Contamination of soils with heavy metals in the parks of Vologda

S M Hamitova¹,², E I Fedchenko¹, M A Ivanova¹,³, A S Pestovskij², O A Vlasova⁴, A N Naliukhin⁵ and R S Khamitov⁶

¹ Vologda State University, 15, Lenina, Vologda, 160000, Russian Federation
² FGBNU All-Russian Research Institute of Phytopathology, 5, Institute, Odintsovo district, Bolshie Vyazemy, 143050, Russian Federation
³ North (Arctic) Federal University named after M. V. Lomonosov, 17, Embankment of the Northern Dvina, Arkhangelsk, 163002, Russian Federation
⁴ FGBU GCAS Vologodsky, 11, Student, Vologda, 160555, Russian Federation
⁵ All-Russian Scientific and Research Institute of Agrochemistry named by D.N. Pryanishnikov, 31a, Pryanishnikova, Moscow, 127434, Russian Federation
⁶ Vologda S DFA, 2, Shmidt, Vologda, Molochnoe, 160555 Russian Federation

E-mail: xamitowa.sveta@yandex.ru

Abstract. Soil contamination with heavy metals is a major threat to both the natural environment and human health. The study of soil contamination with heavy metals in urban environments is an important applied task. In the course of this study, the gross content of heavy metals in the soils of parks in Vologda was determined, consolidate figures of soil contamination were calculated and a comparative analysis of soil contamination in parks was made. Determination of the gross content of heavy metals in soils was carried out at the Agrochemical Service Centre "Vologodsky" in the Molochnoye settlement using generally accepted methods. The level of chemical contamination of soils was assessed on the basis of a total contamination indicator. The study concluded that sod-podzolic, loamy soil type with acidity ranging from 6.7 to 7.2 prevails in the parks of the city of Vologda under study. In general, 6 parks in the city of Vologda are classified as a permissible pollution category in terms of total soil pollution, while 2 parks are classified as a moderately hazardous pollution category. The most heavily metal-contaminated soils are found in Victory Park and the Kremlin Garden. The least heavily metal-contaminated soils are Evkovka, Mira and 50th anniversary of October parks.

1. Introduction

One of the most important environmental issues is the flow of pollutants into the environment, including heavy metals. The main sources of their inflow are transport, industry and the heat and power industry [1]. In recent years, numerous studies have been carried out in various countries around the world on the content of heavy metals and their compounds in soil [2-4].

Heavy metal pollutants are among the most harmful to the Earth's biosphere. They have a wide variety of harmful effects on human health and the livelihoods of living organisms. Heavy metals include more than 40 metals of D.I. Mendeleyev’s periodic system. Particularly dangerous are mercury, lead and cadmium [5].
Heavy metals are dangerous because they can form highly toxic organometallic compounds, enter the metabolic cycle, accumulate in living organisms, and change their forms when they move from one natural environment to another without biodegradation. They can cause the development of certain diseases, the spread of which is quite significant on a global scale and is estimated at several million people [6].

Transport is the main source of environmental pollution. As the number of motor vehicles increases, air pollution is steadily increasing. Heavy metals enter the near road space as a result of engine operation and other impacts [7]. All this causes an increase in the content of heavy metals in the biosphere compared with the natural background level [8].

Recently, scientists have been paying particular attention to urban soils. Contaminated soils are a source of secondary pollution of surface air and water flowing from it into the world's oceans [9]. Therefore, studying soil contamination with heavy metals is an important applied task.

The aim of the study is to analyse soil contamination with heavy metals in parks in Vologda.

Objectives: to determine the gross content of heavy metals in soils of the parks, to calculate the total soil pollution index and to carry out a comparative analysis of soil pollution in the parks.

2. Materials and methods
The object of the study is soils from parks in the city of Vologda. For this study, we selected soil samples from 8 parks in the city of Vologda (figure 1).

