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Soils of the Settlements of the Yamal Region (Russia): Morphology, Diversity, and Their Environmental Role

Evgeny Abakumov [1,*], Alexandr Pechkin [2], Sergey Kouzov [1] and Anna Kravchuk [1]

[1] Department of Applied Ecology, Saint-Petersburg State University, Saint-Petersburg 199178, Russia; skouzov@mail.ru (S.K.); anna3571@yandex.ru (A.K.)
[2] Arctic Research Center, Salekhard, Yamal Autonomous Region 629008, Russia; a.pechkin.ncia@gmail.com
* Correspondence: e.abakumov@spbu.ru

Abstract

The landscapes of the Arctic seem endless. But they are also subject to anthropogenic impact, especially in urbanized and industrial ecosystems. The population of the Arctic zone of Russia is extremely urbanized, and up to 84% of the population lives in cities and industrial settlements. In this regard, we studied the background soils of forests and tundras and the soils of settlements. The main signs of the urbanogenic morphogenesis of soils associated with the transportation of material for urban construction are revealed. The peculiarities of soils of recreational, residential, and industrial zones of urbanized ecosystems are described. The questions of diversity and the classification of soils are discussed. The specificity of bulk soils used in the construction of industrial structures in the context of the initial stage of soil formation is considered. For the first time, soils and soil cover of settlements in the central and southern parts of the Yamal region are described in the context of traditional pedology. It is shown that the construction of new soils and grounds can lead to both decreases and increases in biodiversity, including the appearance of protected species. Surprisingly, the forms of urban soil formation in the Arctic are very diversified in terms of morphology, as well as in the ecological functions performed by soils. The urbanization of past decades has drastically changed the local soil cover.

Keywords: soils; vegetation; Arctic; technogenic grounds; soil sealing; biodiversity; pedodiversity

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1. Introduction

Soils of urban ecosystems in Russia have been studied actively for more than 40 years. They are perceived by the majority of scientists as an independent group of soils in terms of genesis, profile structure, and morphology, connected with the development and existence of urbanized ecosystems. The initial comprehensive works on the soil of urban environments in Russia have been published by G. Dobrovolskiy [1] and M. Stroganova [2]. It should be noted that within the International Society of Soil Scientists, the SUITMA (Soils of Urban, Industrial, Traffic, Military, and Mining areas) working group has existed for more than a quarter of a century. This group focuses on the investigation of urban soils and regularly organizes international thematic conferences.

Many classifications and taxonomic issues have arisen in the study of urban soils. Classification issues are solved within the framework of two classifications—WRB [3,4], which is used in many national soil classifications, including Russian soil taxonomy [5].

According to Stroganova and Prokofieva [6], urban soil classification will be intensively developed in the near future. Urban soils may have suffixes defining the peculiarities of their formation, e.g., urbic, thechniq, transportic, toxic, and thapto (the latter in case of buried material). In addition, the terms "Ekranic" and "Ekranozems" are widely used for soil covered by some external material, e.g., in the case of soil sealing in urban ecosystems [7]. At the same time, many soils of the present urban areas have undergone an agricultural stage of development in the past—this applies both to the central parts of cities and the suburbs.

Soils of megacities of the boreal and subboreal belt are more intensively studied than soils of the Arctic belt. It is difficult to enumerate all the studies; we will only mention the main ones conducted in Moscow [1,2], which are background studies for Russia. Many surveys have been conducted in the Rostov-on-Don region [8], Ufa [9], Nizhniy Novgorod [10], Saint-Petersburg [11–13], Vorkuta [14], and other polar urbanized areas [15,16]. Numerous studies have been conducted in North America [17], the Slovak Republic [18], Poland [19], Germany [20], and France [21]. Thus, the role of soils in the formation of urban environments has been reported in [22,23]; it was suggested that urban ecosystems of the Arctic are a well-established concept [24,25]. Arctic coastal settlements are faced with numerous geocryological problems and infrastructural risks [26]; the same was reported for cities located on permafrost [27,28]. The city of Salekhard recently organized an urban thermal monitoring program to evaluate the thermal regime of soils and parent materials [29]. The impact of climate change on agricultural soils is monitored in Northern Finland [30]. Much attention has been paid to the study of polychemical pollution of northern soils, including urbanized ecosystems [31,32]. A few interesting works on the soils of the ancient highland cities of the Tibetan plateau [33–35], including agricultural soils [36], have also been produced.

The economic development of the region of Western Siberia between the decades of the 1960s and 1980s of the twentieth century is a unique phenomenon for the entire Arctic circumpolar region. There are similar examples only in Alaska and Canada. In a short time, not only was the key fuel base of the state created, which provided 2/3 percent of all oil production and above 90% of natural gas, but a huge space was socially mastered literally from scratch. Most of the towns and cities in Yamal arose in connection with the development of mineral deposits. Thus, the reason for the establishment of the village of Gaz-Sale was the discovery of natural gas deposits in 1963 as a result of the Tazov oil and gas exploration expedition. For the same reason, in 1966, the village of Urengoy was transformed from a small fishing trading post to a geological and geophysical village with a transferred experimental expedition from the village of Berezovo.

The settlements that sprang up around the deposits quickly grew into cities due to the influx of specialists and workers. For example, Novy Urengoy, founded in 1973 near the largest gas field, became the "gas capital" of the country by the 1980s. Nadym (which became the center of the development of the Medvezhye gasoline deposit) and Noyabrsk, which grew out of the village of oil workers in the 1970s, developed similarly. These cities were originally created as planned settlements with typical buildings adapted to permafrost: houses were built on stilts, and modular structures were used to minimize the impact on the ground [37].

The population of the Yamalo-Nenets Autonomous District has grown tenfold over half a century: if in 1959 there were about 62,000 people living here, then by 2020, there were over 540,000. The demographic explosion is associated with migration: during the Soviet period, people traveled here on Komsomol vouchers (the "Komsomol" was a union of young communists in the USSR). Nowadays, indigenous peoples (Nenets, Khanty, and Selkups) make up about 10% of the population, preserving their traditional way of life, but facing problems due to the industrial development of their lands. In the 1980s and

1990s, despite the crisis, hydrocarbon production did not stop, which allowed the cities to avoid depopulation [38]. In the 2000s, rising energy prices gave a new impetus: modern satellite cities such as Gubkinsky appeared and infrastructure developed—railways (Surgut–Novy Urengoy line), airports, and highways.

For a long time, the soils of the Arctic cities of Russia remained extremely poorly studied in terms of morphology and diversity. The chemical state of urban soils was somewhat better since, in Arctic cities, it was related to the assessment of the polychemical state of ecosystems in the context of mining and transporting minerals [39]. The most important studies of soils in the Arctic zone of Eurasia included the following areas: urban soils of the European Arctic [14,28–30], the central part of the Yamal region [16,31], Norilsk [40,41], and Yakutsk city [42]. Urbic soils of archaeological monuments of Komi village (this settlement is now transformed into the ethno park of the city of Labytnangi) were also discovered [43,44].

Urban soils of the Arctic are of special interest because they are characterized by extremely specific morphology. They develop under conditions of permafrost degradation and the formation of relatively deep bulk material strata. Urbanization is accompanied by synanthropization of the flora of urban areas, which probably affects the quality of soil organic matter and the levels of soil respiration. This study is characterized by certain methodological limitations: inaccessibility of study objects and difficulties in obtaining a permit for access to study objects in cities with complex infrastructure. It should also be noted that the summer field season in the Arctic is limited, which does not provide an opportunity to study a large number of soil sections in one village, as it may be in the European part of the continent. It is clear that this makes our study largely descriptive, but urban soil science in the Arctic should develop despite the listed restrictions. Methodologically, soil studies of polar regions cannot compete with pedological studies of densely populated and easily accessible areas of the country. But this is why they are valuable, since, in this way, white spots are closed and the soil map of Siberia is supplemented and filled. Another problem related to Siberian soil research is that the available classifications are poorly adapted to the diversity of these very poorly studied soils. Therefore, we only apply the WRB classification for the primary identification of research objects, and not for the complete criterion diagnosis of soils. The same applies to Russian national soil classifications.

