1. **Lomonosov Moscow State University (LMSU).**

**Soils on technogenic deposits of 60 years age\***

\*Study has been carried out at financial support of Russian Fund of Basic Research (project no. 15-04-04702)

One of the oldest Russian institutions of higher education, Moscow State University (Fig. 6) was founded in 1755. In 1940, it was named after Mikhail Lomonosov (1711 - 1765), an outstanding Russian scientist, who greatly contributed to the establishment of the university in Moscow.

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| Fig. 6 LMSU Main BuildingView from Botanical Garden |

Mikhail Lomonosov was one of the famous polymaths of the 18th century. The great Russian poet Alexander Pushkin described him as a person of formidable willpower and keen scientific mind, whose lifelong passion was learning. Lomonosov’s interests ranged from history, rhetoric, art and poetry to mechanics, chemistry, mineralogy. His activity is a manifestation of the enormous potential of the Russian scientific community whose representatives occupied the leading positions in the world at the time. Peter the Great reformed Russia, which allowed the country to reach the standards of the contemporary European powers in many areas. Great importance was placed on education. In 1724, the St. Petersburg Academy of Sciences, founded by Peter the Great, founded a university and a grammar school to educate intellectuals and researchers the country needed; however, these educational establishments did not fulfill the task they took on. It was Mikhail Lomonosov who suggested, in his letter to Count Shuvalov, the idea of establishing a university in Moscow. An influential courtier and the favorite of Empress Elizaveta Petrovna, Count Shuvalov was a patron of the arts and science; he supported Lomonosov’s plans for a new university and presented them to the Empress.

In 1755, on 25 January, St. Tatiana’s Day according to the Russian Orthodox Church calendar, Empress Elizaveta Petrovna signed the decree that a university should be founded in Moscow. The opening ceremony took place on April 26th, when Elizaveta Petrovna’s coronation day was celebrated. Since 1755, both dates – January 25thand April 26th are marked by special events and festivities at Moscow State University; the annual conference where students present results of their research work is traditionally held in April.

Moscow State University is a major traditional educational institution in Russia. It offers training in almost all branches of modern science and humanities. Its undergraduates may choose one of 128 qualifications in 39 faculties, while post-graduate students may specialize in 18 branches of science and humanities and in 168 different areas. The total number of Lomonosov Moscow State University (LMSU) students exceeds 40,000; and about 10,000 high school students attend various clubs and courses at LMSU.

Besides its 39 faculties, Moscow State University comprises 15 research institutes, 4 museums, 6 local branches in Russia and abroad, about 380 departments, Science Park, botanical gardens, library, the University Publishing House and a printing shop, a recreational center and a boarding school for talented children.

From the engineering and operational point of view Moscow State University campus is an extremely complex system, with its 1,000,000 m2 floor area in 1,000 buildings and structures, with its 8 dormitories housing over 12,000 students and 300 km of utility lines. Nevertheless, this system had to be updated and developed for the University to meet the modern requirements both as a center of higher learning and a center of research. According to the plan, approved by the government in 1987, a number of new buildings had to be erected in the area adjacent to the campus on Vorob’evy Gory. Under the project (architect G.N. Tsytovitch) new blocks for some faculties and state-of-the-art research laboratories were to be constructed, together with a library building, a swimming pool, a stadium, a recreation center, and some services. The Main Library Building was opened in January, 2005. The first Humanities Building opening ceremony on the new campus was held on September 1, 2007, the new block housing Faculties of History, Public Administration, Philosophy, Political Science. The “old” campus area was also developed, the new Economics Building opened in 2009. At the moment the construction of the LMSU Medical Center on the New Campus is being finished. The expansion and development of the New Campus is going on, a true sign of dynamic development of Moscow University.

The LMSU Main building is a high-rise of the famous Stalin’s architecture, one of the highest points of Moscow. Among the creators of the complex of the University campus were such prominent Soviet architects as Boris Iofan (1891-1976) and Leo Rudnev (1885-1956). The sculptural decoration of facades is the workshop of Vera Mukhina. The grand opening ceremony of the LMSU Main Building took place on September 1st, 1953. The height of the central 32-storey part of the Main Building is 239.5 m, its total structural volume is 1,370,000 m3. In the wings, there are 5,754 dorm rooms for students and graduate students and 184 apartments for professors and faculty members. The Main Building has three gymnasiums, an indoor swimming pool, the 1500-seat Assembly Hall and a recreation center with an 800-seat concert hall.

In 1953, the Physics Building and Chemistry Building were opened, their total structural volume being 274,600 m3 and 267,700 m3, respectively. At the same time a number of other buildings and facilities were set into operation, among them the Botanical Garden, a 22,500-m3 field-and-track pavilion, a 19,000 m3 ball-game pavilion and open team-game fields. The LMSU meteorological station began its work on the Lenin Hills the same year. The Building of Biology (with Soil Sciences branch) was opened in 1955.

When you look up at the golden spire of the Main Building from the ground, it seems to be weightless and delicate. In reality, it weights over 12 tons and its mounting at the height of 200 m proved to be a difficult and unsafe operation. The builders came up with an original idea to assemble the framework of the spire inside the building and then use a hauling winch to put it in place. To make this operation possible the two upper beams of the star at the top had to be detached. High above the ground welders assembled the golden star adorning the spire. Both the star and the spire were coated with aluminium amalgam underlying the yellow glass outer layer (Lomonosov Moscow State University, 2017).

**1**. **The Earth Science Museum of Moscow State University**

[](http://www.mes.msu.ru/)The Earth Science Museum was founded in 1950 in the Main Building of the Moscow State University as an inter-faculty teaching museum for LMSU students (Fig. 7). The museum was named to comprise a wide range of interrelated Earth Sciences, which deal with the structure and composition of the complex geospheres, including the geographic environment as a whole, the humans’ life and activity. The basic principle of the Earth Science Museum’s exhibitions is to show a dialectical approach in the studies of nature diversity on our planet and the history of its development.

