification of A.I. Perelman and N.S. Kasimov (1999). Calculations were carried out in the STATISTICA and Microsoft Excel software packages at a significance level of 0.05.

RESULTS

First of all, we have to emphasize that discussing the results obtained was not a simple task due to the following circumstances. First, the data obtained characterized a rather heterogeneous territory as it is represented by a combination of different types of landscapes, from various types of forests to meadow ecosystems and arable lands. Second, these lands occupied different positions in the system of elementary landscapes, from eluvial to superaquatic (Perelman and Kasimov, 1999). Third, it turned out that the lands, regardless of their belonging to the type of elementary landscape or the nature of the vegetation, were characterized by different proximities to probable sources of pollution, which included the Moscow–St. Petersburg M-10 highway, on the one hand, and populated areas, on the other. Fourth, the construction of a map reflecting the composition of the snow cover revealed an area with a minimal level of pollutant input.

Our research has shown that the depth of snow cover for the entire study area varies within a fairly wide range (27–40 cm) (Table 3). The total reserves of snow cover vary within the range of 90–130 kg/m^2. These values correlate with the total depth of the snow cover; however, the variations in snow density are rather weak (on average, 0.3 g/cm^3).

It is shown that the average depth and reserves of snow cover naturally increase in the eluvial–transit–superaquatic system of conjugate elementary landscapes (Table 3). It has been established that the depth and reserves of snow cover did not depend on the type of vegetation.

The weakly acidic reaction of melted snow is natural; as a rule, the pH values did not exceed 5. A similar picture was revealed during comparison the data characterizing conjugate elementary landscapes (Table 3). Under forested areas, the pH_{wat} values are significantly lower than in open areas.

It is noteworthy that snow waters within the entire study area are characterized by low electrical conductivity values; the measured average values did not exceed 0.01 mS/cm.

Analyses of the components showed that a regular series Ca > Na > K > Mg > Sr > Ba is formed in the group of cationogenic elements (Table 4). It has been established that in areas near the highway and populated areas the content of Ca, Mg, and Na increases significantly. However, the proximity to pollution sources has no effect on the concentrations of K, Sr, and Ba.

In the group of anionogenic elements, there are two subgroups. The first subgroup characterized the total content of elements, while the second subgroup characterized anions (Table 5). In the first subgroup (C, N, S, Si, and P), the leading place belongs to carbon. Its average content is almost an order of magnitude higher than the content of total nitrogen, while the content of all other elements is one or two orders of magnitude lower compared to that of this element. According to the concentration of elements, the general series in this subgroup is C > N > S > Si > P. However, the content of all elements varies significantly, which does not allow any patterns to be identified.

According to the concentration of anions, the general series in the second subgroup is HCO_3^- > Cl^- > NO_3^- > SO_4^{2-} > F^-. This series is also characterized by the maximum values determined for forest ecosystems. However, the chloride ion concentration significantly increased in the areas close to the highway.

According to concentration, the elements of the group of complexing agents form the sequence Al > Zn > Cu > V > Ti (Table 6). It should be mentioned that the concentration of these elements, as a rule, varies from 0.1 to 30 μg/kg. In areas remote from the sources of pollution, all elements of this group (with the exception of Zn) can be considered as trace elements. The members of the group of transitional elements (Fe and Mn) are characterized by similar concentrations in different studied areas (Table 6); however, the values of concentrations varied significantly.

Calculation of the reserves of elements in snow waters revealed a clear correlation between the concentrations of elements and their total content, which leads to the preservation of the sequences (series) established during the comparison of concentrations. The determined patterns of an increase in the concentrations of elements near pollution sources were also found during comparison of the total reserves of these elements in snow with an increase in their variability.

Content and Reserves of Elements in Snow Waters in a System of Conjugate Landscapes

The grouping of data in a system of conjugate landscapes showed that the main pattern is a clear increase of element concentrations in snow waters formed in eluvial landscapes. However, the reserves of elements are higher in the transit–accumulative landscapes (although this should only be considered as a trend). Unfortunately, it is impossible to insist that the differences in concentrations are significant, including the reserves of elements in the snow waters of the compared elementary landscapes, due to the obvious high variability of the values of the parameters under consideration.

According to the Spearman's correlation coefficients, the Ca and Ba reserves correlate positively and significantly (0.78). A similar good level of correlation was found for Na and Cl^- reserves (0.86). Also, close relationships (0.89) were determined for the reserves of Mg, Ca, and Ba. A slightly smaller relationship was shown when comparing Si reserves with Al, Fe, and Ti reserves (0.7). A positive correlation was revealed between the reserves of Zn and the reserves of the most mobile NO_3^- (0.7). The same level of correlation (0.7) was determined for the reserves of SO_4^{2-} and total S reserves.

DISCUSSION

Our research allows the most important patterns to be established in the nature of the distribution of snow cover within the landscapes of the upper reaches of the Klyazma River. It was shown that the depth of snow cover tends to increase from eluvial–transit to superaquatic landscapes; however, this often does not correlate with an increase in total snow reserves due to different snow density.

