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ON SOME PHYSICAL AND CHEMICAL PROPERTIES OF SOILS OF SAND OUTCROPS OF NORTHERN REGIONS OF WESTERN SIBERIA

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The technogenic transformation of the ecosystems of the northern taiga forests and forest tundra in the north of Western Siberia, associated with the development of the oil and gas industry, leads to the formation of sandy outcrops on soils of light mechanical composition. Sandy soils of man-made deserts not fixed by vegetation are transferred by wind, representing a real danger to undisturbed ecosystems. The purpose of the research was to study a number of the physicochemical properties of sandy outcrop soils in the northern regions of Western Siberia. Studies were carried out in the Purovsky District of the Yamalo-Nenets Autonomous District (Tyumen Region). Soil samples were taken in accordance with GOST 17.4.3.01-83. In the selected soil samples, the granulometric composition, humidity, and actual acidity were determined. The research results show significant changes in the studied physicochemical properties of podzolic sandy soils occurring as a result of anthropogenic impact. A statistically significant decrease in the acidity of the surface soil layer to 5–6 pH units was revealed due to the destruction of the upper soil horizons and exposure of the illuvial horizon, a decrease in the content of fine fractions of clay and silt particles, a decrease in the soil moisture content.

Keywords: anthropogenic desertification; sandy outcrop; eroded soil; granulometric composition; acidity; humidity; north-taiga subzone; forest-tundra; Tyumen Region; Yamalo-Nenets Autonomous Okrug.

Техногенная трансформация экосистем северотаежных лесов и лесотундры на севере Западной Сибири, связанная с развитием нефтегазодобывающей отрасли промышленности, приводит к формированию песчаных обнажений на почвах легкого механического состава. Не закрепленные растительностью песчаные почвы техногенных пустынь перевеваются ветром, представляя реальную опасность для ненарушенных экосистем. Цель исследований заключалась в изучении ряда физико-химических свойств почв песчаных обнажений в северных районах Западной Сибири. Исследования проводили в Пуровском районе Ямало-Ненецкого автономного округа (Тюменская область). Почвенные пробы отбирали в соответствии с ГОСТ 17.4.3.01-83. В отобранных почвенных образцах определяли гранулометрический состав, влажность, актуальную кислотность. Результаты исследований показывают значительные изменения изученных физико-химических свойств подзолистых песчаных почв, происходящие в результате техногенного воздействия. Выявлено статистически значимое снижение кислотности поверхностного слоя почвы до 5–6 единиц pH вследствие уничтожения верхних почвенных горизонтов и обнажения иллювиального горизонта, уменьшение содержания мелкодисперсных фракций — глины и пылеватых частиц, сокращение содержания почвенной влаги.

Ключевые слова: песчаные обнажения; антропогенное опустынивание; эродированные почвы; гранулометрический состав; кислотность; влажность; лесотундра; северная тайга; Ямало-Ненецкий автономный округ; Тюменская область.

INTRODUCTION

Widespread in the territory of Western Siberia, the areas of the ancient eolian relief, composed of a lightweight granulometric substrate [Western Siberia ..., 1963, p. 63; Zemtsov, 1976, p. 245], are natural objects that are easily destroyed due to anthropogenic factors [Zemtsov, 1976, p. 256-257]. Particularly acute negative processes are manifested in the northern regions of the region in conditions of poor development of soil and vegetation cover, where intensive economic development of territories, mainly the development of the oil and gas industry, leads to the transformation or complete destruction of vegetation and, as a result, exposure of the sandy substrate [Sizov, 2015 p. 65]. As a result of this impact, there is an intensification of modern aeolian processes, leading to the development of anthropogenic sandy outcrops — deserted areas with unfixed vegetation sand. The effect of the wind increases the negative effect of sandy exposures, slowing down their overgrowing, transferring sand to undisturbed communities, burying them under the sandy masses. This process has now acquired the status of one of the most acute environmental problems in the conditions of northern taiga [Soromotin, 2010, p. 186].

A long period of studying the soil cover of the north of Western Siberia [Gavrilova et al., 1971; Liverovskaya, 1971; Vasilievskaya et al., 1986] suggests that by now the soil properties of this region, including areas of development of aeolian processes, have a fairly high level of knowledge, including under the conditions of various natural and anthropogenic factors. A comprehensive view of the soils of the cryolithozone of Western Siberia, including the physicochemical properties of the soils of the podzolic series, is given in the work of V.Ya. Khrenova [Khrenov, 2011, p. 116-148]. The main regularities of soil formation in northern taiga landscapes of Western Siberia under conditions of cryogenesis with the characteristic of the most important features of the soil cover of this territory have been established [Matyshak, 2009]. The soil properties of the Western Siberian cryolithozone are studied in detail in connection with the intensive development of the oil and gas industry in the region. Large-scale phenomena of technogenic chemical pollution and soil degradation within oil and gas fields in the taiga zone of the Tyumen region, including northern taiga areas with high activity of deflationary processes, which registered positive dynamics of sandy outcrop growth in developed territories, were identified [Soromotin, 2007, p. 28; Soromotin, 2010, p. 185-186]. Years of research conducted from the end of the 60s of the last century to the present in the area of the Nadym hospital (Nadym district of the Yamal-Nenets Autonomous District, northern taiga subzone) have shown an increase in the thickness of the seasonally thawed layer due to the destruction of soil and vegetation when laying linear structures, which affects vegetation restoration processes [Kazantseva, 2007; Moskalenko, 2009]. The effect of fires, construction of linear structures and other types of anthropogenic impact on the properties of forest-tundra and north-taiga soils in Western Siberia is shown: in addition to changes in the hydrothermal regime, morphological and physico-chemical parameters, the biological properties of the soils also change, resulting in a change of dominant vegetation [Vasilyevskaya et al. 1986, p. 168-187; Moskalenko, 2012, p. 38-42]. It has been revealed that sand podzols, which are actively used for laying quarries, are among the least resistant to anthropogenic impacts [Vasilyevskaya et al., 1986, p. 191]. The most resistant to deflation are considered to be humified, ground and well-moistened soils [Sizov, 2015, p. 49].

