Heavy metals in sod-podzolic soils under forest stands of Moscow

V D Naumov, N L Kamennyh, A V Lebedev, A V Gemonov and P S Gemonova

Russian State Agrarian University - Moscow Timiryazev Agricultural Academy, 49, Timiryazevskaya st., Moscow, 127550, Russia Federation

E-mail: alebedev@rgau-msha.ru

Abstract. In large cities, soil pollution occurs with heavy metals. Forest stands react to environmental pollution by a decrease in growth and an increase in mortality. A typical object for the city of Moscow is the Timiryazev Academy Forest Experimental District. A comparison of the content of gross forms with the clark content of trace elements in the soil profile revealed a significant excess for the following chemical elements: copper, zinc, lead, arsenic. The content of chromium, nickel, vanadium is lower than the clark content. Comparison of the content of gross forms of trace elements with maximum permissible concentrations showed that the content of nickel, vanadium, cobalt is lower than the maximum permissible concentration. The distribution of the gross forms of the elements along the soil profile is heterogeneous. The maximum content in the profile of sod-podzolic soils falls on the humus horizon, which is associated with the biogenic accumulation of these elements.

1. Introduction

The Timiryazev Academy of Forest Experimental District is located almost in the center of the city of Moscow. Surrounded on all sides by residential areas, industrial buildings, roads and railways, the territory of the Forest Experimental District significant anthropogenic pressures. For the townspeople, the Forest Experimental District is a favorite place to visit, so this area experiences, along with man-made and large recreational loads [1].

Currently, on the territory of the Forest Experimental District there are more than 100 existing permanent trial plots laid at different times by leading forestry scientists of Russia. For more than 100 years, these monitoring sites have been continuously monitoring the growth and development of forest stands.

It is known that in conditions of environmental pollution, two main closely interconnected processes occur: a decrease in growth and an increase in the decay of trees [2]. Conifers contain less heavy metals than hardwoods. Pine needles contain 2-8 times less heavy metals than birch, but the first dies with a significantly lower content of heavy metals than the second. Heavy metals fall from the air to the vegetation cover and are washed away from there into the soil [3]. When heavy metals enter the surface of sod-podzolic soil, first of all, metals come into contact with a layer of forest litter, which, on the one hand, can be identified as a trap for heavy metals. On the other hand, the saturation of the litter with water-soluble organic compounds promotes the transformation of metals into a more migratory-active form. The development of a soddy soil-forming process leads to the accumulation of toxicants in horizon A1. They precipitate there also in connection with the neutral reaction of the medium in this
horizon. The combination of the processes of aerial and biological accumulation of heavy metals and their elution leads to their redistribution along the soil profile [4].

But how applicable are these findings to the territory located in a large metropolis? How does anthropogenic impact on clean and mixed stands occur? There is a close relationship between soil and woody plants; therefore, the study of the technogenic impact on the soil-plant system has important theoretical and practical significance. The results of observations over more than 150 years make it possible, on the one hand, to assess the stability of stands against the powerful press of the city, on the other hand, they can be used to solve landscaping of the territory of Moscow.

2. Methodology
The object of research was the permanent trial plots located in the 7th and 8th quarters of the Forest Experimental District. The characteristics of the test areas are shown in table 1.

| Trial plot | Stand composition | Site index | Age, years | Soil              |
|------------|-------------------|------------|------------|-------------------|
| 8/Н        | 80 % Oak,         | II         | 110        | Sod-podzolic sandy loam |
|            | 20 % Linden       |            |            |                   |
| 7/II       | I: 100 % Larch    | Ia         | 130        | Sod-podzolic loamy |
|            | II: 40 % Elm,     |            |            |                   |
|            | 40 % Acer,        |            |            |                   |
|            | 20 % Linden       |            |            |                   |
| 7/E        | I: 60 % Larch,    | II         | 130        | Sod-podzolic gley loamy |
|            | 20 % Acer,        |            |            |                   |
|            | 10 % Scots Pine,  |            |            |                   |
|            | 10 % Linden       |            |            |                   |
|            | II: 80 % Acer,    |            |            |                   |
|            | 20 % Elm          |            |            |                   |

Soil sections were laid on the test plots, morphological descriptions of soil profiles with the definition of a classification name were carried out. Soil samples were taken along genetic horizons for subsequent analytical research in the laboratory. Laboratory and analytical studies were performed at the Department of Soil Science of the Russian State Agrarian University - Moscow Timiryazev Agricultural Academy according to the methods adopted in accordance with state standard (GOST).