In particular, due to this circumstance, the maximum values of the total reserves of components were determined in the transit–accumulative landscapes, which on average are characterized by increased snow density. However, this should be considered only as

Table 3. Characteristics of snow cover in the study area of the Chashnikovo Training and Experimental Soil Ecological Center of Moscow State University

Site characteristics	N	Depth of snow cover, cm	Snow-cover reserves, kg/m^2	Snow density, g/cm^3	pH	Es, mS/cm	Sum of components, mg/kg	Sum of components, mg/m^2
Small-leaved forest	6	32.9 ± 2.3	100.3 ± 4.4	0.31 ± 0.05	4.93 ± 0.23	0.01 ± 0.01	18.01 ± 6.80	1605.7 ± 467.9
Complex spruce forest	4	40.9 ± 4.1	129.2 ± 17.0	0.31 ± 0.10	4.62 ± 0.46	0.01 ± 0.01	9.33 ± 0.66	1134.6 ± 597.1
Spruce forest	8	37.3 ± 3.9	114.1 ± 10.1	0.31 ± 0.06	4.83 ± 0.20	0.02 ± 0.02	13.89 ± 2.51	1235.7 ± 274
Floodplain meadow	10	33.3 ± 2.0	108.9 ± 6.1	0.33 ± 0.04	5.08 ± 0.35	0.04 ± 0.02	11.40 ± 1.88	1319.4 ± 208.8
Dry meadow	6	32.6 ± 3.1	98.6 ± 7.8	0.31 ± 0.02	5.02 ± 0.17	0.01 ± 0.01	12.88 ± 4.36	1194.8 ± 359.1
Short-grass fallow meadow	4	29.3 ± 1.9	87.9 ± 5.8	0.3 ± 0.020	5.10 ± 0.29	0.02 ± 0.01	17.29 ± 9.97	1488.6 ± 733.9
Arable area	8	31.0 ± 1.7	116.2 ± 7.4	0.38 ± 0.07	5.09 ± 0.08	0.01 ± 0.01	13.46 ± 2.23	1626.2 ± 698.8
Eluvial–transit	4	26.8 ± 1.9	99.4 ± 7.2	0.37 ± 0.10	5.01 ± 0.26	0.01 ± 0.01	16.17 ± 8.22	1374.8 ± 1076.7
Transit	18	32.9 ± 1.4	101.7 ± 3.7	0.31 ± 0.03	4.99 ± 0.11	0.01 ± 0.01	14.92 ± 2.79	1337.6 ± 200.8
Transit-accumulative	6	28.9 ± 1.5	104.7 ± 11.3	0.36 ± 0.09	5.08 ± 0.11	0.01 ± 0.01	14.7 ± 2.50	1703.0 ± 975.2
Superaquatic	18	37.8 ± 2.1	118.8 ± 6.2	0.32 ± 0.03	4.91 ± 0.22	0.03 ± 0.01	11.29 ± 1.09	1310.6 ± 139.0
Background sites	32	32.9 ± 1.2	108.2 ± 4.0	0.33 ± 0.02	4.98 ± 0.12	0.02 ± 0.01	12.48 ± 1.17	1339.4 ± 178.4
Sites near the highway	6	30.4 ± 1.9	95.0 ± 4.6	0.32 ± 0.04	5.03 ± 0.29	0.02 ± 0.01	21.92 ± 3.66	1854.9 ± 276.2
Sites near populated areas	8	39.8 ± 3.6	120.1 ± 9.1	0.31 ± 0.05	4.90 ± 0.15	0.01 ± 0.01	11.72 ± 1.28	1174.2 ± 293.0
Forested area	18	36.7 ± 2.1	112.9 ± 6.2	0.31 ± 0.03	4.81 ± 0.13	0.02 ± 0.01	14.25 ± 2.57	1336.6 ± 203.5
Forestless area	28	31.9 ± 1.1	105.8 ± 3.8	0.33 ± 0.02	5.07 ± 0.12	0.02 ± 0.01	13.15 ± 1.52	1356.1 ± 222.1
“Clean” territory: no sites near sources of pollution								
Small-leaved forest	2	38.9 ± 2.5	108.4 ± 7.1	0.28 ± 0.32	4.92 ± 0.38	0.01 ± 0.02	10.63 ± 5.65	1134.5 ± 514.2
Complex spruce forest	2	44.6 ± 7.5	155.2 ± 26.2	0.35 ± 0.70	4.48 ± 2.22	0.01 ± 0.04	9.06 ± 3.36	1322.3 ± 4676.1
Spruce forest	4	32.9 ± 2.7	96.8 ± 7.9	0.29 ± 0.10	4.78 ± 0.55	0.03 ± 0.05	15.45 ± 6.04	1312 ± 311.5
Floodplain meadow	8	31.9 ± 2.3	107.5 ± 7.3	0.34 ± 0.05	5.08 ± 0.46	0.04 ± 0.03	11.14 ± 2.35	1296.5 ± 267.6
Short-grass fallow meadow	2	27.4 ± 1.9	83.5 ± 5.9	0.30 ± 0.14	4.96 ± 0.06	0.01 ± 0.01	12.28 ± 0.87	1102.2 ± 188.3
Transit	12	32.4 ± 1.9	103.6 ± 4.9	0.33 ± 0.04	5.03 ± 0.09	0.01 ± 0.01	13.27 ± 2.41	1249.5 ± 209.8
Superaquatic	14	35.1 ± 1.9	113.6 ± 6.6	0.32 ± 0.03	4.89 ± 0.28	0.03 ± 0.02	10.92 ± 1.31	1267.3 ± 167.5
Forested area	8	37.4 ± 2.6	114.3 ± 10.0	0.30 ± 0.05	4.74 ± 0.25	0.02 ± 0.02	12.65 ± 3.30	1270.2 ± 209.2
Forestless area	24	31.4 ± 1.2	106.2 ± 4.2	0.34 ± 0.03	5.06 ± 0.14	0.02 ± 0.01	12.47 ± 1.29	1312.5 ± 251.2

Notes for Tables 3–5: N, number of measurements. (32.9 ± 2.3): 32.9 is the arithmetic mean, 2.3, 95% confidence interval.

