Ecological state of soils in recreational areas

Svetlana Hamitova1,2,3*, Marina Ivanova1,2, Elena Fedchenko4, Aleksandr Pestovskij1, Aleksandra Popova1, and Olga Vlasova4

1Vologda State University, Vologda, Russian Federation
2North (Arctic) Federal University named after M. V. Lomonosov, Arkhangelsk, Russian Federation
3FGBNU All-Russian Research Institute of Phytopathology, Odintsovo district, Bolshie Vyazemy, Russian Federation
4FGBU GCAS Vologodsky, Vologda, Russian Federation

Abstract. Study of heavy metal contamination of soil is carried out by means of various methods in many countries of the world. The review of to-date research works performed by us has shown that the Chinese scientists have been particularly active in this issue. Analysis of the land cover of the Vologda region is not well examined yet, which enhances the relevance of our research. In 2018, with the support of veterans, Olympic champions, the administration of the Verkhovazhsky rural settlement, State Duma deputy E.B. Shulepov in the village of Smetanino, we created the People's Garden, Veterans Park, and the Olympic Cedar Grove. The aim of the research is to study the soils of the recreational areas of the village of Smetanino, Verkhovazhsky district, Vologda region. The research methods included determining the chemical composition of the soils selected, as well as processing and summarizing the data obtained. The sampling was carried out in 2019. The chemical tests of soil were performed according to the approved GOSTS and methods in the accredited laboratory of the FSBI Federal Centre of Agrochemical Service Vologodsky. In general, Veterans Park has the greatest heavy metal contamination of the soil, while the Olympic Cedar Grove has the least.

1 Introduction

Forests are the most important ecological framework of the biosphere that stabilize a lot of natural processes. Forests emit phytoncides that kill pathogenic bacteria, serve as a refuge and custodian of the diversity of the living world, being the most outstanding representative of biodiversity, as well as an essential component of an environmentally sustainable and productive landscape, they create a comfortable environment for people and the entire animal kingdom. Not only do forests provide human beings with a lot of material benefits but they also offer spiritual ones, as well as the ecologically sound environment for life and mass recreation [1].

Provision of recreational areas is relevant at all times and everywhere. Parks, public gardens, gardens and groves are used for recreation by most of the local population, particularly in urban areas. In rural territories, however, it is more pleasant for people to...
relax in specially designed places - recreational areas, especially when local residents were actively involved in their creation. For example, Tenley M. in the article “Tending their urban forest: Residents’ motivations for tree planting and removal” considered the issue of tree planting by urban residents and their motivation in choosing species [2].

The safety of recreational areas, including environmental compliance, should not be overlooked. Soil is the surface layer of the Earth’s land mass. The soil cover of the Earth provides life for plants, animals and humans. Soil contamination is a very serious environmental problem.

Soil contamination by heavy metals is studied in various ways in many countries of the world. Wei Zhang, Miao Liu and Chunlin Li in their article consider the concentration levels, spatial distributions and potential sources of arsenic (As), cadmium (Cd), chromium (Cr), copper (Cu), mercury (Hg), nickel (Ni), lead (Pb) and zinc (Zn) with a geographic information system (GIS), principal component analysis (PCA) and canonical correspondence analysis (CCA) in the Hong Taiji River watershed, which includes the main part of the Liaoning central metropolitan area, containing six cities with an 80-year industrial history. The soil samples Hg and As were measured by HG-AES, while Cr, Cu, Ni, Pb, Zn and Cd were measured by inductively coupled plasma mass spectrometry (ICP-MS, PerkinElmer, Waltham, MA, USA) [3].

Binggan Wei, Linsheng Yang in their article review quite a few heavy metal contamination related studies in several cities from China over the past 10 years. In this study there were widely compared and discussed concentrations, sources, contamination levels, sample collection and analytical tools of heavy metals in urban soils, urban road dusts and agricultural soils [4].

Mohamed S. Shokr, Ahmed A. El Baroudy and others in the article “Spatial distribution of heavy metals in the middle Nile delta of Egypt” used remote sensing, Geographical Information Systems (GIS), and X-ray fluorescence (XRF) spectrometry as the main research tools [5].