Specially conducted research in the northern taiga of Western Siberia shows the effect of natural and anthropogenic factors on the processes of modern aeolian relief formation, studied in detail the soil in the areas of modern aeolian processes, mainly covering the basin. Nadym [Sizov, 2015]. Observations on the restoration of vegetation on anthropogenic sandy outcrops made it possible to establish the characteristics of their vegetation [Shilova, 1977; Druzhinin, Myalo, 1990; Moskalenko, 1991; Koronatova, Milyaeva, 2011; Sizov, Lobotrosova, 2016].

The noted ability of transformed soils to overgrowth indicates that they retain a number of properties that are of fundamental importance for the restoration of vegetation. However, floristic and geobotanical materials are not always accompanied by information about the properties of ecotops, which change not only as a result of their man-made transformation, but also in the process of succession development. In this regard, the features of the initial stage of the overgrowing of sandy outcrops indicated by us in the northern regions of Western Siberia [Selivanov et al., 2016; Kapitonova et al., 2017a, b] in this report are supplemented with data on a number of physico-chemical characteristics of the soils of the surveyed sites, which was one of the tasks of a comprehensive study of the biota's recovery potential in areas of anthropogenic disturbance of natural eolian formations in the forest tundra and northern taiga of Western Siberia. The main objective of this study is to study some properties of ecotopes of sandy outcrops of different genesis in the northern regions of Western Siberia, which have experienced varying degrees of anthropogenic stress.

MATERIALS AND METHODS

The studies were conducted in the Purovsky District of the Yamalo-Nenets Autonomous District (Tyumen Region). The territory is located within the northern part of the West Siberian Plain, between the rivers Pur and Nadym, in the Pleistocene repeatedly exposed to ice cover and marine transgressions, resulting in the accumulation of significant strata of sedimentary rocks of light mechanical composition. It is believed that these deposits later became the source material for the formation of the ancient (Pleistocene) eolian relief, on which modern processes of wind erosion develop [Sizov, 2015, p. 26, 29]. By the nature of the terrain, the terrain belongs to flat, highly marshy multigrained lowlands, composed of fluvioglacial and marine sediments, which in many areas are redeposited by ancient aeolian processes. In terms of geomorphology, lowland belongs to the class of submerged accumulative plains, which turn into typical (normal) accumulative plains in the north [Western Siberia, 1963, p. 24, 63, 68]. In the territory under consideration, gley-podzolic soils and light mechanical texture podzols are generally developed, having a relatively powerful profile (up to 100–150 cm) and characterized by a small thickness of the humus horizon (up to 10 cm), often moist and superficially glued [Western Siberia, 1963, with. 167; Dobrovolsky et al., 1998, p. 63–65, 148–153]. Poor nutrients, such soils are mainly occupied by pine forests, less often by mixed coniferous-small-leaved forests [Western Siberia, 1963, p. 170].

Field studies conducted in July 2017 in the territory, which was surveyed in 2016, covered 3 areas of sandy outcrops of natural genesis, currently experiencing varying degrees of anthropogenic load (Fig. 1).

1. Sandy outcrops within the boundaries of the natural swelling 27 km south of the city of Muravlenko. It is located within the northern taiga subzone of the taiga natural zone. The outcrop consists of two parts (western and eastern), separated by a nameless stream, which is a left tributary of the r. Pyakupur (Fig. 2). The area of the western part is 0.9 km^2, the eastern part is 3.3 km^2, the total area of the outcrops is 4.2 km^2. On the south-western and southern periphery of the outcrops a roll of sleep up to a height of 4.5–5.5 m is formed. The site is experiencing significant anthropogenic stress. In the surveyed area, there are several technological dirt roads to the existing oil producing wells, and on its western outskirts there is a busy highway Surgut — Novy Urengoy and a surface pipeline. On the territory there are unauthorized dumps of industrial waste (pipes, metal cable sheath, abandoned cabins, etc.), as well as household garbage (cans, plastic bottles, polyethylene, etc.).

The studies were carried out within both parts of the sand-covered area (symbol — Section 1.1), and also outside the sandy outcrops — in the area of the natural pine of lichen-shrub, adjacent to the sandy exposure (Section 1.2).