![Soil sampling sites.](image)

Determination of the gross content of heavy metals in the soils of parks in Vologda was carried out at the Agrochemical Service Centre "Vologodsky" in the settlement of Molochnoye. To determine the concentrations of copper, zinc, lead, cadmium, nickel and chromium, FR.1.31.2018.31189 Methodology for measuring the mass fraction of toxic metals in soil samples using the atomic absorption method was used [10]. Methodical guidelines for determining arsenic in soils using the photometric method were used to determine arsenic, Moscow 1993 [11]. CRD F 16.1.1-96 Methods for measuring the mass concentration of mercury in soil samples by free atomic absorption with thermal decomposition of samples were used [12].
A comparison of the obtained indicators for parks' soils was carried out based on the hygienic standards of GN 2.1.7.2041-06 "Maximum Permissible Concentrations (MPC) of Chemicals in Soil" [13] and GN 2.1.7.2511-09 "Approximate Permissible Concentrations (APC) of Chemicals in Soil" [14].

The assessment of the level of chemical contamination of soils was carried out on the basis of a total contamination index \( Z_c \), which is equal to the sum of concentration coefficients of chemical pollutant elements and expressed by formula (1):

\[
Z_c = \sum (K_{ci} + \ldots + K_{cn}) - (n - 1)
\]

Where: 
- \( n \) - number of substances to be determined;  
- \( K_{ci} \) - concentration factor of the \( i \)-th pollution component.

Evaluation of the degree of danger of contamination of soils with a complex of metals by indicator \( Z_c \), was carried out on an evaluation scale [15].

3. Results

The city of Vologda is dominated by sod-podzolic, loamy soil types with acidity of over 5.5. In the soil parks under study, acidity ranges from slightly acidic to slightly alkaline, with acidity ranging from 6.7 to 7.2.

In the soils of all the parks studied the copper content does not exceed APC (132.0 mg/kg). The highest copper content was found in the soils of Victory Park and Kremlin Garden - 44.6 mg/kg and 40.9 mg/kg respectively, which is 0.31-0.34 APC. The lowest copper content in the soil was found in Mira park, 50th anniversary of October park and Children's garden - 14.1 mg/kg, 14.5 mg/kg and 16.9 mg/kg respectively.

The zinc content of park soils also does not exceed the upper limit of the APC (220 mg/kg). The highest zinc content was found in Osanovskaya Grove, Victory Park and Kremlin Garden - from 134.8 to 153.2 mg/kg, which is 0.6-0.7 APC. The smallest amount of zinc was found in Evkovka and Mira parks - 68.2-68.4 mg/kg.

Cadmium content is within APC (2.0 mg/kg). The highest cadmium content is found in Victory Park and Kremlin Garden - 0.92 mg/kg and 0.82 mg/kg - 0.46 APC and 0.41 APC. The lowest content is found in the parks of Mira, Evkovka, Children's and the 50th anniversary of October - 0.50-0.56 mg/kg.

The nickel content of park soils does not exceed APC (80.0 mg/kg). Increased nickel content is observed in Evkovka, Victory and Kremlin parks (20.9 mg/kg, 17.6 mg/kg and 17.2 mg/kg). The lowest nickel content is in the soils of Mira Park (9.2 mg/kg).

MPC and APC have not been defined for the gross chromium content in the soil. The highest chromium content is found in Victory Park (17.4 mg/kg) and the lowest in the 50th anniversary park of October park (6.2 mg/kg).

MPC have been determined for lead, arsenic and mercury.

MPC of lead in soil is 32.0 mg/kg. In the soils of the majority of the studied parks this index is exceeded by several times. Soils of Victory Park (104.0 mg/kg) and Kremlin Garden (103.0 mg/kg) exceed MPC of lead more than 3 times. Values below the MPC are observed only in the parks of Mira (21 mg/kg) and 50th anniversary of October (23.0 mg/kg).

