Anthropogenic pollution of big cities and its realization in soil-plant system (case study of Saint-Petersburg)

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Abstract. Soils in megalopolises are an integral part of urban environment. Soils determine the possibility of creating green spaces and their functioning. Accumulation of pollutants in urban areas is characterized by complexity and heterogeneity. Conducted studies have shown no direct correlation between the level of soil contamination and the condition of the vegetation in St. Petersburg. Soils of higher fertility although more polluted have lower negative effect on the plant growth. Species resistance to atmospheric pollution, level of soil preparation for planting, the timeliness and quality of maintenance are of particular importance. High-quality soil preparation, soil fertility and its ecological condition are determinative aspects of creating green spaces in megalopolises. Based on conducted studies, the main methodological approaches to the soil’s quality were formulated for different kind of use. The strictest quality requirements should be imposed on the soils of: 1) agricultural lands, 2) children's and medical institutions, 3) residential areas, 4) recreational areas, 5) suburban forests, 6) industrial and transport zones.

1. Introduction
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]. The combination of anthropogenic factor and the natural processes of soil is taking place in the condition of urban environment. Natural soils in the territory of St. Petersburg during city 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 urban environment is characterized by existing of numerous sources of pollution (industrial, transport, municipal), their uneven accumulation, a very complex spread of contaminants, inhomogeneity of soil and vegetation cover. Movement of air masses transporting technogenic aerosols in the city, in contrast to the country landscapes, is adjusted by the height and character of the building, the flow through the blocks and the streets direction, the ratio of paved and green areas, the possibility of blowing and washing away the dust containing contaminants from the roofs of buildings, roads and its relocation to other areas. In suburban conditions the exhaust gases of motor transport spread to the sides of the highway, and in the city, emissions stay between the walls near the houses,
additionally have a negative impact. The contribution of individual components of emissions with complex and diverse composition, to the pollution of the natural environment, including soil, varies.

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 industry and traffic, but also such parameters of soils as the content of organic matter, cation exchange capacity, pH value, granulometric composition. Some substances accumulate in soils as a result of an ingress with atmospheric precipitation, the others do not remain in it and migrate along a soil profile, the third undergo degradation or transformation [3].

2. Methods and Materials
The object of the research is soils of St. Petersburg, sampled at various sites.

The specific features of urban soils are characterized by a disturbance of the natural soil profile during site development, roads construction, laying underground communications, etc. 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 its ecological state. The reproducibility of both sampling and analysis should be ensured.

The state standard 17.4.2.01-81 "Nature protection. Soils. Nomenclature of sanitary condition indices" was put into circulation in Russia, providing control over the condition of soils and their protection from pollution [4]. According to the standard, 23 indicators should be controlled in soils, 19 of which are mandatory for populated areas.

To date, following standards in the area of soil protection have been put into circulation in Russia: Classification of chemicals for pollution control, general requirements for selection, methods of sampling and preparation of samples for chemical, bacteriological and helminthological analysis, general requirements to methods of determination of pollutants, etc. (GOSTs 17.4.3.01-83 [5], 17.4.1.02-83 [6], 17.4.4.02-84 [7], 17.4.3.03-85 [8], 17.4.4.04-85 [9], 17.4.3.06-86 [10]). In the practice of assessment of urban soils, the following documents developed by various institutes are used: "Methodical instructions on the assessment of urban soils in the development of urban planning, architectural and construction Documentation", (2003) [11]; "Recommendations for determining the level of pollution of urban soils and soils and conducting an inventory of areas requiring remediation" (2004) [12]; "Sanitary and epidemiological requirements for soil quality" (SanPin 2.1.7.1287-03) [13] and other regulations.

GOST 17.4.4.02-84 "Nature protection. Soil. Methods of sampling and preparation of samples for chemical, bacteriological, helminthological analysis" provides for sampling by different methods depending on the type of polluting substance [7].