The soil cover of the trial plots is represented by soddy-podzolic soils, differing in the degree of manifestation of the soddy soil-forming process (power soddy and deep-soddy), in the intensity of the podzolic process (medium and strongly podzolic), in the depth of podzolization (deep-podzolic). All soils belong to the variety - light loam. Soil-forming rock - moraine deposits of sandy loam and light loam granulometric composition.

Test plots are located on the top and the hillside of the eastern exposure. Trial area 7/E is located on the top of a moraine hill (175 m above sea level), 7/II on the top of the slope (174 m above sea level) and 8/II in the lower part of the slope (168 m above sea level).

Soddy-podzolic soils are characterized by the presence of an extended humus horizon \((A_1'+A_1'')\) with a humus content of 2.82 to 5.67 % in the \(A_1'\) horizon and 1.18 to 3.20 in the \(A_1''\) horizon. The \(A_2\) podzolic horizon lies deep, below 31 cm, and its lower boundary is located at a depth of 46 cm. The soils are strongly acidic over the entire profile, the amount of exchange bases ranges from 5.90 to 16.43 mEq. per 100 g, hydrolytic acidity from 1.88 to 9.19 mEq. per 100g, the degree of saturation ranges from 63 to 85 %. The content of mobile phosphorus ranges from 24.5 to 345 mg/kg, exchange potassium from 65 to 75 mg/kg.

A comparative assessment of the physicochemical properties of soils under the studied stands showed that soils under complex pure plantations are characterized by a higher humus content (5.67%), less than 5.15% in soils under complex mixed stands, the thickness of humus horizons is
In soils under simple mixed stands, the humus content is much lower - 2.82%, the thickness of the humus horizon is 31 cm, soils are characterized by a higher content of hydrolytic acidity (9.19 mEq. and 100 g), whereas in a complex mixed soil (2.63 meq. per 100 grams), under pure complex (1.88 meq. per 100 grams) below it. The number of exchangeable bases in soils under simple mixed stands (5.90 mEq per 100 g), under complex pure and mixed soils (16.43 and 15.83 mEq per 100 g). A very low content of mobile phosphorus is determined in soils under complex mixed stands (24.5 mg / kg), under complex clean and simple mixed stands, respectively 345 and 146 mg / kg. No differences were found in the content of metabolic potassium.

The determination of the gross composition of soils in areas under different stands did not reveal any differences. The nature of the distribution of gross SiO\textsubscript{2}, R\textsubscript{2}O\textsubscript{3} and sludge fractions is a clear confirmation of the manifestation of the podzolic soil formation process. The profile of sod-podzolic soils revealed a distinct accumulation of SiO\textsubscript{2} in the upper part of the profile, the removal and accumulation of R\textsubscript{2}O\textsubscript{3} and silt in horizon B, which confirms the position that this type of soil is formed with the participation of sod and podzolic soil-forming processes. The data obtained do not confirm the opinion that under coniferous stands more favorable conditions are created for the manifestation of the podzolic process.

3. Results and discussion

The content of heavy metals in soils depends on many factors: on the particle size distribution, physicochemical properties of soils, distance from the source of pollution, and so on. The closest location to the road (Timiryazevskaya street) has a test area of 8/Н (250 m), the remaining test areas are at a more remote distance (the farthest test area is 7/П (500 m). Table 2 presents the Clarke content of the element, the regional background for sod-podzolic soils, and the maximum permissible concentrations of these elements [5].