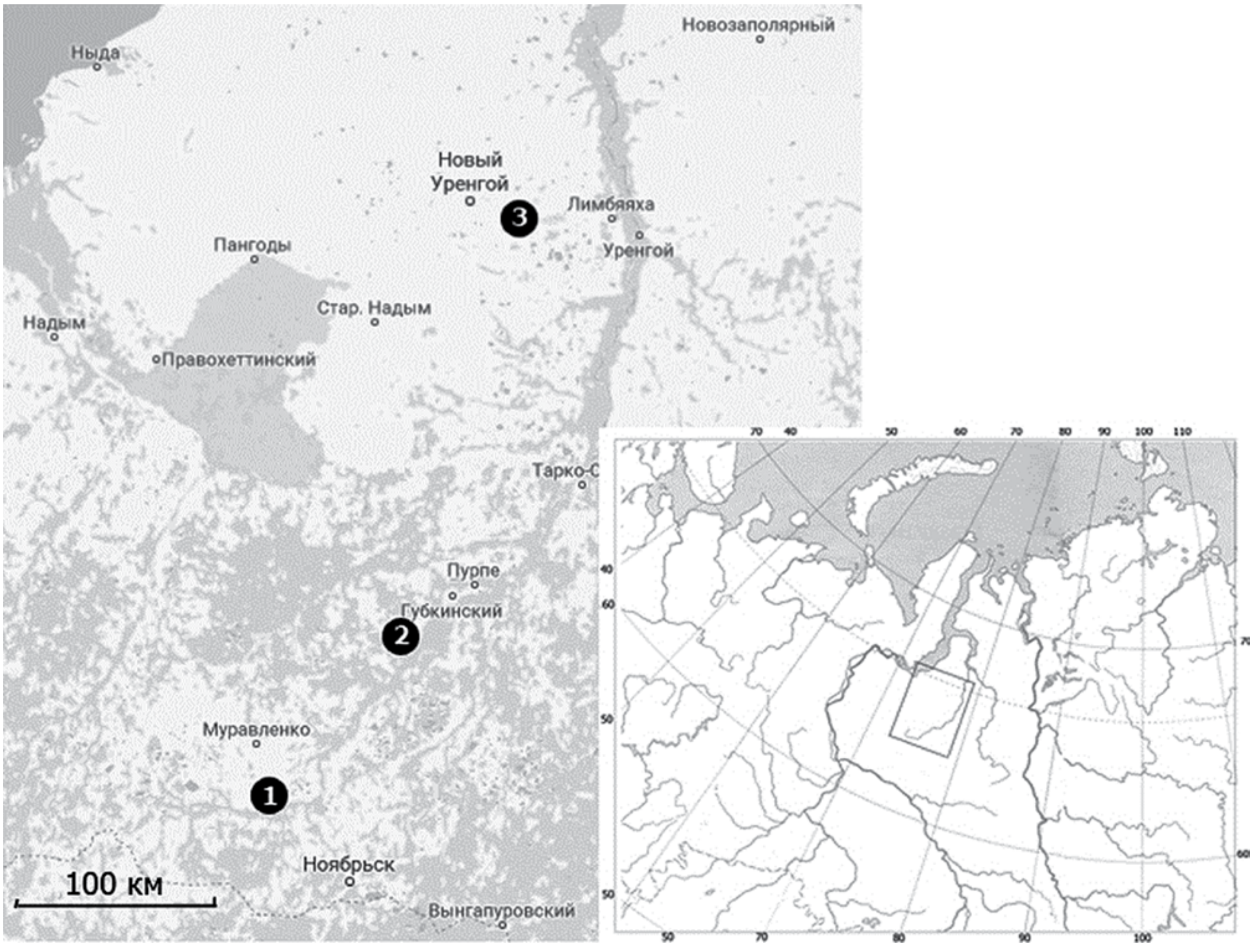

Fig. 1. The location of the surveyed areas of sandy outcrops. In the sidebar, the outline shows the research area. The numbering corresponds to the designation of sections in the text

Рис. 1. Местоположение обследованных участков песчаных обнажений. Во врезке контуром показан район проведения исследований. Нумерация соответствует обозначению участков в тексте

2. Sandy outcrops within the natural swelling 32 km south-west of the town of Gubkinsky. It is located in the northern taiga subzone of the taiga natural zone. The outcrop is almost devoid of vegetation due to a fire, as a result of which a section of the pine forest completely burned down (an outburst of a burnt car was found within the limits of exposure, there are traces of fire in the lower part of the trunks of preserved trees). The territory is characterized by the flatness of the terrain and the absence of depressions, which creates extremely harsh living conditions for both plants and animals within the impure territory at a distance from the borders with undisturbed biotopes, mainly represented by white-shrub forests. The nearest source of water is r. Hekudiaha, which flows 800 meters north of the sandy outcropping border. The studied territory is experiencing a weak anthropogenic impact, which consists in the periodic passage of motor vehicles along a dirt technological road to a nearby high-voltage transmission line. The area of the territory is just over 1.1 km^2 (Fig. 3). The studies were carried out on sandy outcrops (Plot No. 2.1) and on a plot of natural undisturbed lichen pine (Plot No. 2.2).

3. Sandy outcrop at the site of an open pit mine, 23 km east-southeast of Novy Urengoy (Fig. 4). The territory is located at the southern limit of the forest-tundra zone. 1 km north of its borders a large left tributary of the r. Pur — r. Evoyakha, and 350 meters to the east — its small right tributary of the river. Halzutayah In the vicinity of the pit there are numerous lakes and swamps, and on the territory there are about 20 reservoirs (from small pools to lakes with a length of 40 m and a depth of 1.5 meters). The terrain is heavily indented and largely altered as a result of sand mining and sand and gravel mix. In the middle of the site, a hill with a triangulation geodesic sign rises above the surrounding territory. The relative height of the hill is 11 m, the height of the quarry walls is 4–5 m. The elevated areas in the central and eastern parts of the site remaining after the extraction of sand are subject to water erosion, leading to the formation of narrow and deep cracks and cracks. On the territory there are numerous unauthorized dumping of household, technical and construction waste. In close proximity to the railway and highway with heavy traffic. The plot area is small, about 0.5 km^2. Sandy outcrops within the developed quarry (Plot No. 3.1) and a plot of natural birch-coniferous lichen-shrub forest-tundra light forest near the quarry (Plot No. 3.2) were surveyed.