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

During the research we have developed and taken as a basis, not contrary to GOST 17.4.4.02-84 [7], the following method of sampling, uniform for all green areas - parks, squares, gardens, transport highways, courtyard areas (intra landscaping), departmental territories. Samples were selected by two titanium soil drills in compliance with the conditions of aseptics (carried out washing of drills distilled water, burning alcohol after taking samples at each site). The combined samples were made of 30–35 individual (spot) samples, collected from depths of 0–5 cm, and 17–20 samples, collected from the depth of 5–20 cm. Points of collection of individual (spot) samples were evenly placed throughout the territory of the green area. Only in large parks sampling was carried out in a specific area with fixation of the location of the sampling points. On the highway’s median strips and adjacent areas of lawns, sampling was carried out on the plots of 100–200 meters length with a record of the street name and
house number, in the neighborhoods (courtyard areas) street name, building and house number were indicated.

To estimate the degree of migration of polluting substances the sections of soil were made. From the sections of soil samples were collected from different depths in order to trace the nature of the spread of contaminants: preferential accumulation in a surface layer vs washing down on a profile, and also to estimate the way of distribution of root systems of woody and herbaceous plants in soil layers, to study morphological structure of a soil profile.

Soil samples intended for chemical analysis in laboratory conditions dried to air-dry state according to GOST 5180-84 [14], purified from inclusions (roots of plants, insects, stones, glass, etc.), rubbed, kernelsed through a sieve with cells 1 mm and subjected to analysis. To determine the content of heavy metals soil samples were additionally rubbed up to powder condition. To control the correctness of the analysis results in determining the content in the soils of heavy metals 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 degree of soil contamination of each studied green area as a whole.

3. Results and Discussion
Soils are a depositing environment in relation to the many pollutants of industry and transport emissions. One of the reasons for urban soils degradation 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. Climate 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, trees and shrubs plantings, 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 quality of lawns and roadways of traffic arteries, as well as the general content of toxic substances in the dust.

In St. Petersburg, soils for creating green spaces: parks, squares, gardens, streets and courtyards have been imported from former agricultural lands, currently used for construction and are relatively clean. Removal of the top fertile layer and its export to the green areas is carried out. Creating green spaces in new microdistricts is carried out by covering existing (local) mineral soils by imported vegetative substrate.

A complex ecological assessment of the soils of the green spaces of St. Petersburg was carried out [3]. The content of heavy metal, benzo(a)pyrene, pesticides (means of protection of plants), also content of humus, nutrients and other indicators was defined in the soils. While sampling the state of trees, shrubs and herbaceous vegetation was recorded. Environmental-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 by A P Vinogradov and D P Maljuge [15].

A Kabata-Pendias and X Pendias [16] summarize the data of a number of authors on 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 in different authors by 3, 5 and more times. This seems to be due to the fact that the studies were conducted in different climatic conditions, types of soils, various intensity of soil cultivation, with different modes of land use, as well as with species of plants with different resistance to a particular chemical element.
Table 1. Background and average content of chemical elements in sod-podzolic soils, mg/kg$^a$.

| Chemical Element | Hazard Class | For the middle band of Russia [17] | Moscow Region | St. Petersburg | Average content in soil/lithosphere [15] |
|------------------|--------------|-------------------------------------|---------------|---------------|----------------------------------------|
| 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         | 10/16                                   |
| 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 concentrations 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 [17].

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-Pendias, X Pendias [16]).

