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Advanced Technologies for Sustainable Development of Urban Green Infrastructure

Proceedings of Smart and Sustainable Cities 2020

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ISSN 2194-315X ISSN 2194-3168 (electronic)
Springer Geography
ISBN 978-3-030-75284-2 ISBN 978-3-030-75285-9 (eBook)
https://doi.org/10.1007/978-3-030-75285-9

This Springer imprint is published by the registered company Springer Nature Switzerland AG
The registered company address is: Gewerbestrasse 11, 6330 Cham, Switzerland

Preface

This volume contains a selection of edited, refereed and revised papers, which were presented at the International Conference "Smart and Sustainable Cities – 2020 (SSC-2020)" entitled "Advanced technologies for sustainable development of urban green infrastructures." For the second time, the SSC conference was organized by RUDN University, Moscow, Russia, on July 8–10, 2020. The SSC-2020 followed an international multi-disciplinary discussion on the challenges and opportunities for urban green infrastructures in context of sustainable urban development, started by the series of previous conferences on the topic: Megacities 2050 (2016), SUITMA 9 (2017) and SSC-2018. The program of SSC-2020 was mainly focused on the technologies available for environmental monitoring and assessment, sustainable urban planning and development.

SSC-2020 attracted a broad expert audience, including municipal services, environmental protection agencies, landscape planners and researchers. The conferences coincided with the international summer school "modeling, monitoring and management of urban green infrastructures and soils," which facilitated a broader dissemination of the conference outcomes and allowed addressing a future generation of researchers and practitioners to be involved in sustainable urban development.

We would like to thank more than 200 participants and 80 speakers who contributed with plenary, oral and poster presentations, round tables and keynote lectures. We wish to express our especial gratitude to the authors who contributed to these proceedings. The volume contains from 29 research papers, which were selected by the scientific committee with additional help of over 40 external expert reviewers from over 60 submissions. The authors were asked to consider the reviewers' comments and have made all necessary edits to improve the quality of the papers. The organizational and financial support to the SSC-2020 conference was provided by "RUDN University Program 5-100" and the "Erasmus+ Capacity Building project #586247-EEP-1-ITEPPKA-CBHE-JP "Training Capacities in Agriculture and Urban-Rural Interactions for Sustainable Development of Megacities (TAURUS)". We would like to express our gratitude to all the people who put essential efforts to ensure this successful conference: members of

organizing and scientific committees, conveners of sessions and round tables, reviewers and technical editors. We wish to express our sincere thanks to Rajan Muthu, project coordinator, for his help and cooperation.

We hope, these conference proceedings will be interesting and useful for researchers, practitioners and policymakers, involved in sustainable urban development.

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Michael Leuchner

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About the Editors

Viacheslav Vasenev is an associate professor at the Department of Landscape Design and Sustainable Ecosystems and coordinator of the Smart Urban Nature research center in RUDN University. The main research directions include ecosystem services provided by urban soils and green infrastrcutures as a core to support sustainable urban development.

Elvira Dovletyarova is the director of Agrarian Technological Institute RUDN University of Russia and an associate professor. Under her leadership, RUDN University's Department of Landscape Design and Sustainable Ecosystems was established. Dr. Dovletyarova is the vice-president of the Association of Landscape Architects of Russia and a Member of the Soil Science Society, named after V. V. Dokuchaev.

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Carlo Calfapietra is the director of the Institute of Research on Terrestrial Ecosystems (IRET), National Research Council (CNR), Member of Czechglobe, Center of Excellence for Studies on Climate Change of AVCR, Brno (Czech Republic), and expert of European Commission for Nature-Based Solutions. Fields of interest include green infrastructure, urban forests, urban resilience and sustainability, plant ecophysiology in relation to stress, adaptation-mitigation to global change, air pollution, carbon and GHG fluxes, VOC, forest plantations, forest fires and extreme environments.

Luis Inostroza is a researcher in Geography institute of Ruhr University of Bochum. His studies integrate spatially explicit quantitative analysis, remote sensing and GIS to investigate the metabolism of socio-ecological systems and its links to ecological and economic functions, from local to global scales. Luis Inostroza is an editor of the journals Change and Adaptation in Social-ecological Systems (CASES) and Ecosystem services.

Michael Leuchner is a professor of Physical Geography and Climatology in RWTH University of Aachen. The research interests include atmospheric environmental research, energy and matter fluxes of terrestrial surfaces and the atmosphere, ecological climatology and ecohydrology.

Tree Health of *Larix sibirica* Ledeb. in the Railway Impact Zone on Kola Peninsula

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http://pabgi.ru

Abstract. The environmental conditions on Kola Peninsula are affected by industry and transport with substantial consequences for tree health. The research aimed to assess the tree health of *Larix sibirica* in the railway impact zone in four settlements: Apatity, Murmansk, Polyarnye Zori, and Olenegorsk. The methodology included determining the state of plants, a comparative analysis of the heavy metals' content in soil and needles, and seed regeneration analysis. In results, the middle-weakened specimens were shown to dominate the forecourt areas in all locations excluding Murmansk, where only the highly weakened plants were observed. Soil survey revealed pollution by Ni, Cu and Zn, which contents were 2 to 6 times above the health thresholds. The content of Ni and Cu in needles was also 3 to 8 times higher compared to the natural references. The extremely high Fe contents in needles ranging from 1.87 g kg^{-1} in Murmansk to 4.28 g kg^{-1} in Apatity also witnesses the impact of railway transport. At the same time chloroses or any other damage to the assimilating apparatus were not found in the observed *Larix sibirica* trees. It was also shown that the ability to natural regeneration in *Larix sibirica* was preserved. Laboratory seed germination rates ranged from 4% (Murmansk) to 31% (Polyarnye Zori). No viable seeds were found in Olenegorsk. Based on the research outcomes, *Larix sibirica* can be recommended for introduction to the protective plantings along the railway track and used for greening train stations due to high resistance to pollution and long lifetime.

