An integrated approach to the study of ecosystem state for soil and vegetation cover of urban areas

A V Cheremisin1, 2, A N Chusov1, M P Fedorov1, F Switala3, L R Valiullin2, 4 and D N Shurupov1

1Peter the Great Saint Petersburg Polytechnic University, Saint Petersburg, Russia
2All-Russian Research Institute of Phytopathology, Moscow Region, Russia
3Samara State Technical University, Samara, Russian Federation
4Federal Center for Toxicological, Radiation and Biological Safety, Kazan 420075, Russia

E-mail: laksacher@yandex.ru

Abstract. The article substantiates the need for a comprehensive assessment of the state of the ecosystem. To do this, it is necessary to perform studies of the state of the soil, water and vegetation cover using various devices. The studies were carried out both in a stationary laboratory using samples taken from the territory, and in the field using devices for express control. For additional control of the vegetation cover, the results of video filming and research carried out using a thermal imager and radar stations were used. The latter method is extremely effective if the soil or plants contain large amounts of radioactive substances or heavy metals. For research, previously compiled maps of contamination of territories using GIS technologies were used. Comparison of these data will help to establish the causal factors of pollution. In addition, it is possible to identify the migration of pollution under the influence of various climatic phenomena, etc. The use of high-resolution instruments (for example, an X-ray spectrometer or a power optical microscope) allows one to determine the entire spectrum of contamination in soil, water and on plant samples. This allows in the future to assess the behavior of chemical elements in the "soil-plant" system to determine the possibility of cleaning the area using plants. Of particular interest is the burning of fallen leaves with burying waste in the ground.

1. Introduction

Soil is not a renewable resource, in case of loss or degradation it cannot be restored in a period comparable to the duration of human life [1-13]. The state of soils affects food, water, air, human health and the health of all life on Earth [5, 12, 14-22]. The developed modern devices do not allow to fully establish contamination in the soil during express control [3, 5, 15, 17, 18, 22-31]. This is due to the large amount of harmful substances that get there [1-4, 7, 8, 31, 32]. Soil pollution affects soil biodiversity, reduces the reserves of soil organic matter and its filtering capacity. Due to soil pollution, soil moisture and groundwater are polluted, the balance of nutrients in the soil is disturbed [1-4, 7, 8, 33-36]. The most common soil pollutants include heavy metals, persistent organic pollutants and hazardous sediments [36–42]. Especially high load on the soil in cities [1-5, 19, 20, 39, 40-45]. A comprehensive ecological and chemical assessment of the soil and vegetation cover of urban ecosystems will help to establish the causal factors of pollution and, in addition, will help to identify the migration...
of pollution under the influence of various climatic phenomena. Monitoring studies of the soil and vegetation cover, especially with the use of optical devices [46-48], will make it possible to assess the levels of supply of biophilic elements and heavy metal pollution of the soil and city vegetation.

2. Soil research method

Monitoring studies, which included an assessment of the state of the soil and vegetation cover, were carried out on the territory of St. Petersburg (Russian Federation). The choice of the place of work is due to the diversity of the housing stock: there are buildings from the era of Peter the Great to modern elite buildings. In addition, the city has a large number of green areas. The city has a record number of research institutes, in addition, industrial enterprises are widely represented.

The selected sites covered the most common functional zones of urban ecosystems, namely: industrial, residential and recreational [1-5].

Soil sampling was carried out in accordance with state standards. From each test site, 2 combined samples were taken from a depth of 20 cm, consisting of 5 point samples by the envelope method (Fig. 1.).

![Figure 1. Place of sampling of soil](image1)

Further, the samples for analysis were delivered to the laboratory. To improve the quality of work at the first stage of laboratory studies, an express analysis of samples was carried out using a portable X-ray fluorescence analyzer Niton XLt 500, which made it possible to establish a list of heavy metals contained in the samples. After that, each of the taken samples underwent special preparation, including the stages of drying, grinding and sieving, for subsequent analysis (Fig. 2.).

![Figure 2. Sample preparation: a - grinding in a mortar; b - weighing and drying](image2)
The samples were measured by atomic emission and atomic absorption spectrometry.

3. Results
As a result of the research, the following results were obtained. More than 35% of the studied soils are characterized by abnormally high contents of Pb, Ni, Cr, Mo, Cu, Mn, Co, and Fe. Analysis of water-soluble and acid-soluble forms of metals showed that 30-50% of the total content of pollutants are in the mobile phase and have an increased migration ability.

The values of the specific electrical conductivity of soil extracts obtained during the analysis indicate an increased salt content. The samples taken along the roads show a significant excess of the chloride content.

To analyze the soil-vegetation cover, the vegetation samples were analyzed. Before analysis, the samples were washed, dried, and ground in a mortar to a powdery state, after which they were ashed in a muffle furnace. Analysis of soils showed an excess in the following elements: Pb, Ni, Cr, Mo, Cu, Mn, Co and Fe. On this basis, plant samples were analyzed for the indicated metals by atomic absorption spectrometry with electrothermal atomization.

To interpolate the obtained data, their mathematical processing was carried out, which included the determination of the coefficient of variation, concentration coefficient, indicator of total pollution, coefficient of biological accumulation, as well as in the construction of geochemical series of associations in order to identify priority sources of pollution. Also during the study it was revealed that most often the excess of background values is observed for Pb, Ni, Cu and Mn. These elements are typical for industrial facilities in the city and for road emissions and accumulate most in deciduous plants.

At the final stage, ecological-geochemical mapping of the study area was carried out using the MapInfo software product. For this, IDW methods of data interpolation were used (Fig. 3.).

![Figure 3. A cartographic representation of the contrast ratio for chlorides using IDW interpolation.](image-url)

As can be seen from Figure 3, data interpolation using this method gives a significant error, since the specification of urban development is not taken into account. This can be avoided by creating an additional clipping layer.

4. Conclusion
The obtained results of the study of the soil showed that the developed technique can be used for further operational assessment of the state of the soil and vegetation cover, forecasting changes in the urban ecosystem and development of measures to reduce the toxic and ecological consequences of pollution of soils and green spaces with heavy metals.
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