Consideration of soil quality in landscape and urban planning (by the example of Saint-Petersburg)

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Abstract. The article considers peculiarities of the urban environment, factors of negative influence on soils and green plantations which should be treated in landscape and urban planning process. The basic properties of urban soils, their pollution by heavy metals, pesticides benzo(a)pyrene are highlighted. The general requirements to the urban soils for creation of green plantings in megacities are formulated.

1. Introduction

The beginning of the design of parks, gardens, squares, street landscaping and other facilities is preceded by engineering and environmental surveys. They are performed to assess the current state and forecast possible changes in the environment under the influence of anthropogenic impact in order to prevent, minimize and eliminate unwanted environmental consequences.

Consideration of soil characteristics at the design stage is a necessary state for ensuring good growth and the condition of urban vegetation.

Urban soils are an important and integral part of the urban environment. They largely determine the possibility of creating and functioning of green spaces [1, 2]. In the urban environment the imposition of anthropogenic factor on the natural processes of soil formation takes place. Natural soils in the territory of St. Petersburg during its construction and development have been destroyed or undergone radical changes. They differ significantly from forest and agricultural land. The formation of soil cover in the megacity has specific features: There is filling and cutting of soils, mixing of soil horizons, accumulation in the surface layer of products of city life. The main transformations of urban soils, primarily due to the influence of industrial enterprises and transport are considered on the example of the soils of St. Petersburg.

The research has shown that in the real conditions of a big city with a diversified industry, the accumulation of pollutants and their effect on soil and vegetation is characterized by considerable complexity and heterogeneity and is highly dependent not only on the emission sources, such as industrial enterprises and transport, but also such parameters of soils as the content of organic matter, cation exchange capacity, pH value, particles size composition. Some substances accumulate in soils as a result of washing out from an atmosphere, the others do not linger in it and migrate along a soil profile, the third are subjected to degradation or transformation [3].
2. Methods and Materials
The object of the study was the soil of St. Petersburg, samples of which were selected at various sites.

The specific features of urban soils are characterized by a violation of the natural addition of soil profile in the construction of roads, laying underground utilities. Therefore in the conditions of the city the following is very important: high quality and the same-type sampling, representativeness of the combined sample, correct use of physico-chemical and biological methods of analysis, allowing to receive reliable qualitative and quantitative information on the presence of polluting substances in the soil and objectively assess the degree of its ecological condition. The reproducibility of both sampling and analysis should be ensured.

In our opinion, sampling for pollution control and assessment of the qualitative condition of urban soils of natural and disturbed addition should be carried out simultaneously for the definition of chemical, bacteriological and helminthological indicators.

During the research we have developed and adopted as a basis, not contrary to GOST 17.4.4.02-84, the following method of sampling, uniform for all objects of landscaping-parks, squares, gardens, transport highways, courtyards in residential areas, departmental territories. Samples were selected by two titanium soil drills in compliance with aseptic conditions (the washing of drills with distilled water and sterilizing by flaming of burning alcohol after taking samples at each site was carried out). The combined samples were made of 30–35 individual (spot) samples, taken from depths of 0–5 cm, and 17–20 samples, taken from the depth of 5–20 cm. Points of selection of individual (spot) samples were evenly placed throughout the territory of the landscaping object. Only in large parks sampling was carried out in a separate part of the park with the record of the location of the selection points. On the median strips of highways and adjacent areas of lawns, sampling was carried out on the plots of 100–200 meters length with the record of the street name and house numbers, in the neighborhoods (courtyards areas) street name, building and house numbers were indicated.

Soil samples intended for chemical analysis in laboratory conditions dried to air-dry state according to GOST 5180-84, purified from inclusions (roots of plants, insects, stones, glass, etc.), rubbed, kernelled through a sieve with cells 1 mm and subjected to analysis. To determine the content of heavy metals the soil samples were additionally rubbed up to powder condition. To control the correctness of the analysis results in determining the content of heavy metals in the soils we used soil standards, i.e. samples of sod-podzolic soils with a known number of defined elements. This method of selection and subsequent analysis allows to increase the representativeness of the sample and to avoid significant material and labor costs for carrying out the analyses. It allows to characterize the level of soil contamination of each landscaping object.