Keywords: Subarctic climate · Urbanization · The rail station territory · Heavy metals · Greening

1 Introduction

The ecological state of the cities of the Kola North is mainly affected industry and transport [18]. Rail transport is the core component of logistics in the Murmansk region, responsible for 60% of the total cargo turnover of coal, phosphorus fertilizers, black metallic nickel, and other raw materials and their products. Railway and road areas are exposed to the highest environmental impacts [4, 9, 11]. Oil products and heavy metals are the main pollution sources in these areas, whereas the impact zone can differ depending on the meteorological conditions, topography and other attributes of pollution sources [17].

V. Vasenev et al. (Eds.): SSC 2020, SPRINGERGEOGR, pp. 1–8, 2021.
https://doi.org/10.1007/978-3-030-75285-9_1

Environmental stress adversely affects plant growth, productivity, reproductive capacity and survival. The toxic effects of pollution on the tree health can be expressed through plant injury, changes of plant anatomy, inhibition of seed germination, decrease of vegetative and reproductive growths, early senescence, and even mortality [14, 24]. However, other environmental factors (abiotic and biotic) can cause similar consequences [1, 23], therefore parallel observation of environmental factors and pollutants' contents in soils and biomass is needed to assess the pollution effect on tree health in urban areas.

Green spaces play an important role in improving quality of life in cities and maintaining favorable environmental conditions in urban areas [2, 3, 6, 15, 20]. Technogenic pollution, especially in the extreme climatic conditions of the Russian North, has a negative impact on urban vegetation and constrains greening and landscaping. The information on the impact of industrial pollution on the viability of tree plantings in the arctic cities is lacking but necessary to support sustainable urban development in this unique region. Selection of the tree species resistant to pollution is the basic research direction to support urban greenery on Kola North. *Larix sibirica* introduced into the world culture by the Komarov Botanical Institute of RAS (St. Petersburg) is a promising example [5, 21]. In the Kola North, *Larix sibirica* was introduced by the Polar-Alpine Botanical Garden Institute (PABGI) in the 1930s. It was included in the list plant for urban greening in 1956 [7].

In this paper, tree health of *Larix sibirica* was studied in the urban environment of the Kola North, specifically in the green areas adjacent to railway stations. The aim of this work was to assess the resistance of *Larix sibirica* in the impact zone of railway transport.

2 Objects and Methods

The research was carried out in 2018 at observation plots located in areas adjacent to railway stations, in the immediate vicinity of the tracks (5–10 m) in Apatity, Murmansk,

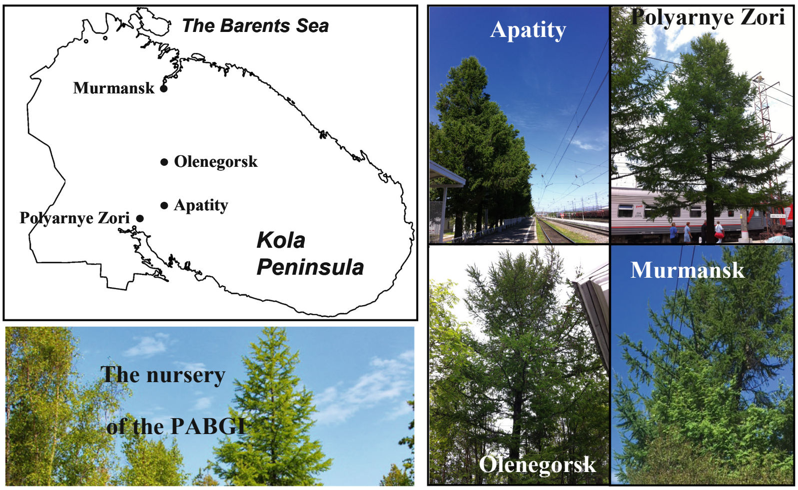


Fig. 1. Location and view of observation plots

Polyarnye Zori, and Olenegorsk (Fig. 1). The nursery of the PABGI (1 km from the city of Apatity) was selected as a natural reference.

Railway transport in the Murmansk region has been developing since 1917, when the Murmansk railway was built (currently the Murmansk segment of the Oktyabrskaya railway) [22]. Large railway junctions are located in the cities of Murmansk and Apatity. Junction stations with a moderate transport load are located in Olenegorsk and Kandalaksha. The city of Polyarnye Zori has a station for stopping passenger trains and transit for freight trains, with minimal anthropogenic impact.

In August, the state of *Larix sibirica* was evaluated at each site according to the study's methodology, Table 1 [16]. The needles of the current year were sampled from the middle branches of middle-aged trees. Soil samples from the top 10 cm layer were collected at the same period [25]. The cones were sampled from model specimens belonging to the middle-aged category in November–December, when the seeds were fully formed. In the laboratory, the collected samples of soil and biomass were prepared for the analysis of the total content of heavy metals (Ni, Cu, Pb, Cd, Zn, and Fe). Soil suspension was ground to powder and decomposed with a mixture of the HF, HNO_3, and $HClO_4$ acids (3:2:1). Biomass samples were decomposed with concentrated HNO_3. The content of the elements was determined by the atomic absorption method using Shimadzu 6800 and Quantum-AFA spectrophotometers. In laboratory conditions, seed germination was assessed by germination in triplicate.

Table 1. Description of classes of the tree state [16]

Classes of the tree state	Main signs	Additional signs
Without signs of weakening	The needles are green, dense canopy, the foliage is 100%	
Weakened	The needles are green, up to 25% of dry branches	Local damage to branches, trunk
Middle-weakened	Crown thinning, dry branches 25–50%, the needles are smaller	Local damage to branches, trunk, presence of stem pests
Highly weakened	The crown is very thinned, dry branches 50–75%, the needles are smaller than the previous class	Local damage to branches, trunk, presence of stem pests, water shoots on the trunk and branches
Shrinking	In crown more than 75% dry branches, the needles are small, light yellow, falls off prematurely	The trunk and branches are inhabited by pests and diseases, a partially withered tree
Deadwood	No needles, 100% dry branches	The trunk and branches are affected by pests and fungi

3 Results and Discussion

Tree health assessment of *Larix sibirica* showed that Olenegorsk, Apatity, and Polyarnye Zori had the highest percentage of middle-weakened plants (47%, 43%, and 56%, respectively), characterized by sparse crowns and one-sided, dry branches (Fig. 2). In Apatity and Olenegorsk, the proportion of highly weakened plants was also significant (25% and 26%, respectively). There was dead wood, which was caused by damage during the construction of utilities. In Murmansk, all the plants belonged to the highly weakened category, which was determined by unilateral crowns, curved trunks, and reduced needle length. Healthy plants, without signs of weakening, were the minor class ranging from 7% in Olenegorsk to 14% in Apatity.