In accordance with the geomorphological zoning of the territory of the Tyumen region (Lazukov, 1971), the studied areas are concentrated on the

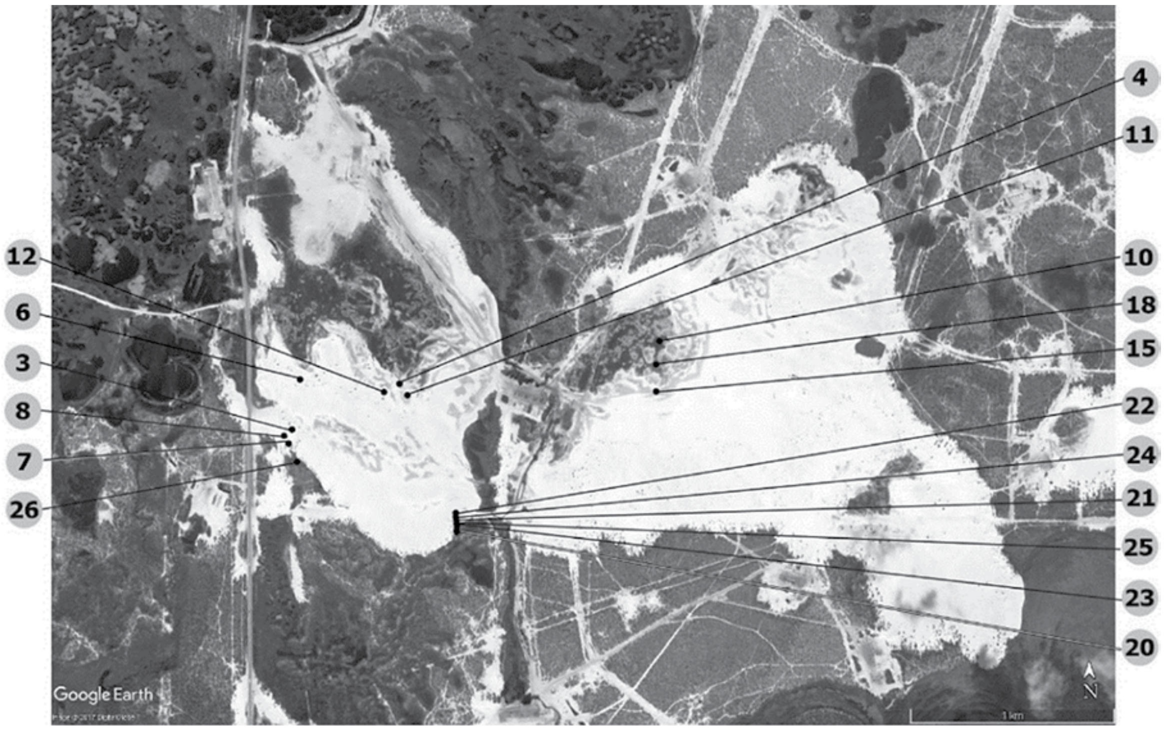

Fig. 2. Satellite image of sandy outcrop No. 1 (environs of Muravlenko, Purovsky district of the YNAO). The circles indicate the numbers of laboratory samples (see Appendix, Table 1). Image of DigitalGlobe, Landsat / Copernicus, CNES / Airbus. Map Data © 2017 Google

Рис. 2. Космоснимок песчаного обнажения № 1 (окрестности г. Муравленко, Пуровский р-н ЯНАО). В кружочках указаны номера лабораторных проб (см. Приложение, табл. 1). Изображение DigitalGlobe, Landsat / Copernicus, CNES / Airbus. Картографические данные © Google, 2017