| Element      | Kovalskiy, 1974 | El-Bas-Sam, 1977 | Kabata-Pendias, 1979 | Linzon, 1978 | Kloke, 1979 | Kita-Gishi, 1981 |
|--------------|-----------------|------------------|----------------------|--------------|-------------|-----------------|
| Silver       | -               | -                | -                    | 2            | -           | -               |
| Arsenic      | -               | 50               | 30                   | 25           | 20          | 15              |
| Bor          | 30              | 100              | 100                  | -            | 25          | -               |
| Beryllium    | -               | 10               | 10                   | -            | 10          | -               |
| Bromine      | -               | -                | 20                   | -            | 10          | -               |
| Cadmium      | -               | 5                | 5                    | 8            | 3           | -               |
| Cobalt       | 30              | 50               | 50                   | 25           | 50          | 50              |
| Chrome       | -               | 100              | 100                  | 75           | 100         | -               |
| Copper       | 60              | 100              | 100                  | 100          | 100         | 125             |
| Fluoride     | -               | 500              | 1000                 | -            | 200         | -               |
| Mercury      | -               | 5                | 5                    | 0.3          | 2           | -               |
| Manganese    | 3000            | -                | -                    | 1500         | -           | -               |
| Molybdenum   | 4               | 10               | 10                   | 2            | 5           | -               |
| Nickel       | -               | 100              | 100                  | 100          | 100         | 100             |
| Lead         | -               | 100              | 100                  | 200          | 100         | 400             |
| Antimony     | -               | -                | 10                   | -            | 5           | -               |
| Selenium     | -               | 10               | 10                   | 5            | 10          | -               |
| Tin          | -               | -                | 50                   | -            | 50          | -               |
| Thallium     | -               | -                | -                    | -            | 1           | -               |
| Vanadium     | -               | -                | 100                  | 60           | 50          | -               |
| Zinc         | 70              | 300              | 300                  | 400          | 300         | 250             |
Tables 3 and 4 summarize the content of contaminants in the soils of various landscaping sites in St. Petersburg.

**Table 3.** Content of organic matter in the soils of St. Petersburg.

| Objects of the Study                          | Number of addresses | Number of samples | Depth of sampling, cm | Organic matter |
|-----------------------------------------------|---------------------|-------------------|-----------------------|----------------|
|                                               |                     |                   |                       | Amount of DDT metabolites, mg/kg<sup>a</sup> | Benzo(a)pyrene, µg/kg<sup>b</sup> |
| Parks, gardens, squares                       | 17                  | 561               | 0-5                   | 0.059-2.72   | 43-370         |
|                                               |                     | 289               | 5-20                  | 0.048-2.98   | 44.8-360       |
| Highways                                      | 9                   | 297               | 0-5                   | 0.045-1.65   | 254-1425       |
|                                               |                     | 153               | 5-20                  | 0.03-0.75    | 259-1650       |
| Yard areas                                    | 9                   | 297               | 0-5                   | 0.040-1.70   | 280-1680       |
|                                               |                     | 153               | 5-20                  | 0.024-1.58   | 270-1620       |
| Departmental Territories                     | 8                   | 264               | 0-5                   | 0.039-1.40   | 43-320         |
| (medical institutions, schools, etc.)         |                     | 136               | 5-20                  | 0.018-1.76   | 44-315         |

<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

**Table 4.** Content of chemical elements in the soils of St. Petersburg.

| Objects of the Study                          | Number of addresses | Number of samples | Depth of sampling, cm | Chemical elements, mg/kg<sup>a</sup> |
|-----------------------------------------------|---------------------|-------------------|-----------------------|---------------------------------------|
|                                               |                     |                   |                       | 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 |
| Yard 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                     | 8                   | 264               | 0-5                   | 48-160       | 27-190 | 110-385 | 0.31-0.58 | 0.22-1.08 | 68-142 |
| (medical institutions, schools, etc.)         |                     | 136               | 5-20                  | 46-148       | 28-196 | 112-378 | 0.27-0.73 | 0.25-1.20 | 78-140 |

<sup>a</sup> in the numerator — the limits of oscillations, in the denominator — the average values.
The given data testify to the different content of polluting substances in the soils of the city. On the basis of estimation of soils by categories of objects (parks, gardens, squares; yard areas; transport highways; departmental territories) it is established that the greatest number of benzo(a)pyrene is recorded in soils of transport highways and courtyards, that is caused by emissions of polluting substances by automobiles' engines of internal combustion, and the maximal quantity of pesticides (means of protection of plants) is recorded in soils of green areas with high trees. This is due to the increased standards of consumption of pesticides in the processing of crowns.

The migration of heavy metals along the soil profile is due to the abundance of precipitation. St. Petersburg is located in the leaching water regime zone. Table 5 shows the contents of heavy metals: gross and movable forms in soils of one of studies green spaces — Mars field.