In connection with the above ideas, the aim of our work was to establish the morphology, diversity, and taxonomic position of soils of cities and settlements in the Yamal region (without claiming to be an exhaustive study, since many settlements are difficult to access). The objectives of the study included the following: (1) conduct field research, including expedition organization and logistical support, (2) analyze the history of polar Arctic settlements to fully interpret the soil data obtained, (3) perform morphological and taxonomic analysis of soil specifics of cities and settlements in comparison with background variants, (4) provide general soil chemical characteristics and data on the content of heavy metals in topsoils. The working scientific hypothesis was that the development of urbanized territories radically changes the soil formation process, soil morphology, and soil functioning processes even in relatively young Arctic cities. It is assumed that intensive urbanization in the Arctic can lead to a radical transformation of the soil cover and pedological diversity. It is suggested that the emergence of new soils and subsoils in urbanized ecosystems would alter the composition of the faunal complex, increasing the number of animal species inhabiting urban environments. We also assume that the soil of urban environments will demonstrate a higher level of heavy metal content in superficial layers than natural soils.

2. Materials and Methods

Field studies were carried out during trips to the Yamal region (Western Siberia, Russia) between 2019 and 2024. This area belongs to the Arctic zone of the Russian Federation and consists of six natural subzones. The research was conducted in the tundra and forest-tundra regions, which are the most populated parts of the Yamal region. The parent materials are presented by loams and clays with spatial alternations of sands. The climate is Dfc subarctic type with long winters and very short summers according to the Koppen classification [45].

In the case of the cities of Nadym and Novy Urengoy, private cars were used. In the case of remote settlements, which are usually located along river banks, water transport was employed. This significantly affects the degree to which the territory is explored, since it is very difficult and expensive to penetrate deep into watershed territories. Additionally, sandy parent materials often dominate in coastal areas, determining the specifics of the background soils that are transformed during human activity. As a result, research is geographically limited in these areas.

In total, about 22 soil sections were described according to the WRB 2022 y. version [4], and about the same descriptions of the area and landscape were provided; key cities and settlements are given in Figure 1. Traditional methods in Russian classical soil science were used, including comparative geographical and comparative morphological methods. Soil diagnostics were carried out according to substantive and morphological features [3–5]. The field strategy was as follows: a background ecosystem, a recreational area, a residential area, and an industrial area were identified, where at least one soil section was laid. In other cases, we were only able to survey natural and urbic soils for various reasons. All the soils and landscapes were provided by A.S. Pechkin from his personal archive. The purpose of this work was to characterize the morphology and genesis of various soils; thus, we did not use a statistical method, because every soil is unique in terms of morphology and profile organization. Unfortunately, we do not have information about the properties of soils prior to urbanization. Previous soil research in the area focused on natural soils, and we began our study of the morphological organization of urban soils in this region. We also do not have access to chemical or physical analytical data about soils prior to urbanization or in the literature. The same applies to the composition and properties of the material being transported; it is only known that it is local. In this regard, the article is mostly descriptive; we added this feature of the study to the description of the methodology. It is not possible to build space–time models based on limited and sometimes single data. This is the task of a separate article in the future. With regard to local authorities, their soil data are very scattered and mainly relate to petroleum products and biological indicators of pollution.

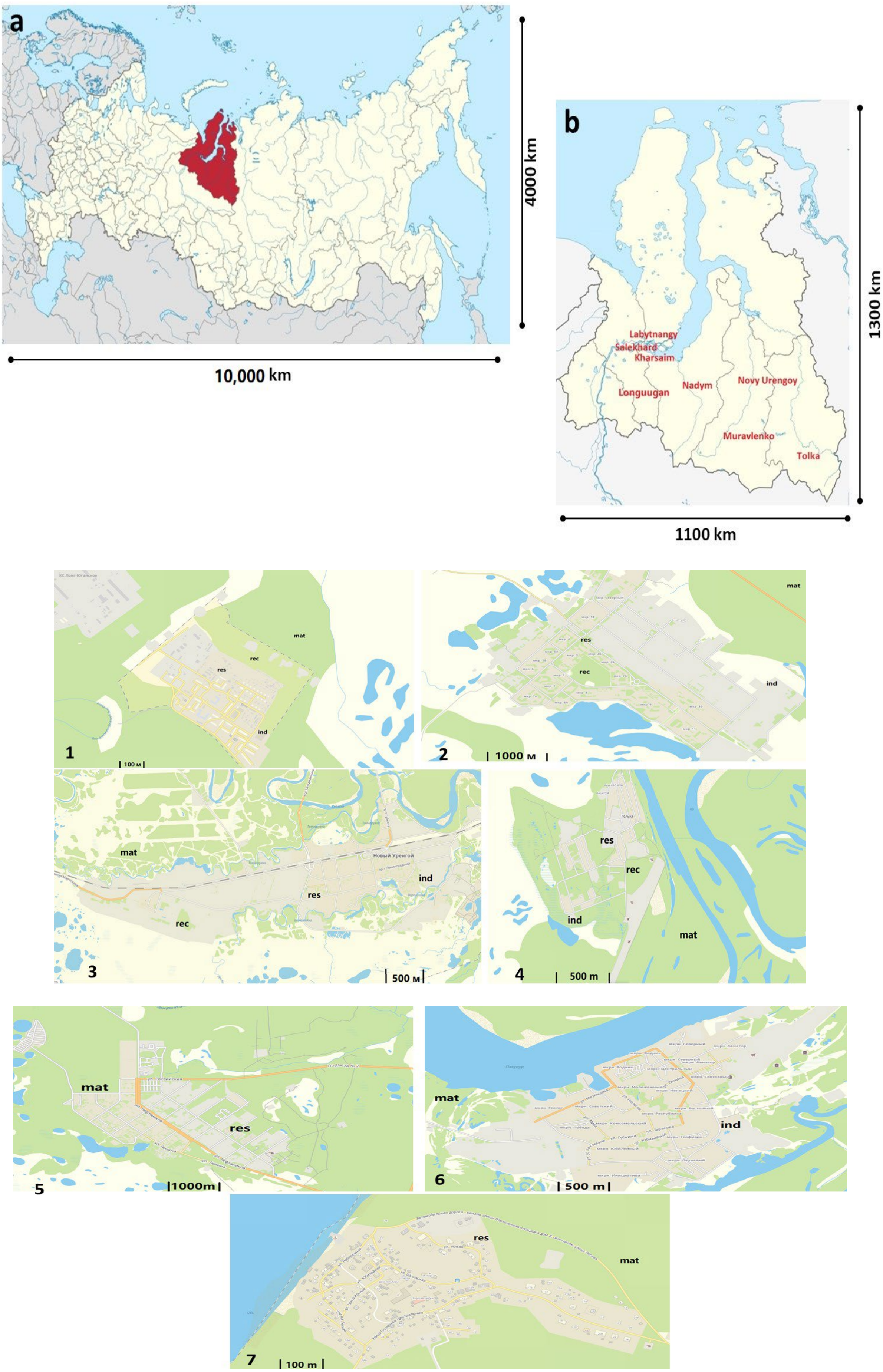
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Figure 1. Regionalization. (**a**) Yamalo-Nenets autonomous region on the map of Russia, (**b**) Cities and settlements involved in this work. Map of the (**c**) collected form: https://map.yanao.ru/eks/Obzor (accessed on 23 July 2025). 1—Longyugan, 2—Nadym, 3—Novy Urengoy, 4—Tolka, 5—Muravlenko, 6—Tarko-Sale, and 7—Khqrsaim.

Laboratory methods: All the chemical analyses were performed in the soil fine earth (<2 mm) fraction. The pH values were measured using the potentiometric method for the ratio of soil weight to volume—1:2.5 for water and 1:2.5 for a 1 n CaCl solution [46] with a detection limit of 0,1 pH unit. Soil carbon content was determined on a CHN analyzer (EA3028-HT EuroVector, Pravia, PV, Italy) with a detection limit of 0.05 gravimetric % of carbon. Cation exchange capacity (CEC) was measured in bulk soil samples using the Bobko–Askinazi–Aleshin method [47] in $BaCl_2$ buffer solution (pH = 6.5) via titration, ending with a detection limit of 0.1 CMP+/kg unit. Determination of the heavy metals was carried out via Atomic Absorption Spectrometry (AAS) using a Kvant-2MT (Cortec, Russia) spectrometer with a detection limit of 0.05 mg/kg. Extraction of metals from soil was performed using the "hot digestion" method—0.5–1 g of soil was flooded with 7.5 to 10 mL of 37% HCl and 2.5 to 5 mL of 65% HNO_3, and the solution was boiled for 5 h at 95–105 °C [48].