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| **Fig. 7** Exposition of the Earth Science Museum of LMSU |

The Museum’s activity is undertaken in three main directions: conducting classes, research work and disseminating scientific knowledge. The combination of educational and scientific work makes wide activity field for the Museum. Every year more than 2500 academic hours are held in the museum. University teachers conduct classes with students of Geographical, Geological and Biological Faculties and Faculty of Soil Science. During seminars on biogeography, geology, mineralogy, soil science and other disciplines, students have the opportunity to study full-scale exhibits. Practical work of students in the museum allows them to gain knowledge and experience working with natural objects and to prepare for field investigations.

Students of the Soil Science Faculty can learn in the Museum such disciplines as geology, mineralogy (27thand 28th floor), general soil science and special courses. Classes are held on the 25th floor of the museum in the exhibition “The Natural zones”. The principal theme of this division is the land scape zonality and the resources of nature with special emphasis on the complex character and relation of all landscape features. Much consideration is given for the soil, which is considered as the “mirror” of the landscape. The division comprises 54 exhibition cases, which has been hand-painted, and includes 230 soil profiles, from tundra soils to subtropical soils. There are also hundreds of samples of soil-forming rocks and 15 three-dimensional exhibits showing fragments of ecosystems from various zones. The division contains three terrestrial globes, which depict the distribution of vegetation, animals and soils on our planet. There are more than a dozen displays with animals from various zones and hundreds of herbarium and individual specimens of plants, including those which are landscape-forming, relict or endemic or in some way useful for humans.

Exhibit cases visualize the complex picture of climate, relief, soils and vegetation interdependences in the natural zones (Complex profile by P.M. Chiszhicov) (Fig. 8). The principle of constructing the profiles may be regarded as a contribution of the Museum to the methodology of the complex geographic presentations.

One of the halls at the 25thfloor, “Nature and Resources,” has high significance for a holistic perception of the environment changes in natural conditions. The hall deals with the structure of the Earth’s landscape and its fundamental laws. The visitors can observe and study the idea of the geographic belts and important elements of the landscape formation (climate, vegetation, soil and soil-forming rocks, animals) as well as the various aspects of the usage of nature. Twenty-six soil profiles are shown at the central exhibition of the hall “Nature and Resources.”



Fig. 8 “Nature and Resources”- central exhibition of the hall

The generalized introductory demonstration of “The Earth’s Landscape Envelope” reflects the most general regularities of the surface envelope’s structure, first and foremost the laws of entity and irregular development in time and space. The map in this display reproduces the same idea of the distribution of the geographic belts and landscape zones on the Earth.

**2.Botanical Garden of Lomonosov Moscow State University on the Vorob’evy (Leninskie) Hills**

The LMSU Botanical Garden (BG) is located on the Vorob’evy Hills, 800 m to the southwest from the side of the high right bank of the Moskva River. The area is a plain with a slope of 1–2° to the northwest (to the Ramenka River Valley). The total surface area is 33.0 ha; mantle silty clays and loams of 1–3 m thickness on moraine are natural parent rocks in the area (Rappoport, 2004).

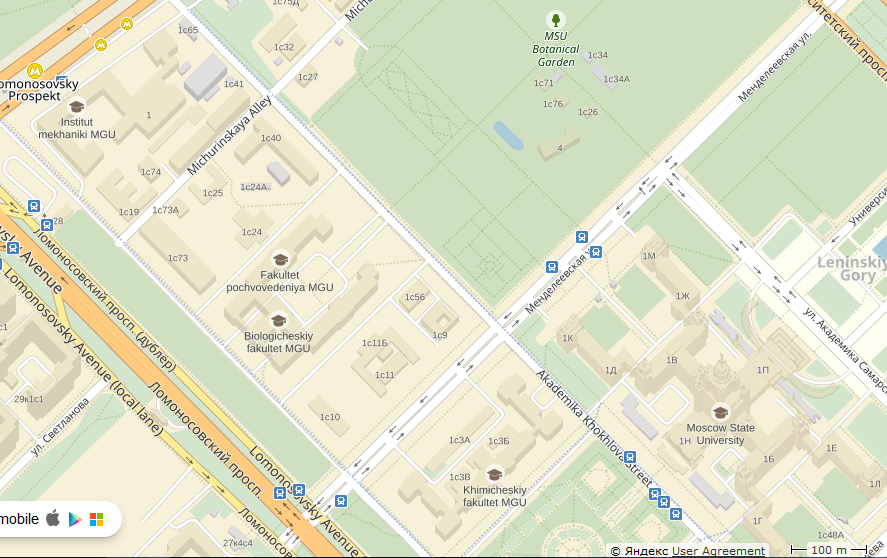
The area was leveled before the construction of LMSU campus. After the end of construction, the area was releveled and manured. Thus, the BG soils were remediated and at the moment they have the age of 50–60 years. Major gardening work was done in 1950–1951 (Fig. 9). The main work was in the arboretum, which occupied an area of about 10 ha, was completed in1958 (Aksenova and Boiko, 2000). Different phytocenotic communities of global and national flora were simulated in the arboretum area by planting different woody edifier species. Large volumes of low-moor peat were used for garden construction. Low-moor peat and mineral fertilizers were annually applied onto the soil during the first 10–20 years of garden development to increase the soil fertility in the arboretum. Later on, the application of fertilizers was used only around tree trunks, and nothing was applied in the last 20 years (Rappoport, 2004). Today, the BG arboretum is an area with high quality plantations of different high-stem woody species. Compost applications incorporated into soils are still used in other parts of the BG.



Fig. 9 The place of the Botanical Garden of LMSU in 1950 (www.botsad.msu.ru)

Residuals of the agro transformed Albic Retisols profiles form the natural basis of the LMSU BG soils, as evidenced by plow horizons, natural illuvial textural Bt- horizons, and fragments of eluvial horizons revealed in the profiles of BG soils. Recent soils formed during the 50–60 years of garden existence develop on the residual profiles of soddy-podzolic soils (Albic Retisols) overlain by technogenic horizons composed of fragments of soddy-podzolic soils and material of mantle loams containing construction and household waste ([Stroganova](http://www.maikonline.com/maik/articleParamSearch.do?author=M.+N.+Stroganova), [Rappoport](http://www.maikonline.com/maik/articleParamSearch.do?author=A.+V.+Rappoport), 2005;Rozanova et al., 2016).

