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MANAGEMENT OF ENVIRONMENTAL AND GEOCHEMICAL CONDITION OF URBAN LANDSCAPES

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The physical, mechanical and chemical features of urban soils were considered in the article. The influence of basic soils macro- and microelements vital functions of plants and animals was explored, as well as information about dependence of some human diseases distribution on anomalous concentration of certain chemical elements in soil. Basic factors and physical and chemical parameters of soils which affect distribution of chemical elements in soil were defined. It was established, that the level of plant provision with mobile forms of basic nutrition elements affected inhibition of chemical elements accumulation by the plants. The test-system for the efficient express potassium, nitrogen and phosphorus analysis was offered and recommendations for adjusting accumulation processes and carry-over of chemical elements in the soil–plant system of urban landscapes were developed.

Keywords: heavy metals; human endemics; macro- and microelements of soil; mineral fertilizers; soil.

Problem formulation

Human activity became an important soil genesis factor in the the last centuries. At urban territories it is possible to consider anthropogenic factor dominanting over natural factors of soil genesis. Under such influence physical properties and chemical composition of soils are changed, and this leads to formation of new soil types with decreased content of nutrientsand increased concentrations of technogenic components.

Background information analysis

The study of soil composition was in the research field of many scientists, including the founders of geochemistry, as a science, V.V.Dokuchaev [2] and V.I.Vernadsky [4]. First, the special role of soil elements in biological processes was specified by V.I. Vernadskiy. He pointed that composition of soils is not random, but it is closely connected with composition of other parts of biosphere. Chemical elements are constantly and naturally present in vegetable and animal organisms. V.I. Vernadsky defined in his studies, which chemical elements of mineral and living matter belong to the range of elements vitally needed for any living organism [1]. If these elements are lacking in a body the basic physical and biochemical reactions of living organism cannot run normally. At the same time V.I. Vernadskiy was the first to specify the predominant role of modern man in the change of geochemical processes direction and intensity at all levels. This influence is especially noticeable at residential areas.

The issues of interaction between soil components content and health condition of the relevant population were studied by A.P.Vinogradov [3], A.V.Chaklin [11], Y.G.Rikhman [9], V.V.Kowalsky [6], N.A.Protasova [8], G.P. Dubikovsky [11], Y.G.Pokatilov [7].

Cities are covered with technozems or urbozems, which are the soils, created by man in the process of recultivation or cultivation of certain plots of land.

Technozems have inherited properties of zonal soils and partly soil parent material, and the rest was formed under the influence of powerful equipment, used for the top soil layer cultivation. Their characteristic traits include absence of the clearly expressed horizons, often intrusive character of coloring, increased density and as a result lower porosity [11].

Fullprofile soils, similar to natural, can be kept unchanged under urban conditions in the area of forest-parks and old parklands.

Regardless of soil type and location the most basic property, which they are estimated after, is fertility. Fertility of soils is predefined by the presence of organic and mineral nutrients in their composition, certain structure, which supports normal gas and water circulation, physical and chemical properties (pH level and salt mode), which support normal physiology processes running in plants. Fertility of soil provides certain biological productivity of natural and artificial vegetation of urban ecosystems. Thus, soil executes the functions of regulator, which supports necessary composition of atmosphere due to transformation of dead biota and products of human activity. This role of soil in biological circulation of elements, makes soil the major constituent of ecosystems of cities.

The use of soils in cities, as a rule, has nonagricultural character. Major direction of their use is creation of parks, public gardens, lawns, covers for sporting facilities.

The top layer of soil is used for strengthening slopes and embankments at transport ways construction, etc.

Infertile soils together with loams and other materials are applied as the basis for construction of buildings. Due to high absorptive ability soil play the role of filter for superficial flow cleaning.

Clays and loams are used for creation of insulating screens on the landfills for solid domestic and industrial wastes.

All this functions of city soils result in gradual accumulation of mechanical, chemical (first of all heavy metals) and biological pollution in them.

At the same time aesthetical reformation of green planting, removal of fallen leafage, result in loss of considerable volumes of nutrientsfrom soil, which promotes accumulation of pollutants, especially heavy metals, by plants of city territories.