Hanna Jaworska and Joanna Lemanowicz in their article evaluated the influence of car traffic on the content of selected heavy metals in the soil from a park area to define the dependency between their content and enzyme activity. The research was carried out in a forest park in central Poland. The total content of heavy metals was measured by atomic absorption spectroscopy using a SOLAR 969 (Unicam) after digestion in a mixture of HF and HClO4 acids using Crock’s and Severson’s method [6].

Diana Malinova, Ludmila Malinova, Kameliya Petrova, Biser Hristov in their research “Coefficients of heavy metal accumulation in forest soils” state that “in a number of publications, it is reported that the surface soil layer in forest territories often contains increased heavy metal quantities, but at present there are lack of criteria for evaluation of their origin” and offer to calculate the coefficients of heavy metal accumulation (CA) in the surface soil layers of landscapes, distant from industrial and urban centres in order to numerically define the extent of natural accumulation processes as criteria to distinguish them from the aerosol soil contamination. The heavy metal content in soils was determined by decomposition with Aqua regia and Flame AAS (ISO 11466) Perkin Elmer 5000. The data were obtained from permanent sample plots from the 16 x 16 km network in beech (Fagus Sylvatica L.) landscape of the Balkan Mountains and the coniferous (pure and mixed stands of Pinus sylvestris L., Picea abies L., Abies alba Mill.) landscape of the Rhodope Mountains and Sredna Gora, as well as the results obtained at 2 intensive monitoring field stations in the Balkan Mountains – „Vitiniya” and „Staro Oryahovo” [7].

Some authors investigate soil contamination with one or more heavy metals [8 – 11].

Anastasiia Olegovna Splodytel in the article “Landscape and geochemical assessment of ecological condition of environmental protection territories” looks at the regularity of heavy metal distribution in the modern soil cover of the territory of the Nizhny Sulsky national
natural park. The extraction of the gross forms of heavy metals contained in the soil was carried out with concentrated HNO₃ in accordance with the requirements, while the extraction of mobile (fixed) forms of heavy metals – In HNO₃. The presence of heavy metals in phytomass of plants was determined in their ash solutions by atomic absorption spectrometry [12].

Aleksey A. Buluktaev in the article “Physical and chemical composition of soils of the Kharbinsky federal nature reserve” reviews the current state of the soil chemistry of the Kharbinski federal nature reserve located in the territory of the Justin and Yashkul districts of the Republic of Kalmykia. For general soil characteristics, the following analyses were carried out: water extraction analysis (soil was analyzed for Ca²⁺, Mg²⁺ and Na⁺ cations, HCO₃⁻, Cl⁻ and SO₄²⁻ anions and pH), nitrogen, phosphorus and potassium content analysis, and heavy metals determination. Determination of heavy metals (Cu, Zn, Pb, As, Mn, Cd, Ni, Co, Cr, Hg) was carried out by atomic absorption spectrophotometry using selective lamps [13].

Hyunuk Kim, Mina Lee and others in their study investigated heavy metal (loid) contamination of agricultural lands near fifteen industrial complexes [14].

Hui-Hao Jiang, Li-Mei Cai and others in their article write that it is necessary to establish local geochemical baseline concentrations (GBCs) due to the lack or the inapplicability of regional background values in the study area. The establishment of GBCs of heavy metal (HM) in soil helps in making the accurate assessment of pollution, and then provides a basis for pollution control. Based on this, a case study was undertaken to study the GBCs of the Jiedong District, Guangdong Province, China. In this research, cumulative frequency distribution curves were utilized to determine the local GBCs in the subsoils [15].

Evandro B. da Silva, Peng Gao and others determined the background concentrations of 9 trace metals including As, Ba, Cd, Co, Cu, Ni, Pb, Se, and Zn in 214 urban soils in Florida from two large cities (Orlando and Tampa) and 4 small cities (Clay County, Ocala, Pensacola and West Palm Beach) and compared background concentrations to Florida Soil Cleanup Target Levels (FSCTLs) [16].

Jong Cheol Pyo, Seok Min Hong and others in their study implemented a deep learning method on reflectance spectra of soil samples to estimate heavy metal concentrations. A convolutional neural network (CNN) was adopted to estimate arsenic (As), copper (Cu), and lead (Pb) concentrations using measured soil reflectance [17].