The excess of MPC (2.0 mg/kg) in arsenic content in the soil of the Children's Park (2.26 mg/kg) was recorded. High arsenic content has also been registered in the soils of the Veterans' Park (1.18 mg/kg), Victory Park (0.97 mg/kg) and Kremlin Garden (0.97 mg/kg). The lowest arsenic content in the soil is observed in the 50th anniversary of October (0.59 mg/kg).

Excess of MPC in the content of mercury (2.1 mg/kg) in the soil has not been recorded. The highest mercury content in the soil was registered in the Kremlin Garden and Victory Park - 0.46 mg/kg and 0.42 mg/kg. The lowest concentration was found in the park of the 50th anniversary of October (0.034 mg/kg).
Table 1. Soil pollution hazard assessment.

| No | Name                           | Zc  | Soil pollution category | Changes in health indicators of the population in the centres of pollution |
|----|--------------------------------|-----|-------------------------|-------------------------------------------------------------------------|
| 1  | Kremlin Garden                 | 20.03 | Moderately hazardous    | Increase in the overall morbidity                                       |
| 2  | Osanovskaya Grove              | 11.73 | Permissible             | The lowest morbidity rate of children and the lowest frequency of occurrence of functional abnormalities |
| 3  | Veterans’ Park                 | 9.45  | Permissible             | The lowest morbidity rate of children and the lowest frequency of occurrence of functional abnormalities |
| 4  | Victory Park                   | 20.89 | Moderately hazardous    | Increase in the overall morbidity                                       |
| 5  | Mira Park                      | 5.09  | Permissible             | The lowest morbidity rate of children and the lowest frequency of occurrence of functional abnormalities |
| 6  | Children’s Park                | 7.04  | Permissible             | The lowest morbidity rate of children and the lowest frequency of occurrence of functional abnormalities |
| 7  | Yevkovka Park                  | 5.98  | Permissible             | The lowest morbidity rate of children and the lowest frequency of occurrence of functional abnormalities |
| 8  | The 50th Anniversary of October Park | 5.84 | Permissible             | The lowest morbidity rate of children and the lowest frequency of occurrence of functional abnormalities |

Evaluation of the degree of danger of soil contamination by a complex of metals on the total pollution index Zc (table 1), which reflects the differentiation of pollution of the air basin of cities with metals and other most common ingredients (dust, carbon monoxide, nitrogen oxides, sulfuric anhydride), is carried out on an evaluation scale [15], which reflects changes in health indicators of the population in the centers of pollution.

4. Discussion
According to the total pollution index in 6 parks of Vologda city, the soils belong to permissible pollution category (Zc < 16). These include Osanovskaya Grove, Veterans’ Park, Children’s Park, Mira Park, Yevkovka Park and the 50th anniversary of October Park, and in the last three parks Zc is the lowest and is within 5-6. In the Kremlin Garden and Victory Park, the soil is classified as moderately hazardous pollution (Zc = 20-21). Here such changes in health indicators of population in the centers of pollution as increase in general morbidity are possible.

The causes of soil pollution in the Kremlin Garden and Victory Park are motor vehicles. These parks are located in close proximity to highways with heavy traffic, and there is a railway close to Victory Park. The parks of Yevvkovka, Mira and the 50th Anniversary of October are at a significant distance from the intensive traffic flows on the outskirts of the city of Vologda, so the soils there are less contaminated with heavy metals.

5. Conclusion
Thus, it can be concluded that sod-podzolic, loamy type of soil with acidity ranging from 6.7 to 7.2 prevails in the parks of the city of Vologda studied. In total, 6 parks in Vologda are classified as a permissible pollution category in terms of total soil pollution, while 2 parks are classified as a
moderately hazardous pollution category. The most heavily metal-contaminated soils are found in Victory Park and the Kremlin Garden. The least polluted soils are Evkovka, Mira and 50th anniversary of October parks.

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