Table 4. Concentration of elements of the cationogenic group in the snow of the study area of the Chashnikovo Center

Site characteristics	N	Na, mg/kg	K, mg/kg	Ca, mg/kg	Mg, mg/kg	Sr, μg/kg	Ba, μg/kg	Total, mg/kg
Small-leaved forest	6	0.96 ± 0.35	0.26 ± 0.15	0.99 ± 0.35	0.28 ± 0.05	6.2 ± 1.3	1.9 ± 0.6	2.50 ± 0.78
Complex spruce forest	4	0.43 ± 0.07	0.18 ± 0.10	0.59 ± 0.55	0.21 ± 0.12	4.2 ± 2.9	1.5 ± 1.8	1.42 ± 0.80
Spruce forest	8	0.85 ± 0.24	0.57 ± 0.24	0.84 ± 0.28	0.27 ± 0.04	5.2 ± 1.3	2.0 ± 0.5	2.53 ± 0.49
Floodplain meadow	10	0.62 ± 0.09	0.12 ± 0.10	0.56 ± 0.11	0.19 ± 0.04	5.3 ± 2.2	1.3 ± 0.3	1.49 ± 0.19
Dry meadow	6	0.60 ± 0.13	0.80 ± 1.98	0.49 ± 0.16	0.18 ± 0.05	5.2 ± 3.4	1.1 ± 0.4	2.08 ± 2.17
Short-grass fallow meadow	4	1.29 ± 1.20	0.09 ± 0.12	0.89 ± 0.32	0.25 ± 0.05	5.0 ± 1.0	1.9 ± 1.0	2.51 ± 1.58
Arable area	8	0.70 ± 0.14	0.07 ± 0.09	0.62 ± 0.17	0.20 ± 0.04	4.5 ± 0.8	1.6 ± 0.4	1.60 ± 0.25
Eluvial–transit	4	0.92 ± 0.55	0.35 ± 0.17	1.08 ± 0.41	0.31 ± 0.05	6.6 ± 1.6	2.1 ± 0.8	2.66 ± 0.41
Transit	18	0.84 ± 0.23	0.44 ± 0.54	0.74 ± 0.17	0.24 ± 0.03	4.7 ± 0.6	1.6 ± 0.3	2.27 ± 0.64
Transit-accumulative	6	0.64 ± 0.13	0.08 ± 0.11	0.60 ± 0.17	0.19 ± 0.04	5.9 ± 2.9	1.6 ± 0.6	1.52 ± 0.22
Superaquatic	18	0.67 ± 0.13	0.22 ± 0.11	0.60 ± 0.10	0.21 ± 0.03	5.0 ± 1.3	1.4 ± 0.3	1.70 ± 0.33
Background sites	32	0.64 ± 0.05	0.29 ± 0.30	0.56 ± 0.06	0.19 ± 0.02	4.8 ± 0.8	1.3 ± 0.2	1.68 ± 0.33
Sites near the highway	6	1.41 ± 0.46	0.26 ± 0.15	1.10 ± 0.26	0.29 ± 0.03	6.0 ± 0.7	2.2 ± 0.4	3.07 ± 0.36
Sites near populated areas	8	0.75 ± 0.30	0.37 ± 0.20	0.95 ± 0.23	0.29 ± 0.03	6.0 ± 0.9	2.3 ± 0.5	2.36 ± 0.61
Forested area	18	0.79 ± 0.16	0.38 ± 0.13	0.83 ± 0.17	0.26 ± 0.03	5.3 ± 0.8	1.9 ± 0.4	2.27 ± 0.38
Forestless area	28	0.73 ± 0.14	0.25 ± 0.34	0.61 ± 0.08	0.20 ± 0.02	5.0 ± 0.9	1.4 ± 0.2	1.79 ± 0.40
“Clean” territory: no sites near sources of pollution								
Small-leaved forest	2	0.58 ± 1.46	0.14 ± 0.83	0.67 ± 1.84	0.23 ± 0.25	6.1 ± 22.9	1.5 ± 5.7	1.61 ± 4.41
Complex spruce forest	2	0.44 ± 0.70	0.13 ± 0.51	0.41 ± 1.91	0.16 ± 0.51	3.0 ± 9.5	0.8 ± 0.6	1.14 ± 3.63
Spruce forest	4	0.73 ± 0.17	0.62 ± 0.58	0.57 ± 0.19	0.23 ± 0.07	4.1 ± 1.4	1.4 ± 0.4	2.14 ± 0.65
Floodplain meadow	8	0.62 ± 0.09	0.10 ± 0.11	0.49 ± 0.07	0.17 ± 0.02	5.2 ± 2.9	1.1 ± 0.3	1.39 ± 0.12
Short-grass fallow meadow	2	0.65 ± 0.76	0.05 ± 0.64	0.77 ± 0.32	0.23 ± 0.19	4.5 ± 0.6	1.6 ± 7.6	1.70 ± 0.90
Transit	12	0.69 ± 0.10	0.56 ± 0.85	0.59 ± 0.13	0.21 ± 0.03	4.2 ± 0.7	1.3 ± 0.3	2.04 ± 0.91
Superaquatic	14	0.59 ± 0.07	0.15 ± 0.08	0.51 ± 0.07	0.18 ± 0.02	4.8 ± 1.7	1.2 ± 0.2	1.44 ± 0.17
Forested area	8	0.62 ± 0.13	0.37 ± 0.30	0.55 ± 0.14	0.21 ± 0.04	4.3 ± 1.4	1.3 ± 0.4	1.76 ± 0.48
Forestless area	24	0.64 ± 0.06	0.26 ± 0.40	0.56 ± 0.07	0.19 ± 0.02	4.9 ± 1.1	1.3 ± 0.2	1.66 ± 0.43

