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Development of Soils Containing Heavy Metals in Southwestern Administrative District of Moscow

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***Abstract* — The article presents the results of ecological and geochemical assessment of the soils of the South-Western administrative district of Moscow on the content of heavy metals. In general, a satisfactory environmental situation was observed. However, in the territories subjected to industrial zones, there was an excess of background concentrations of heavy metals. In the course of the research, 6 clusters representing different types of heavy metals assemblages were identified.**

Keywords—pollution, heavy metals, industrial impact, direct and indirext effect, metals assemblage.

I. Introduction

During the process of urbanization, a new natural-urban system is being formed, consisting of natural ecosystems, industrial zones, highways etc. Anthropogenic disruption of the functional cycle of substances in urban ecosystem is largely determined by the source of impact, and the disruption of ecological balance primarily affects the soil, since it is the main receiver and accumulator of toxic elements [13, 4, 7]. Being in the conditions of the city, the soil is experiencing a powerful anthropogenic impact. One of the components of this impact is pollutants, including heavy metals.

Heavy metals are among the main pollutants of atmospheric air, soil and water of reservoirs on a global and regional scale, which is largely determined by their biological activity [14, 2]. They are stable in the environment, they able to accumulate in the tissues of living organisms and transmit through food chains [14, 6].

As a result of pollution, there is a change not only in physical properties (porosity, bulk density), but also a drastic change in the chemical properties of the soil [10, 11, 8, 9, 3].

The soils of the city perform important ecological functions - this is the environment for the development of plants with anti-noise effect, absorbing the excessive intensity of electromagnetic fields, which are part of phyto-design and, above all, purifying the air.

Contaminated soils have both direct and indirect effects on the health of citizens. Indirect exposure manifests itself in secondary pollution of adjacent environments, possibly in inhalation exposure (inhalation of contaminated soil dust) [1].

The purpose of our research was to assess the state of the soils of the South-Western administrative district of Moscow on the content of heavy metals and to conduct cluster analysis on the total pollution indicator and the concentration index of heavy metals in the soil.

II. Methods and materials

The basis for complex research was presented by the methodology of ecological and geochemical monitoring of territories, taking into account regional factors.

In ecological conditions of Moscow, specific soil groups and complex soil cover are formed. This process is aggravated by the considerably dissected relief of the territory, which creates differences in the conditions of drainage and the nature of the wetting of individual regions. The complexity of the soil cover is conditioned by the difference in the age of the territories: from the ancient city center with the formation of soil on a powerful cultural layer to new areas of residential construction, where soil formation develops on fresh embankments or mixed soils.

The contrast and heterogeneity of the soil cover are also reasoned by the complex history of the city's development and the intertwining of the buried uneven historical soils and cultural layers.

The major part of the study area is a hilly gently sloping plain, composed of moraine and cover loam. The soil cover (SC) of the hilly hollow-ridge watershed is formed on the moraine and surface loams, partially covered by sandy layer, and occupies about 24% of the city. This SC is distributed in the southwestern, southern, partly in the northern areas of the city.

In the residential zone (14%), poorly, moderately humus and poorly medium-power urbanozems are widespread. Urbanozems in the central part of the city are formed on the cultural layer; large areas are occupied by sealed soils - ecranozems [12].

In the industrial zone (5%), the soils are chemically polluted by industrial plants on bulk and imported soils, urbanozems are partially preserved, peat - bog soils are widespread in depressions.

Intrusems (around some gas stations) are fragmented in small areas, in the areas of new buildings - replantozem. The best-preserved SC is represented in urban forests and forest parks, where sod-podzolic and sod-urban-podzolic soils are common on moraine and integumentary loam, and in lowlands - peat-bog and sod-podzolic soils of gleic and gleic soils [12].

Mixed soil samples were taken in accordance with all-union State Standard 17.4.4.02-84 [5] in several functional areas of the city: lawns along highways with different carrying capacity, landscaped public gardens, courtyards of residential houses, and territories of forest-park zones. A total of 30 soil samples were selected. The sampling sites are shown in table 1.