Table 5. The content of gross and movable forms of heavy metals in the soil.

| No | Sampling depth, cm | Cu (mg/kg) | Pb (mg/kg) | Co (mg/kg) | Ni (mg/kg) | Zn (mg/kg) |
|----|--------------------|------------|------------|------------|------------|------------|
| 1  | 0-5                | 49.8/5     | 149/34     | 56.5/6     | 120/13     | 126.9/29   |
| 2  | 5-20               | 59.5/6     | 123.2/48   | 52.9/7     | 115/9      | 132.8/32   |
| 3  | 20-40              | 66/16      | 149.5/64   | 52.8/8     | 112/15     | 142.5/38   |
| 4  | 40-63              | 15/5       | 105/25     | 62/7       | 114/14     | 105/18     |
| 5  | 63-72              | 13.3/6     | 89/17      | 73/6       | 116/10     | 79.7/14    |
| 6  | 72-110             | 4/2        | 79/12      | 56/6       | 115/4      | 56/7       |
| 7  | 110-130            | 3/1.5      | 59/7       | 23.2/4     | 108/5      | 47/7       |
| 8  | 130-150            | 3.5/1.5    | 57/7       | 21/3.5     | 90/4       | 42/6       |
| 9  | APC                | (3)        | 32 (6)     | (5)        | (4)        | (23)       |
| 10 | APC                | 33-132     | 32-130     | -          | 20-80      | 55-220     |

The numerator contains the contents of gross forms, in the denominator — movable; Movable forms of heavy metals were defined in the acetate-ammonium buffer hood; Values of MPC: in parentheses are the movable forms, for the lead gross content is given (without brackets) and movable form (in brackets); APC — The first digit (low values) for sand and sandy soils, the second digit — for loamy and clay soils with pH values (KCl) > 5.5.

Different species of woody plants are characterized by different resilience to the urban environment. They have a multifaceted negative impact. Industrial emissions containing dust, heavy metals, organic pollutants, cover the of laminas surface, violate the photosynthesis process, clog the stomata openings. The use of deicing agents on roads in winter time, in particular sodium chloride, at their penetration into the soil, leads to disruption of its functioning, destruction of a soil absorbing complex under influence of ions of sodium. Excess chlorine-ion in the soil can lead to the death of trees and shrubs.

Soils and green spaces of St. Petersburg are characterized by the violation of small biological cycle of substances and elements. Mowing and removing grass from the lawns in the summer, collecting fallen foliage trees and shrubs in autumn violate the biochemical cycles typical of natural forest and meadow communities. Removal of the fallen foliage and grass causes an elimination of both nutrients and contaminants, natural decomposition in the soil does not occur, the subsequent receipt of the products of mineralization of organic substances is violated. The presence of soils in the leaching water regime zone in St. Petersburg causes the removal of parts of contaminants and nutrients into the ground water. Soil profile of urban soils of St. Petersburg in the spring and autumn periods, and with abundant rains also in summer, washed by precipitation up to the level of groundwater.

The content of organic carbon, which is part of soil humus in urban soils, is caused not only by purely soil processes, but also by settling dust, including underoxidized products: soot, oil products and other carbonaceous industrial and transport emissions. The elevated amounts of carbon that are recorded in urban soils are sometimes taken as soil fertility indicators. Actually carbon of technogenic origin is not related with processes of natural soil and distorts real estimation of soil fertility.
Environmental conditions for green spaces vary in different districts of St. Petersburg and are determined not only by anthropogenic load, but also by the level of fertility of bulk soil, as well as by the quality of its preparation in the implementation of landscaping works.

In the city under the influence of industry and transport emissions, elevated recreational loads, unfavorable hydrological conditions there is a gradual loss of soil structure of the bulk fertile layer [18], decrease in the content of organic matter and humus, accumulation of polluting substances. Reduction of porosity of soils entails deterioration of water-air regime, reduction of permeability. There is a decrease in hydrophilic properties and increase hydrophobicity, which is due to the loss of organic matter and significant accumulation in the soil aerial technogenic dust, giving hydrophobic properties, clearly fixated in surface layer of soil. On separate sites, in particular, highway’s median strips, surface runoff begins to prevail over vertical filtration. The soils of St. Petersburg in most cases are characterized by neutral or alkaline reaction (in zonal natural soils the reaction is acidic), increased content of carbonates and sulfates.