Concept and methods

For the development of efficient measures to reduce pollution of plants with heavy metals and increase productivity of green plantations of urban territories the content of basic nutrients and elements in soils of cities must be investigated, as well as their correspondence to the regulations of harmful components and dangerous concentrations of obligate elements accumulation in plants. The next step is to study the geochemical situation formed in cities as a result of interrelated process of pollution input and valuable soil components withdrawal.

Biological role of macro- and microelements of soil

To the group of macronutrients of soil include chemical elements, which form the basis of plant associations productivity and reach levels over 0,1% by mass, – it is foremost nitrogen, phosphorus, potassium.

Nitrogen for plants is the basic component of nutrition, it is directly responsible for the increase of plants mass and intensity of green leaves growth.

The lack of nitrogen causes turning leaves yellow and oppression of growth.

Surplus of nitrogen causes excessive growth of leaves and detains flowering; a plant becomes sickly, and fruit have low quality.

Growing plants also need phosphorus as it is the basic constituent of genetic aparatus, which is responsible for development of seed. The lack of phosphorus results in oppression of growth and sterility of seed. Phosphoric acids are necessary for plants, as they provide ripening, increase the amount of seed, increase the productivity of fruit, promote content of vitamins and help plant resist illnesses and frosts.

Potassium strengthens plants, participates in carbonhydrates formation and albumens synthesis, improves fruit color and smell, and also provides early growth, strengthens bark and frost-resistance. Plants lacking potassium are undersized with undeveloped rootage, their leaves are spotted, twisted up and dry at edges. Productivity in the case of decreased potassium content is low [6].

Rare chemical elements (elements) also play an important role in the life of organisms, although their concentrations necessary for plants are less than 10-3%. Their lack in soils, as well as their surplus, results in the decline of cultural plants productivit, and occasionally is the reason (local) of endemic diseases of plants, animals and human, related to acute violation of metabolism.

Microelements take part in such major biochemical processes, as [3, 8]:

- breathing (copper, zinc, manganese, cobalt);
- photosynthesis (manganese, copper);
- synthesis of albumens (manganese, copper, cobalt, nickel, chrome);
- hematogenesis (cobalt, manganese, copper, nickel, zinc);
- carbohydrate and fat metabolism (molybdenum, vanadium, cobalt, tungsten, manganese, zinc);
- synthesis of humus (copper).

Living organisms need certain concentration of microelements in the environment, certain correlation between them and specific forms of their connections. The lack of copper causes dryness of tops of fruit-trees, ataxia (hypotaxia) of sheep and cattle; surplus of copper causes the disease known as animals zinc anemia [7].

The rosetting of fruit-trees, spotted leaves of citrus, corn apex whitening, detained growth, parakeratosis (bulge of skin) of animals appear as a result of zinc lacking.

In case of strong boric starvation flowers do not appear at plants, sugar beet has ill core and dry rot, flax suffers from backteriosis.

In case of molybdenum insufficiency itomatoes have spotted and curled leaves, cauliflower has thread-like leaves.

The lack of manganese results in the disease of tobacco, corn, chlorosis of cotton plant, bobs, oat, sugar beet. In case of high content of boron plants are undersized, have spread or bushy shape.

Strontium in small doses is able to promote starch accumulation in potato tubers. But surplus content of strontium in soils predetermines degeneration of plants shape [8].

It is also well known that plants have the unique ability to accumulate separate elements. Thus, leguminous plants take up molecular nitrogen from the atmospheric air. This absorption is under control of three other metals, molybdenum, cobalt and vanadium, which stimulate this fixation and at the end synthesis of albumen. Titanium is also assumed to be important participant of all these phenomena.

Some separate plant species also absorb microelements preferentially from soil: corn absorbs gold and zinc, wormwood – manganese, red fly agaric – vanadium, violets and tobacco – zinc, cotton plant – cobalt.