3. Results and Discussion

Soil pictures are provided in Figures 2–7. Soils of Longyugan settlement are presented in Figure 2. It is located on the first floodplain terrace of the Heigiyukha River (Longyugan), a tributary of the Nadym River. The soils of the Longyugan settlement are shown in Figure 1. The name of the settlement translates to "river of holy spirits" in the Khanty language. The settlement was established between 1972 and 1977 as a base for workers of the Long-Yuganskoye Linear Production Department of Main Gas Pipelines (LPUMG) as part of a large-scale program to develop the Tyumen Oil and Gas Province, aimed at exploiting the giant hydrocarbon fields of Western Siberia—Medvezhye, Urengoy, and Yamburg [30]. The creation of the settlement was driven by the need to provide logistical support for geologists, construction workers, and gas industry personnel involved in laying and maintaining main gas pipelines that connected Siberian fields to consumers in the European USSR and abroad. Initial infrastructure included temporary residential barracks, administrative buildings, warehouses, and roads. The settlement was expanded through the construction of permanent residential buildings, schools, hospitals, and social and cultural facilities between 1980 and 1990 [49]. The official population is approximately 1800.

The parent materials for the Nadym-Pur area consist of sandy and sandy loams from the geochemical province of Nadym-Pur. Permafrost can be found at depths greater than 1.5 m in sandy areas, while it occurs closer to the surface in wetlands and near hydrolaccoliths. Vegetation in the Nadym region is typical of the northern taiga and forest-tundra zones, with sandy soils supporting taiga flora and loamy soils supporting forest-tundra vegetation. The mature soil is a Stagnic Albic Podzol (arenic, Siltic, Turbic) [4]. According to Russian soil taxonomy [5], this soil is a Podzol cryoturbated pseudofibric (O-Etur-BFtur-Cff). The last pedological feature is a result of the presence of spring meltwater at various depths of the soil profile and further oxidation of the iron accumulated in the form of convoluted layers. In Figure 2, from left to right, one can see how the soil morphology changes dramatically from background to recreational, residential block, and industrial areas. In the case of the recreational zone, the forest floor horizon and podzolized layer have been partially destroyed (the horizons sequence is O-AY-BF-Cff). Most likely, they were both destroyed first. Then, the forest floor recovered a little, but the podzolized horizon did not. In soils of residential (AYur-RAT-BF-C) and industrial (AYur-TCH) areas, one can see technogenic material (RAT and TCH) transported on the plot. RAT is material used for soil construction with the aim of city greening [4], TCH is transported material of any origin, but it is not used for fertile soil construction [4]. In the case of a residential plot, we can see remnants of buried topsoil of the initial Podzol. In the case of the industrial plot, transported technic materies overlap the BF—the iron illuviation horizon. In both of these soils, the soil type grows upward. Generally, in many Arctic cities, sand is piled up during economic activity, which drains the urban landscape and, to some extent, isolates the cold of permafrost. As a result, Constructozem and Technosol with buried horizons from previous soils are formed. Therefore, over the past 50 years, the Longyan settlement's soil cover and morphological structure have undergone significant changes.

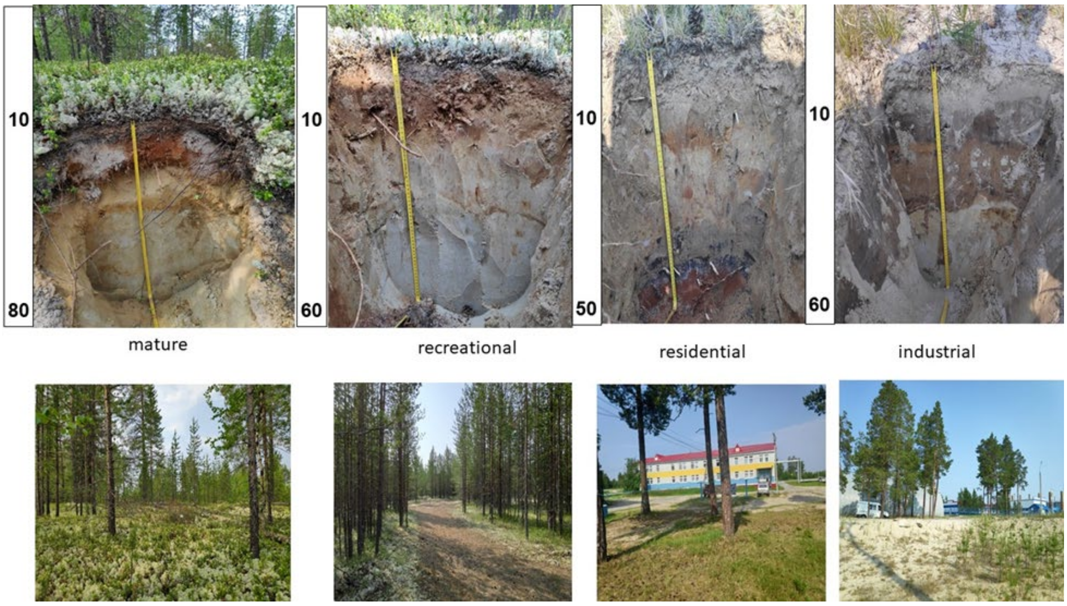

Figure 2. Soils and landscapes of the Longyugan settlement (mature, recreational, residential, and industrial areas).

The soils of the Nadym region are presented in Figure 3. Nadym is a relatively old city for the Arctic territories [49,50]. It has a long history, with a trading post established here at the beginning of the 20th century. The city grew up on the left bank of the Nadym River in 1972, and today, its population is around 45,000. The main industry that has shaped the city is Gazprom Dobycha Nadym, accounting for around 11% of gas production in Russia. Additionally, Nadym is home to Novatek, the largest independent gas producer in the region, operating the Yurkharovskoye and Yarudeyskoye gas fields. The city of Nadym is a prime example of the successful social policies of the Soviet era, which were aimed at creating highly urbanized, fully equipped settlements in extreme environments. Built practically from scratch near the 65th parallel—just half a degree south of the Arctic Circle—Nadym became one of Western Siberia's most developed cities. Its establishment was directly tied to the exploitation of the Medvezhye gas field, which necessitated permanent housing for industry workers. Development began in 1969 with the construction of two residential buildings and the Nadym Hotel on the shore of Yantarnoye Lake. By 1970, a temporary airport (Nadym) and the Nadym–Pristan road had been built to transport cargo from the river port to the city.

The settlement grew rapidly, attracting specialists and their families from all over the Soviet Union. In May 1972, the first five-story apartment building was completed, and on September 1st of the same year, Secondary School No. 1 opened in a brick building. In

1975, Nadym's population reached 20,000. In recent decades, new sports facilities and entertainment centers have been built [31].

The transformation of Nadym from a remote outpost to a modern Arctic city highlights the synergy between industrial development and planned urbanization in the resource-rich region of Siberia. Its infrastructure and population growth reflect the crucial role of hydrocarbon extraction in shaping Arctic settlements during the Soviet era. The mature soil is a Stagnic Albic Podzol (arenic, Siltic, Turbic) [4]. The lower part of the solum is well stratified, indicating an alluvial origin for this parent material (inherited alluvial genesis is designated as C~~, and ff is designated as pseudofibric pedological features according to [5]). The soils in the recreational, residential, and industrial areas do not inherit the characteristics of the original mature soils. They are completely new, constructed from transported material with a sandy texture. These soils could be classified as arenosol, technic, and transportic. In the recreational zone, the initial soil is destroyed, and only a thin organic profile forms on the sandy parent material (O-C~~). In the residential area, one can see stratified sandy textured parent material C~~ covered by RAT material, transported here for greening purposes. The soil in the industrial zone of Nadym is technozem, with a topsoil of transported technogenic material, which is known as the TCH horizon. As a result, the soil cover in this relatively large city has been completely replaced. However, in the settlements of the Nadym district, some of the soil profiles from previous natural soil types remain.

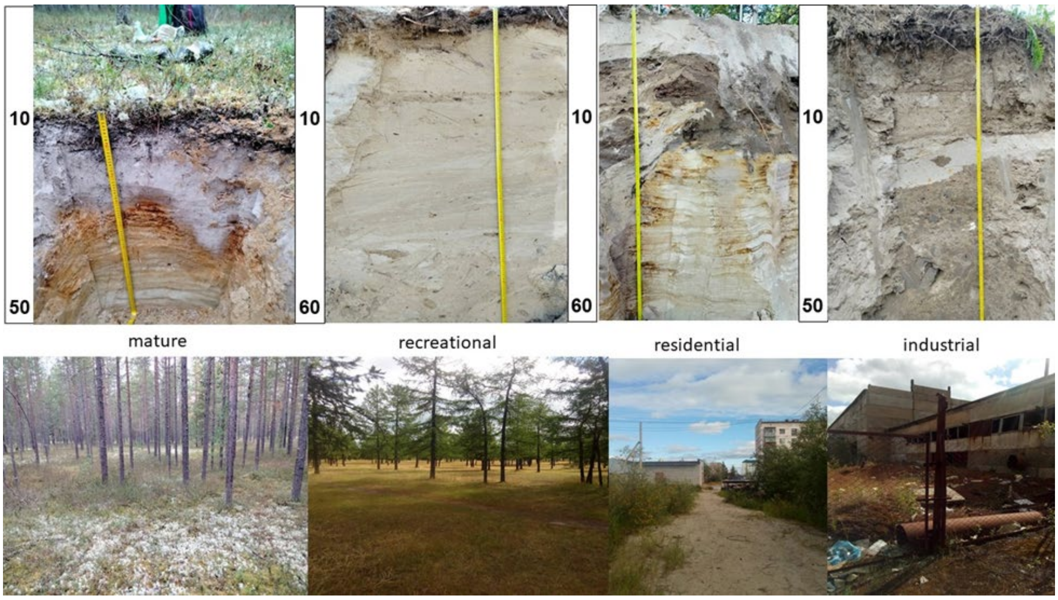

Figure 3. Soils and landscapes of the Nadym settlement (mature, recreational, residential, and industrial areas).