Table 5. Concentration of anionogenic elements and anions in the snow of the study area of the Chashnikovo Center

Site characteristics	N	Anionogenic group elements						Anions					
		C, mg/kg	N, mg/kg	P, μg/kg	Si, μg/kg	S, μg/kg	Total, mg/kg	F^-, mg/kg	Cl^-, mg/kg	NO_3^-, mg/kg	SO_4^{2-}, mg/kg	HCO_3^-, mg/kg	Total, mg/kg
Small-leaved forest	6	2.75 ± 3.64	0.27 ± 0.29	19.8 ± 23.4	59.5 ± 29.6	298.7 ± 67.2	3.4 ± 3.6	0.05 ± 0.02	1.83 ± 0.72	1.30 ± 0.11	0.47 ± 0.14	8.44 ± 2.90	12.08 ± 3. 72
Complex spruce forest	4	0.81 ± 0.27	0.76 ± 0.79	26.3 ± 23.9	47.3 ± 27.9	220.0 ± 40.6	1.86 ± 0.9	0.05 ± 0.02	0.91 ± 0.02	1.58 ± 0.65	0.27 ± 0.04	3.20 ± 0.84	6.01 ± 1. 05
Spruce forest	8	1.86 ± 0.91	0.60 ± 0.45	12.0 ± 6.8	45.8 ± 12.1	295.5 ± 42.8	2.82 ± 1.0	0.07 ± 0.05	1.80 ± 0.31	1.18 ± 0.38	0.43 ± 0.10	5.03 ± 1.82	8.51 ± 1. 78
Flood-plain meadow	10	1.64 ± 1.74	0.57 ± 0.22	24.9 ± 37.7	36.4 ± 9.6	228.8 ± 16.4	2.5 ± 1.8	0.05 ± 0.01	1.17 ± 0.12	1.42 ± 0.31	0.35 ± 0.08	4.39 ± 0.59	7.39 ± 0. 77
Dry meadow	6	0.93 ± 0.82	0.17 ± 0.20	145 ± 357.3	42.0 ± 15.9	255.2 ± 106.6	1.54 ± 1.3	0.07 ± 0.05	1.31 ± 0.38	1.44 ± 0.51	0.31 ± 0.14	6.10 ± 2.99	9.24 ± 2. 96
Short-grass fallow meadow	4	3.35 ± 3.08	0.14 ± 0.09	15 ± 19.3	53.8 ± 16.6	248.8 ± 37.4	3.8 ± 3.1	0.05 ± 0.06	2.45 ± 1.99	1.21 ± 0.35	0.37 ± 0.07	6.86 ± 6.44	10.94 ± 8. 37
Arable area	8	0.98 ± 0.92	0.94 ± 0.85	8.9 ± 11.2	59.4 ± 33.4	205.1 ± 27.9	2.19 ± 1.2	0.04 ± 0.01	1.36 ± 0.31	1.54 ± 0.44	0.28 ± 0.06	6.41 ± 1.75	9.63 ± 1. 77
Eluvial–transit	4	2.17 ± 3.49	0.40 ± 0.57	29.0 ± 36.5	77.5 ± 33.4	317.5 ± 75.7	3 ± 3.3	0.05 ± 0.04	1.84 ± 0.89	1.27 ± 0.21	0.46 ± 0.15	6.86 ± 5.88	10.48 ± 6. 57
Transit	18	1.85 ± 1.11	0.50 ± 0.37	58.6 ± 97.2	53.9 ± 14.1	260.6 ± 36.4	2.72 ± 1.1	0.06 ± 0.02	1.71 ± 0.40	1.38 ± 0.24	0.37 ± 0.07	6.37 ± 1.29	9.89 ± 1. 61
Transit-accumulative	6	1.68 ± 1.66	0.56 ± 0.76	7.5 ± 5.5	41.8 ± 11.7	209.2 ± 38.8	2.5 ± 1.6	0.03 ± 0.01	1.30 ± 0.31	1.42 ± 0.50	0.28 ± 0.10	7.63 ± 3.47	10.66 ± 3. 53
Supera-quatic	18	1.43 ± 0.92	0.57 ± 0.17	19.7 ± 19.5	38.1 ± 6.0	237.6 ± 18.7	2.3 ± 1.0	0.05 ± 0.02	1.29 ± 0.21	1.40 ± 0.19	0.35 ± 0.05	4.17 ± 0.42	7.27 ± 0. 54
Back-ground sites	32	1.55 ± 0.61	0.60 ± 0.23	35.7 ± 53.0	43.9 ± 8.5	237.3 ± 20.4	2.47 ± 0.7	0.06 ± 0.01	1.31 ± 0.13	1.38 ± 0.16	0.35 ± 0.04	5.20 ± 0.78	8.30 ± 0. 82
Sites near the highway	6	3.58 ± 3.54	0.12 ± 0.04	22.2 ± 24.3	63.8 ± 27.4	301.2 ± 56.9	4.09 ± 3.6	0.06 ± 0.03	2.66 ± 0.75	1.29 ± 0.15	0.46 ± 0.15	10.27 ± 0.17	14.73 ± 0. 77

Table 5. (Contd.)