The result of selective absorption of microelements from soil is their different accumulation in plants. For example, lentil intensively concentrates titanium and arsenic, buckwheat accumulates boron, strontium, molybdenum, tea - cobalt, copper, fluorine, corn - copper, selenium, tin, zinc, beet accumulates zinc, manganese, fluorine, copper, boron, leguminous absorb molybdenum and vanadium [8]. These features of plants influence on formation of geochemical anomalies and redistribution of microelements in soil, as aftee dying or consumption of these plants the concentration of microelements is accordingly increased or diminished in soils.

Influence of chemical composition of soil on distribution of human diseases

Numerous researches show the presence of certain connection between content of certain elements in soil and frequency of some diseases origin [12]. Usually certain factors in complex affect humans, and elements of soil are only one of many constituents of this process.

A difficult chain of migration of elements is from soil and water to plants, organism of animals, and then to human organism is specific in each biogeochemical district and highly depends on climate and geographical conditions [12].

Under the conditions of urban territories, on which the anthropogenic halos of heavy metals are formed, uptake of harmful components by human organism with local food is minimum, but under the influence of wind and heat dry particles of soil are blown up and suspended in the air, thus getting into lungs and digestive system. So, the final consequences for human health depend on interaction of few factors, instead of one element.

The dependence of iodine mobile forms content in soil and development of thyroid gland disorder are well known, but considerable influence on iodine uptake is also made by fluoride, cobalt and manganese. At the same time the surplus income of manganese into human organism results in carcinogenic effects in relation to bone tissue and digestive system. Cobalt, copper, manganese and zinc play major role in the development of digestive organs and liver pathologies. Chrome, cobalt, nickel, zinc, cadmium have carcinogenic effect. [7]

Increased content of strontium is the cause of more frequent urolithiasis, bones fragility. At normal content of calcium and phosphorus in soils, but lower concentration of copper number of rachitis cases grows correspondingly [11].

Tooth decay develops in case of fluorine and molybdenum deficit, and fluorosis appears at fluorine surplus. The surplus income of molybdenum causes development of gout or molybdenum toxicosis. High concentrations of zinc cause tumors of skin.

Chrome, cobalt, copper, iodine, manganese, molybdenum, nickel, vanadium, zinc in abnormal concentrations may lead to development of cardio-vascular diseases. The content of strontium, titan, chrome, nickel in soil was defined to be connected with heart ischemia [13].

Analysis of factors affecting accumulation and distribution of soilelements

Content and distribution of microelements in soils depend on direction and degree of development of soil genesis process and regularities of microelements migration in a landscape. Character of elements distribution in soil is determined by its humus content, soil grading, medium reaction, redox potential, sorption capacity, content of CO2, soil horizons properties. There is noticeable accumulation of microelements in humus horizon of grey forest soils and black earths (copper, beryllium, manganese, iodine). Strontium is always accumulated in carbonate horizon [3]. Some microelements, for example, boron, form soluble connections with the organic substances of soil and others (iodine and copper) are bound and become unavailable for plants [6].

From the above-mentioned factors, one of the most basic, which it is possible to influence on, is medium reaction. Mobility of molybdenum is diminished in acid environment, but mobility of copper, manganese, zinc, vanadium, nickel and cobalt grows. Such microelements, as boron, fluorine and iodine are mobile both in acid and alkaline environment. It is also known, that soil reaction has general influence on basic nutrients absorption by plants described with corresponding mathematical dependences [10].

Extremely important research results are presented by Walevsky D. et al., they show the influence of the basic soil nutrients content on absorption of certain elements by plants, in particular, zinc, manganese, cobalt, copper, nickel and chrome [13]. It was set that the presence of surplus amount of phosphorus (2–2,5 times over the average) reduces the accumulation of manganese, nickel and copper on 28–36% (Fig.1), and the increased input of potassium (by 50–60% over the necessary minimum) slows absorption of chrome (Fig.2).