Xiaolin Jia, Tingting Fu and others selected 13 environmental factors related to the accumulation of soil heavy metals based on the source-sink theory. Then, the fuzzy k-means method in combination with the random forest (RF) method was used to classify potential risk areas [18].

El Hassania El Hamzaoui, Mohamed El Baghdadi and others determined the degree of soil pollution in Beni-Moussa irrigated perimeter. The soil is sampled at 25 various stations all through the perimeter to analyze a set of physical–chemical parameters like pH, organic matter (OM), carbonate content (CaCo₃), granulometry, magnetic susceptibility at low frequency (χLF) and heavy metals (Zn, Cr, Pb, Cu, As, Ni, Cd, and Fe). The samples of soil were analyzed using an inductively coupled atomic plasma emission spectroscopy (ICP-AES) [19].

Studies of heavy metal concentrations in soil and woody vegetation in the context of urban agglomeration were conducted in the Vologda region [20]. The authors analysed the content of heavy metals in the soil and woody plants at different distances from motor roads in urban areas (the city of Vologda).

Thus, as a result of our review of the research available to date, it can be concluded that soil contamination studies are being carried out in different countries, particularly by
Chinese scientists. The analysis of the soil cover of the Vologda region is not well studied yet, therefore the relevance of our research is increasing.

The aim of the research is to study the soil under the cedar plantations of the recreational areas of the village of Smetanino in the Verkhovnazyshky district of the Vologda region.

Objectives: to determine the chemical composition of soils, as well as the gross content of heavy metals in the soils of recreational areas, and to make a comparative analysis of soil contamination in these areas.

2 Methods

The object of the research are the soils of the recreational areas of the village of Smetanino, Verkhovnazyshky district, Vologda region. In 2018, with the support of veterans, Olympic champions, the administration of the Verkhovnazyshky rural settlement, State Duma deputy E.B. Shulepov in the village of Smetanino, we created the People's Garden, Veterans Park, and the Olympic Cedar Grove. New recreational areas are places of rest for local people.

The plant spacing is 4 metres. The planting spot for each seedling was prepared with sand and mineral fertilizer application [21].

The research methods included determination of the chemical composition of the soils selected in the People’s Garden, Veterans Park and the Olympic Cedar Grove, as well as processing and consolidation of the data obtained. Sampling was carried out in 2019 in accordance with GOST 17.4.4.02-2017 “Nature Conservation (SPS). Soil. Sampling methods for chemical, bacteriological, helminthic and bacteriological analysis”.

The samples were taken at the selected recreational area using an envelope method. The samples were mixed and placed in cloth bags. The soil was dried on laboratory trays at room temperature. It was then ground in a porcelain jar and sieved through a sieve.

The chemical tests of soil were performed according to the approved GOSTS and methods in the accredited testing laboratory of the FSBI Federal Centre of Agrochemical Service Vologodsky (Certificate of Accreditation No POCC RU.0001.21ПЧ08). Gross heavy metal content (copper, zinc, lead, cadmium, nickel, chromium) in soil was determined by the atomic-absorption method using the atomic-absorption spectrophotometer Spectre-5-4 based on FR.1.31.2018.31189 “Method of measuring mass fractions of toxic metals in soil samples by atomic absorption method”, arsenic was measured by the photometric method using the UNICO equipment, mercury was determined by means of the UCR-1 mercury complex, 5M nitric acid was used as an extractant. Arsenic was measured by the photometric method using the UNICO – 1201 equipment based on the “Methodological guidelines for the determination of arsenic in soils by photometric method, Moscow, 1993”, the sample was prepared using a wet degradation method based on the interaction of the soil with acids. Mercury was measured on the UCR-1 mercury complex by END F 16.1.1-96 “Method for measuring mercury mass concentration in soil samples by flameless atomic absorption with thermal decomposition of samples”.