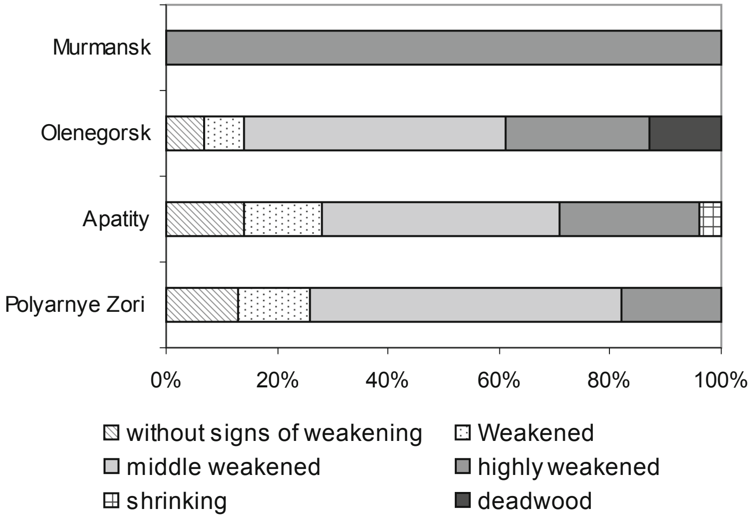


Fig. 2. The state of *Larix sibirica* in the cities

Soil survey on the station territories of cities showed different levels of metal contamination, which was estimated using the approximate permissible concentrations (APC: Ni-20 mg kg^{-1}; Cu-33 mg kg^{-1}; Pb-32 mg kg^{-1}; Zn-55 mg kg^{-1}; Cd-0.5 mg kg^{-1}, [8]). The highest metal content was found in the soil of Olenegorsk, where an excess of the APC was detected for Ni (6 times), Cu (3 times), and Zn (1.6 times). Increased amounts of Ni and Cu were found in the other cities, but to a smaller extent. It should be noted that the Ni content was slightly higher than the APC value in the soil of the PABGI nursery selected as a conditional background site. This indicates regional soil contamination associated with the activities of the copper-nickel enterprise located in the central part of the Kola Peninsula. The contents of Pb and Cd, which are highly toxic for living organisms, did not exceed the health thresholds. There are no legal threshold limit values for the Fe content in the soil of populated areas. However, the Fe content in Olenegorsk was very high, that was likely caused by the activity of the mining and processing plant, which produces iron ore concentrate.

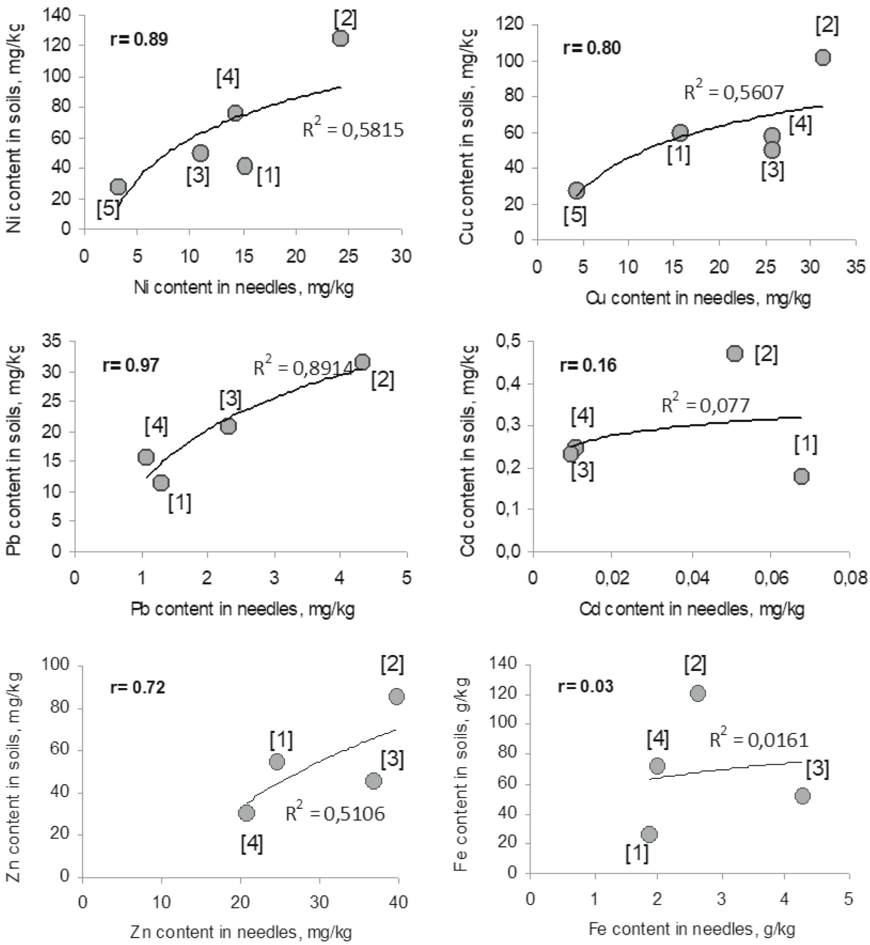
The metal content in the assimilation organs of *Larix sibirica* varied significantly, depending on the location of growth. In comparison with the natural reference plot (data presented only for Ni and Cu), the contents of these metals were higher in all the cities: for Ni, from 3 (Apatity) to 8 times (Olenegorsk) and for Cu, from 4 (Murmansk) to 7 times (Olenegorsk). The selected background area, as shown above, is subject to partial pollution from regional sources, but *Larix sibirica* is an introduced species: there is not encountered naturally in the Murmansk region. The lowest contents of Zn, Pb, and Cd were recorded in Polyarnye Zori; the highest were found in Olenegorsk. The amount of Fe in the needles ranged from 1865 mg kg^{-1} (Murmansk) to 4278 mg kg^{-1} (Apatity), which is defined as extremely high in comparison with data from other regions [10].

