Soil cover of areas of mining sand and sand-gravel material in the Leningrad region

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Abstract. The article considers the component composition of soil cover in the areas of mining sand and sand-gravel material in the Leningrad region. The sites under study are anthropogenically transformed soil that have a direct and indirect impact on the natural soil cover. Direct impact should include the burial of natural soils under dumps, the complete removal of soil profile as a result of quarrying and changes in the relief. The process of rock removal can lead to a change in the parent rock. Indirect influences include stratification of soil surface by dust, soil over-consolidation, and the formation of recreational zones, dumps and bonfires. At all the studied sites, the same type of soil cover organization was detected. Nonsoils formations were found where soils had been completely destroyed. These were found at places including access roads, dumps, rock outcrops and pits filled with water. Slopes, roadsides and cavaliers of the network of protective ditches typically feature turbocharged and stratified natural soils. Ditch bottoms are formed by Nudiargic Luvisols and Nudialbic Podzols. Soil combinations of slightly altered and fully natural soils are identified in the areas adjacent to quarries.

1. Introduction
Anthropogenic activity currently affects vast areas of natural landscapes. Of the variety of anthropogenically altered lands, technogenic landscapes which formed as a result of mining operations take up significant share. During such mining, areas of disturbed lands increase, the landscape degrades, and soils and vegetation undergo geochemical transformation [1].

Anthropogenic activity leads to significant changes that result in the formation of new forms of relief. Sandy mounds are converted into excavations that consist of ledges, platforms, slopes and a pit bottom. The bottom of an abandoned quarry pit features an uneven surface with elevations up to several meters. Sometimes, excavation pits get filled with water due to the high level of groundwater.

Quarries change the natural soil cover radically, forming new soil combinations. Quarry pits flooded with water turn into recreation spots for the local population. The natural soil cover gets subjected to change owing to excavation as well as the further recreational load. As a result, the particle size distribution of the soil may change, as well as the soil’s properties, namely the bulk density, humus content, content of exchange bases, etc. [2]. The intensity of anthropogenic pressure on soil cover depends on the location of the quarry and its accessibility for the local population.

The purpose of the study was to learn soil cover in the areas of mining.
The objectives were to analyze the component composition and structure of soil cover on the territories adjacent to the quarries for the mining operations.

2. Objects and methods
Soil cover in the area of quarries and their adjacent territories was studied across the Leningrad region. The mineral resource base of the region today includes almost 400 deposits of solid minerals, recorded by the State Balance of Reserves [3].

Subsoil plots containing common minerals are primarily exploited nowadays. Mostly these are sands and sand-gravel material. They are found in 70% of all operated facilities in the mining industry of the region [4].

The predominance of sand deposits is associated with the geological structure of the territory. Quaternary deposits, which are widespread throughout the region, feature outcrops of common minerals used mainly to produce bulk building materials (sand and sand-gravel).

8 sand and sand-gravel pits were selected as sites for this study. Of these, 2 are still in operation. The other quarries are no longer operational (figure 1).

The soil cover study sites of the areas disturbed as a result of the mining of sand and sand-gravel material included: territories damaged by bulk soil (waste heaps, spoil tips, dumps); territories damaged by excavation (open pit mines); and adjacent territory suffering indirect effects (stratification by dust, landfill, over-consolidated soils).

Sand and sand-gravel quarries are clearly visible in satellite images. These images can be distinguished and identified by the presence of one or several rounded bright spots of considerable size (up to several km2) with clear boundaries [5].

All open sand and sand-gravel quarries are developed using open pit mining. Technogenic strips which originated during the exploitation of such deposits may be detected in various landscapes, completely destroying or significantly altering them. The studied sand and sand-gravel pits are confined to glacial deposits (the quarry near the settlement of Shugozero), lacustrine-glacial deposits (Shapkinsky quarries, an abandoned quarry near the village of Verkhniye Mandrogi, open pit "Travniki tract", open pit "Shiltsevo", "Small Luga Canyon") and fluvioglacial deposits ("Tolstoye" and "near the airfield" quarries) [6]. At the same time, new ecosystems may form, which may be significantly different from the natural environment preceding them.
3. Soil cover of the areas of mining sand and sandy-gravel material

In order to study the soil cover of quarries and their adjacent territories in detail, the following sites were considered closely: "Small Luga Canyon", "near the airfield" open pit and the "Tolstoye" active open pit.

3.1. "Small Luga Canyon" site

The "Small Luga Canyon" site is located in the Luga District, 7 km southwest of the Tolmachevo railway station. According to the map of quaternary deposits [6], the territory is composed of lacustrine-glacial formations.