| Trial plot | Soil horizon | Cr  | Ni  | Cu  | Zn  | Pb  | V   | Co  | Sr  | As  |
|------------|--------------|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| 7/II       | A\textsubscript{1} | 87.7| 39.0| 39.2| 95.6| 146.7| 89.4| 13.6| 120.2| 32.3|
|            | A\textsubscript{1}'' | 87.8| 42.9| 45.9| 68.9| 36.9| 95.7| 14.2| 124.9| 13.8|
|            | A\textsubscript{2} | 70.9| 15.8| 19.5| 33.0| 67.5| 79.3|  8.4| 147.5| 20.7|
|            | B             | 89.9| 41.9| 21.7| 55.3| 89.7| 84.2|  7.6| 120.0| 19.7|
|            | C             | 89.2| 36.4| 28.3| 57.2| 97.1| 92.2|  5.9| 130.0| 19.1|
| 7/E        | A\textsubscript{1} | 70.7| 23.6| 33.8| 61.1| 45.4| 90.7| 11.3| 121.1| 16.9|
|            | A\textsubscript{1}'' | 68.8|  8.4| 17.3| 50.8| 24.4| 93.3|  9.0| 121.0| 12.4|
|            | A\textsubscript{2} | 61.4| 20.1| 25.1| 33.4| 81.2| 83.8| 10.9| 121.1| 24.1|
|            | B             | 74.4| 20.5| 24.2| 37.3| 40.0| 90.0| 14.3| 125.7| 19.4|
|            | C             | 81.9| 38.8| 40.1| 56.0| 19.9| 94.3|  8.2| 133.6| 12.1|
| 8/H        | A\textsubscript{1} | 112.1| 9.8 | 84.1| 123.9| 153.6| 126.3|  9.7| 116.1| 29.6|

As can be seen from the data in Table 2, for a number of elements, the background content of Ni, Cu, Zn, Pb exceeds their Clarke content. The maximum permissible concentrations of elements significantly exceed the background content in sod-podzolic soils. Data on the gross content of trace elements are presented in table 3.
Comparison of the content of gross forms with the clark content of trace elements in the soil profile of the trial plots revealed a significant excess for the following elements: copper, zinc, lead, arsenic. The content of chromium, nickel, vanadium is lower than the clark content.

Comparison of the content of gross forms of trace elements with maximum permissible concentrations revealed a significant excess of this indicator for lead and arsenic under complex stands, under simple mixed ones - for copper and zinc. The total content of nickel, vanadium, cobalt is below the maximum permissible concentration.

The distribution of the gross forms of the elements along the soil profile is heterogeneous. The maximum content in the profile of sod-podzolic soils of the trial plots of the Forest Experimental District falls on the humus horizon, which is associated with the biogenic accumulation of these elements. The content of gross forms of zinc, copper, lead, vanadium and chromium under simple mixed stands is higher than under complex mixed and pure stands. For other elements (Ni, Co, Sr, As), there is no dependence of accumulation on the composition of the wood tree.

4. Conclusions

The content of gross forms of zinc, copper, lead, vanadium and chromium under simple mixed stands is higher than under complex mixed and pure stands. The contents of the gross forms of lead and copper are higher than the maximum permissible concentrations in the soils of the trial plots under complex clean and mixed stands. Under simple mixed stands, an excess of the maximum allowable concentrations for copper and zinc was revealed. The gross content of nickel, vanadium, and cobalt in the sod-podzolic soils of the Forest Experimental District is below the maximum permissible concentration.

References

[1] Dubenok N N, Kuzmichev V V and Lebedev A V 2018 Forest area dynamics of the Experimental Forest District of Russian Timiryazev State Agrarian University over a period of 150 years Izvestia Timiriazevskoy selskohozajstvennoy akademii. 4 5-19
[2] Frisvoll A A and Presto T 1997 Spruce forest bryophytes in central Norway and their relationship to environmental factors including modern forestry Ecography. 20 3-18
[3] Gracheva N M 1992 The influence of anthropogenic pollution on the forest-growing properties of sod-podzolic (Moscow: Moscow Order of Lenin and The Order of Labor of The Red Banner Timiryazev Agricultural Academy)
[4] Sazonov R N 2000 Ecological resistance of soils of LOD MSHA to anthropogenic loads (Moscow: Dios) p 115
[5] Kuznetsov A V et al. 1992 Guidelines for the determination of heavy metals in farmland soils and crop production (Moscow: QINAo) p 61