Site characteristics	N	Anionogenic group elements						Anions					
		C, mg/kg	N, mg/kg	P, µg/kg	Si, µg/kg	S, µg/kg	Total, mg/kg	F^-, mg/kg	Cl^-, mg/kg	NO_3^-, mg/kg	SO_4^{2-}, mg/kg	HCO_3^-, mg/kg	Total, mg/kg
Sites near populated areas	8	0.85 ± 0.31	0.53 ± 0.22	36.8 ± 47.7	53.9 ± 11.6	261.3 ± 50.7	1.74 ± 0.4	0.04 ± 0.01	1.42 ± 0.44	1.45 ± 0.39	0.33 ± 0.11	4.35 ± 0.78	7.59 ± 0. 97
Forested area	18	1.92 ± 1.06	0.53 ± 0.23	17.8 ± 7.8	50.7 ± 10.1	279.8 ± 29.4	2.8 ± 1.0	0.06 ± 0.02	1.61 ± 0.29	1.31 ± 0.19	0.41 ± 0.07	5.76 ± 1.46	9.15 ± 1. 67
Forestless area	28	1.54 ± 0.72	0.53 ± 0.25	44.6 ± 61.7	46.6 ± 9.7	230.5 ± 20.6	2.39 ± 0.8	0.05 ± 0.01	1.44 ± 0.25	1.43 ± 0.17	0.32 ± 0.04	5.69 ± 0.93	8.93 ± 1. 08
“Clean” territory: no sites near sources of pollution													
Small-leaved forest	2	0.56 ± 0.10	0.57 ± 2.93	9.5 ± 31.8	42.5 ± 31.8	248.0 ± 597.2	1.4 ± 2.2	0.04 ± 0.15	1.00 ± 2.02	1.24 ± 0.23	0.38 ± 0.92	4.88 ± 0.01	7.55 ± 3. 32
Complex spruce forest	2	0.93 ± 0.86	1.11 ± 4.14	17.5 ± 82.6	40.0 ± 88.9	206.0 ± 304.9	2.3 ± 4.5	0.04 ± 0.10	0.91 ± 0.17	1.59 ± 2.86	0.26 ± 0.40	2.75 ± 0.01	5.55 ± 2. 54
Spruce forest	4	2.67 ± 1.49	0.71 ± 1.18	14.0 ± 17.9	35.8 ± 22.2	292.3 ± 60.6	3.7 ± 1.4	0.11 ± 0.13	1.79 ± 0.57	1.09 ± 1.08	0.46 ± 0.14	6.10 ± 4.48	9.54 ± 4. 31
Floodplain meadow	8	1.90 ± 2.24	0.53 ± 0.27	8.1 ± 5.7	33.1 ± 7.6	232.6 ± 20.0	2.7 ± 2.4	0.05 ± 0.02	1.17 ± 0.13	1.35 ± 0.26	0.39 ± 0.08	4.04 ± 0.35	7.01 ± 0. 56
Short-grass fallow meadow	2	3.64 ± 7.18	0.17 ± 0.54	13.5 ± 31.8	52.0 ± 127.1	242.0 ± 343.1	4.1 ± 6.4	0.03 ± 0.05	1.40 ± 2.77	1.24 ± 3.02	0.38 ± 0.63	3.36 ± 0.01	6.40 ± 6. 46
Transit	12	1.38 ± 0.83	0.64 ± 0.56	78.6 ± 152.5	55.8 ± 21.4	247.8 ± 48.3	2.4 ± 1.0	0.07 ± 0.03	1.46 ± 0.26	1.38 ± 0.36	0.34 ± 0.07	5.49 ± 0.97	8.73 ± 1. 05
Superaquatic	14	1.63 ± 1.19	0.59 ± 0.21	11.1 ± 4.8	34.5 ± 5.1	240.4 ± 24.1	2.5 ± 1.2	0.06 ± 0.02	1.18 ± 0.18	1.37 ± 0.19	0.38 ± 0.06	3.92 ± 0.40	6.92 ± 0. 52
Forested area	8	1.71 ± 1.01	0.77 ± 0.48	13.8 ± 7.3	38.5 ± 8.7	259.6 ± 44.9	2.8 ± 1.0	0.07 ± 0.05	1.38 ± 0.43	1.25 ± 0.43	0.39 ± 0.09	4.96 ± 1.97	8.05 ± 2. 10
Forestless area	24	1.50 ± 0.77	0.54 ± 0.28	43.0 ± 71.8	45.7 ± 11.1	229.9 ± 23.9	2.4 ± 0.8	0.05 ± 0.01	1.29 ± 0.13	1.43 ± 0.18	0.33 ± 0.04	5.29 ± 0.91	8.38 ± 0. 94

Table 6. Concentration of transitional and complexing elements in the snow of the study area of the Chashnikovo Center