Comparison of the results obtained for the soils of the parks was performed based on the sanitary-hygienic standards GS 2.1.7.2041-06 “Maximum Allowable Concentration (MAC) of Chemicals in Soil” and GS 2.1.7.2511-09 “Approximate Allowable Concentration (JDC) of Chemicals in Soil.”
3 Results and Discussion

Analysis and summary of the assessment results obtained for the chemical composition of soil showed that silicon dioxide content ranged from 77.2 to 82.7%. The calcium content of the soil ranged from 65–70 mg-eq, magnesium is about 48 mg-eq. The iron content is between 4 – 5%. The ammonium content of the studied soils is below the background values.

Gross content of heavy metals in the soils of the recreational areas of Smetanino village is presented in the table.

| № and name                     | Copper | Zinc  | Lead  | Cadmium | Nickel | Chromium | Arsenic | Mercury | pH   |
|--------------------------------|--------|-------|-------|---------|--------|----------|---------|---------|------|
|                               | C  | A     | C  | A | C  | A | C  | A | C  | A | C  | A | C  | A | mg/kg in air-dried basis | pH kcl |
| 1. The People's Garden         | 8.4 | 5.7   | 1.9 | 1.3 | 38.4 | 32.2 | 14.2 | 10.6 | 22.4 | 2.2 | 0.32 | 0.42 | 0.88 | 0.10 | 10.4 | 3.8 | 3.1 | 2.7 | 0.19 | 0.09 | 0.023 | 0.024 | 0.011 | 0.011 | 5.9 | 0.1 |
| 2. Veterans Park               | 11  | 1.1   | 38.4 | 32.2 | 14.2 | 10.6 | 22.4 | 2.2 | 0.32 | 0.42 | 0.88 | 0.10 | 10.4 | 3.8 | 3.1 | 2.7 | 0.19 | 0.09 | 0.023 | 0.024 | 0.011 | 0.011 | 5.5 | 0.11 | 0.1 |
| 3. The Olympic Cedar Grove     | 1.9  | 1.6   | 32.2 | 130 | 20-80 | - | 2.0 | - | 2.0 | - | - | 2.0 | - | 2.1 |
| JDC (GS 2.1.7.2511-09)         | 33-132| 55-220| 32-130 | 0.5-2.0 | 10.0 | - | 2.0 | - | 2.0 | - | - | 2.0 | - | 2.1 |
| MAC (GS 2.1.7.2041-06)         | - | - | 32.0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |

4 Conclusions

In the course of work, we have studied the soils under the cedar plantations of the recreational areas of Smetanino village in the Verkhovnaziysky district of the Vologda region. We have determined the chemical composition of the soil, as well as the gross content of the heavy metals, also, we have conducted a comparative analysis of the soil contamination in these areas. In the village of Smetanino, the soil type is podsolic. The soils are acidic (pH 5.1 – 5.9). In all the soils of the studied areas, the copper content does not exceed the JDC. The highest concentration of copper was found in the soils of the Veterans Park – 8.4 mg/kg respectively, which is 0.13 JDC. The lowest copper content in the soil was found in the Olympic Cedar Grove, 4.6 mg/kg. The zinc content of the parks is also less than the JDC. The highest concentration of zinc is found in the Veterans Park – 43.6 mg/kg, which is 0.4 JDC. The lowest is in the People’s Garden – 32.2 mg/kg. The cadmium content does not exceed the JDC. The highest cadmium content is found in the Veterans Park – 0.42 mg/kg, which is 0.4 JDC. The lowest is in the Olympic Cedar Grove – 0.32 mg/kg. The content of nickel in soils does not exceed the lower limit of the JDC (20.0 mg/kg). The highest concentration of nickel was found in the Veterans Park at 13.7 mg/kg, the lowest is in the Olympic Cedar Grove – 8.9 mg/kg. No MAC or JDC has been determined for the gross soil chromium content. The highest chromium content is found in the People’s Garden (10.4 mg/kg) and the lowest is in the Olympic Cedar Grove (8.6 mg/kg). MAC was measured for lead, arsenic and mercury. The MAC for lead in the soil is 32.0 mg/kg. In the soils of this area, this value has not been exceeded. Lead content is the highest in the Veterans Park (11.2 mg/kg), the lowest level is in the Olympic Cedar Grove (7.8 mg/kg). MAC
exceedence (2.0 mg/kg) was recorded for arsenic in the People’s Garden soil (2.7 mg/kg). High levels of arsenic are also found in the soils of the Olympic Cedar Grove (1.54 mg/kg). The lowest arsenic content in the soil is found in the Veterans Park (0.70 mg/kg). For mercury content (2.1 mg/kg) in the soil no exceedance of MAC was observed. This indicator has a relatively low value in the soils under study.