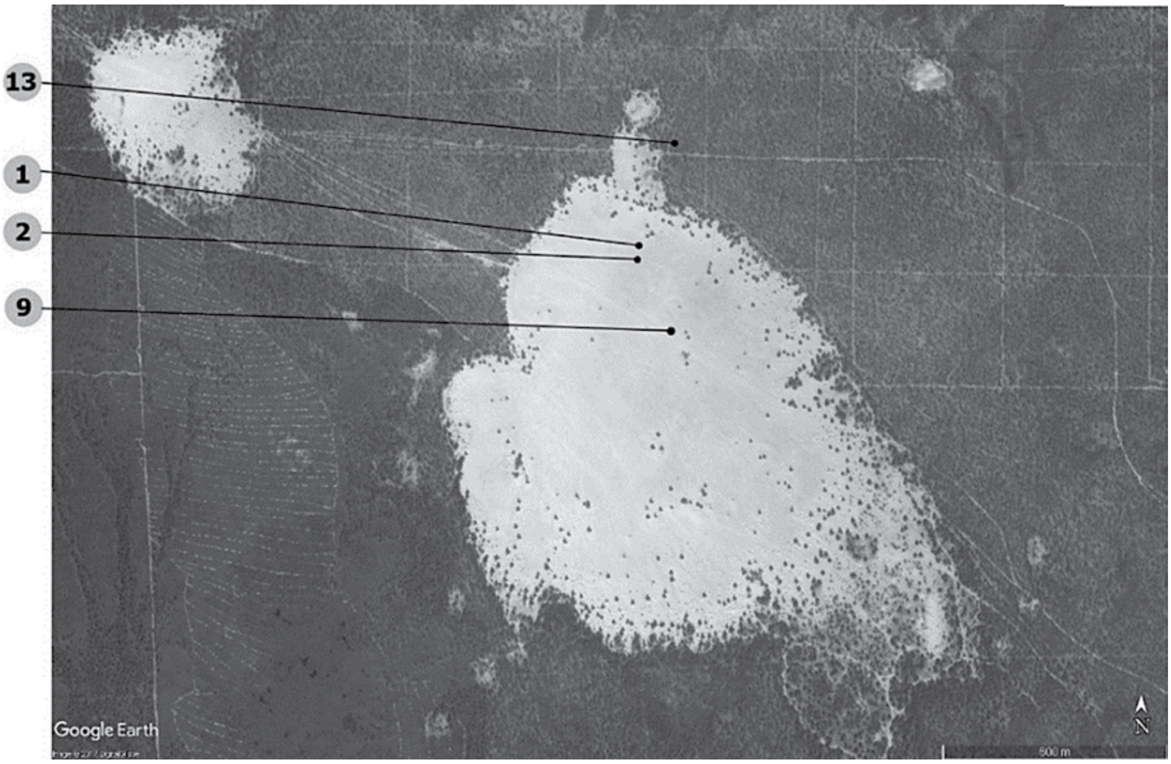

Fig. 3. Satellite image of sandy outcrop No. 2 (environs of the town of Gubkinsky, Purovsky District of the YNAO). Designations as in fig. 2. Image of DigitalGlobe, Landsat / Copernicus, CNES / Airbus. Map Data © 2017 Google

Рис. 3. Космоснимок песчаного обнажения № 2 (окрестности г. Губкинский, Пуровский р-н ЯНАО). Обозначения как на рис. 2. Изображение DigitalGlobe, Landsat / Copernicus, CNES / Airbus. Картографические данные © Google, 2017

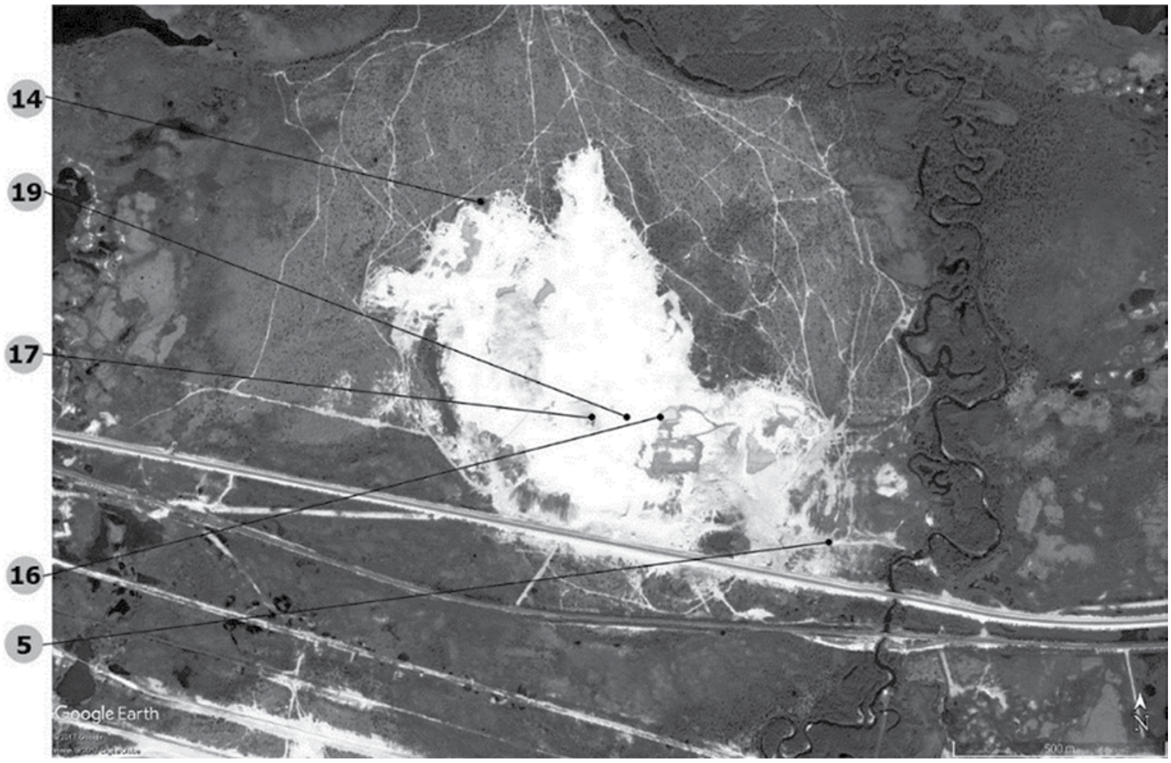

Fig. 4. Satellite image of sandy outcrops number 3 (environs of Novy Urengoy, Purovsky district of the YNAO). Designations as in fig. 2. Image of DigitalGlobe, Landsat / Copernicus, CNES / Airbus. Map Data © 2017 Google

Рис. 4. Космоснимок песчаного обнажения № 3 (окрестности г. Новый Уренгой, Пуровский р-н ЯНАО). Обозначения как на рис. 2. Изображение DigitalGlobe, Landsat / Copernicus, CNES / Airbus. Картографические данные © Google, 2017 elevated, sea-shaped, slightly wavy, and boggy, deeply processed denudation of the Yamal transgression times with absolute marks of 80–120 m. All investigated sites belong to the basin. At the same time, the first two sandy outcrops are located within the subzone of the northern taiga taiga zone [Western Siberia, 1963, p. 316] and represent areas located on ancient aeolian sand massifs, on which local anthropogenically caused processes of wind erosion are currently developing as a result of the destruction of natural vegetation. The third surveyed site differs from the first two not only by its location at the southern boundary of the forest-tundra, in the area of its gradual transition to northern taiga, but also by a slightly different genesis (it is a relic of glacial relief), as well as by the absence of transhuvized sands.