		Complexing elements						Transitional elements		
Site characteristics	N	V, μg/kg	Ti, μg/kg	Cu, μg/kg	Zn, μg/kg	Al, μg/kg	Total, mg/kg	Fe, μg/kg	Mn, μg/kg	Total, mg/kg
Small-leaved forest	6	Tr.	0.2 ± 0.6	0.7 ± 0.8	5.8 ± 6	6.9 ± 13.2	0.01 ± 0.01	7.5 ± 7.4	4.4 ± 2.5	0.01 ± 0.01
Complex spruce forest	4	0.3 ± 0.8	Tr.	Tr.	9.3 ± 12.2	5.6 ± 7.1	0.02 ± 0.02	8.0 ± 6.4	26.5 ± 75.1	0.03 ± 0.08
Spruce forest	8	0.2 ± 0.4	Tr.	1.5 ± 1.0	7.7 ± 7.1	1.9 ± 2.2	0.01 ± 0.01	5.9 ± 1.9	11.6 ± 2.7	0.02 ± 0.01
Floodplain meadow	10	0.1 ± 0.2	Tr.	0.7 ± 0.8	11 ± 3.3	Tr.	0.01 ± 0.01	5.3 ± 3.8	4.2 ± 1.7	0.01 ± 0.01
Dry meadow	6	0.2 ± 0.5	Tr.	0.8 ± 1.5	8.3 ± 5.7	5.6 ± 10.9	0.01 ± 0.01	8.0 ± 13.4	4.0 ± 4.5	0.01 ± 0.01
Short-grass fallow meadow	4	0.3 ± 0.8	Tr.	0.3 ± 0.9	16.1 ± 14.0	2.6 ± 8.4	0.02 ± 0.01	5.6 ± 4.6	4.5 ± 4.6	0.01 ± 0.01
Arable area	8	0.3 ± 0.4	0.4 ± 0.6	0.4 ± 0.5	29.9 ± 25.2	9.9 ± 14.4	0.04 ± 0.02	3.5 ± 0.9	9.6 ± 10.2	0.01 ± 0.01
Eluvial–transit	4	0.3 ± 1.0	0.3 ± 1.0	0.9 ± 1.0	2.8 ± 2.0	12.7 ± 20.0	0.02 ± 0.02	11.5 ± 10.2	9.1 ± 9.1	0.02 ± 0.01
Transit	18	0.2 ± 0.2	0.2 ± 0.3	0.6 ± 0.6	14.4 ± 11.3	7.7 ± 6.3	0.02 ± 0.01	9.3 ± 5.2	10.5 ± 10.9	0.02 ± 0.01
Transit-accumulative	6	0.3 ± 0.5	Tr.	0.6 ± 0.7	21.5 ± 9.2	Tr.	0.02 ± 0.01	2.7 ± 0.5	3.2 ± 1.2	0.01 ± 0.01
Superaqual	18	0.1 ± 0.1	Tr.	0.8 ± 0.5	11.0 ± 3.1	0.7 ± 1	0.01 ± 0.01	5.1 ± 2.0	5.4 ± 2.0	0.01 ± 0.01
Background sites	32	0.1 ± 0.1	0.1 ± 0.1	0.7 ± 0.4	15.1 ± 6.4	4.1 ± 3.6	0.02 ± 0.01	6.7 ± 3.1	4.8 ± 1.3	0.01 ± 0.01
Sites near the highway	6	Tr.	0.2 ± 0.6	0.4 ± 0.7	8.3 ± 6.5	8.6 ± 12.8	0.02 ± 0.01	8.2 ± 7.3	6.0 ± 2.6	0.01 ± 0.01
Sites near populated areas	8	0.4 ± 0.5	Tr.	1.1 ± 0.6	8.1 ± 6.4	2.5 ± 3.3	0.01 ± 0.01	7.1 ± 2.7	18.8 ± 26.8	0.03 ± 0.03
Forested area	18	0.1 ± 0.2	0.1 ± 0.2	0.9 ± 0.5	7.4 ± 3.6	4.4 ± 3.8	0.01 ± 0.01	6.9 ± 2.2	12.5 ± 10.8	0.02 ± 0.01
Forestless area	28	0.2 ± 0.2	0.1 ± 0.2	0.6 ± 0.4	16.5 ± 7.1	4.4 ± 4.2	0.02 ± 0.01	7.0 ± 3.6	4.1 ± 1.0	0.01 ± 0.01
“Clean” territory: no sites near sources of pollution										
Small-leaved forest	2	Tr.	Tr.	0.7 ± 8.9	2.6 ± 32.4	Tr.	0.01 ± 0.04	4.5 ± 6.4	1.9 ± 4.4	0.01 ± 0.01
Complex spruce forest	2	Tr.	Tr.	Tr.	15.6 ± 8.3	5.9 ± 19.7	0.02 ± 0.01	6.0 ± 0.1	3.1 ± 5.1	0.01 ± 0.01
Spruce forest	4	Tr.	Tr.	1.6 ± 2.9	4.0 ± 9.2	1.4 ± 4.5	0.01 ± 0.01	5.3 ± 4.2	11.8 ± 5.8	0.02 ± 0.01
Floodplain meadow	8	Tr.	Tr.	0.5 ± 1.0	12.1 ± 3.6	Tr.	0.01 ± 0.01	5.3 ± 5	4.6 ± 2.1	0.01 ± 0.01
Short-grass fallow meadow	2	0.5 ± 6.4	Tr.	0.6 ± 7.6	22.1 ± 39.4	Tr.	0.02 ± 0.05	4.6 ± 8.3	2.5 ± 6.4	0.01 ± 0.01
Transit	12	0.2 ± 0.3	0.3 ± 0.4	0.8 ± 0.9	17.3 ± 17.5	9.9 ± 9.5	0.03 ± 0.02	10.8 ± 7.9	5.1 ± 2.5	0.02 ± 0.01
Superaquatic	14	Tr.	Tr.	0.6 ± 0.5	10.4 ± 3.4	0.8 ± 1.3	0.01 ± 0.01	5.0 ± 2.6	5.3 ± 2.4	0.01 ± 0.01
Forested area	8	Tr.	Tr.	1.0 ± 1.2	6.5 ± 5.8	2.2 ± 2.6	0.01 ± 0.01	5.3 ± 1.5	7.2 ± 4.7	0.01 ± 0.01
Forestless area	24	0.2 ± 0.2	0.1 ± 0.2	0.6 ± 0.42	17.9 ± 8.2	4.7 ± 4.9	0.02 ± 0.01	7.2 ± 4.2	4.1 ± 1.1	0.01 ± 0.01