As stated in the archives of the Luga district, the quarry was established in the 1970s to use quartz sands of the quarry as a raw material at the Ploskoye glassware factory. Exploitation of the quarry ended over 40 years ago.

The boundaries of the studied area at the "Small Luga Canyon" site were as follows: access dirt roads, a rectangular-shaped mine filled with water, a network of protective ditches used to drain the surface runoff and recreational areas. Currently, the adjacent territory is actively used for recreational purposes. This is facilitated by the close location of settlements, roads and railways. In addition to the coastline of the quarry, an artificial canyon which attracts many tourists with a varied color palette of quartz sands is used for recreation. The height difference from the site outer boundary to the water is about 8 m (figure 2).

![Figure 2. Soil map of the "Small Luga Canyon" site.](image)

Soil cover in the territory adjacent to the water part of quarry is represented mainly by Arenosols and Turbic Arenosols (33% of the total area).

Combination of Arenosols and Regosols (21% of the total area) is noted in the northern part of the site. Regosols are confined to morainic deposits that were exposed during the exploitation of the sand deposit. Within the boundaries of that complex there are stand-alone mounds up to 1.5 m to 1.7 m high, which formed as the external embankments took shape. Nudiargic Luvisols are formed here.

Nonsoils formations are shaped by dirt roads, rock outcrops and a flooded pit. These cover 41% of the total area of the site.

A network of protection ditches to drain surface runoff is located in the northern part of the site, parallel to the long edge of the excavation and perpendicular to the slopes. Nudialbic Podzols or
Nudiargic Luvisols are formed at the bottom of the ditch, depending on the rock. Stratified soils are associated with cavaliers. The ditch complex occupies 1% of the total area of the site.

In the western part of the site there are Turbic Umbric Albic Luvisol and Umbric Albic Luvisol area stretched along the moraine. Most likely this area was reclaimed and used for agricultural purposes.

3.2. The "Tolstoye" quarry

Only soil cover adjacent to the open pit was studied at the operating "Tolstoye" open quarry. Quarrying has taken place since 1984 and gravel-sand material is mined here.

The territory adjacent to the quarry features a pronounced natural-and-man-made landscape, shaped by outer dumps accumulating next to quarries as a system of ridge-like or single hilly elongated embankments [8]. These hills are elongated, and in places they go down in small terraces. Depressions feature secondary undulations that create a mounded surface. The height difference can be up to 7 m around these mounds (figure 3).

Figure 3. Soil sequence in different sections of the "Tolstoye" open pit:
1 – Albic Podzols, 2 – Turbic Arenosols, 3 – Protic Arenosols, 4 – Arenosols, 5 – Nonsoils formation.

Areal of lichens and pines are confined to the tops of the hills. Lichens, mosses and sparse undergrowth of pine, birch and goat willow cover middle parts of the hillsides and depressions. These observations are confirmed by Yu. I. Danilov et al. [9], who noted that the best pine growth is observed on hilltops and banks of stripped overburden. Moderate growth is observed on gentle slopes of different exposure, while the poorest growth is seen at the bottoms of open pits.

The soil cover is represented by combinations of Arenosols at the bottom and slopes, and combinations of Albic Arenosols, Protic Arenosols and Arenosols at the top. Signs (of podzolization) in the form of grains which have been washed away are found only under the pines. On the slopes, due to the different input of material by runoff and the different colors of sand, the Arenosols have a different morphological structure (figure 4).

Figure 4. Schematic map of soil cover of the "Tolstoye" open pit mine.
3.3. Open pit area "near the airfield"

The "near the airfield" open pit is located in the northeastern part of the Tikhvin district, 10 km northwest of the Shugozero village. Quarrying has taken place there since the 1980s. The site consists of two pits of different ages, access dirt roads and a recreation area. Exploitation of one part of the quarry was completed more than 30 years ago. The other part of the quarry is currently exploited intermittently.

The landscape is of a transitional character, progressing from a hilly-moraine to a lacustrine-glacial plain. A field survey of the territory has demonstrated that at the highest points of the relief the profile of underdeveloped soils is formed on fine-grained sand. Further on, when moving down the relief, the bedding is replaced by gravelly sand with loam and pinkish-gray sand patches in places and brown sand with pebbles found at the bottom of the open pit (figure 5). The top to bottom height difference of the pit is almost 13 m.