3. Results and Discussion
Soils are a depositing environment in relation to the many pollutants present in the emissions of industrial enterprises and transport. One of the reasons for the degradation of urban soils is the negative effects of gases, aerosols and suspended particles settling from polluted air. Reverse transfer of contaminants from the soil into the air is possible when raising dust. We consider the following factors determining the intensity of the dust drift in urban conditions:

1. Climatic or Weather — formation and transfer of dust is possible only in dry, windy weather.
2. City-forming and Landscape — dustiness of air arises in the absence of wind-proof obstacles (building structures, woody vegetation, etc.).
3. Soil — structural state (aggregate composition) and soil moisture
4. The factor of Ecological and hygienic state of the territories — formation and transfer of dust is determined by the degree of soil vegetation coverage, the condition of lawns and roadways of traffic arteries, as well as the general content of toxic substances in the dust.

In St. Petersburg, soils for establishing green areas, creation of parks, squares, gardens, landscaping the streets and courtyards have been imported from country places and are relatively clean, taken from former agricultural lands reassigned for development. Removal of the top fertile layer and its export to
the objects of landscaping is carried out. The creation of green areas of new microdistricts is carried out by applying imported vegetative soil on existing (local) mineral ground.

A comprehensive ecological assessment of the soils of the green areas of St. Petersburg was carried out [3]. The content of heavy metals, benzo (a) pyrene, pesticides (plant protection products), as well as the reaction of the environment, the content of humus, the main plant nutrients and other indicators were determined in the soils. When sampling the soil, the condition of woody, shrub and herbaceous vegetation was recorded. Ecological and geochemical assessment of soil condition was carried out by comparison of indicators with background and average numerical values, as well as with approved standards of MPC (maximum permissible concentrations) and APC (approximate permissible concentrations). Table 1 shows the numerical values of the background concentrations of chemical elements in zonal sod-podzolic soils, as well as the prevalence (average content — clarks) of elements in lithosphere and soil according to the method A P Vinogradov and D P Maljuge. [4].

**Table 1.** Background and average content of chemical elements in sod-podzolic soils, mg/kg.

| Chemical Element | Element Hazard Class | Background content of elements in sod-podzolic soils\(^a\) | Average content in soil/lithosphere [4] |
|------------------|----------------------|------------------------------------------------|----------------------------------------|
|                  |                      | For the middle band of Russia [5] Moscow Region St.-Petersburg |                                       |
| Zn               | 1                    | 28/45 50 | 43/73 | 50/85 |
| As               | 1                    | 1.5/2.2 6.6 | 2.62 | 5/1.7 |
| Cd               | 1                    | 0.05/0.12 0.3 | 0.17 | 0.5/0.13 |
| Pb               | 1                    | 6/15 26 | 17/21 | 0.5/1.7 |
| Hg               | 1                    | 0.05/0.1 0.15 | 0.03 | 0.01/0.083 |
| Cu               | 2                    | 8/15 27 | 18/23 | 20/47 |
| Co               | 2                    | 3/10 7.2 | 4.6/5.3 | 10/18 |
| Ni               | 2                    | 6/30 20 | 19/24 | 40/58 |
| Cr               | 2                    | - 46 | 13/34 | 200/83 |
| Mn               | 3                    | - | 600/1260 119/471 | 850/1000 |
| V                | 3                    | - | 83 | 16.2 | 100/90 |

\(^a\) Background concentration of elements are given in the numerator for sand and sandy soils, in the denominator — for clay and loamy soils. For the soils of the Russian middle band values are given in accordance with SP 11-102-97 [5].