TABLE I. THE PLACES OF SOIL SAMPLES SELECTION

The address of the places of soil samples selection		
1. Academician Glushko St.12	11.Project pass way №680	21. Novoyasenevsky avenue, 12
2. Koktebel St., 8	12. Bitsevsky forest, 3rd quarter	22. Lenin avenue, 43
3. Ivan Tyulenev St., 5, .1	13. Bitsevsky forest, 15th quarter	23. Vavilov St., 17
4. Butovsky forest	14. Bitsevsky forest, 26th quarter	24. Sevastopol avenue, 17A, 1
5.Profsoyuznaya St.,.43, 1	15. Balaklavsky avenue	25. Lenin avenue, 74
6. Square, 23rd quarter of New Cheryoumushki	16. Soloviiny avenue	26. Lenin avenue, 109
7. Profsoyuznaya, 43	17. Profsoyuznaya St., 86	27. Chechyorsky avenue, 31
8. Northern side of MRHW, 35th km	18. Namyotkin St., 10, 1	28. Admiral Lazarev St., 50
9. Yasenevsky forest and park	19. Profsoyuznaya St., 77	29. Ostafievskaya St., 8
10. Southern side of MRHW, 35th km	20. Profsoyuznaya St., 142, 1	30. Krasnolimanskaya St., 21

At ecological and geochemical indication of soil pollution one of the most common indicators is the total rate of soil pollution (TRSP) relative to the background level proposed by Y. Saet.

TRSP is calculated by the formula: TRSP = ∑Ks- (p-1),

where Kc = C / Sf is the concentration coefficient,

Ci - the content of the element in the object under study,

Cf - the background content of the element,

p- is the number of elements.

The determination of background concentrations is the main problem in the assessment of the contamination of a territory by TRSP. Considering that there are practically no areas on the territory of Moscow that have not undergone an anthropogenic change, we took the minimum values for each of the elements as background: for Zn - 18.7 ± 1.41; Pb - 3.83 ± 0.35; Cu - 5.0 ± 0.5; Cd - 0.03 ± 0.01 Cr 8.33 ± 0.6 mg / kg of soil.

The analysis of the content of heavy metals in the soil was carried out in the branch of the Federal Budgetary Healthcare Institution “Sanitary and Epidemiological Center of Moscow” using atomic absorption spectrometry, on spectrometers “KVANT-AFA-A” and “KVANT-Z.ETA”.

III. RESULTS

On the basis of the research results, it is possible to ascertain the uneven spatial distribution of heavy metals in the soil, especially for cadmium, the content of which in some areas varied by more than 140 times (Table IV). For zinc, the excess of the minimum value was more than 20 (Table II), for lead - 11 times (Table III).

TABLE II. THE CONTENT OF ZN IN THE SOIL OF INVESTIGATED TERRITORIES, MG/KG

№ of site	Zn	№ of site	Zn	№ of site	Zn
1	59.6 ± 4.5	11	77.1 ± 5.8	21	85 ± 6.5
2	65 ± 5	12	17 ± 1.3	22	100.7 ± 7.6
3	60.6 ± 4.6	13	19 ± 1.4	23	121.9 ± 9.2
4	38.2 ± 2.8	14	18.7 ± 1.4	24	132.5 ± 10
5	12 ± 0.9	15	34.7 ± 2.6	25	85.2 ± 6.4
6	11 ± 0.8	16	33.3 ± 2.5	26	86.3 ± 6.5
7	84 ± 6.3	17	85.4 ± 6.4	27	39.9 ± 3
8	111.3 ± 8.4	18	88.4 ± 6.7	28	24.6 ± 1,9
9	83.72 ± 6.3	19	78.4 ± 5.9	29	6.5 ± 0.5
10	75.02 ± 5.7	20	49.5 ± 3.7	30	7.8 ± 0.6

According to the TRSP values, the areas of the South-Western Administrative District studied by the authors have the following degree of contamination: very weak (TRSP <8) - 2 sites, weak (TRSP 8-16) - 6, moderate (TRSP 16-32) - 8, severe pollution (TRSP 32- 64) -3; high (TRSP 64-128) - 9, extremely high (TRSP > 128) - 2 sites.

TABLE III. THE CONTENT OF PB IN THE SOIL OF INVESTIGATED TERRITORIES, MG/KG

№ of site	Pb	№ of site	Pb	№ of site	Pb
1	8.89 ± 0.9	11	12.95 ± 1.3	21	15.7 ± 1.5
2	7.2 ± 0.7	12	11.8 ± 1.1	22	14 ± 1.4
3	16.72 ± 1.6	13	11.2 ± 1	23	28 ± 2.7
4	12.06 ± 1.2	14	11.2 ± 1.08	24	31.9 ± 3.1
5	4.5 ± 0.4	15	27.7 ± 2.7	25	10.5 ± 1
6	4 ± 0.4	16	16.3 ± 1.6	26	12 ± 1.2
7	9 ± 0.9	17	12.9 ± 1.2	27	13.7 ± 1.3
8	17.94 ± 1.7	18	13.1 ± 1.3	28	8.7 ± 0.8
9	13.22 ± 1.3	19	12.7 ± 1.2	29	2.9 ± 0.3
10	10.37 ± 1	20	3.7 ± 0.4	30	4.7 ± 0.5