The comparative analysis of the distribution of metal content in the needles of *Larix sibirica* and in the soil showed high correlation coefficients for Ni, Cu, and, especially, Pb (Fig. 3). The dependence of the metal content, except Fe in needles, on the load of railway transport was not revealed. Although Murmansk and Apatity are the busiest railway stations, the maximal contents of Ni, Cu, Pb, and Zn were found in Olenegorsk. Likely it can be explained by gas and dust emissions of the Severonickel plant, which is wind-tensported over considerable distances.

The action of railway transport can be explained by the extremely high Fe content in needles (1.87–4.28 g kg^{-1}) when its bioaccumulation occurs. It has been shown that an excess of active Fe can cause a disturbance in the course of photosynthetic processes and create a stress state in plants [13]. However, the assessment of the state of *Larix sibirica* did not reveal significant abnormalities, chlorosis, or other damage. The state of the plants was more affected by factors such as illumination, thickening of plantings, and violation of the root system due to trampling.

The reproductive capacity of woody plants, especially conifers, is crucial for their continued existence and the creation of sustainable landscapes in urban areas. The success of seed reproduction depends on the quantity and quality of seeds formed and ripened in cones under the influence of climate conditions and plant habitat characteristics. This success also hinges on the conditions of seed germination and the further development of emerging young plants [12, 19]. Therefore, the study of seed productivity is the most important task of plant research.

A study of the morphometric characteristics of the cones and seeds of *Larix sibirica* showed that they were within the size of the botanical description of the species. The largest cones, with the highest seed weight, were noted in Apatity (Table 2). The determination of the seed germination rate demonstrated that the germination interval varied from 4 to 20 days. The period of maximum emergence of seedlings fell between 7 and 10 days. The seed germination index was the highest in Polyarnye Zori, and no viable seeds were found in Olenegorsk. In other cities, laboratory germination was at the level of the background plot (PABGI nursery). When surveying the territory of railway stations in Apatity and Polyarnye Zori, seedlings (2–3 years old) of *Larix sibirica* were found on the railway track, which indicates their high viability.



Note: [1] - Murmansk; [2] - Olenegorsk; [3] - Apatity; [4] - Polyarnye Zori; [5] - The tree nursery PABGI (data are presented only for Ni, Cu);
r - Correlation coefficient

Fig. 3. The ratio of metal content in the needles of *Larix sibirica* and in soils on railway station areas

Table 2. Morphometric and weight characteristics of cones and seeds

Place of selection	Length cone, cm	Width cone, cm	Weight, g 1000 seeds	Seed germination, %
Murmansk	2.21 ± 0.08	1.72 ± 0.06	7.76 ± 0.54	4.0–10.0
Olenegorsk	2.42 ± 0.11	1.49 ± 0.11	3.75 ± 0.70	0.0
Apatity	3.24 ± 0.16	1.86 ± 0.08	8.50 ± 0.72	4.0–25.0
Polyarnye Zori	2.78 ± 0.09	1.68 ± 0.07	6.65 ± 0.47	7.0–31.0
The tree nursery PABGI	2.85 ± 0.28	1.87 ± 0.12	6.93 ± 0.30	4.0–11.0

4 Conclusion

Larix sibirica is the only coniferous dendrointroducent used in landscaping of railway station territories in the cities of the Murmansk region. On the observation plots, middle-weakened specimens dominated in Olenegorsk, Apatity and Polyarnye Zori) predominate, whereas highly weakened plants were mainly observed in Murmansk. Healthy plants make up a relatively low part - 7 to 14% from the sample. The environmental conditions for the health of *Larix sibirica* in the railway station areas are not satisfactory. The soils contain increased contents of Ni and Cu. The maximal contents of heavy metals (especially Fe) were found in Olenegorsk. Highly toxic metals for plants (Pb, Cd) are within the normal range. The heavy metals content in the assimilatory organs of *Larix sibirica* varied significantly, but were above the natural reference for all the experimental plots. Despite this, the assessment of the state of this species did not reveal significant deviations in the development of plants and at the same time showed a relatively high reproductive ability of *Larix sibirica* in the areas near the station. This proves the relevance of using *Larix sibirica* in protective plantings along the railway track.

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The Influence of Soil Quality on Trees' Health in Urban Forest

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Abstract. Urbanization leads to a higher degradation of soil quality and trees' health in the parks. A comprehensive assessment of the green spaces state and soil properties in the recreational zone of urban forest fund was carried out. The research work included chemical (pH, K_2O and P_2O_5 content and heavy metals) and physical (bulk density) composition of urban soils, visual trees assessment with a species diversity description. It was found that the concentrations of trace elements in the soils located in different parts of the park differ depending on their localization. Therefore, two sample points with the same functional component produce various results. Correlation analysis did not reveal the effect of potassium on trees' health. The phosphorus content in the soil was insufficient. The Nemerow Pollution Index showed heavy pollution of soil. High levels of cadmium and arsenic in the soil were observed in comparison with the backgrounds. The topsoil horizons (0–10 cm) are more polluted, but have less impact on generative trees' quality. Other factors can also influence the ecology of parks, for instance, location, proximity to highways, filling functional zones, etc.

Keywords: Urban soils · Trees assessment · Urbanization · Soil pollution

1 Introduction

Urbanization is the main characteristic of civilization. More people live in urban areas with 55% of the world's population residing in urban areas in 2018 and by 2050, 68% is projected to be urban [17]. Urbanized landscapes are highly dynamic, complex, and multifunctional. Cities around the world are facing challenges that making more sustainable urban futures vulnerable. Many of these challenges are being driven by increases in urban populations and climate change [5]. Monitoring of change landscape conditions in cities is required to receive correct data for good decision-making [4].