During the excursion two soil pits in the Botanical Garden (BG 6 and BG 9) and two soil pits outside it (MSU 2 and MSU 5) will be examined (Fig. 10).



**MSU 2**

**MSU 5**

**BG9**

**BG6**

Fig. 10 Soil pits of the excursion

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| --- | --- | --- | --- | --- |
| **Soil BG 6**  *Location:* Moscow University Campus.  *Land use:* Arboretum in LMSU Botanical Garden, lime-tree (*Tilia cordata*) with ash-tree and maple regrowth, the ground cover is composed of goutweed (*Aegopodia podagrarium)*.  *Topography:* flat upland (moraine plain).  *Elevation:* 196m a.s.l.  *Coordinates*: 55°42’27” N and 37°31’41” E.  *Soil temperature regime:* Mesic; temperate with seasonal freezing (mean annual temperature is +5.8 °C (from 1981 to 2010); mean T January – −6.5 C; mean T July is +19.2 C).  *Soil moisture regime*: Udic; percolative (mean annual precipitation is 700 mm).  *Parent and underlying material*: technogenic sediments, mantle loam.  *Soil name (WRB-14):* HorticAnthrosol (Siltic, Epytechnic, Novic).  Natural analogue: Albic Retisol.  *Soil name (RSC+Prokof’eva et. al., 2014):* grey-humus calcareous shallow silty loamyon technogenic sediments on a buried agrozem on mantle loam. | | | |  |
| **Hori-zons RSC** | **Hori-zons WRB** | **Depth, cm** | **Description of horizons** | |
| **О** | **O** | **0-0.5** | Litter – weakly decomposed falloff of 2015. | |
| **AYur** | **Au,k** | **0.5-10** | Slightly moist to dry, brownish grey 10YR 2/2, silty or sandy loam, strong to medium crumbly granular structure, voids not visible, friable, many roots, fine calcareous inclusions; clear transition, wavy boundary; at the boundary coarse (2-3 cm) calcareous artifacts. | |
| **ТСН** | **Cu,k** | **10-26** | Slightly moist to moist, heterogeneous in colour: brownish ocherous dark grey, greyish brown and whitish carbonate mottles (10YR 4/4 and 10YR 3/2), medium crumbly fine subangular blocky structure, very few voids, few roots, firm, effervescent; heterogeneous in texture. Iron segregations (ortsteins), glittering bleached mineral grains; many coprolites in earthworm channels. Anthropogenic artefacts >10%: fragments of brick, limestone, coal, glass, porcelain, etc.). Abrupt transition by density and colour, weakly wavy boundary. | |
| **[P1]** | **Ap,b1** | **26-48** | Slightly moist to moist, homogeneous in colour – grey (10YR 3/3), silty to sandy loam, crumbly platy structure with distinct horizontal stratification, few voids less firm that the above horizon, clay coatings on ped faces, ocherous iron soft segregations, earthworm casts. Arte facts are smaller and compose ~5% of the soil mass (brick, glass, bones, etc.), gradual transition. | |
| **[P2]** | **Ap,b2** | **48-65** | Slightly moist and drier that the above horizon, homogeneous brown but darker than the above layer (10 YR 4/4) silty loam to sandy loam. Weak lumpy, platy and blocky structure with rather strong aggregates, approximately 5% of urban artefacts + fragments of coal and limestone, dense; dead partly decomposed root along the lower boundary. Thin humus-clay coatings on ped faces, ocherous mottles, weak effervescence of few limestone fragments, clear transition by colour, structure, artefacts, wavy boundary. | |
| **[BT]** | **Bt,b** | **65-105** | Dry, reddish brown (7.5 YR 5/6) loam, fine blocky subangular and prismatic structure, dense, more firm than the above horizon, very few voids; distinct humus-clay coatings and few silty ones, coprolites in passage ways; Fe-Mn soft segregations. | |

***Soil PitBG6Analytical Data***

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Horizon | Depth, cm | рНwater | CaCO3, % | Р2О5 | К2О | Eh, mV | USDA  texture | χ, SI unit | Bulk density, g/cm3 |
| available, mg/kg | |
| AYur | 0,5-10 | 6.8 | <1 | 69 | 288 | 587 | SL | 0.640 | 1.1 |
| TCH | 10-26 | 7.2 | <1 | 40 | 128 | 593 | SiL | 0.662 | 1.3 |
| [P1] | 26-48 | 7.2 | n.d.\* | 78 | 140 | 596 | SiL | 0.706 | 1.3 |
| [P2] | 48-65 | 7.2 | n.d. | 128 | 163 | 611 | -\*\* | 0.338 | 1.1 |
| [BT] | 65-105 | 7.3 |  | 42 | 193 | 638 | - | 0.154 | 1.4 |

*\*“n.d.” – not detected; \*\* “–” no data*

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Horizon | Depth, cm | Corg, % | Cha/Cfa | 0.001%HA  *E*465nm,1cm | E4/6 | Degree of humification |
| AYur | 0,5-10 | 4.65 | 1.29 | 0.070 | 6.2 | High |
| TCH | 10-26 | 0.83 | 0.87 | 0.093 | 3.6 | Medium |
| [P1] | 26-48 | 2.27 | 0.99 | 0.074 | 5.2 | High |
| [P2] | 48-65 | 2.55 | 0.96 | 0.061 | 5.3 | Medium |
| [BT] | 65-105 | 0.29 | 0.69 | 0.012 | 4.3 | very low |

Organic carbon pool (in 0-30cm layer) -80t/ha; Organic carbon pool (in 0-100cm layer)- 195t/ha.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| horizon | Depth, cm | Exchangeable cations, cmol (+)/kg | | | | |
| Na+ | K+ | Ca2+ | Mg2+ | ∑ |
| AYur | 0,5-10 | 0.28 | 0.97 | 17.54 | 1.63 | 20.42 |
| TCH | 10-26 | - | - | - | - | - |
| [P1] | 26-48 | - | - | - | - | - |

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| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| horizon | Depth, cm | Water-soluble compounds | | | | | | | | |
| Cations, cmol (+)/kg | | | | Anions, cmol (-)/kg | | | | |
| Na+ | K+ | Ca2+ | Mg2+ | F- | Cl- | NO3- | PO43- | SO42- |
| AYur | 0,5-10 | 0.042 | 0.152 | 1.275 | 0.188 | 0.013 | 0.074 | 0.022 | 0.048 | 0.066 |
| TCH | 10-26 | - | - | - | - | - | - | - | - | - |
| [P1] | 26-48 | - | - | - | - | - | - | - | - | - |