On each of the surveyed areas, test sites were laid, the sizes of which varied from 0.1 ha to 0.5 ha, depending on the contour of the phytocenosis. The geographical coordinates of sampling sites are presented in Table. 1 (see Appendix) and shown in Fig. 2–4. From the test sites, 10 point samples of the surface soil layer were taken according to GOST 17.4.3.01-83 [GOST..., 2004], 125 cm^3 each, to a depth of 5 cm [Gilyarov, 1965]. Point samples were mixed; the combined sample thus obtained was packed in a tight plastic bag and labeled.

Table 1 / Таблица 1

Physico-chemical caracteristics of the soil samples studied

Физико-химические показатели исследованных почвенных образцов

field soil number	№ of laboratory sample	symbol	geographical coordinates of sampling sites	date of sampling	W, %	pH	S (0,05–2 мм), %	C (<0,001 мм), %	Sl (0,001–0,05 мм), %
1	3.	Plot 1.1	N63.541306° E74.602028°	18.07.17	2.141	4.93	100.0	0.0	0.0
2	8.	Plot 1.1	N63.541143° E74.602121°	18.07.17	9.690	4.91	95.0	1.134	3.8665
3	7.	Plot 1.1	N63.540913° E74.602674°	18.07.17	1.904	6.26	100.0	0.0	0.0
20	15.	Plot 1.1	N63.542616° E74.638430°	18.07.17	20.924	4.85	100.0	0.0	0.0
21	18.	Plot 1.1	N63.543402° E74.637936°	19.07.17	28.611	4.88	100.0	0.0	0.0
22	10.	Plot 1.1	N63.544460° E74.638923°	19.07.17	34.388	4.70	95.0	1.134	3.8665
24	11.	Plot 1.1	N63.542124° E74.612298°	20.07.17	2.115	4.92	100.0	0.0	0.0
25	4.	Plot 1.1	N63.542381° E74.612432°	20.07.17	10.069	4.68	100.0	0.0	0.0
28	12.	Plot 1.1	N63.542933° E74.612184°	20.07.17	2.850	4.53	95.0	2.267	2.733
30	6.	Plot 1.1	N63.543181° E74.602910°	20.07.17	22.446	5.66	100.0	0.0	0.0
1.1	22.	Plot 1.1	N63.536578° E74.619895°	19.07.17	1.120	5.06	100.0	0.0	0.0
1.2	24.	Plot 1.1	N63.536573° E74.619884°	19.07.17	0.700	6.42	100.0	0.0	0.0
1.3	21.	Plot 1.1	N63.536570° E74.619884°	19.07.17	1.425	4.88	95.0	1.134	3.8665
1.4	25.	Plot 1.1	N63.536568° E74.619884°	19.07.17	0.320	5.08	100.0	0.0	0.0
1.5	23.	Plot 1.1	N63.536565° E74.619878°	19.07.17	3.140	4.74	100.0	0.0	0.0
1.6	20.	Plot 1.2	N63.536565° E74.619860°	19.07.17	52.301	3.72	45.0	4.534	50.466
6	26.	Plot 1.2	N63.539140° E74.602321°	19.07.17	27.970	3.56	55.0	3.401	41.60
1a	9.	Plot 2.1	N64.277500° E75.889040°	20.07.17	3.090	4.78	100.0	0.0	0.0
37	1.	Plot 2.1	N64.280209° E75.886975°	21.07.17	2.666	4.85	100.0	0.0	0.0
37a	2.	Plot 2.1	N64.279837° E75.887265°	21.07.17	2.107	4.90	85.0	0.0	15.0
49	13.	Plot 2.2	N64.281938° E75.888631°	21.07.17	8.207	2.84	55.0	0.0	45.0
51	17.	Plot 3.1	N66.000089° E77.292324°	22.07.17	0.181	4.70	100.0	0.0	0.0
52	19.	Plot 3.1	N66.000011° E77.294246°	22.07.17	1.985	5.10	100.0	0.0	0.0
53	16.	Plot 3.1	N65.999985° E77.295579°	22.07.17	24.019	6.00	100.0	0.0	0.0
110	5.	Plot 3.1	N65.997645° E77.306655°	23.07.17	4.229	4.92	100.0	0.0	0.0
56	14.	Plot 3.2	N66.005200° E77.286498°	23.07.17	0.865	3.16	35.0	2.267	62.733

Note: W – moisture, S – proportion of sand fractions, C – proportion of clay fractions, Sl – proportion of silt fractions. Gray filling indicates undisturbed forested areas.