In the process of growth and development of green spaces there is a decrease in the content of nutrients in the inhabited layer of soils due to washout (leaching water regime zone) and their removal with a beveled grass, fallen foliage. It leads to gradual degradation of a bulk fertile layer of soil, decrease of stability of green plantations, loss of the cultural grasses demanding higher machinery cultivation, and occurrence of weeds. These factors cause reduction of decorative and aesthetic qualities of green spaces, weakening of sanitary and hygienic functions [19, 20]. Such objects of landscaping require a major overhaul, which consists in removing a 10-centimeter layer of upper depleted and contaminated soil, in the delivery of clean fertile land and new creation of lawns, and if necessary, plants replacing.

Carrying out of these works is a necessary action on increase of stability of plants in an urban environment and the basic direction on perfection of system of green spaces of megacities.

Studies have shown that there is no direct correlation between the degree of soil contamination by metals (gross content) and the state of woody and grass vegetation on the studied green areas. Soils of high fertility, though contaminated, have a less appreciable negative effect on plant growth. The woody plants species resistance to atmospheric pollution, the level of preparation of soils for plantings, the timeliness and quality of the maintenance performed are of great importance.

The assessment of the quality of green spaces, based on the determination of physical and chemical characteristics of soils, the extent of their pollution requires a long time and considerable resources and nevertheless is not a reliable criterion of expediency of appointment and renovation of the green area. Existing in practice visual assessment of the external appearance of a green object, conducted by landscapers, based on the complex accounting of the state of green spaces, such as trees, shrubs, herbaceous plants, their decorativeness is a more reliable indicator in determining the feasibility of the maintenance and overhaul of the green area.

Heterogeneity of ecological situation in different regions of the city, multifactoriality of negative influence on green plantations necessitate carrying out a detailed research on each specific object in order to clarify the reasons for deterioration of their condition and development of measures to improve landscaping works.

Soil formation in urban ecosystems can be represented in the following processes (table 6).

| Soil | Plants |
|------|--------|
| 1. Removal of the fertile soil layer from the site of the future building before the beginning of construction works with the purpose of its subsequent use on the objects of landscaping | 1a. In the production of landscaping works — artificial application of fertile soil layer to the surface of mineral soils under the lawns. Preparation of planting places under trees and shrubs with replacement of ground in landing pits on vegetative ground. |
| 2. Removal of nutrients with crop grass, fallen foliage, resulting in reduced soil fertility. | 2a. Fertilization of green plantings with organic and mineral fertilisers to replenish nutrient content in soils. |
Violation of the natural cycle of nutrient circulation.

3. Violation of the hydrological regime, drying of soils due to the construction of foundations, laying of engineering communications, drainage of water through the storm sewers.

3a. Carrying out of artificial irrigation of green plants, such as trees, shrubs, lawn grasses in the period of long stood hot weather.

4. Degradation of soils under the influence of negative factors of urban environment (decrease of humus content, capacity of humus horizon, increase of soil density, cluttering territory, etc.).

4a. Periodic overhaul of landscaping facilities. Removal of contaminated and depleted moisture. Harvesting, delivery of plant land from country places, its use on the objects of landscaping.

As can be seen from table 5, anthropogenic factor is the leading in urban ecosystems and allows to maintain green spaces in satisfactory condition [21].

4. Conclusion
Questions of qualitative preparation of soils, their fertility and ecological condition are the key questions in a problem of creating green spaces in megacities. The requirements we have developed for urban soils and artificial soil mixtures – soil substitutes to create green spaces must meet the following requirements:

1) Contain sufficient amount of organic matter and nutrients of plants, necessary for prolonged growth of lawn grasses, trees and shrubs;
2) Ensure the creation of optimal water-air regime for plant growth;
3) Do not contain substances that are toxic to plants and hazardous to the environment.

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 plants, 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.

The control over the state of the natural environment (atmospheric air, soils, green spaces) should be in a high priority.

On the basis of the conducted research, the basic methodical approaches to quality of soils 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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