Every large city has its own functional zones, which are divided into the following: residential, municipal and warehouse zone, traffic zone and recreational zone. The recreational zone becomes an important place for people's leisure activity [19]. It can be sport grounds, beaches, resorts, tourist places, and, of course, urban parks.

Green infrastructure helps in preventing the urban heat island effect, creates a special microclimate, and improves urban infrastructure [20]. Also, it helps people feel well in an urban environment and it has a positive impact on peoples' health [7].

V. Vasenev et al. (Eds.): SSC 2020, SPRINGERGEOGR, pp. 9–20, 2021.
https://doi.org/10.1007/978-3-030-75285-9_2

Urban trees are exposed to complex adverse environmental conditions, such as inadequate essential nutrient supply, very often an unfavorable water regime, polluted air, and soil [3, 11, 20]. Plants can act as indicators of air and soil pollution. The responses of trees to higher concentrations of soil contaminants are changed by environmental factors and by plant physiological status.

Urban soils have versatile functions especially the ability to buffer and purify pollutants. Soil structure is often under degradation due to artifacts and technogenic substrata, mechanical compaction, and human trampling [18]. The increased content of heavy metals is also evidence of anthropogenic impact [12, 16].

The land-use history gives an idea of the urban landscape and how past human activity affects the urban parks. Comparing the two maps of 1981 and 2016 of epy New Moscow, we can see that in addition to increasing urban areas, forest areas also prevail over arable lands. Under the urbanization influence, the conversation of forests into urban forests has led to a negative effect on soil microbiota, while the conversation of arable lands into urban areas has shown an increase of soil microorganisms' activity [8].

The research relevance conditioned by the fact that urbanization in the New Moscow is rapidly developing, the territories are expanding and being populated by a large number of new residents. This increases the need for recreational areas, for example, forest parks. In addition to the construction of new recreation areas, it is necessary to think about the environmental consequences and conduct a thorough study of effects on the structure and properties of soil [2, 18] and vegetation [7].

The study aims are to analyze the chemical and physical properties of soils and to identify their impact on trees' health in the urban forest park.

2 Materials and Methods

Research Area

The object of research was the park of the 3-rd microdistrict in Moskovsky city, which is located in Moskovsky settlement in the New Moscow (Fig. 1). The eastern part of Valuevsky forest was reconstructed for the Moskovsky settlement needs in 2016.

The main task of landscaping the territory was to create not only a recreational zone for residents, but also a communication zone. The park was built in 2017, with a total area about 16 ha. In the park 9 points were selected, trees were described inside each point with a radius of 20 m. Total amount of trees exceeded 10 species (Fig. 2).

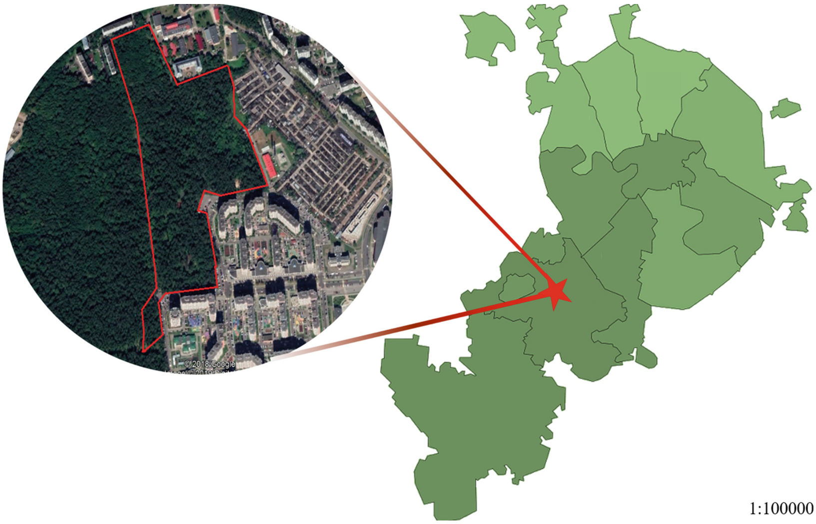

Fig. 1. The location of the study area in Moscow

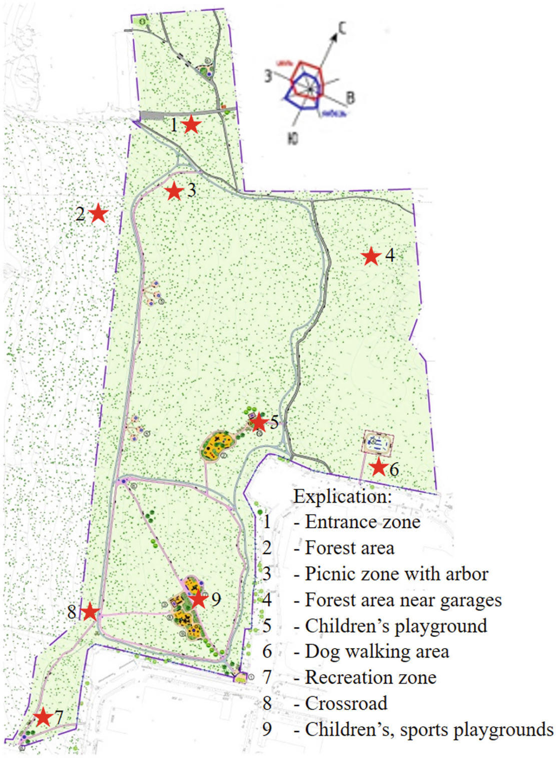

Fig. 2. The master plan with description the functional zones and soil sampling points (1:1000)

The park borders the Polio-institute district in the North, further - with the Kievskiy highway, the 3rd microdistrict of the city Moscovsky - in the South, Valuevsky forest park - in the West. The Eastern part connects with abandoned premises, garages and an old boiler house.