A total of 26 combined soil samples were selected, including 17 samples from sandy outcrops № 1, 4 samples from outcrop № 2, and 5 samples from outcrops № 3 (Appendix., Table 1). The physico-chemical analysis of the sampled samples was carried out in the chemical-ecological laboratory of the Tobolsk Complex Scientific Station of the Ural Branch of the Russian Academy of Sciences. The granulometric composition of the soil samples, their humidity and acidity were determined. The soil size distribution was determined according to GOST 12536-2014 [GOST..., 2015], the current acidity (pH H_2O) — according to GOST 26423-85 [GOST..., 1985], soil moisture — according to GOST 28268-89 [GOST..., 1989]. The dimension of soil fractions is given according to the classification by V.V. Okhotin [Okhotin, 1933, p. 9]. To classify the soils according to the particle size distribution, the triangular coordinates method (Ferret triangle) was used, taking into account the ratio of sandy, clayey and silt fractions [Definition ..., 2007]. The height of the sand mounds and shafts, as well as trees, was measured with a Suunto PM-5/1520 PC altimeter.

The data obtained were subjected to standard statistical analysis [Ivanter, Korosov, 1992]. Statistical data processing was carried out in the Microsoft Excel 2013 software environment, and the main statistical characteristics were calculated: the average value and the error of the mean ($M \pm m$), the range of the observed signs (Lim (min — max)), the mean square (standard) deviation (σ). Characteristic variability was determined using the coefficient of variation (CV). The significance of the difference between the two sample means was evaluated using Fisher's test (F) at $p < 0.05$. Statistical characteristics are given for all soil samples, and separately for samples taken in the northern taiga (sections 1 and 2) and the forest-tundra zone (section 3).

RESULTS AND DISCUSSION

The results of the analyzes performed show significant differences in the studied physicochemical properties of the soil samples studied. According to the data obtained, the indicators of the measured parameters vary widely (App., Tables 1, 2). This is especially true of soil moisture and the content of clay and dust particles.

It has been revealed that the soils in research sites in the northern regions of Western Siberia are predominantly acidic, the pH value varies from 2.84 to 6.42, with the lowest values of this indicator characteristic of the soils of natural undisturbed areas of northern taiga and forest-tundra ecosystems, where acidity varies from 2.84 to 3.72 units (sections 1.2, 2.2, and 3.2), which is generally consistent with the literature data [Western Siberia, 1963, p. 168; Dobrovolsky et al., 1998, p. 149]. On eroded soils of sandy exposures, acidity varies from 4.52 to 6.42 pH units (sections 1.1, 2.1 and 3.1). The obtained values have statistically significant differences (App., Table 2). Consequently, it is possible to speak of a decrease in soil acidity in ecotopes experiencing varying degrees of anthropogenic impact within the studied sandy outcrops, as compared with soils of undisturbed forest and tundra ecosystems up to 5–6 pH units and above (weakly acid and neutral environment). This can be explained by the erosion of the upper soil horizons that have a strongly acidic reaction in the northern taiga soils of the podzolic series due to the presence of high concentrations of water-soluble fulvic acids, and the exposure of the illuvial and eluvial horizons as a result of the destruction of the vegetation cover, since it is known that the soil acids are found down the profile of the considered soils., and, therefore, acidity decreases [Vasilyevskaya et al., 1986, 116–118; Dobrovolsky et al., 1998, p. 148–153; Kovrigo et al., 2008, p. 234–239].

The moisture index of the investigated soil samples varied from 0.181% to 52.301%. In soils of undisturbed forest ecosystems, this indicator ranged from 0.865% to 52.301%. Within the sandy outcrops, the humidity was significantly lower — from 0.181% to 34.388%, which shows more extreme conditions for the habitat of animals and plants in these ecotopes. Although the moisture content of the substrate largely depends not on the degree of disturbance of the habitat, but on its position in the terrain, and, as a rule, reduced areas have higher values of this indicator compared to elevated areas, nevertheless, the statistically significant differences indicate essential role of anthropogenic disturbance of an ecotope in reducing the soil moisture content, which is most likely due to an increase in porosity and a decrease in the content of finely divided mineral fractions soil on non-vegetated sands.

According to the percentage of mechanical elements of the solid phase of the soil, all the samples studied from sandy outcrops belong to loose sands (with a sand content of 95–100%), with the exception of one sample (laboratory sample No. 2) containing 85% of the sandy fraction and characterized as loamy sand. Forested undisturbed soil habitat characterized as opeschanennye loam (laboratory sample № 13 — pine and lichen № 26 — pine lichen-shrub) or silt (mud) loam (laboratory sample № 14 — birch-pine woodland lichen-shrub and № 20 — marsh pine lichen-shrub).

The change in the particle size distribution of the soil samples is manifested in an increase in the proportion of sand particles to 100% in areas of sandy exposures compared to undisturbed forested

Table 2 / Таблица 2

Statistical characteristics of the physico-chemical properties of the soil samples studied

Статистические характеристики физико-химических свойств исследованных почвенных образцов