Thus, it can be concluded that the most heavy metal contaminated soils are found in the Veterans Park. The least polluted are the soils of the Olympic Cedar Grove.

We express our gratitude to State Duma deputy Yevgeny Borisovich Shulepov and Candidate of Economic Sciences Zadumkin Konstantin Alekseevich.

References
1. N. A. Moiseev, Lesnoy Zhurnal 5, 203–207 (2019)
2. M. Tenley, Urban Forestry & Urban Greening 17, 23-32 (2016)
3. Wei Zhang, Miao Liu and Chunlin Li, Scientific Reports 10, 8730 (2020)
4. Binggan Wei and Linsheng Yang, Microchemical Journal 94, 99–107 (2010)
5. Mohamed S. Shokr, Ahmed A. El Baroudy, Michael A. Fullen, Talaat R. El-beshbeshy, Ali R. Ramadan, A. Abd El Halim, Antonio J.T. Guerra and Maria C.O. Jorge, International Soil and Water Conservation Research 4, 293–303, (2016)
6. Hanna Jaworska and Joanna Lemanowicz, Scientific Reports 9, 19981 (2019)
7. D. Malinova, L. Malinova, K. Petrova, and B. Hristov, Bulgarian Journal of Agricultural Science 25(3), 519–526 (2019)
8. M. Pogrzeba, D. Ciszek, R. Galimska-Stypa, B. Nowak and A. Sas-Nowosielska, Plant Soil 409, 371–387 (2016)
9. Mingxing Sun, Ting Wang, Xiangbo Xu, Linxiu Zhang, Jing Li and Yajuan Shi, Ecosystem Health and Sustainability 6, 1, (2020)
10. Jerzy Weber, Agnieszka Dradrach, Anna Karczewska and Andrzej Kocowicz, Journal of Soils and Sediments 18, 2387–2398 (2018)
11. Brian Pavilonis, Andrew Maroko and Zhongqi Cheng, International Journal of Hygiene and Environmental Health 229 (2020)
12. A. O. Spolodytel, Visnyk of V. N. Karazin Kharkiv National University, series «Geology. Geography. Ecology» 51 (2019)
13. A. A. Buluktaev, South of Russia: ecology, development 13(4), 86-96 (2018)
14. Hyunuk Kim, Mina Lee, Jae-Hwang Lee, Kye-Hoon Kim, Gary Owens and Kwon-Rae Kim, Applied Biological Chemistry 63(31) 2020
15. Hui-Hao Jiang, Li-Mei Cai, Han-Hui Wen and Jie Luo, Scientific Reports 10(6460) (2020)
16. Evandro B. da Silva, Peng Gao, Min Xu, Dongxing Guan, Xianjin Tang and Lena Q. Ma, Environmental Pollution 264 (2020)
17. JongCheol Pyo, Seok Min Hong, Yong Sung Kwon, Moon Sung Kim and Kyung Hwa Cho, Science of The Total Environment 741 (2020)
18. Xiaolin Jia, Tingting Fu, Bifeng Hu, Zhou Shi, Lianqing Zhou and Youwei Zhu, Journal of Hazardous Materials 393 (2020)
19. El Hassania El Hamzaoui, Mohamed El Baghdadi, Hakima Oumenskou, Mohamed Aadraoui and Abdessamad Hilali, Modeling Earth Systems and Environment 6, 1387–1406 (2020)
20. E. B. Karbasnikova, O. S. Zalyvskaya and O. V. Chukhina, Lesnoy Zhurnal 5, 216–223 (2019)
21. S. Khamitova, Y. Avdeev, M. Ivanova, A. Popova, D. Titov, and L. Tarabayev, IOP Conference Series: Earth and Environmental Science 390 (2019)