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| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Horizon | Depth, cm | Heavy metals content, mg/кg | | | | | | | |
| Cu | | Zn | | Pb | | Cd | |
| total | mob | total | mob | total | mob | total | mob |
| AYur | 0,5-10 | 2.2 | 0.2 | 97.6 | 25.4 | 63.4 | n.d. | 0.6 | n.d. |
| TCH | 10-26 | 2.2 | 0.7 | 63.4 | 15.9 | 15.6 | n.d. | 0.4 | n.d. |
| [P1] | 26-48 | 4.2 | 0.6 | 141.1 | 56.2 | 85.5 | n.d. | n.d. | n.d. |
| [P2] | 48-65 | 11.0 | 1.8 | 143.2 | 66.9 | 67.6 | n.d. | n.d. | n.d. |
| [ВT] | 65-105 | 17.6 | 2.4 | 32.1 | 3.2 | n.d. | n.d. | 0.1 | n.d. |

***Biological activity***

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Depth, cm | Biomass from respire-tion, μg/g | Enzyme activity | | | Abundance of bacteria, billion/g | Fungal myceliumlength, m/g | Fungal spores, billion/g |
| Catalase,  cm3О2/ (g min) | Dehydrogenase,  mg TTP/(10 g day) | Invertase,  mg glucose/(g day) |
| 0-10 | 612.8 | 4.6 (medium) | 0.46 (very poor) | 2.31 (very poor) | 3.4 | 490 | 7 |

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| **Soil BG 9**  *Location:* Moscow University Campus.  *Land use:* lawn with group of shrubs. Department of garden plants of the Botanical Garden LMSU.  *Topography:* moraine plain.  *Elevation:* 195 m a.s.l.  *Coordinates*: 55°42’18’’N and 37°31’35’’E.  *Soil temperature regime*: Mesic; temperate with seasonal freezing (mean annual temperature is +5.8 °C; mean T January – −6.5 C; mean T July is +19.2 C).  *Soil moisture regime*: Udic, or percolative (mean annual precipitation is 700 mm).  *Parent and underlying material*: technogenic sediments over mantle loam.  *Soil name (WRB-14):*Urbic Technosol, Eutric Regosol (Siltic, Relocatic, Organotransportic, Technic).  Natural analogue: Albic Retisol.  *Soil name (RSC+Prokof’eva et. al., 2014):* Grey-humus stratified sandy loamy on technogenic material (Recreazem) on a buriedagrosoddy-podzolic soil. |  |

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| --- | --- | --- | --- |
| **Hori-zons RSC** | **Hori-zonsWRB** | **Depth.cm** | **Description of horizons** |
| **RAT** | **AOu** | **0-12** | Dry, brownish grey (10YR 3/2); in the upper 1.5-4 cm – weakly developed sod; lower, the soil mass is densely pierced by roots. Moderate granular crumbly structure, partially composed of coprolites, clusters of aggregates on roots, sandy loam with glitter bleached grains of primary minerals, friable, very few artefacts (fragments of ceramics, bricks, stones). Gradual transition by structure and colour. |
| **AYrh1** | **Au** | **12-23** | Slightly moist, heterogeneous in colour: greyish brown (10 YR 4/2) with dark grey mottles (10 YR 3/2) – earthworm channels, strong crumbly fine granular structure, more soft than the above horizon, friable, many roots, sandy loam with glittering mineral grains, fine anthropogenic artefacts are common. Clear transition by colour, structure, abundance of roots, wavy boundary. |
| **AYrh2** | **Au2** | **23-37** | Slightly moist, greyish brown (10 YR 4/3) with dark mottles of crushed charcoals and more light mottles of ‘inverse’ krotovinas. Sandy loam with very few glittering sand grains, 10% of coarse artefacts (pieces of brick, wire and stones) rather compact with a moderate crumbly structure, weak clay-humus coatings on ped faces, soft iron segregations, earthworm channels, roots are less abundant than above, few fine voids partly filled with coatings; abrupt transition, even boundary. It may be a former plow horizon. |
| **TCH** | **Cu** | **37-72** | Slightly moist, heterogeneous in colour: reddish brown (10YR 4/4) with yellowish brown and grayish brown mottles, dark grey straight earthworm channels, dark reddish brown rounded mottles (7-10 cm) – krotovinas; platy lumpy and crumbly structure, loam with lenses of clay loam; glittering bleached mineral grains, clay and silt-clay coatings on ped faces, dense, with many fine (gravel, brick crumbs) and coarse (fragments of bricks, limestone, cobbles, coal, rubber, porcelain) artefacts, approximately 20% in total, Soft Fe-Mn segrerations and fine nodules (ortsteins) are common; clear transition by colour, moisture and structure, wavy boundary. |
| **[Pur,g]** | **Ap,u,g,b** | **72-90** | Moist, heterogeneous in colour: brownish, pinkish brown and grey (10YR 4/4, 4/3 and background: 10 YR 3/1), silty loam, weak angular prismatic structure, firm sticky, very few fine voids, many soft Fe-Mn segregations, gleyed coatings on ped faces with ocherous iron mottles over them; many fine inclusions and coarse anthropogenic artefacts (coal and brown coal fragments, stones, etc.) ~10-20%; clear transition by structure and colour, the boundary is wavy or irregular so that the horizon lenses out in some places. |
| **[BTg]** | **Bt,b,g** | **90-115** | Moist, heterogeneous in colour: reddish brown with more dark coatings, namely, dark reddish brown humus-clay and light grey silty coatings (10YR 4/6, 5/8), loam to clay loam, coarse and fine prismatic structure, many Fe-Mn segregations (ortsteins) and black manganic films, no artefacts, few indistinct fine pores, Effervescence was recorded only for few calcareous artefacts in all the horizons. |