The soils of Novy Urengoy are shown in Figure 4. In terms of geology and climate, this city is very similar to Nadym. Novy Urengoy is a city in the Yamalo-Nenets Autonomous District of Russia. Novy Urengoy is the first large city in the region and one of the few Russian regional cities that surpasses the administrative center of its constituent entity (in this case, Salekhard) both in terms of population and industrial development. The city emerged during the development of Tyumen oil and is located on the bank of the Evo-Yakhi River, a tributary of the Pur River 579 km east of Salekhard. In terms of geology and climate, this city is very similar to Nadym. Novy Urengoy is a city in the Yamalo-Nenets Autonomous District of Russia. The territory of the urban district is surrounded by the Nadym district from the west and the Purovsky district from the east. The permanent population is 106,890 people. As the production center of the largest gas-bearing region, Novy Urengoy is the unofficial “gas capital” of Russia.

The city of Novy Urengoy was founded after the Urengoy gas condensate field, one of the largest in the world in terms of reserves, was discovered in 1966. In 1973, construction of the working settlement of Yagelnoye began, intended for workers in the gas industry. Early residents lived in temporary barracks, railcars, and tents. By 1975, the settlement had been officially named Novy Urengoy and had minimal infrastructure, including shops, a canteen, a bathhouse, and a medical post. However, by 1977, the population had grown to 4000, although housing shortages persisted, and self-built structures made from makeshift materials became more common.

In 1980, the settlement was granted city status, driven by ambitious gas production targets planned to reach 250 billion cubic metres per year by 1985. The population surged from 16,400 in 1981 to an estimated 90,000 by 1985. However, infrastructure lagged behind. Housing and social facilities (schools, kindergartens, and a cinema) faced challenges: material shortages, poor-quality supplies, and logistical hurdles. For example, the railway connecting the city to mainland Russia was only completed in 1985.

Urban planning initially ignored the master plan, and government departments focused on gas production quotas often led to construction norms being bypassed, resulting in informal neighborhoods like “Nakhalovka” (makeshift settlements). Residents frequently participated in the construction, repurposing materials from dismantled barracks from the 1940s and 1950s. By 1987, despite the opening of new schools and kindergartens, housing density remained high—4 m^2 per person [51]. By the late 1980s, Novy Urengoy had become a major gas production hub. Landmarks such as the Oktyabr Cultural Palace, a hospital, and sports complexes were built. However, planning errors, administrative fragmentation, and extreme climatic conditions hindered development [52]. Despite these challenges, the city evolved from a temporary settlement into the “gas capital of Russia”, reaching a population of around 118,000 by 2023.

The mature soil is similar to that in Nadym City (O-E-BF-C), which is logical given the shared geology and natural zone. As for the recreational zone (park), the topsoil here has been replaced by a transported mixture of turf and minerals. Only a few centimetres of the E (podzolic) horizon remain in the solum. This soil may be named Podzol, Ekranic, transportic, or arenic, and, in some cases, Spolic, i.e., soils with a high proportion of waste materials (these artifacts accumulate until a 30 cm depth and comprise less than 10% of the soil volume). The soils in the residential and industrial zones have lost their topsoil and only demonstrate mineral parent materials (Ctur) with features of cryoturbation. Thus, urbanization always leads to the replacement of natural soil profiles and their transformation into new, highly modified soils within the first few decades of the existence of urban ecosystems.

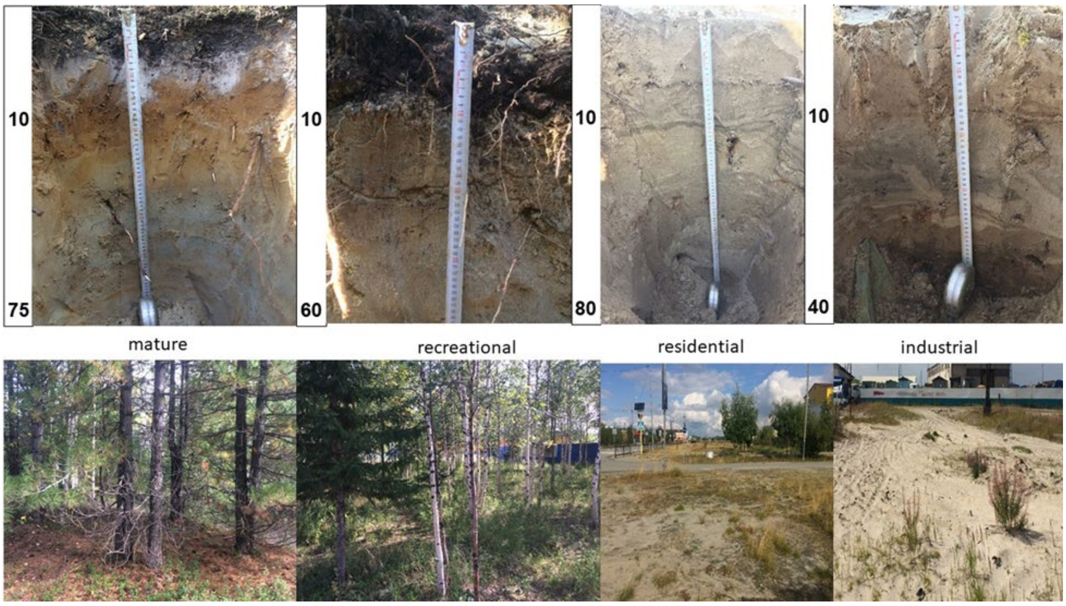

Figure 4. Soils and landscapes of the Novy Urengoy settlement (mature, recreational, residential, and industrial areas).

The soils of the Tolka settlement are shown in Figure 5. Tolka is a village located in the Krasnoselkupsky District in the southern part of the Yamal Region. It has a population of about 1800 people. The village is located away from the main road network and is connected to other settlements by a winter road during winter. The village has a small aviation airport and a pier on the Taz River. The woodworking company produces business timber, sawn timber, and firewood. The Tolka agricultural holding produces dairy products, venison, pork, beef, and processed fish. Despite its remote location within the Yamalo-Nenets Autonomous Okrug's transportation network, Tolka maintains connections with other regions. Critical infrastructure in the area includes a local airport for passenger transportation, a river port for seasonal cargo and passenger operations, and a network of winter roads that ensure access during the colder months [53]. The parent materials of the settlement and its surroundings are sandy-textured alluvial sediments, and the vegetation type is northern taiga forests. Natural soils as well as soil of recreational zones are presented by weakly developed Podzols with a low thickness of E horizon—Entic Podzols, folic, and arenic (O-e-BF-C~~). These soils demonstrate stratification inherited from alluvial parent materials. The topsoil in the residential area has been completely replaced by transported material of a sandy texture; the BF horizon of the original podzols is covered by this transported material (RAT-BF-C). The soils in the industrial area have been completely replaced and contain at least three different layers of technogenic sediment (TCH-C). It appears that these soils contain solid remnants of technogenic waste. Therefore, recreation does not have a significant impact on the soil, as there has not been any greening or park development. Instead, recreation is expressed through the degradation of the forest floor due to the pressure of vacationer foot traffic.