![Figure 5. Soil profiles of underdeveloped soils of the area "near the airfield", formed on different rocks.](image)

Arenosols formed on gravelly sand are common for the area of the open pit which have been left the longest since mining was completed. They occupy about 60% of the entire study area (figure 6). Row by row planting of pines point to the site reclamation campaign carried out previously. The relief of that part of the site is formed by slopes and depressions in which Arenosols are formed on fine-grain sand (occupying 12% of the total area of the site).

![Figure 6. Soil map of the area "near the airfield".](image)

Most of the site is represented by underdeveloped soils formed on various types of rock (fine-grain sand and gravelly sand). In addition, underdeveloped soils in combination with nonsoils formations are
found along the bottom and slopes of the pits. This kind of combination occupies 21% of the total study area.

Patches not affected by exploitation of the open pit are encountered at the bottom of the mine. They rise above the bottom of the quarry and their soil cover is formed by Entic Podzols. In terms of coverage, these spots account for 4% of the area.

Access dirt roads are represented by Nudiumbric Entic Podzols. Novic Entic Podzols forms on the side of the road, its bulk layer overlapping the humus horizon of the natural soil. The ditch complex occupies 2% of the total area of the site.

The area around the road and mine is negatively affected and suffers from dust and over-compaction. The area of such soils is about 2%.

Despite the fact that the pit site is not filled with water and is not within any kind of walking distance of the neighboring settlements, the quarry and its adjacent territory are used for recreation. This evidenced may be drawn from the traces of bonfires, parking and recreation areas. It all result in over-compaction of soil cover. Natural soils are represented by Entic Podzols.

3.4. Open quarry “Travniki tract”
The “Travniki tract” sand and gravel pit located in the Podporozhye district is characterized by the structure of soil cover of the pit and its adjacent territory similar to those of the other open pits studied.

The peculiarity of this site is that the quarry is located in the Zvonets hills. Zvonets hills are represented by reddish brown clays. They have rounded outlines and are steep, often terraced slopes and plateau-like hilltops. Zvonets clays are deposited in spots of different areas on the tops of flat hills, underlain by moraine loams. This site is located a considerable distance away from settlements and is not used as any kind of recreational area. During the extraction of sand and gravel material, these Zvonets hills were torn off, with their underlying moraine deposits exposed as a result.

3.5. Vegetation of quarries
Essentially, vegetation on slopes and dumps of all the studied quarries is represented by the Pinus sylvestris L. This tree has almost no alternative as the main species for restoring disturbed lands in North-West Russia. It is widely used as a forest culture planted on dumps of sand and gravel pits [9].

Four abandoned quarries and the entry strip of one active quarry demonstrate some reclamation activity as indicated by pine trees planted in rows. However, such reclamation has only been done on small areas. The rest of the sites feature spontaneous regrowth.

The level of biodiversity in the early years of overgrowing is generally low. In cases of self-overgrowing areas that feature high amount of fine earth, this increases over time [10]. In all such quarries the plant diversity is represented by green moss, lichen, willowherb, sedge and strawberry in the ground cover. Shrubs of heather and blueberry are formed. Undergrowth is composed of spruce, goat willow, birch and mountain ash. Grown trees combine pine, spruce and birch.

4. Conclusion
The impact of the mining industry results in either a complete or partial change in the natural soil cover. Complete destruction of soil takes place in the areas of bulk dumps formed in the territory of open mines. Areas adjacent to the quarries suffer from indirect disruptive effects. Fragments of natural soil cover may remain intact in such cases.

The following arrangement of soil cover is typical for the territory of sand and sand-gravel material mining in the Leningrad region.

Soil cover in the center of quarry pits is formed by nonsoils formations combined with underdeveloped soils. Exceptions to this are those quarries that have their pits filled with water (Shapkinsky quarries and the “Small Luga Canyon”), as well as active quarries.

The sides of the quarries may get overgrown with vegetation, and underdeveloped soils are formed on the lateral surface of the quarries in such cases. The surface of quarry slopes is represented by nonsoils
formations or combination of nonsoils formations and Arenosols. The Nonsoils formations coverage of quarry slopes may vary from several percent to 20% of the total studied area.

When developing small to medium-sized open pits (1–10/15 hectares in size), their outer dumps are formed next to the open pits as a system of ridge-like or separate elongated mound-like embankments. Such relief contributes to the formation of a mosaic structure of soil cover.

Recreational zones have a greater influence on the soil cover of areas adjacent to the quarry pits. The respective transformation of the natural soil cover is associated with the laying of dirt roads, trampling, the formation of bonfires and dumps.

Quarrying leads not only to complete or partial changes in the natural soil cover but also alters the natural factors of soil formation. Quarrying may result in changes in the soil rock and relief.

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