***Analytical data of Soil BG 9***

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| horizon | Depth, cm | рНwater | CaCO3, % | Р2О5 | К2О | Eh, mV | USDA  Texture | χ, SI unit | Bulk density, g/cm3 |
| available,mg/kg | |
| RAT | 0-12 | 7.1 | <1 | 62 | 128 | 592 | SiL | 0.736 | 1.0 |
| AY1 | 12-23 | 7.0 | <1 | - | - | 597 | SiL | 0.700 | 1.3 |
| AY2 | 23-37 | 6.9 | <1 | 36 | 83 | 598 | SiL | 0.510 | - |
| TCH | 37-72 | 7.2 | <1 | 42 | 135 | 631 | SiL | 0.482 | 1.6 |
| [Pur,g] | 72-90 | 7.2 | n.d. | 40 | 78 | 618 | SiL | 0.520 | 1.6 |
| [BTg] | 90-115 | 6.4 | n.d. | - | - | 592 | - | 0.320 | - |

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| horizon | Depth, cm | Corg, % | Cha/Cfa | 0.001%HA  *E*465nm,1cm | E4/6 | Degree of humification |
| RAT | 0-12 | 4.89 | 1.04 | 0.083 | 5.5 | medium |
| AY1 | 12-23 | 1.63 | 1.02 | 0.085 | 4.4 | medium |
| AY2 | 23-37 | 1.12 | 0.94 | 0.081 | 4.2 | medium |
| TCH | 37-72 | 0.56 | 0.92 | 0.043 | 4.1 | Low |
| [Pur,g] | 72-90 | 5.63 | - | - | - | - |
| [BTg] | 90-115 | 0.10 | - | - | - | - |

Organic carbon pool (in 0-30cm layer) -92t/ha; Organic carbon pool (in 0-100cm layer)-246t/ha.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Horizon | Depth, cm | Exchangeable cations, cmol (+)/kg | | | | |
| Na+ | K+ | Ca2+ | Mg2+ | ∑ |
| RAT | 0-12 | 0.54 | 0.42 | 16.43 | 1.53 | 18.92 |
| AY1 | 12-23 | 1.19 | 0.35 | 22.34 | 1.43 | 25.31 |
| AYur2 | 23-37 | - | - | - | - | - |
| TCH | 37-72 | - | - | - | - | - |
| [Pur,g] | 72-90 | - | - | - | - | - |
| [BTg] | 90-115 | - | - | - | - | - |

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Horizon | Depth, cm | Water-soluble compounds | | | | | | | | |
| Cations, cmol (+)/kg | | | | Anions, cmol (-)/kg | | | | |
| Na+ | K+ | Ca2+ | Mg2+ | F- | Cl- | NO3- | PO43- | SO42- |
| RAT | 0-12 | 0.03 | 0.035 | 0.480 | 0.119 | 0.008 | 0.029 | 0.001 | 0.061 | 0.048 |
| AY1 | 12-23 | 0.03 | 0.028 | 0.409 | 0.100 | 0.010 | 0.032 | n.d. | 0.003 | 0.049 |
| AY2 | 23-37 | - | - | - | - | - | - | - | - | - |
| TCH | 37-72 | - | - | - | - | - | - | - | - | - |
| [Pur,g] | 72-90 | - | - | - | - | - | - | - | - | - |
| [BTg] | 90-115 | - | - | - | - | - | - | - | - | - |

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Horizon | Depth, cm | Heavy metals content, mg/кg | | | | | | | |
| Cu | | Zn | | Pb | | Cd | |
| total | mob | Total | mob | total | mob | total | mob |
| RAT | 0-12 | 25.0 | n.d. | 121.3 | 22.4 | 196.3 | n.d. | n.d. | n.d. |
| АY1 | 12-23 | 85.9 | 6.2 | 86.5 | 16.3 | 76.2 | n.d. | 0.7 | n.d. |
| АYur2 | 23-37 | 56.3 | n.d. | 91.8 | 22.7 | 23.5 | n.d. | 0.0 | n.d. |
| TCH | 37-72 | 25.0 | 12.9 | 38.9 | 3.7 | n.d. | n.d. | 0.3 | n.d. |
| Pur,g | 72-90 | 19.8 | 1.8 | 32.3 | 5.6 | n.d. | n.d. | 0.2 | n.d. |
| [BTg] | 90-115 | 16.3 | 1.2 | 26.8 | 1.4 | n.d. | n.d. | 0.1 | n.d. |

***Biological activity***

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Depth,cm | Biomass from respire-tion,μg/g | Enzyme activity | | | Abundance of bacteria, billion/g | Fungal myceliumlength, m/g | Fungal spores, billion/g |
| Catalase,  cm3О2/(g min) | Dehydrogenase,  mg TTP/(10 g day) | Invertase,  mg glucose/(g day) |
| 0-10 | 624.5 | 2.0 (poor) | 0.43 (very poor) | 0.53 (very poor) | 1.5 | 200 | 6 |

**3.The Meteorological Observatory of Moscow State University. The measurements of the surface and soil temperatures**

|  |
| --- |
| **Fig. 11** Meteorological Observatory within  the campus of LMSU |

The Moscow State University Meteorological Observatory (MSU MO) was established in 1954 as a teaching and scientific center to study Moscow climate (Fig. 11). Itis located at the distance of about 8 km to South-West from the city center(Kremlin). The MSU MO provides the unique continuous measurements of the environmental and climatic characteristics of the atmosphere, which are being collected on the base of comprehensive methods in accordance with the Russian and international standards adopted by World Meteorological Organization and Russian Hydrometeorological Service. The complex of measurements comprises an extended program of meteorological observations, including the acoustic remote sensing of the atmosphere, and a broad program of solar radiation measurements, which also includes the observations of natural illuminance and UV radiation. Within the frame of international AERONET program monitoring of aerosol parameters is being carried out. The measurements of chemical composition of precipitation and snow cover are also being performed. A new station for atmospheric air composition has been organized together with the Obukhov Institute of Atmospheric Physics of Russian Academy of Sciences, which provides continuous measurements of minor atmospheric gases.

At the Meteorological Observatory of LMSU the measurements of the surface temperature Tsurf and the soil temperature Ts have been collected continuously almost since its foundation, i.e. since 1954 at standard depths from 0 to 320 cm below the ground. There are two areas used for observations: a traditional area with natural cover (that is snow cover in winter and grass and sod during other seasons) and a special bare soil area of 12×20 m2plottage. In the 19th century, Ts was measured at several locations with bare soils in the Russian Empire. However, the only bare soil area in the European part of Russia now remains at Moscow State University.