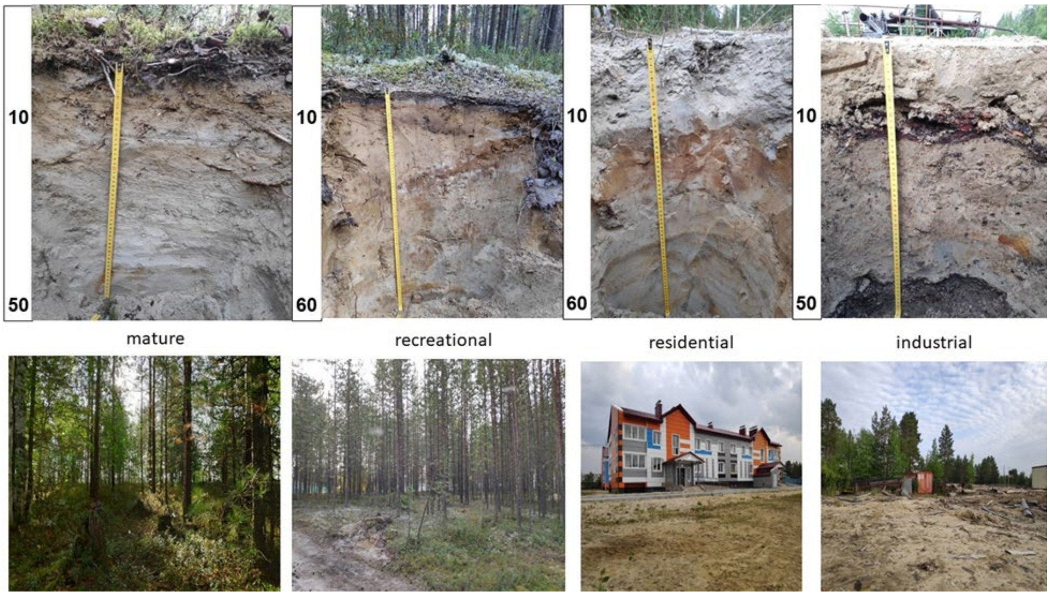

Figure 5. Soils and landscapes of the Tolka settlement (mature, recreational, residential, and industrial areas).

The city of Muravlenko is located in the southern part of the Yamalo-Nenets Autonomous Okrug (YaNAO), within the northern taiga subzone, on alluvial–glacial sandy deposits. Originally founded in 1982 as a settlement for oil workers, it gained city status in 1990 due to the intensive development of the region's hydrocarbon resources. The population of Muravlenko is approximately 30,000, reflecting its role as a hub for oil extraction infrastructure [52]. The city's establishment was directly tied to the discovery of the Sutorminskoye (1967 y.) and Muravlenkovskoye (1983 y.) oil fields, which catalyzed the urbanization of this previously undeveloped territory. Initially, a temporary settlement existed on the site of modern Muravlenko, providing logistical support for geological exploration expeditions. A pivotal moment came in 1981 with the decision by the USSR Ministry of the Oil Industry to construct a permanent settlement for oil industry workers. By 1985, the first apartment buildings, a school, a hospital, and the Neftyanik cultural center had been commissioned, enabling workforce retention under extreme climatic conditions. The key city-forming enterprise in Muravlenko is RN-Purneftegaz LLC, a subsidiary of Rosneft, which is responsible for field operations. By the 2000s, Muravlenko had become the center of oil production in the Purovsky district, accounting for up to 12% of regional hydrocarbon extraction. Examples of the soils found in Muravlenko can be seen in Figure 6. Mature soils include podzols, entic soils, cryotubated soils (O-Etur-BFtur-C), and folic arenic soils (O-C). In this case, urban soil is presented by an example from a residential area. Technosol Arenic is the soil of the residential area (AY-RAT-C). This soil demonstrates tactile features and well-expressed stratification of the solum due to the limited transportation of sandy material.

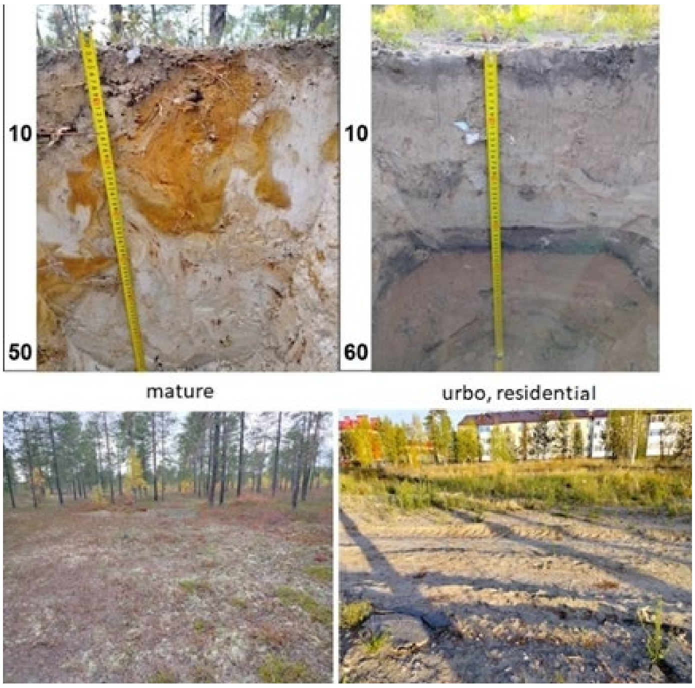

Figure 6. Soils and landscapes of the Muravlenko city (mature and residential areas).

Tarko-Sale is the administrative center of Purovsky District in the Yamalo-Nenets Autonomous Okrug. It is located at the confluence of the Pyakupur and Aivasedapur Rivers, on the right bank of the latter. The city's history is inextricably linked with the development of oil and gas fields in Western Siberia. Founded in 1932 as a temporary settlement, Tako-Sale acquired city status in 2004, reflecting the typical Arctic urbanization pattern driven by industrial resource extraction. Geomorphologically, the area is characterised by flat terrain with extensive wetland complexes and a dense network of lakes and small rivers. Forest–tundra landscapes predominate, with narrow strips of coniferous forest forming alongside bodies of water. The city's core enterprise is the LLC RN-Purneftegaz company. Tarko-Sale has a population of around 19,000 people.

The soil parent materials are predominantly sandy and layered. The natural soil here is Fluvisol Arenic (AY-C~~) on alluvial sediment of the former floodplain (Figure 7). The urbic soil is Transportic Technosol (AY-TCH-C) without any morphological features of initially mature soil.

The Kharsaim settlement is located in the Priuralsky District of the Yamalo-Nenets Autonomous Okrug and is one of the region's oldest settlements. Its name, which comes from the Khanty language, means "A village between two streams", reflecting its geographical location. Founded in 1937, Kharsaim has become an important center for the local fishing community. Since 1936, a lime kiln has been operating in the area of the village, which has significantly influenced the development of infrastructure and the economy. The village has a population of around 640. The village is located halfway between the city of Salekhard and the Aksarka settlement, on the high right bank of the Ob River. The source materials are layered sediments of the Ob River floodplain, modified by the Aeolian accumulation process. The soils of this area are shown in Figure 8. The mature and urban soils here are both Fluviosols (O-AY-C~~) that are not actively affected by the flooding zone. The urban soil in the surface layer shows signs of pyrogenic effects (Opir-TCH-C~~).

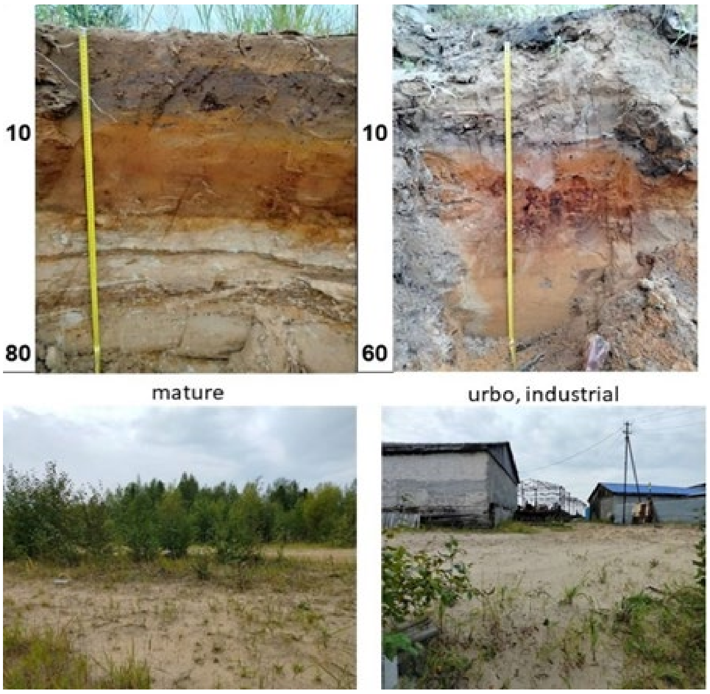

Figure 7. Soils and landscapes of Tarko-Sale city (mature and industrial areas).