Visual Trees Assessment

The visual trees assessment was used Alekseev's method where 1 point is a healthy type and 5 is old or young snag. Tree ratings are given based on visual inspection. Trees assessment is affected by mechanical damage, having hollows, cracks, trunk tilts, the presence of fungies, poor lighting [1]. There is also an age description of trees, such as immature, virgin, young generative, middle-aged generative, old generative. The description is based on the trunk diameter, vegetation, the order of branching, presence of skeletal roots, tree height, and canopy size [6]. Also, the species variety was described too.

Soil Chemical and Physical Analysis

Soil bulk density was analyzed by the weight approach as the mass of a unit volume of soil dried at 105 °C (FAO, 2006). Each sample was sifted through 2 mm sieve to do the chemical analysis. Soil pH in water (1:2,5) was determined using a pH meter (Ekoniks, Moscow, Russia) according to GOST 26423-85 [22]. The content of potassium (K_2O) and moving phosphorus (P_2O_5) was determined according to GOST R 54650-2011 [21]. The method is based on the extraction of phosphorus and potassium compounds from the soil with a solution of hydrochloric acid (extraction solution) with a molar concentration of 0.2 mol/dm and subsequent quantitative determination of phosphorus compounds on a photoelectrocolorimeter, and potassium - on a flame photometer.

Heavy Metal Analysis in Soils

Before analysis, each sample was sifted through 2 mm sieve. Analysis for heavy metals was performed using portable X-ray fluorescence in laboratory (XRF). The method is based on recording and subsequent analysis of the spectrum obtained by exposure to the sample under study by x-ray radiation [13]. Each sample was scanned three times with 90 s exposure time. Samples were remixed between scans. The results were tabulated in a database. Mean concentrations from the three scans were recorded. The average value and standard deviation for each heavy metal of each sample were subtracted from three samples. The Single Pollution Index is mainly used to assess the risk of a kind of heavy metal pollution. Its expression is:

$$PI = \frac{Ci}{B} \tag{1}$$

In the formula (1), where Ci - an actual content of the i-th HM in soils, mg/kg; B– the geochemical background contents of HM: Ni (29), Cu (38.9), Zn (70), Pb (27), Cd (0.41), As (0.67) [10]. If PI $\leq$1.0, it shows the content of this heavy metal is within its background value, and the soil is not contaminated; If PI $>$ 1.0, it shows the content of this heavy metal has exceeded its background value, and the soil is contaminated [14].

The Single Pollution Index can only evaluate the pollution situation of a kind of heavy metal. Nemerow Pollution Index evaluated a comprehensive pollution status of several heavy metals:

$$PI_{Nemerow} = \sqrt{\frac{\left(\frac{1}{n}\sum_{i-1}^{n} PI\right)^2 + (PI_{max})^2}{n}} \quad (2)$$

In the formula (2), where PI - single pollution index of a particular heavy metal, PI_{max} - maximal value of the single pollution index of all HMs, n - number of studied heavy metals.

If $PI_{Nemerow} \leq 0.7$, it indicates no pollution; If $0{,}7 \leq PI_{Nemerow} \leq 1$, it means warning limit; If $1 \leq PI_{Nemerow} \leq 2$, it indicates a slightly polluted; If $2 \leq PI_{Nemerow} \leq 3$, it indicates a moderate pollution; $PI_{Nemerow} > 3$, it indicates a heavy pollution [15].

3 Results and Discussion

3.1 Visual Trees Assessment

A big variety of forest tree species was noted in park of the 3-rd microdistrict in Moscovsky city, such as *Betula pendula, Betula alba, Acer platanoides, Quercus robur, Corylus avellana, Alnus incana, Alnus glutinosa, Sorbus aucuparia, Pinus sylvestris, Tília cordata, Populus tremula, Fraxinus excelsior* (Fig. 3). Species diversity is represented by large amount of *Acer platanoides, Betula alba* and *Betula pendula.* There are quite common in Central Russia forests. The 2rd strata is dominated by shrubby plants, for example *Cornus alba, Crataegus oxyacantha* and *Sambucus racemose.*

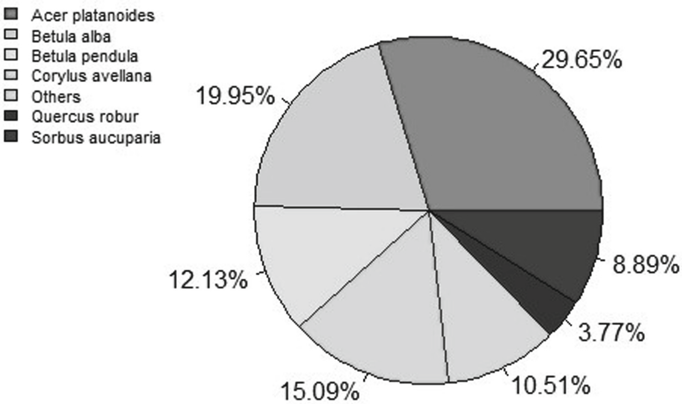

Fig. 3. Diagram of species diversity as a percentage in the forest park

The forest park is mainly dominated by young generative and middle-aged generative tree species. Also, the trees vital condition in the park is good and healthy (Fig. 4). There are very few snags, damaged and weakened trees in the whole park. However, the point 5 in children playground includes weakened trees status close to 2 marks in Alekseev's method.