It should be noted that the soil temperature mostly follows the main tendency of the air temperature T increase in the 20th and the beginning of the 21stcenturies. However, Ts increases slower than T so that the air temperature in Moscow increased nearly by 2.3 °C during the 20th century (Lokoshchenko and Vasilenko, 2009), whereas the soil temperature at the 150–160 cm depth increased for the same 100 years only by 1.3 °C (Fig. 12).

It is well known that in the second half of the 20th century the global warming accelerated. More detailed analysis has been carried out by the data only of University Observatory for the period of 1955–2013 (Fig. 13). According to these data the rate of air temperature (T) growth in Moscow equaled to +0.04 °C/year in average from 1955 to 2013. The rate of the soil warming during the same period below bare soils on the depth of 160 cm was the same: +0.04 °C/year. However, the warming rate of Ts below natural cover was only +0.02 °C/year (Lokoshchenko and Korneva, 2012). This effect can be explained by different thermal conductivity of natural and bare soil surfaces. Besides the total warming, another more likely reason of the Ts increasing is urbanization, which is growing as well. However, the data of the rural ‘Podmoskovnaya’ station located at the distance of 24 km from Moscow city demonstrates similar increase of the Ts for the period from 1956 to 2013 with an average rate of +0.02 °C/year. Thus, rates of soil warming both inside the city and outside it is the same. Hence, the general tendency of warming was detected not only in Moscow city, but also in the rural zone.

During the last 116 years the soil temperature increased in Moscow by 1.8–1.9 °C. During the last half century, this growth was more rapid at the University below the bare soils (with a rate of nearly +0.04 °C/year) than below natural cover (+0.02 °C/year).

Note that the soil temperature in the Moscow city center (close to Kremlin) is up to 1.0–1.2 °C higher than at the city periphery (e.g. University) and up to 1.6–1.7 °C higher than in the rural zones (Podmoskovnaya and other stations). Mean difference between urban and rural values of the soil temperature is equal to +0.6÷ +0.8 °C and between only urban periphery and rural zone (without the city center) is from +0.4 to +0.6 °C. Thus, the underground urban heat island effect has been detected in Moscow region using the data from meteorological stations. This phenomenon is confirmed based on the soil temperature in the subsurface layer up to the depth of at least 3.2 m. The annual trend of the difference between urban and rural soil temperatures has a maximum in winter (from +0.9 to +1.2 °C) due to strong urban heating and a minimum in summer (from +0.5 to +0.4 °C on different depths).



**Fig. 12** Dynamics of mean annual values of soil temperature in Moscow at the depth of 150–160 cm (natural cover) for the period from 1898 to 2013. Linear trend is marked by the black line, cubic trend – by blue line and polynomial one of the 6th degree – by red line.



Fig. 13 Dynamics of mean annual values of the soil temperature in Moscow at the depth of 160 cm below natural cover/bare soil and of the air temperature (top); dynamics of average and accumulated snow cover depths (bottom) for the period from 1955 to 2013

**4. Soils of the Moscow University campus**

Following the completion of the buildings, a botanical garden was established together with general land ameliorations within the LMSU campus. Prior to the campus construction, the whole area of the Vorob’evy Hills was occupied by rural settlements, fields and woodland patches.

The soils studied were formed on technogenic deposits – ‘building grounds’, from 0.3 to 3 m in thickness, composed of mixed silty-loamy materials with fragments of horizons of native soils (Albic Retisols) and inclusions of construction waste. Calcareous inclusions were very fewor absent within the surface layer, where the modern pedogenesis takes place. The pedogenesis on these deposits began over 60 years ago, at the time of general land ameliorations following the construction of the LMSU campus. The land management involved the complete removal of fallen leaves in fall, except the arboretum of BG. However, since 2011, only a partial removal of leaves has been practiced. The lawns have been regularly improved by additions of fertile composts.

Soils of the territory can be subdivided into two groups depending on general pedogenetic trends. The first group includes soils having typical postlithogenic pedogenesis and the А-АС-С profile, located within areas of low anthropogenic pressure. The second group connected with the synlithogenic trend of pedogenesis (the A1-A2-….-C profile) comprises a greater diversity of soils: some of them have an incrementally growing humus horizon due to compost additions, while others have a specific urban humus horizon (urbic) and have been termed by us as Urbostratozems (Prokof’eva et al., 2014).

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Soil MSU 2**  *Location:* Moscow University Campus.  *Land use:* lawn with group of trees (larches) between buildings and the road.  *Topography:* flat upland (moraine plain).  *Elevation:* 202 m a.s.l.  *Coordinates*: 55°42’19” N and 37°31’21” E.  *Soil temperature regime*: Mesic; temperate with seasonal freezing (mean annual temperature is +5.8 °C; mean T January – −6.5 C; mean T July is +19.2 C).  *Soil moisture regime*: Udic; percolative (mean annual precipitation is 700 mm).  *Parent and underlying material*: technogenic sediments.  *Soil name (WRB-14):* Urbic Technosol or Eutric Regosol (Siltic, Relocatic).  *Soil name (RSC+Prokof’eva et. al., 2014):* Grey-humus calcareous shallow to medium-deep sandy loamy on technogenic deposits. | | | |  |
| **Horizons RSC** | **Hori-zonsWRB** | **Depth, cm** | **Description of horizons** | |
| **О** | **O** | **0-1** | Fragmentary litter composed of pine needles, small branches and remnants of cones. | |
| **АYur(сa)** | **Au,к** | **1-16** | Slightly moist, greyish-brown (10YR 3/2) sandy loam, weak to moderate crumbly structure, many roots (grass roots in the upper part, and tree roots in the lower one), soft, friable, few fine rock and brick fragments, strong local effervescence with HCl; clear transition, even or slightly wavy boundary. | |
| **ATCH** | **ACu** | **16-27** | Slightly moist, grey light brownish (2.5Y 5/4) sandy loam, blocky sub-angular to crumbly structure; very few roots; slightly firm; slightly compact; few fragments of brick and glass; few earthworm channels; no effervescence with HCl; clear transition by the decreasing number of earthworm channels, wavy boundary. | |
| **TCH1** | **Cu** | **27-60** | Slightly moist, heterogeneous in colour: grey light brownish (2.5Y 5/3) with dark grey and reddish brown mottles (10YR 4/4), sandy loam, prismatic and blocky sub-angular structure, very few roots; hard and firm, clay-humus coatings on ped faces, charcoal, brick and stone fragments are common (20%), some of them effervesce with HCl; clear transition by colour, abundance of artefacts and density, wavy boundary. | |
| **TCH2** | **Cu,k** | **60-100** | Slightly moist, light brown, more dark than the above layer (2.5Y 4/4), sandy silty loam, prismatic and blocky sub-angular structure, no roots, firm and dense, many charcoal, brick and stone fragments ( 50%), strong effervescence with HCl. | |