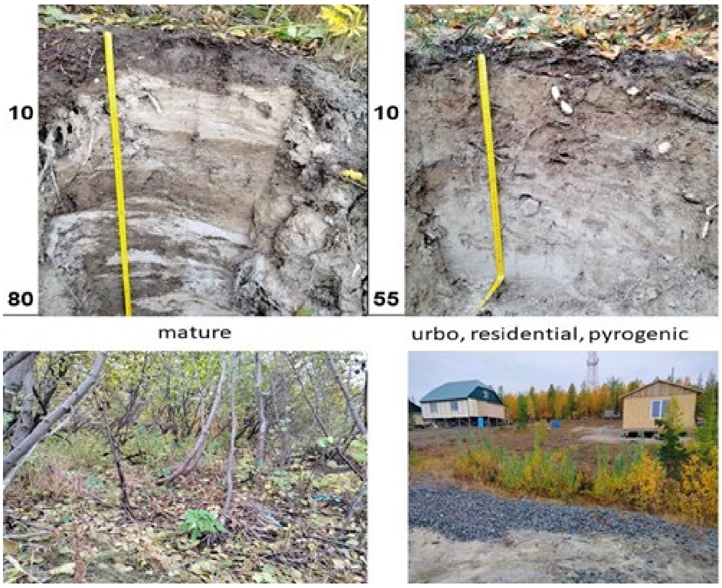

Figure 8. Soils and landscapes of the Kharsaim settlement (mature and residential areas).

A different type of habitat is represented by sandy and sandy loamy dumps, which are created during the construction of buildings and permanent roads on permafrost. In many respects, they are an artificial analogue of the scattered sands found on tundra hillocks, representing the initial stages of vegetation succession. Nevertheless, they provide a habitat for a large number of local birds and mammals. According to modern classification concepts, these are not soils, but rather soil-like bodies or technogenic surface formations. However, they represent the initial stage in the creation of settlement soils, as it is from the bulk soil material that the aforementioned soils are formed.

Technogenic dumps, which are typical of areas near cities and pipelines, provide ideal conditions for herbaceous plants and birds (Figure 9). These dumps, especially those with sandy and gravel substrates, are often attractive habitats for both plants and animals.

The biodiversity of these areas can be significantly increased due to the presence of anthropogenic factors. In fact, numerous red-listed species of animals have been found in anthropogenic habitats in Yamal.

Figure 9. Transported soils and ground as a habitat for animals: (**a**) temporary dumps and waterlogging of the adjacent area; (**b**) snowy owl (*Bubo scandiaca*) on transported ground; (**c**) brood of sea blackbird (*Aythya marila*) on the pond near road embankments; (**d**) snow bunting (*Plectrophenax nivalis*) feeding on a road embankment; (**e**) young red-throated pipit (*Anthus cervinus*) at a road embankment; (**f**) migration of migrating ruffs (*Calidris pugnax*) on road embankments.

Species that typically inhabit sandy river channel beaches, such as the ringed plover, white wagtail, and red-throated pipit, readily breed on these sandy, anthropogenic, soil-like surface formations. These species may be significantly more abundant and dense on embankments than in natural tundra habitats [54].

Abundant puddles and extensive wetlands with loamy bottoms are often found along anthropogenic embankments, which are formed due to the partial thawing of permafrost and, in some places, the backwatering of small local watercourses. These wetlands resemble the final stages of thermokarst lakes, known as khasyreas. They attract large numbers of birds that nest in the damp tundra, including red-necked phalaropes, dunlins, Temminck's stints, and little stints. In addition, broods of river and diving ducks may be present if the water surface is sufficiently extensive near such linear features. During autumn migration, the number of these bird species increases significantly in these habitats. New positive landforms created by artificially deposited soils attract birds of prey, who use them as roosting sites and as a place where small mammals running across the sand can be easily detected and captured. Arctic foxes and ermines are attracted by the presence of prey and are constantly present near roads. In quieter areas of embankments, these animals may also burrow, as it is easier to dig burrows in these soils than in permafrost. Therefore, soils and similar materials contribute to changes in local biodiversity in urban ecosystems. The ecological role of soils in urbanized Arctic ecosystems is underestimated. For a long time, researchers have focused on the soils of natural tundra and areas where gas and oil are produced. Urban soils in the Arctic have been neglected, yet they play a crucial role as a substrate for green spaces in cities, providing important aesthetic and recreational benefits. Furthermore, urban soils contribute to preserving and enhancing biodiversity in fragile cryolithozone ecosystems.

The data on the chemical composition of the soils are provided in Table 1. Since the purpose of our work was mainly to characterize the morphological transformation of soils, soil samples to determine their chemical characteristics were taken from the upper horizons in a single repetition without taking into account the spatial location of soils relative to possible sources of pollution, which will be the material for a separate article. In the case of the Longyugan and Nadym soils, the natural soils are more acidic than the urban soils. This is caused by the accumulation of cations in urban ecosystems and soils [55], as well as the disturbance or disappearance of the forest floor, which is a source of organic acids in soils. The content of organic matter in urban soils is higher than in natural soils. In some cases, this could result from urban greening practices, such as the planting of grasses in parks or residential zones, which can accelerate humus content. Conversely, some organic matter may have a technogenic origin [56]. With regard to heavy metals, there is no doubt that they are more concentrated in urban soils than in background soils in settlements.

Table 1. Chemical characteristics of the soil superficial layer (mature—mat; recreational—rec; restoration—res; industrial—ind).

Soil	TOC, %	pHH_2O	$pHCaCl_2$	CEC, CMP+/kg	Cr, mg/kg	Ni, mg/kg	Cd, mg/kg	Zn, mg/kg	Cu, mg/kg	Pb, mg/kg
Longyugan, mat	1.20	6.3	4.2	3.8	0.10	1.71	0.17	1.43	0.71	0.10
Longyugan, rec	1.45	6.4	4.5	1.9	2.77	2.28	0.16	9.16	2.44	1.34
Longyugan, res	1.71	7.2	n.d.	1.8	1.65	1.71	0.24	3.60	2.56	0.43
Longyugan, ind	1.90	6.7	4.1	3.6	4.05	3.20	0.26	14.12	1.67	2.05
Nadym, mat	0.65	4.5	2.8	6.0	1.54	0.10	0.02	1.10	2.40	0.10
Nadym, recr	0.70	5.0	3.9	3.2	6.25	4.47	0.19	24.92	2.02	4.43
Nadym, res	1.20	5.6	4.4	3.6	3.38	3.26	0.08	8.22	1.95	1.01
Nadym, ind	0.95	5.7	4.2	4.1	5.63	3.26	0.15	7.21	2.32	1.10
Kharsaim, mat	3.56	7.2	n.d.	4.0	16.19	26.53	0.48	43.24	12.81	5.48
Kharsaim, ind	3.68	7.5	n.d.	4.5	23.28	23.31	0.46	32.35	12.68	5.99
Muravlenko, mat	0.78	6.0	4.4	3.0	4.01	1.18	0.32	2.64	0.32	0.65
Muravlenko, res	1.05	6.9	4.6	3.2	5.63	5.28	0.36	6.94	3.85	0.53
Tarko-Sale, mat	2.50	5.9	3.7	5.1	1.05	0.58	0.15	1.23	0.10	0.10
Tarko-Sale, ind	2.80	6.4	4.4	4.5	3.43	2.30	0.30	6.30	1.02	3.02

Thus, urbanized ecosystems not only undergo a transformation in the morphological organization of the soil profile, but also a significant transformation in the chemical parameters of the soil's fine earth. The soils of the Kharsaim settlement are essentially contaminated with heavy metals, both naturally occurring and urbic. This is due to intensive economic and transportation activity in the settlement itself and its vicinity. Intensive chemical impact is confirmed by the neutral and alkaline reaction of the fine earth in Kharsaim soils. The soils of Tarko-Sale and Muravlenko demonstrate the same trend as the soils of Nadym and Longyugan: urban soils are less acidic, enriched with organic matter, and accumulate heavy metals compared to natural soils. In spite of the fact that the studied settlements have existed for a shorter period in comparison with cities in European Russia, urban soils show a significant transformation of chemical state along with strong morphological changes. The low absorption capacity of sandy soils (namely, those that prevail in our study) does not contribute to a strong accumulation of pollutants. Considering that most of the soils we have studied are characterized by an acidic environment, it is not surprising that heavy metals are not fixed in the upper soil layers, as is the case in soils in large cities in the European part of Russia. In those areas, the alkalization of urban soil is more pronounced. Of course, these are the primary data of chemical analysis of soils; it is necessary to analyze a much larger number of soil samples. An important issue is the sampling strategy used for chemical analysis. We used a profile horizon approach, while most government researchers and containment organizations use a surface sampling strategy from depths of 0–5 and 5–20 cm. This does not fully track the depth of transformation of soil profiles. At this stage of our research, we can say that in young urban ecosystems in the Arctic, new soil-forming processes are not initiated at the chemical level. Existing processes are modified, and humus accumulation is somewhat activated.