Soil properties	Ecotope character	N	M ± m	Lim (min — max)	σ	CV, %
All plots						
pH	- undisturbed biotopes - sandy outcrops	4 22	3.32 ± 0.199 * 5.08 ± 0.111 *	2.84 — 3.72 4.53 — 6.42	0.3973 0.5187	11.97 10.21
W, %	- undisturbed biotopes - sandy outcrops	4 22	22.336 ± 11.512 * 8.187 ± 2.240 *	0.865 — 52.301 0.181 — 34.388	23.0237 10.5057	103.08 128.32
S, %	- undisturbed biotopes - sandy outcrops	4 22	47.500 ± 4.787 * 98.409 ± 0.763 *	35.0 — 55.0 85.0 — 100.0	9.5743 3.5812	20.16 3.64
C, %	- undisturbed biotopes - sandy outcrops	4 22	2.551 ± 0.968 * 0.258 ± 0.128 *	0.0 — 4.534 0.0 — 2.267	1.9359 0.5991	75.89 232.21
Sl, %	- undisturbed biotopes - sandy outcrops	4 22	49.950 ± 4.636 * 1.333 ± 0.718 *	41.60 — 62.733 0.0 — 15.0	9.2718 3.3680	18.56 252.66
Plots 1 and 2						
pH	- undisturbed biotopes — sandy outcrops	3 18	3.37 ± 0.271 * 5.06 ± 0.123 *	2.84 — 3.72 4.53 — 6.42	0.4688 0.5215	13.91 10.31
W, %	- undisturbed biotopes - sandy outcrops	3 18	29.493 ± 12.751 * 8.317 ± 2.523 *	8.207 — 52.301 0.320 — 34.388	22.0864 10.7062	74.89 128.73
S, %	- undisturbed biotopes - sandy outcrops	3 18	51.667 ± 3.333 98.056 ± 0.916	45.0 — 55.0 85.0 — 100.0	5.7735 3.8877	11.17 3.96
C, %	- undisturbed biotopes - sandy outcrops	3 18	2.645 ± 1.362 * 0.315 ± 0.153 *	0.0 — 4.534 0.0 — 2.267	2.3596 0.6513	89.21 206.76
Sl, %	- undisturbed biotopes - sandy outcrops	3 18	45.689 ± 2.582 1.629 ± 0.866	41.60 — 50.466 0.0 — 15.0	4.4729 3.6743	9.79 225.56
Plot 3						
pH	- undisturbed biotopes - sandy outcrops	1 4	3.16 5.18 ± 0.285	- 4.7 — 6.0	- 0.5706	- 11.02
W, %	- undisturbed biotopes - sandy outcrops	1 4	0.865 7.604 ± 5.534	- 0.181 — 24.019	- 11.0682	- 145.55
S, %	- undisturbed biotopes - sandy outcrops	1 4	35.00 100.0 ± 0.0	- 100.0 –100.0	- 0.0	- 0.0
C, %	- undisturbed biotopes - sandy outcrops	1 4	2.267 0.0	- 0.0 — 0.0	- 0.0	- 0.0
Sl, %	- undisturbed biotopes - sandy outcrops	1 4	62.733 0.0	- 0.0 — 0.0	- 0.0	- 0.0

Note: the legend as in the table 1; an asterisk (*) denotes statistically significant differences (at $p < 0.05$).

biotopes, where the proportion of sand ranged from 35 to 55%. The obtained values turned out to be statistically significant when all the soil samples were taken into account, as well as the differences in the content of the clay fraction and dust particles (Appendix, Table 2). However, the reliability of the differences in the compared samples for the content of sand and silt particles was not achieved when considering sections 1 and 2 without section 3, whereas the percentage of clay particles has statistically significant differences, which is probably due to a small sample size from undisturbed areas. The data obtained indicate a significant change in the grain size distribution of the soils of the northern taiga and forest-tundra sand massifs that are experiencing anthropogenic impact. Losing the finest fractions — clay and dust particles — the soils become more friable, porous, prone to wind exposure, and easily giving up moisture to atmospheric air.

Thus, studies have shown that the studied sand outcrops experience different forms (laying of linear structures in the form of dirt roads and pipelines, fire, mining of sand and CBC) and the degree of anthropogenic influences (fires occur both due to man's fault and natural genesis; roads, pipelines and other engineering structures often affect only the upper soil horizons, although the effect of the wind can later aggravate the process of soil destruction, while dry rut pits consider are among the most powerful factors influencing natural landscapes), and also located within different natural zones (northern taiga — forest-tundra). Nevertheless, they show great similarity in a number of physicochemical properties of soils, with significant differences in these indicators from those located near undisturbed forested ecosystems. To date, as a result of the complex effect of causes, both natural and anthropogenic in nature, very specific conditions have developed within the studied sand massifs of the northern regions of Western Siberia, which can be described as extreme for a variety of environmental factors (very low humidity, no fine soil fractions, a high level of porosity and mobility of the substrate, a low content of mineral nutrients). The ecotops formed under the influence of these factors can be developed only by a small number of species of erosiophil plants, which turn into disturbed sandy habitats from similar natural ecotopes with loose sandy and sandy, often mobile soils, characteristic of sea and lake shallows, river alluvium, screes, gully slopes [Dorogostayskaya, 1972, p. 17–18]. For example, we have previously shown that the most common and common plants in the studied sandy outcrops within the Yamal-Nenets Autonomous Okrug were rhizome and densely ground perennial grasses, well adapted to the loose substrate: *Juncus trifidus* L., *Calamagrostis epigeios* (L.) Roth, *Festuca ovina* L. s. l., *Bromopsis inermis* (Leyss.) Holub и др. [Капитонова и др., 2017a].

CONCLUSIONS

Intense anthropogenic impact on the podzolic soils of light grain size distribution of the northern taiga and forest-tundra regions of Western Siberia within the basin of the r. Pur leads to the formation of disturbed areas within the boundaries of natural sand massifs. Regardless of the degree and form of such effects of the soil, sandy outcrops acquire characteristic properties that distinguish them from undisturbed forested ecosystems in a number of physicochemical indicators. It is revealed that the transformed soils become less acidic, drier, almost completely lose the finest fractions — clay and dust particles. Extreme conditions that develop within anthropogenic ecotopes may be acceptable for development only by a small group of specialized species of erosophilia.

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