***Analytical data of Soil MSU 2***

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Horizon | Depth, cm | рНwater | CaCO3, % | Р2О5 | К2О | Eh, mV | USDA texture | χ, SI unit | Bulk density, g/cm3 |
| available,mg/kg | |
| О | 0-1 | - | - | - | - | - | - | - | - |
| AYur | 1-16 | 7.3 | <1% | 40 | 165 | 645 | SiL | 0.54 | 0.95 |
| AYTCH | 16-27 | 7.2 | n.d. | - | - | 563 | SiL | - | 1.08 |
| TCH | 27-60 | 7.4 | n.d. | 333 | 701 | 658 | SiL | - | 1.34 |
| TCH2 | 60-100 | 8.0 | <1% | 39 | 95 | - | SL | - | - |

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Horizon | Depth, cm | Сorg, % | Cha/Cfa | 0.001%HA  *E*465nm,1cm | E4/6 | Degree of humification |
| О | 0-1 | - | - | - | - | - |
| AYur | 1-16 | 2.22 | 1.49 | 0.063 | 5.8 | low |
| AYTCH | 16-27 | 0.52 | 0.81 | 0.089 | 5.0 | medium |
| TCH | 27-60 | 0.39 | 0.90 | 0.025 | 4.9 | medium |
| TCH2 | 60-100 | 0.36 | - | - | - | - |

Organic carbon pool (in 0-30cm layer) -40 t/ha; Organic carbon pool (in 0-100cm layer)- 52t/ha.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Horizon | Depth, cm | Exchangeable cations, cmol (+)/kg | | | | |
| Na+ | K+ | Ca2+ | Mg2+ | ∑ |
| АYur | 1-16 | 0.17 | 0.30 | 7.71 | 1.04 | 9.22 |
| ATCH | 16-27 | 0.17 | 0.14 | 12.73 | 0.78 | 13.82 |
| TCH | 27-60 | 0.14 | 0.05 | 10.02 | 0.68 | 10.89 |
| TCH2 | 60-100 | - | - | - | - | - |

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| horizon | Depth, cm | Water-soluble compounds | | | | | | | | |
| Cations, cmol (+)/kg | | | | Anions, cmol (-)/kg | | | | |
| Na+ | K+ | Ca2+ | Mg2+ | F- | Cl- | NO3- | PO43- | SO42- |
| АYur | 1-16 | 0.084 | 0.071 | 0.842 | 0.124 | 0.025 | 0.078 | 0.004 | 0.032 | 0.075 |
| ATCH | 16-27 | 0.103 | 0.073 | 0.320 | 0.114 | 0.034 | 0.038 | n.d. | 0.013 | 0.041 |
| TCH | 27-60 | 0.092 | 0.047 | 0.302 | 0.1 | 0.021 | 0.087 | n.d. | 0.006 | 0.051 |
| TCH2 | 60-100 | - | - | - | - | - | - | - | - | - |

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Horizon | Depth, cm | Heavy metals content, mg/кg | | | | | | | |
| Cu | | Zn | | Pb | | Cd | |
| Total | mob | Total | mob | Total | mob | total | Mob |
| АYur | 1-16 | 19.8 | 1.2 | 57.8 | 7.3 | 10.6 | n.d. | 0.5 | n.d. |
| ATCH | 16-27 | 26.8 | 4.2 | 84.8 | 23.3 | 21.9 | n.d. | 0.4 | n.d. |
| TCH | 27-60 | 21.5 | 2.2 | 94.0 | 21.8 | 36.4 | n.d. | 0.6 | n.d. |
| TCH2 | 60-100 | - | - | - | - | - | - | - | - |

***Biological activity***

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Depth, cm | Biomass from respire-tion,μg/g | Enzyme activity | | | Abundance of bacteria, billion/g | Fungal myceliumlength, m/g | Fungal spores, billion/g |
| Catalase,  cm3О2/(g min) | Dehydrogenase,mg TTP/(10 g day) | Invertase,  mg glucose/(g day) |
| 0-10 | 748.82 | 5.23 (medium) | 0.23 (very poor) | 2.28 (very poor) | 1.73 | 499 | 10.63 |

|  |  |
| --- | --- |
| **Soil MSU 5**  *Location*: Moscow University Campus.  *Land use*: lawn with a group of trees (elms) between buildings and the road.  *Topography*: flat upland (moraine plain), slope gradient 3o.  *Elevation:* 203 m a.s.l.  *Coordinates*: 55°42’0’’ N and 37°31’18’’ E  *Soil temperature regime*: Mesic; temperate with seasonal freezing (mean annual temperature is +5.8 °C; mean T January – −6.5 C; mean T July is +19.2 C).  *Soil moisture regime:* Udic; percolative (mean annual precipitation is 700 mm).  *Parent and underlying material*: technogenic sediments, mantle loam.  *Soil name (WRB-14):* Urbic Technosol (Eutric, Siltic, Mollic).  *Soil name (RSC-2004+Prokof’eva et. al., 2014):*Urbostratozem calcaric shallow sandy loamy on technogenic material. |  |