A. Kabata-Pendias and X. Pendias [6-10] summarize the data from a number of sources about the total concentrations of microelements in soils, considered to be the limit in relation to phytotoxicity (Table 2). It should be noted that the given concentrations of elements in table 2 differ from one source to another by 3, 5 and more times. This seems to be due to the fact that the studies were conducted in different climatic conditions, on different types of soils with various degrees of their cultivation and regime of their use, as well as with different species of plants with individual level of resistance to a particular chemical element.
Table 2. Total concentrations of microelements in the surface layer of soils considered to be the limit for phytotoxicity (mg/kg of dry mass (cited by A. Kabata-Pendas, X. Pendias [6])

| Element    | Kovalskiy, 1974 | El-Bas-Sam, 1977 | Kabata-Pendas, 1979 | Linzon, 1978 | Kloke, 1979 | Kita-Gishi, 1981 |
|------------|-----------------|------------------|---------------------|-------------|-------------|------------------|
| Silver     | -               | -                | 2                   | -           | -           | -                |
| Arsenic    | 30              | 100              | 100                 | 75          | 100         | 100              |
| Bor        | 30              | 100              | 100                 | 100         | 100         | 100              |
| Beryllium  | 30              | 100              | 100                 | 75          | 100         | 125              |
| Bromine    | 30              | 50               | 50                  | 25          | 50          | 50               |
| Cobalt     | 30              | 50               | 50                  | 25          | 50          | 50               |
| Chrome     | 30              | 50               | 50                  | 25          | 50          | 50               |
| Copper     | 30              | 50               | 50                  | 25          | 50          | 50               |
| Fluoride   | 30              | 50               | 50                  | 25          | 50          | 50               |
| Mercury    | 30              | 50               | 50                  | 25          | 50          | 50               |
| Manganese  | 3000            | 100              | 100                 | 100         | 100         | 100              |
| Molybdenum | 4               | 10               | 10                  | 2           | 5           | 5                |
| Nickel     | 4               | 10               | 10                  | 2           | 5           | 5                |
| Lead       | 4               | 10               | 10                  | 2           | 5           | 5                |
| Antimony   | 4               | 10               | 10                  | 2           | 5           | 5                |
| Selenium   | 4               | 10               | 10                  | 2           | 5           | 5                |
| Tin        | 4               | 10               | 10                  | 2           | 5           | 5                |
| Thallium   | 4               | 10               | 10                  | 2           | 5           | 5                |
| Vanadium   | 4               | 10               | 10                  | 2           | 5           | 5                |
| Zinc       | 70              | 300              | 300                 | 400         | 300         | 250              |
Table 3. Summarized data of the contaminants content in the soils of various green areas in St. Petersburg (Organic matter).

| Objects of the Study                  | Number of addresses | Number of samples | Depth of sampling, cm | Organic matter<sup>a,b</sup> Amount of DDT metabolites, mg/kg | Benzo(a)-pyrene, μg/kg |
|--------------------------------------|---------------------|-------------------|-----------------------|---------------------------------------------------------------|-----------------------|
| Parks, gardens, squares              | 17                  | 561               | 0-5                   | 0.059-2.72                                                    | 0.048-2.98            |
|                                      |                     |                   |                       | 0.045-1.65                                                    | 0.030-0.75            |
| Highways                             | 9                   | 297               | 0-5                   | 0.040-1.70                                                    | 0.024-1.58            |
| Courtyard areas                      | 9                   | 153               | 5-20                  | 0.040-1.70                                                    | 0.039-1.40            |
| Departmental Territories (medical institutions, schools, etc.) | 8                   | 264               | 0-5                   | 0.039-1.40                                                    | 0.018-1.76            |
|                                      |                     |                   |                       | 0.018-1.76                                                    | 0.018-1.76            |

<sup>a</sup> in the numerator — the limits of oscillations, in the denominator — the average values

<sup>b</sup> MPC in soils of DDT and its metabolites – 0.1 mg/kg; MPC of benzo(a)pyrene — 20 μg/kg