TABLE IV. THE CONTENT OF CD IN THE SOIL OF INVESTIGATED TERRITORIES, MG/KG

в.№ of site	Cd	№ of site	Cd	№ of site	Cd
1	1.08 ± 0.1	11	0.02 ± 0.001	21	0.03 ± 0.001
2	0.01 ± 0.001	12	0.096 ± 0.004	22	0.72 ± 0.03
3	0.01 ± 0.001	13	0.16 ± 0.007	23	0.98 ± 0.05
4	0.609 ± 0.03	14	0.25 ± 0.01	24	1.4 ± 0.06
5	0.1 ± 0.005	15	0.16 ± 0.007	25	0.68 ± 0.03
6	0.08 ± 0.004	16	0.3 ± 0.01	26	0.66 ± 0.03
7	0.6 ± 0.03	17	0.67 ± 0.03	27	0.619 ± 0.02
8	0.04 ± 0.002	18	0.58 ± 0.03	28	0.01 ± 0.001
9	0.01 ± 0.001	19	0.33 ± 0.02	29	0.01 ± 0.001
10	0.02 ± 0.001	20	0.01 ± 0.001	30	4.7 ± 0.5

It is necessary to note that the sites belonging to the dangerous and extremely dangerous category of pollution are located near the industrial zones Vorontsovo, Donskaya street, Cheryomushki.

Depending on the main sources of heavy metal intake, the various assemblages of heavy metals in soils can form in different areas, i.e. the territory differs not only by the level of pollution, but also by the prevalence of one or another element. (Fig. 1).

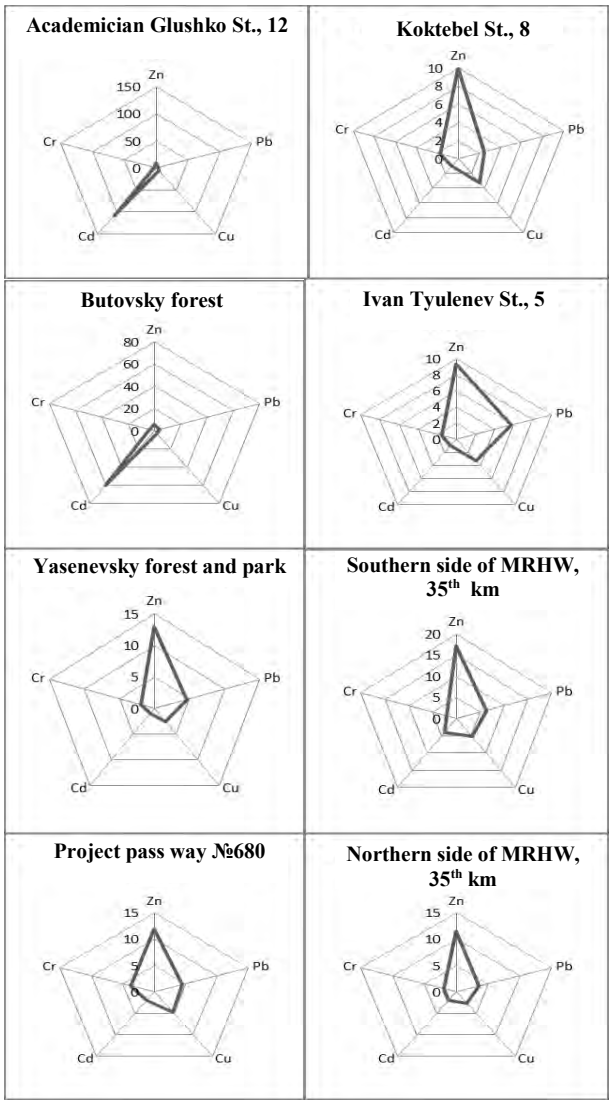

Fig. 1. The assemblages of heavy metals in soils of South-West Administrative district.

It is possible to distinguish groups of points with similar assemblages of heavy metals. In order to achieve this, the data obtained was divided into clusters (STATISTICA program). As the main parameters affecting the division into clusters, the overall level of pollution and the ratio between heavy metals in the composition of pollution were chosen. In total, 6 clusters (groups) were determined (Fig. 2), representing different types of heavy metals assemblages.