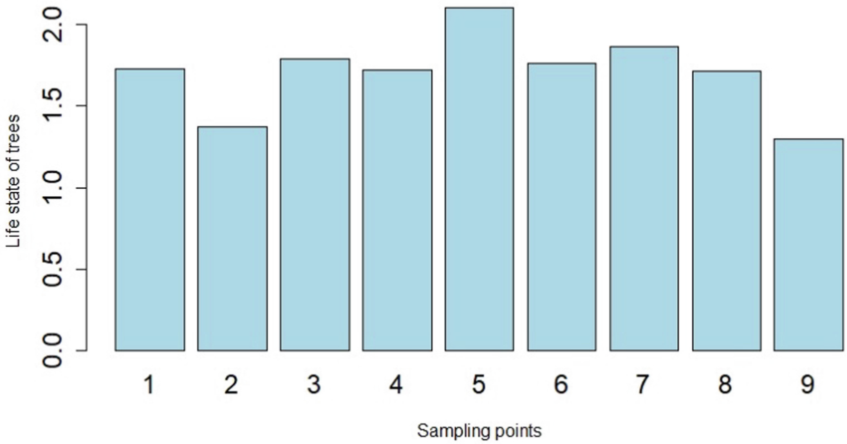

Fig. 4. Comparison of the visual trees assessment in park sampling points

3.2 Results of Chemical and Physical Analysis

The soil in different parts of the forest park has an almost similar bulk density. It is obvious that point 2, which is located in the forest area of the park, has more compacted soil than point 6, located at the dog walking area (Table 1). Also, more compacted soil is represented at points 3 and 8, located near the picnic area and near road, respectively. Values of compacted soil range from 1.00 to 1.02, which indicates a weak compaction. The pH values in the topsoil horizons significantly differ across the functional zones in the forest park. In the forest zone (4 point) the value is less, about 5.37, than in playgrounds (9 point) - 8.21. The maximum dose of P_2O_5 should not exceed 400 mg/kg, because phosphorus can dissolve heavy metals in the soil above this limit. The P_2O_5 content norm is 100–200 mg/kg on average for sod-podzolic soils according Moscow

Table 1. Topsoil (0–10 cm) bulk density, pH, content of P_2O_5 and K_2O in in park's points (mean and SD)

Point	Bulk density (0–10 cm), g/cm^3	pH (0–10 cm), unit pH	P_2O_5 (0–10 cm), mg/kg	K_2O (0–10 cm), mg/kg
1	0,73 ± 0,01	7,64 ± 0,08	26,32 ± 1,23	97,50 ± 1,41
2	1,02 ± 0,08	6,16 ± 0,05	13,96 ± 0,31	180,00 ± 9,90
3	1,01 ± 0,18	6,55 ± 0,06	48,43 ± 3,68	196,00 ± 0,00
4	0,85 ± 0,00	5,37 ± 0,08	21,11 ± 4,91	84,50 ± 26,16
5	0,71 ± 0,00	6,14 ± 0,04	21,55 ± 17,17	98,00 ± 9,90
6	0,64 ± 0,05	6,59 ± 0,01	50,60 ± 15,95	147,25 ± 3,89
7	0,69 ± 0,02	5,72 ± 0,01	31,52 ± 0,61	118,75 ± 5,30
8	1,01 ± 0,13	6,77 ± 0,05	171,16 ± 4,91	101,75 ± 5,35
9	0,98 ± 0,06	8,21 ± 0,03	110,88 ± 2,45	62,75 ± 5,35

government decree № 514. Points 8 and 9 located near road and playground have norm content of P_2O_5. The rest of the sample points are in low values (Table 1). The norm content dose of K_2O is 100–200 mg/kg. At least, half of points have norm values from 101.75 mg/kg to 196.00 mg/kg.

The overall pH value in subsoils is similar to the values of topsoil horizons (Table 2). The highest average of 6.87 is also found in the playground area (9 point). However, the lowest average of 5.48 is located in a different children playground area (5 point) closer to the park's center and in forest zone (2 point). Urbanization has an impact on the subsoil horizons through bulk topsoil horizons. In contrast to topsoils, the P_2O_5 values in subsoils are significantly lower. The K_2O content at point 6 also remains excessive – 159.13 mg/kg, but still normal. However, at points 1 and 9 (the entrance zone and playground), the values were significantly higher than in topsoils.

Table 2. Subsoil (10–50 cm) pH, content of P_2O_5 and K_2O in park's points (mean and SD)

Point	pH (10–50 cm), unit pH	P_2O_5 (10–50 cm), mg/kg	K_2O (10–50 cm), mg/kg
1	6,46 ± 0,65	46,05 ± 1,23	128,13 ± 13,97
2	5,48 ± 0,15	19,05 ± 10,89	85,88 ± 11,14
3	5,83 ± 0,56	28,27 ± 1,23	101,75 ± 22,27
4	6,06 ± 0,04	16,02 ± 5,67	61,63 ± 4,42
5	5,48 ± 0,04	20,46 ± 0,31	90,25 ± 5,30
6	6,43 ± 0,06	91,15 ± 2,76	159,13 ± 11,14
7	5,74 ± 0,01	33,47 ± 16,87	94,25 ± 2,47
8	5,63 ± 0,14	47,13 ± 2,45	88,75 ± 1,06
9	6,87 ± 1,61	94,08 ± 93,37	125,50 ± 54,45

The content of K_2O in the urban forest park is mainly average throughout the territory in different soil horizons. The P_2O_5 content is significantly less in top- and subsoils. In other studies of the soils of parks and parkways in Moscow, they were slightly different in the content of phosphorus and potassium. However, a small variation in values is explained by a large difference in the horizon highs, where migration and accumulation of chemical elements occur [9].

3.3 Heavy Metal Analysis in Soils

The content of heavy metals in the soil varies from depth. In general, heavy metals do not exceed the backgrounds in topsoils (Table 3). However, Cadmium (Cd) and Arsenic (As) exceed the backgrounds levels in each points. Cadmium is very toxic to trees. It is easily absorbed from the soil through the root system, where it mostly localized.

In the subsoils, the content of heavy metals is lower (Table 4). At points 9 (playground) and 8 (crossroad), it is significantly higher than the permissible level of arsenic. At point 1 (the entrance zone), the cadmium content is too high - 4.83 mg/kg.