4. Conclusions

A systematic study of soils in several settlements in the central and southern parts of the Yamalo-Nenets Autonomous Region, one of the world's most important hydrocarbon-producing regions, was carried out for the first time. This study compared the soils of urban areas with background soils located in the surrounding areas. It was found that soil profiles and cover transform most significantly in cities with populations of several tens of thousands. In smaller settlements, the transformation is less pronounced. The following soil transformation processes were revealed: (1) replacement of part or even all of the original soil horizons by displaced materials of natural or anthropogenic origin, (2) sealing (ecraning) of original soil horizons by foreign matrices, (3) pyrogenic transformation of upper horizons, (4) recreational degradation of forest litter in park recreational areas, amd (5) increased drainability of soil habitats due to increased mound thickness. Morphological transformation of soils mainly affects the upper 30–50 cm of the soil profile, mainly due to the replacement of soil material with imported soil; sometimes this happens without destroying the original soil, and in some cases as a result of cutting the original natural soil. Additionally, urbanized soils can be habitats of rare and endangered species of animals and plants, contributing to biodiversity or its conservation in some cases. This study only partially revealed the diversity of urban soils in the subarctic zone, describing them in morphological terms. In the future, it will be necessary to investigate the chemical composition of soil horizons and conduct research on the spatial patterns of soils in urbanized ecosystems. Additionally, it is essential to continue exploring the diversity of soils in different functional areas of urban areas. Soil plays a crucial role as the most significant environmental factor in subarctic urban ecosystems, and its condition should be further explored.

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References

1. Dobrovolsky, G.V.; Stroganova, M.N.; Prokofeva, T.V.; Striganova, B.R.; Yakovlev, A.S. *Soil, City, Ecology*; Foundation "For Economic Literacy": Moscow, Russia, 1997; 320p.
2. Stroganova, M.; Miagkova, A.; Prokofieva, T.; Skvortsova, I. Soil, city, environment. In *Soils of Moscow and Problems of Urban Environment*; Elsevier: Moscow, Russia, 1998; 150p.
3. World Reference Base for Soil Resources. *World Soil Reports 84*; ISSS\ISRIC\FAO: Rome, Italy, 1998; 88p.
4. IUSS Working Group, W.R.B. World Reference Base for Soil Resources. In *International Soil Classification System for Naming Soils and Creating Legends for Soil Maps*, 4th ed.; International Union of Soil Sciences (IUSS): Vienna, Austria, 2022.
5. VV Dokuchaev Soil Institute (VASKhNIL). *Classification and Diagnostics of Soils in Russia*; Oykumena: Smolensk, Russia, 2004; 342p.
6. Stroganova, M.; Prokofieva, T. Urban soils classification for Russian cities of the taiga zone. *Eur. Soil Bur. Res. Rep.* **2001**, *7*, 153–156.
7. Hulisz, P.; Charzyński, P.; Greinert, A. Urban soil resources of medium-sized cities in Poland: A comparative case study of Toruń and Zielona Góra. *J. Soils Sediments* **2018**, *18*, 358–372.
8. Gorbov, S.N.; Bezuglova, O.S. Specific features of organic matter in urban soils of Rostov-on-Don. *Eurasian Soil Sci.* **2014**, *47*, 792–800. https://doi.org/10.1134/S1064229314080043.
9. Suleimanov, R.R.; Obydennova, G.T. Soil-archaeological studies of the bronze-age settlement on the Urshak River floodplain, Bashkortostan. *Eurasian Soil Sci.* **2006**, *39*, 820–825. https://doi.org/10.1134/S1064229306080035.
10. Paramonova, T.A.; Chernogaeva, G.M.; Lukyanova, N.N.; Paramonov, M.S. Heavy Metals in Urban Soils of Volga Federal District: An Integrated Analysis of Official Data. *Eurasian Soil Sci.* **2023**, *56*, 1803–1817. https://doi.org/10.1134/S1064229323601907.
11. Matinyan, N.N.; Bakhmatova, K.A.; Korentsvit, V.A. Soils of the Summer Garden (Saint Petersburg). *Eurasian Soil Sci.* **2017**, *50*, 637–645. https://doi.org/10.1134/S1064229317060060.
12. Polyakov, V.; Kozlov, A.; Suleimanov, A.; Abakumov, E. Soil pollution status of urban soils in St. Petersburg city, North-west of Russia. *Soil Water Res.* **2021**, *16*, 164–173.
13. Aparin, B.F.; Sukhacheva, E.Y. Principles of soil mapping of a megalopolis with St. Petersburg as an example. *Eurasian Soil Sci.* **2014**, *47*, 650–661.
14. Dymov, A.A.; Kaverin, D.A.; Gabov, D.N. Properties of soils and soil-like bodies in the Vorkuta area. *Eurasian Soil Sci.* **2013**, *46*, 217–224.
15. Korneykova, M.V.; Vasenev, V.I.; Saltan, N.V.; Slukovskaya, M.V.; Soshina, A.S.; Zavodskikh, M.S.; Dolgikh, A.V. Analysis of CO2 emission from urban soils of the Kola Peninsula (European Arctic). *Eurasian Soil Sci.* **202**3, *56*, 1653–1666.
16. Alekseev, I.; Abakumov, E. Permafrost-affected former agricultural soils of the Salekhard city (Central part of Yamal region). *Czech Polar Rep.* **2018**, *8*, 119–131.
17. Huot, H.; Joyner, J.; Córdoba, A.; Córdoba, A.; Shaw, R.K.; Wilson, M.A.; Walker, R.; Muth, T.R.; Cheng, Z. Characterizing urban soils in New York City: Profile properties and bacterial communities. *J. Soils Sediments* **2017**, *17*, 393–407. https://doi.org/10.1007/s11368–016-1552-9.
18. Sobocká, J.; Saksa, M.; Feranec, J. Mapping of urban environmentally sensitive areas in Bratislava city. *J. Soils Sediments* **2021**, *21*, 2059–2070. https://doi.org/10.1007/s11368-020-02682-4.
19. Pindral, S.; Kot, R.; Hulisz, P.; Charzyński, P. Landscape metrics as a tool for analysis of urban pedodiversity. *Land Degrad Dev.* **2020**, *31*, 2281–2294. https://doi.org/10.1002/ldr.3601.
20. Burghardt, W.; Kneib, W.D.; Höke, S.; Lehmann, A.; Makowsky, L.; Kocher, B.; Steinweg, B. Soil science within German cities. *J. Plant Nutr. Soil Sci.* **2022**, *185*, 462–474. https://doi.org/10.1002/jpln.202200211.
21. Joimel, S.; Cortet, J.; Jolivet, C.C.; Saby, N.P.A.; Chenot, E.D.; Branchu, P.; Consalès, J.N.; Lefort, C.; Morel, J.L.; Schwartz, C. Physico-chemical characteristics of topsoil for contrasted forest, agricultural, urban and industrial land uses in France. *Sci. Total Environ.* **2016**, *545–546*, 40–47. https://doi.org/10.1016/j.scitotenv.2015.12.035.
22. Wiseman, C.L.S.; Zereini, F.; Püttmann, W. Metal and metalloid accumulation in cultivated urban soils: A medium-term study of trends in Toronto, Canada. *Sci. Total Environ.* **2015**, *538*, 564–572. https://doi.org/10.1016/j.scitotenv.2015.08.085.
23. Reyes, E.S.; Liberda, E.N.; Tsuji, L.J.S. Human exposure to soil contaminants in subarctic Ontario, Canada. *Int. J. Circumpolar Health* **2015**, *74*, 27357. https://doi.org/10.3402/ijch.v74.27357.
24. McBride, J.R.; Douhovnikoff, V. Characteristics of the urban forests in arctic and near-arctic cities. *Urban For. Urban Green* **2012**, *11*, 113–119.