The given data (Table 3, 4) indicate a different content of pollutants in the soils of the city. On the basis of the estimation of soil quality by objects categories (parks, gardens, squares; courtyard areas; highways; departmental territories) it was found that the greatest concentration of benzo(a)pyrene is recorded in soils of highways and public courtyards of residential areas, which is caused by emissions of polluting substances by internal combustion engines of vehicles, and the maximum amount of pesticides (plant protection products) is recorded in soils of green areas with growing tall trees. This is due to the increased standards of consumption of insecticides sprayed on tree crowns.
Table 4. Summarized data of the contaminants content in the soils of various green areas in St. Petersburg (Chemical elements).

| Objects of the Study | Number of addresses | Number of samples | Depth of sampling, cm | Chemical elements, mg/kg** |
|----------------------|---------------------|-------------------|-----------------------|-----------------------------|
|                      |                     |                   |                       | Pb  | Cu  | Zn  | Hg  | Cd  | Cr  |
| Parks, gardens, squares | 17                 | 561               | 0-5                   | 62-268 | 32-209 | 180-310 | 0.28-1.70 | 0.38-1.12 | 55-102 |
|                      |                     | 289               | 5-20                  | 46-290 | 30-245 | 185-400 | 0.25-1.80 | 0.29-1.18 | 61-107 |
| Highways             | 9                   | 297               | 0-5                   | 64-340 | 76-168 | 190-405 | 0.18-1.42 | 0.68-3.85 | 95-196 |
|                      |                     | 153               | 5-20                  | 57-371 | 72-198 | 202-410 | 0.21-1.74 | 0.65-3.90 | 102-202 |
| Courtyard areas      | 9                   | 297               | 0-5                   | 54-285 | 52-210 | 160-403 | 0.20-1.64 | 0.58-2.45 | 88-156 |
|                      |                     | 153               | 5-20                  | 65-315 | 54-270 | 140-397 | 0.29-2.0  | 0.72-2.78 | 90-162 |
| Departmental territories (medical institutions, schools, etc.) | 8 | 264 | 0-5 | 48-160 | 27-190 | 110-385 | 0.31-0.58 | 0.22-1.09 | 68-142 |
|                      |                     | 136               | 5-20                  | 46-148 | 28-196 | 112-378 | 0.27-0.73 | 0.25-1.20 | 78-140 |

* in the numerator — the limits of oscillations, in the denominator — the average values
** MPC in soils of DDT and its metabolites – 0.1 mg/kg; MPC of benzo(a)pyrene — 20 mg/kg

4. Conclusion

Consideration of soil quality in landscape and urban planning is the key issue in creating sustainable green areas in megacities.

Requirements for soil preparation, its nutritional quality and ecological status are crucial. High-quality soil preparation for creating green areas is a prerequisite for successful planting works and good growth of trees, shrubs, and lawn grass. When designing green areas, it is important to take into account the influence of industrial and transport emissions and the accumulation of pollutants in the city soils.

The most realistic way to ensure environmental safety is to maintain the quality of green spaces, to reduce the area of erosive and dust plots in the city, because of the areas covered with greenery, even contaminated, damage health of the population is less than that of polluted air.

Consideration should be given to the potential hazard of increased concentrations of pollutants in the soil, and to assess their health and environmental risks. It is necessary to predict the behaviour of polluting substances in the urban landscape, foresee the possible development of adverse environmental situations, develop and take measures to prevent them in a timely manner.

Based on the conducted research on the assessment of soil pollution, the basic methodical approaches to the planning of green areas and soil management are formulated. The most stringent requirements should be applied to soils of the following types (in descending order) 1) agricultural land (possible migration of polluting substances and elements in the food chain), 2) children's and medical institutions, 3) residential areas, 4) recreational zones, 5) suburban forests, 6) industrial and
transport zones. With other equal conditions within one group, the most stringent indicators should be for areas with high population density.

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