Table 3. Content of heavy metals (mg/kg) in topsoil (0–10 cm) in Park's points (mean) and their backgrounds (Bg) on right side of values

№	Cd	Bg	Zn	Bg	Pb	Bg	Cu	Bg	As	Bg	Ni	Bg
1	5,0	0,41	52,3	70	11,3	27	22,0	38,9	7,6	0,67	21,6	29
2	7,0	0,41	69,0	70	18,6	27	18,3	38,9	8,6	0,67	31,6	29
3	1,6	0,41	86,6	70	23,0	27	23,0	38,9	9,6	0,67	32,3	29
4	5,3	0,41	59,0	70	30,0	27	16,6	38,9	9,6	0,67	31,3	29
5	9,6	0,41	55,0	70	12,6	27	19,3	38,9	23,0	0,67	16,0	29
6	4,3	0,41	66,6	70	10,6	27	17,3	38,9	16,0	0,67	20,0	29
7	5,0	0,41	66,3	70	16,3	27	25,0	38,9	10,3	0,67	34,0	29
8	8,3	0,41	68,0	70	9,0	27	22,3	38,9	10,6	0,67	35,6	29
9	4,3	0,41	112,0	70	19,3	27	22,6	38,9	8,3	0,67	16,0	29

Table 4. Content of heavy metals (mg/kg) in subsoil (10–50 cm) in Park's points (mean) and backgrounds (Bg) on right side of values

№	Cd	Bg	Zn	Bg	Pb	Bg	Cu	Bg	As	Bg	Ni	Bg
1	4,8	0,41	60,5	70	14,5	27	16,3	38,9	7,6	0,67	26,3	29
2	1,6	0,41	61,3	70	14,6	27	20,5	38,9	9,5	0,67	32,5	29
3	3,5	0,41	65,0	70	15,5	27	20,8	38,9	10,0	0,67	36,6	29
4	3,6	0,41	63,3	70	42,0	27	16,0	38,9	10,8	0,67	29,8	29
5	3,6	0,41	60,3	70	21,0	27	25,3	38,9	9,3	0,67	35,0	29
6	2,8	0,41	66,3	70	67,6	27	16,1	38,9	10,8	0,67	25,3	29
7	3,3	0,41	62,0	70	17,0	27	18,3	38,9	7,6	0,67	25,0	29
8	1,6	0,41	62,0	70	13,6	27	28,0	38,9	11,3	0,67	37,0	29
9	4,1	0,41	143,0	70	21,1	27	40,7	38,9	11,7	0,67	30,5	29

The Single Pollution Index is calculated in order to compare visually the extent of heavy metal pollution in each point (Figs. 5 and 6). The Single Pollution Index (SPI) of Arsenic (As) is too high in each depth than others metals. Also, the SPI $>$ 1.0 exceeds Cadmium (Cd).

The most polluted topsoils is located at 5 point (children playground). It's very dangerous, because the SPI exceeds about 30 times by Arsenic (As).

The most contaminated point in subsoil is 4 (forest zone) and 8 (crossroad). If the 8 point can be explained by its location close to parking, then the 4 point is located in a forest area, where an old boiler house and garages are located nearby.

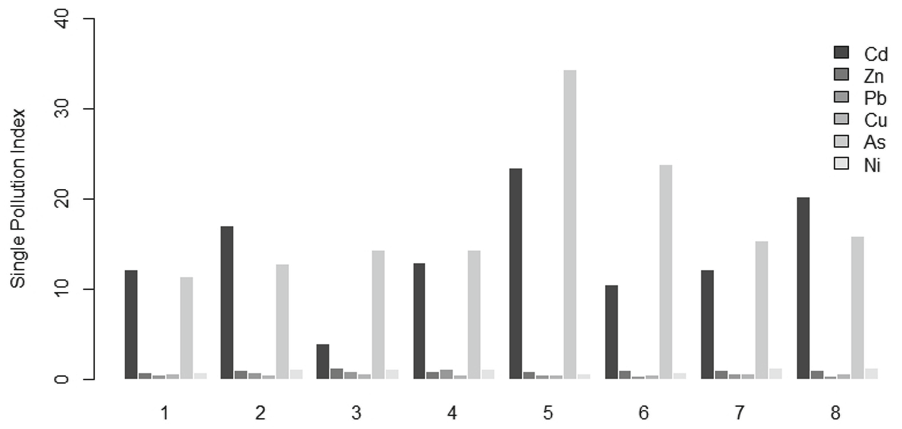

Fig. 5. The Single Pollution Index of topsoils (0–10 cm) in park's points

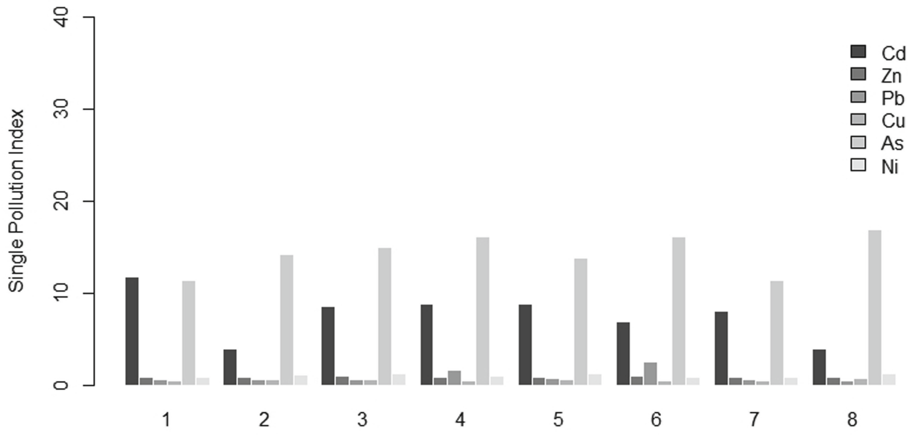

Fig. 6. The Single Pollution Index of subsoils (10–50 cm) in park's points

The Nemerow Pollution Index ($PI_{Nemerow}$) in topsoil (0–10 cm) of all the nine study areas is heavy polluted (Table 5). The $PI_{Nemerow}$ in 5 point (playground) are too high–13.37. The $PI_{Nemerow}$ of the other points was around 6 and still belongs to heavy pollution. The $PI_{Nemerow}$ in subsoil (10–50 cm) close to 6, which also determines as heavy pollution. Among them, the $PI_{Nemerow}$ of 9 point (playground) is the highest ($PI_{Nemerow} = 6.83$), which is moderate pollution.

Research on heavy metal contamination of soil is explained by human activity and urbanization in general. For example, a study of Xiangtan Park areas in China found that pollution decreases gradually along with the increasing of the distance from the city center [19]. Locally in the park, this can be explained by the same distance to the nearest industrial zones or to major highways.