|  |  |  |  |
| --- | --- | --- | --- |
| **Hori-zons RSC** | **Hori-zons WRB** | **Depth, cm** | **Description of horizons** |
| **URw** | **Au** | **0-6** | Slightly moist, greyish and reddish brown (2.5Y 4/2), friable, mostly strong granular crumbly structure. Crumbs are angular, rather firm, and there are also earthworm casts and clusters of coprolites along fine roots, Silty sandy loam. Many roots, plant residues are weakly decomposed. Weak discontinuous effervescence with HCl. Clear transition by the abundance of roots, colour, structure and number of artefacts; wavy boundary. |
| **UR1** | **Au,k1** | **6-41** | Slightly moist, heterogeneous in colour: from dark brownish grey to reddish brown grey (10YR 4/2, 4/3, 3/2); dark mottles are earthworm channels and coprolites. Rather firm, crumbly sub-angular blocky and granular structure with a trend to stratification. Peds are more firm than in the above horizon, coarse silty loam with sand admixture. The heterogeneity is seen as caused by the input of different substrates on the soil surface. Many roots (fine and coarse tree roots). Effervescence is medium and continuous. Many anthropogenic artefacts – construction and municipal wastes (> 30%). Clear transition by colour, slightly wavy boundary. |
| **UR2** | **Au,k2** | **41-50** | Slightly moist, dark brown grey (10YR 4/2, 3/2, 2/2). Moderate to weak granular crumbly structure, more friable that the above horizon, dense tree roots, more abundant than above, many well decomposed plant residues. Silty sandy loam, very few artefacts, continuous effervescence with HCl. Clear transition by colour, abundance of roots and density, slightly wavy boundary. |
| **ТСН** | **Cu** | **50-100** | Slightly moist, but moister than the above horizon, heterogeneous in colour: yellowish grayish brown (10YR 5/2, 5/3, 4/3, 4/4). Angular prismatic structure of several orders (from small to medium-size prisms), peds are firm. Loam with admixture of sand, few voids, (1-2 mm), dense. Fe-Mn segregations and Feortsteins (nodules). Few roots, artefacts of construction wastes 5-10%, fine fragments of soft brick, charcoal, limestone in the fine earth. The colour heterogeneity is due to fragments of soddy-podzolic soil horizons. Weak effervescence of some artefacts. |

***Analytical data of Soil MSU 5***

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| horizon | Depth, cm | рНwater | CaCO3, % | Р2О5 | К2О | Eh, mV | USDA texture | χ, SI unit | Bulk density, g/cm3 |
| available,mg/kg | |
| URw | 0-6 | 7.5 | 2.0 | 29 | 275 | 530 | SL | 1.62 | 0.95 |
| UR1 | 6-41 | 8.1 | 3.2 | 8 | 150 | 555 | SL | 0.98 | 1.24 |
| UR2 | 41-50 | 7.8 | 1.7 | 13 | 120 | 574 | - | - | - |
| TCH | 50-100 | 7.7 | <1 | 41 | 135 | 575 | SiL | 0.48 | 1.37 |

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| horizon | Depth, cm | Corg, % | Cha/Cfa | 0.001%HA  *E*465nm,1cm | E4/6 | Degree of humification |
| URw | 0-6 | 6.96 | 3.52 | 0.082 | 5.8 | Low |
| UR1 | 6-41 | 0.69 | 1.36 | 0.087 | 5.3 | Medium |
| UR2 | 41-50 | 3.91 | 1.7 | 0.065 | 4.4 | Medium |
| TCH | 50-100 | 0.70 | 0.4 | 0.045 | 5.3 | Low |

Organic carbon pool (in 0-30cm layer) -60 t/ha; Organic carbon pool (in 0-100cm layer)-143t/ha.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| horizon | Depth, cm | Exchangeable cations, cmol (+)/kg | | | | |
| Na+ | K+ | Ca2+ | Mg2+ | ∑ |
| URw | 0-6 | 0.41 | 1.17 | 19.50 | 1.52 | 22.6 |
| UR1 | 6-41 | 0.33 | 0.26 | 10.57 | 0.89 | 12.05 |
| UR2 | 41-50 | - | - | - | - | - |
| TCH | 50-100 | 0.72 | 0.43 | 14.26 | 0.69 | 16.1 |

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Horizon | Depth, cm | Water-soluble compounds | | | | | | | | |
| Cations, cmol (+)/kg | | | | Anions, cmol (-)/kg | | | | |
| Na+ | K+ | Ca2+ | Mg2+ | F- | Cl- | NO3- | PO43- | SO42- |
| URw | 0-6 | 0.333 | 0.217 | 0.948 | 0.132 | 0.007 | 0.048 | 0.006 | 0.011 | 0.103 |
| UR1 | 6-41 | 0.399 | 0.086 | 0.463 | 0.101 | 0.041 | 0.054 | 0.000 | 0.036 | 0.060 |
| UR2 | 41-50 | - | - | - | - | - | - | - | - | - |
| TCH | 50-100 | 0.269 | 0.06 | 0.501 | 0.101 | 0.035 | 0.078 | n.d. | 0.008 | 0.063 |

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Horizon | Depth, cm | Heavy metals content, mg/кg | | | | | | | | |
| Cu | | Zn | | | Pb | | Cd | |
| total | mob | total | mob | | Total | mob | Total | mob |
| URw | 0-6 | 20.4 | 1.3 | 67.4 | 9.9 | 26.7 | | 4.2 | 0.1 | n.d. |
| UR1 | 6-41 | 29.5 | 26.5 | 73.0 | 27.0 | 75.8 | | 18.3 | 0.1 | n.d. |
| UR2 | 41-50 | 9.7 | 5.5 | 36.3 | 28.0 | 10.6 | | - | n.d. | n.d. |
| TCH | 50-100 | 0.2 | 1.2 | 158.1 | 4.2 | 112.6 | | 1.7 | 0.2 | n.d. |

***Biological activity***

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Depth, cm | Biomass from respire-tion,μg/g | Enzyme activity | | | Abundance of bacteria, billion/g | Fungal myceliumlength, m/g | Fungal spores, billion/g |
| Catalase,  cm3О2/(g min) | Dehydrogenase,  mg TTP/(10 g day) | Invertase,  mg glucose/(g day) |
| 0-10 | 607.39 | 5.63 (medium) | 0.31 (very poor) | 2.34 (very poor) | 2.61 | 318 | 16.33 |

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