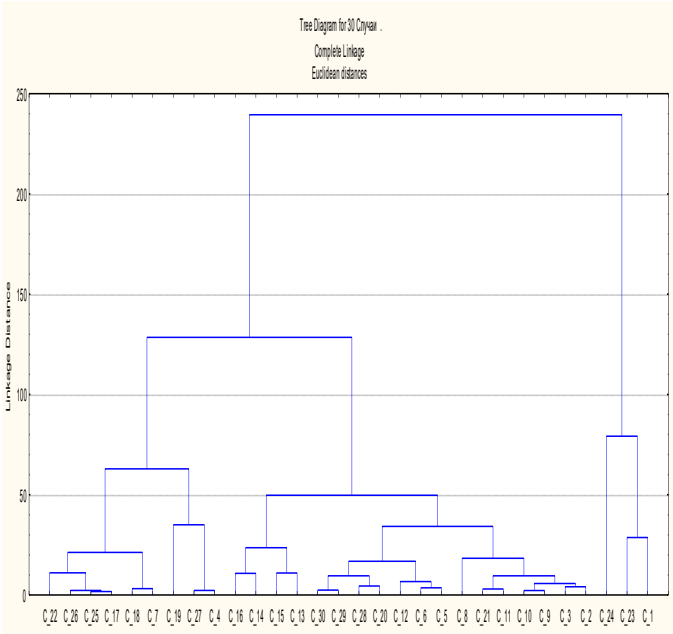

Fig. 2. The division of soils of of South-Western Administrative district into cluster in accordance with the concentration of heavy metals

The first group combined 6 points (22, 26, 25, 17, 18, 7) with a high degree of pollution (TRSP = 106, 97, 98, 99, 91, 89, respectively). In these areas, a high concentration of cadmium compared to the background. These points are located near the roads in the northwestern part of the district and border the industrial areas of Vorontsovo and Donskaya streets.

The second group includes 3 points (19, 27, 4) with a total pollution indicator exceeding 50, but less than 80 (TRSP = 57, 75, 73, respectively). Two sites adjoin the roads (green area); one is located near the park. These points are also characterized by a high concentration of cadmium compared to the background and other elements.

The third group includes 4 points (16, 14, 15, 13) with moderate and high degree of pollution (TRSP = 41, 32, 31, 22), in which cadmium also makes the main contribution to TRSP, but its concentration coefficient is significantly lower than 16 to 30. The sites are located on the border and directly in Bitsevsky Forest.

The fourth group included most of the points, namely 14 (30, 29, 28, 20, 12, 6, 5, 8, 21, 11, 10, 9, 3, 2). These sites are characterized by moderate, low and very low degree of pollution; TRSP on these sites has a maximum value of 31, minimum - 1. These points are located in the north of the central part of the district, in the center and in the south, i.e. occupy most of the territory.

The fifth group included one site No. 24, located in the north of the South-Western Administrative Area between two industrial zones Donskaya Streets and Cheryomushki. The highest TRSP is noted at this point, the level of soil contamination is very high, and the concentration coefficient of cadmium is 140.

The sixth group consists of two points (№№ 23,1), TRSP is 145 and 125 units, respectively.

IV. Conclusion

The environmental situation in big cities is formed by a large amount of emissions of pollutants from industrial plants, vehicles, powerful heat and power plants, household and industrial wastes. The current state of the environment in industrialized regions and cities is characterized by a significant anthropogenic load. In the complex of harmful substances there are substances of 1-2 hazard classes with allergic, carcinogenic, embryo-toxic effects on a living organism, for example heavy metals.

Our research showed that most of the territory of the South-Western Administrative District of Moscow is characterized by a satisfactory environmental situation (TRSP <32), two sites have an extremely dangerous level of pollution (TRSP > 128), these sites are located in the northern part of the South-Western Administrative District near the Don skaya and Cheryomushki streets of industrial zone. In the course of the research, 6 clusters representing different types of heavy metal assemblages were identified. The largest cluster consists of 14 points, with similar heavy metal assemblages and TRSP, not exceeding 31. The clusters characterized by a high and very high degree of pollution are subjected to roads and industrial zones.

In order to improve the efficiency of using the soils of Moscow, taking into account the level of their pollution and its reduction, it is necessary to apply selective processing systems, integrated protection of soils and plants, fertilizer system, crop change systems and their spatial distribution.

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