25. Laruelle, M.; Esau, I.; Miles, M.; Miles, V.; Kurchatova, A.N.; Petrov, S.A.; Konstantinov, P. Arctic cities as an anthropogenic object: A preliminary approach through urban heat islands. *Polar J.* **2019,** *9*, 402–423. https://doi.org/10.1080/2154896X.2019.1685171.
26. Liew, M.; Xiao, M.; Farquharson, L.; Nicolsky, D.; Jensen, A.; Romanovsky, V.; Jones, B. Understanding effects of permafrost degradation and coastal erosion on civil infrastructure in Arctic coastal villages: A community survey and knowledge co-production. *J. Mar. Sci. Eng.* **2022**, *10*, 422.
27. Klene, A.E.; Nelson, F.E. Urban Geocryology: Mapping Urban–Rural Contrasts in Active-Layer Thickness, Barrow Peninsula, Northern Alaska. *Ann. Am. Assoc. Geogr.* **2019**, *109*, 1394–1414. https://doi.org/10.1080/24694452.2018.1549972.
28. Grebenets, V.I.; Streletskiy, D.; Shiklomanov, N. Geotechnical safety issues in the cities of Polar Regions. *Geogr. Environ. Sustain.* **2012**, *5*, 104–119.
29. Filimonov, M.Y.; Kamnev, Y.K.; Shein, A.N.; Vaganova, N.A. Modeling the temperature field in frozen soil under buildings in the city of Salekhard taking into account temperature monitoring. *Land* **2022**, *11*, 1102.
30. Niemeläinen, O.; Hannukkala, A.; Jauhiainen, L.; Hakala, K.; Niskanen, M.; Laine, A. Increase in perennial forage yields driven by climate change, at Apukka Research Station, Rovaniemi, 1980–2017. *Agric. Food Sci.* **2020**, *29*, 139–153. https://doi.org/10.23986/afsci.85141.
31. Pozhitkov, R.; Moskovchenko, D.; Soromotin, A. Trace elements composition of surface snow in the polar zone of northwestern Siberia: The impact of urban and industrial emissions. *Environ. Monit. Assess* **2020**, *192*, 215. https://doi.org/10.1007/s10661-020-8179-4.
32. Allen-Gil, S.M.; Ford, J.; Lasorsa, B.K.; Monetti, M.; Vlasova, T.; Landers, D.H. Heavy metal contamination in the Taimyr peninsula, Siberian Arctic. *Sci. Total Environ.* **2003**, *301*, 119–138.
33. Smith, C.A.S.; Clark, M.; Broll, G.; Ping, C.L.; Kimble, J.M.; Luo, G. Characterization of selected soils from the Lhasa region of Qinghai–Xizang Plateau, SW China. *Permafr. Periglac. Process.* **1999**, *10*, 211–222.
34. Wei, L.; Haitao, G.; Na, Z.; Jing, S.; Sang, B.A.; Xuebin, L.Ü.; Jian, X.I.O.N.G. Distribution characteristics and ecological risk assessment of heavy metals in soil of Lhasa City. *J. Environ. Eng. Technol.* **2022**, *12*, 869–877.
35. Sheng, J.; Wang, X.; Gong, P.; Tian, L.; Yao, T. Heavy metals of the Tibetan top soils: Level, source, spatial distribution, temporal variation and risk assessment. *Environ. Sci. Pollut. Res. Int.* **2012**, *19*, 3362–3370. https://doi.org/10.1007/s11356-012-0857-5.
36. Zhou, P.; Zeng, D.; Wang, X.; Tai, L.; Zhou, W.; Zhuoma, Q.; Lin, F. Pollution Levels and Risk Assessment of Heavy Metals in the Soil of a Landfill Site: A Case Study in Lhasa, Tibet. *Int. J. Environ. Res. Public Health* **2022**, *19*, 10704. https://doi.org/10.3390/ijerph191710704.
37. Zamyatina, N.Y. Arctic urbanization: Phenomenon and comparative analysis. *Bull. Mosc. Univ. Ser. 5 Geogr.* **2020**, *4*, 69–82.
38. Vainshtok, S.M. *The Role of the Oil Industry in the Economic Development of The Cities of the Tyumen*; Vector Books: Tyumen, Russia, 2000; 140p.
39. Ji, X.; Abakumov, E.; Chigray, S.; Saparova, S.; Polyakov, V.; Wang, W.; Wu, D.; Li, C.; Huang, H.; Xie, X. Response of carbon and microbial properties to risk elements pollution in arctic soils. *J. Hazard. Mater.* **2021**, *408*, 124430. https://doi.org/10.1016/j.jhazmat.2020.124430.
40. Korneykova, M.V.; Saltan, N.V.; Kozlova, E.V.; Vasileva, M.N.; Davydova, P.D.; Berezhnoi, E.D. Microbial communities of urban soils in the Norilsk agglomeration. *RUDN J. Agron. Anim. Ind.* **2024**, *19*, 431–446.
41. Yakovlev, A.S.; Plekhanova, I.O.; Kudryashov, S.V.; Aimaletdinov, R.A. Assessment and regulation of the ecological state of soils in the impact zone of mining and metallurgical enterprises of Norilsk Nickel Company. *Eurasian Soil Sci.* **2008**, *41*, 648–659.
42. Polyakov, V.; Nizamutdinov, T.; Abakumov, E.; Morgun, E. Soil diversity and key functional characteristics of yakutsk city: Largest urbanized cryogenic world's Ecosystem. *Energies* **2021,** *14*, 3819.
43. Nizamutdinov, T.; Morgun, E.; Pechkin, A.; Kostecki, J.; Greinert, A.; Abakumov, E. Differentiation of trace metal contamination level between different urban functional zones in permafrost affected soils (The example of several cities in the Yamal Region, Russian arctic). *Minerals* **2021**, *11*, 668.
44. Nizamutdinov, T.I.; Suleymanov, A.R.; Morgun, E.N.; Gusev, A.V.; Tupakhina, O.S.; Gusev, A.V.; Plekhanov, A.V.; Tupakhin, D.S.; Abakumov, E.V. Soils of the polar archaeological site "Settlement Labytnangi 1 (Komy village)": Morphological analysis and chemical composition. *Dokuchaev Soil Bull.* **2023**, *114*, 66–108. https://doi.org/10.19047/0136-1694-2023-114-66-108.
45. Cui, D.; Liang, S.; Wang, D. Observed and projected changes in global climate zones based on Köppen climate classification. *WIREs Clim. Change* **2021**, *12*, e701. https://doi.org/10.1002/wcc.701.
46. Carter, M.; Gregorich, E. *Soil Sampling and Methods of Analysis*; Carter, M., Gregorich, E., Eds.; Taylor & Francis: London, UK, 2006; p. 198.

47. Maskalchuk, L.N.; Baklai, A.A.; Leont'eva, T.G.; Makovskaya, N.A. Removal of Cesium Radionuclides from Aqueous Media with an Aluminosilicate Sorbent Prepared from Belaruskalii Production Waste. *Radiochemistry* **2019**, *61*, 459–463.
48. FAO. *Standard Operating Procedure for Quasi Total Elements in Soil by Acid Digestion, Including Heavy Metals*; FAO: Rome, Italy, 2023; p. 21.
49. Koleva, G.Y. *West Siberian Oil and Gas Complex: A History of Formation*; Tyumen State Oil and Gas University: Tyumen, Russia, 2005; 160p.
50. Efimova, E.A. Development of Social Infrastructure in the Gas Industry During the 1960s–1980s. *Ind. Econ. Manag. Technol.* **2016**, *3*, 20–28.
51. Mochalin, M.S. Urbanization of Yamal in the Second Half of the 20th Century (Case Study of Novy Urengoy). *North Reg Sci. Educ. Cult.* **2022**, *4*, 93–99. https://doi.org/10.34822/2312-377X-2022-4-93-99.
52. Koleva GYu Kumantseva, M.V. Oil and Gas Resources in the Fate of Northern Territories (Krasnoselkup and Krasnoselkup District). *Probl. Mod. Sib. North Collect. Sci. Pap* **2011**, *1*, 199–202.
53. Makarov, V.; Culshaw, M.; Reeves, H.; Jefferson, I.; Spink, T. Soil salinization in northern urban areas is an engineering problem. *Eng. Geol. Tomorrow's Cities. Geol. Soc. Lond. Eng. Geol. Spec. Publ.* **2009**, *22*, 633.
54. Kouzov, S.; Kravchuk, A.; Zaynagutdinova, E.; Abakumov, E. Reactions of shorebirds and passerines to human development in the Russian Arctic under the influence of strict conservation measures. *Czech Polar Rep.* **2019**, *9*, 200–219.
55. Suleymanov, A.; Abakumov, E.; Polyakov, V.; Kozlov, A.; Saby, N.; Kuzmenko, P.; Telyagissov, S.; Coblinski, J.A. Estimation and mapping of soil pH in urban landscapes. *Geoderma Reg.* **2025**, *40*, e00919. https://doi.org/10.1016/j.geodrs.2025.e00919.
56. Krasilnikov, P.V. Stable carbon compounds in soils: Their origin and functions. *Eurasian Soil Sci.* **2015**, *48*, 997–1008. https://doi.org/10.1134/S1064229315090069.