Tr., trace quantities.

a trend, since high variations in the total reserves of components in the system of compared landscapes vary greatly (although, with an exception for the superaquatic landscape that is characterized by the minimum range of the total amount of components concentrated in the snow cover). It has been shown that snow waters are slightly acidic and that the electrical-conductivity values correlate well with the sums of the studied components. Such a picture for the ratio of the concentration and reserves of various elements and anions in the snow, combined with low pH values and electrical conductivity, is generally typical for the southern taiga landscapes located outside the zone of intense pollution (Ermakov et al., 2014a). Note that electrical conductivity is a good indicator to use for pollution cartogram mapping (Ryazanova and Sorokin, 2017).

In general, in this group a series of aluminum—zinc—copper—vanadium is formed, which corresponds, with the exception of vanadium, to the general order of content of these elements in the soils of the soddy—podzolic zone (Kovda et al., 1959).

Apparently, soil mineral impurities do not always have a serious effect on the content of elements in snow water due to their low solubility. It is clear that this does not apply to the soils characterized by a high content of easily soluble salts. It is interesting that, in the iron—manganese group, the iron content is sometimes less than the manganese content, which is found for snow waters under forest plantations. This is probably due to the entry of particles of contaminated material brought into forests, which initially settles on needles and leaves and can then reach the soil surface with snow.

The composition of snow varies quite slightly across areas with differing land use (Tables 3–6). This indicates a weak influence of the type of land use on the composition of snow. However, due to the proximity of agricultural lands to anthropogenic territories, the reserve of the integral indicator of the sum of components in arable conditions tend to be slightly higher (Table 3). At the same time, no significant differences were found in the chemical composition of snow in forested and forestless areas. A similar picture was also found when comparing different ecosystems, including comparison of conjugate elementary landscapes.

At the same time, many of the found patterns should be considered as a trend, since all components are characterized by high rates of variability. However, "clean" areas (which were identified on the created map), on average, are characterized by a rather noticeable decrease in the content of all components. This is explained primarily by the remoteness of these territories from the Moscow—St. Petersburg highway and from populated areas.

It turned out that snow near the highway, unlike snow in areas near populated areas, differs in composition and content of components. Thus, the areas located near the highway are characterized by an increased content of Ca, Na, Cl^-, Al, and Ti in the snow, while areas near populated areas are characterized by increased Ca, Mn, V, and Cu, which is explained by the different nature and intensity of pollution. In particular, the tendency toward an increase in the content of chloride ion, sodium, and calcium is explained by the probable use of de-icing reagents.

There is no doubt that the analysis of anion content is of particular interest, since these components are rightly associated with pollution. In general, for this entire group, there is a natural predominance of HCO_3^-, followed by Cl^- and, in almost equal cases, NO_3^-, followed by SO_4^{2-}, and very low concentrations of F—. The data from this group provide the basis for determining the typology of snow waters, which should be classified as the bicarbonate—calcium—sodium—chloride type. In general, this does not contradict the data on snow cover in Moscow oblast. A comparison of the chemical composition of snow in the studied landscapes with data provided for other areas of Moscow oblast (Ermakov et al., 2014b) showed that the content of the main macroelements and anions in the region studied by us is quite similar and does not characterize these area as polluted. The established patterns are quite logically explained by the low content of components in the studied snow, and the specific formation of their composition is explained by the conditions of the humid climate of southern taiga ecosystems in combination with a weak tendency toward pollution.

The created map diagrams shows that the content of such components as calcium, potassium, chloride ion, and phosphorus depends, on the one hand, on the distance from the Moscow—St. Petersburg M-10 highway, and, on the other hand, on populated areas (Fig. 2). Thus, we identified three areas, which are relatively independent of the type of elementary landscape and land use. The central section, the most remote from both sources of probable pollution, is characterized by a reduced content of these components, and the other two are represented by the western section adjacent to the Moscow—St. Petersburg M-10 highway and the southeastern section bordering settlements near the Chashnikovo and the other two are represented by the western section adjacent to the Moscow—St. Petersburg M-10 highway and the southeastern section bordering settlements near the Chashnikovo Center—they are characterized by an increased content of some components—they are characterized by an increased content of some components.

High snow reserves in the conditions of a superaquatic landscape, combined with the close soil groundwater, reaching 40 cm on lower relief elements,

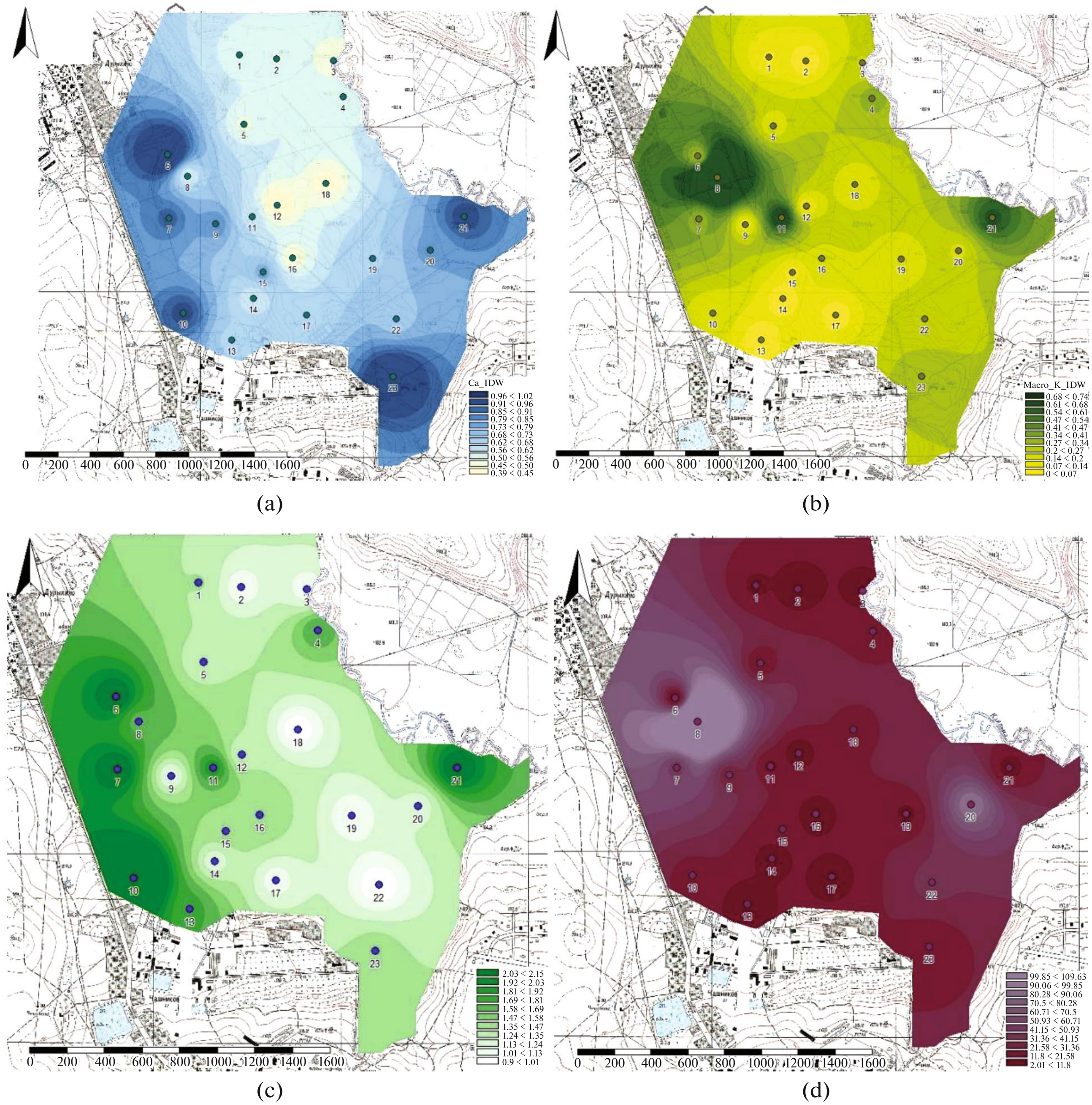

Fig. 2. Scheme maps of concentrations of some components in snow of the Chashnikovo Training and Experimental Soil Ecological Center of Moscow State University. (a) Ca (mg/kg), (b) K (mg/kg), (c) Cl^- (mg/kg). (d) P (μg/kg). Points nos. 6, 7, and 10 are near the Moscow–St. Petersburg M-10 highway; points nos. 20–23 indicate sites near populated areas.

and spring lateral runoff quite naturally provide increased soil hydromorphism in these territories.

CONCLUSIONS

Within the territory of the Chashnikovo Training and Experimental Soil Ecological Center of Moscow State University, snow is characterized by a low content of components and belongs to the bicarbonate–calcium–sodium–magnesium class.

Based on the construction of a digital map of the concentrations of some snow components, it was shown that, regardless of the type of elementary landscape or land use, there are three zones. The first zone was taken as a relative standard. It is confined primarily to the territory of a superaquatic landscape and is characterized by low values of the content of the main components, which is explained by the remote location of this landscape from the Moscow–St. Petersburg M-10 highway and populated areas. The second zone is close to the highway. It is characterized by increased levels of Ca, Na, Al, and Cl^- in the snow cover. The third zone, bordering populated areas, is characterized by increased contents of Ca, Cu, and Mn.

The results obtained suggest that the depth and reserves of snow cover are partially controlled by two factors: the type of elementary landscape and the nature of the land use. At the same time, the spatial distribution of concentrations of elements and anions in snow revealed in combination with a simultaneous analysis of their changes in the system of associated landscapes and the specifics of the land-use is determined mainly by the anthropogenic factor.

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ETHICS APPROVAL AND CONSENT TO PARTICIPATE

This work does not contain any studies involving human and animal subjects.

CONFLICT OF INTEREST

The authors of this work declare that they have no conflicts of interest.

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