Taking into account the resulted dependencies, it is possible to offer introduction of additional amounts of nutrients to the composition of traditional fertilizers to diminish the accumulation of heavy metals by the plants of agrocenosis and urban landscapes. From the other side, some plants are characterized by selective accumulating ability in relation to certain elements of soil, which can impose danger for the inhabitants of urban territories in case of increased concentrations. This property can be used for biological extraction of these elements from technozems and their removal from urban ecosystem together with plants, which accumulated them, during the sanitary cleaning. For this purpose it is necessary to provide express testing of basic nutrients content in soil to determine the necessary doses of mineral fertilizers, which will limit the absorption of certain elements or will stimulate growth of plants which absorb them from soil.

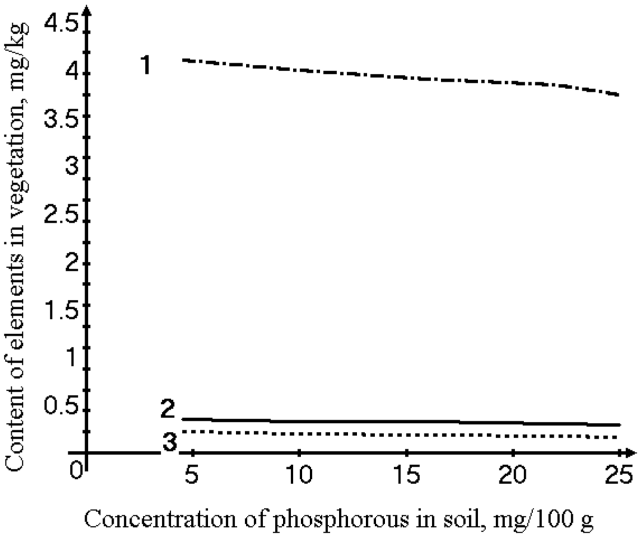

Fig.1. Dependence of Ni, Cu, Mn content on the concentration of phosphorus in soil:

1 – concentration of Ni;

2 – concentration of Cu;

3 – concentration of Mn.

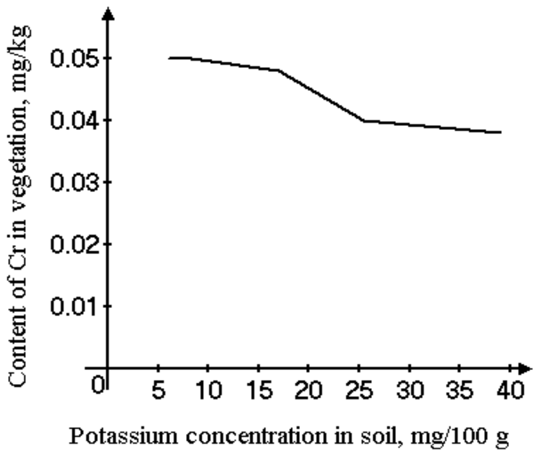

Fig.2. Dependence of Cr content on the concentration of potassium in soil

The most efficient indices include acidity of the soil environment, which determines comfort conditions for growth of plants and uptake of nutrients and hazardous elements.

Universal test system for soil analysis

For efficient determination of basic nutrients content and soil acidity universal testers are used, in particular, products of Rapitest. To conduct the research it is necessary to follow the next steps:

- to take soil samples from certain depth in accordance with standard requirements to soil sampling;

- to remove shallow stones, garbage, organic material (grass, weed, root and coarse particles of lime);
- to grind sample in porcelain mortar, carefully mix and dry up to air dry condition;
- to mix dried sample thoroughly with distilled water;
- to carry this solution after sedimentation of soil particles into the analytical chamber and add capsulated reagent.

After completion of the reaction color of the formed solution determines the content of investigated component, which is set by checking with the proper color comparators, developed a producer.

The results got this way are used for determination of the necessary volume of mineral fertilizers input to achieve the necessary level of urban plant associations productivity and limitation of hazardous elements mobility. Interpreting the results, it is necessary to take into account some urban circumstance, for example, that nitrogen content in technozems could be high enough due to receipt of technogenic nitrogen compounds.

Determination of the necessary volume of mineral fertilizers input

Determination of fertilizers needed volumes is conducted experimentally or with calculation methods, based on nutrients balance – comparison of elements consumption for the formation of vegetative association (taken away with the harvest) with the absorption of nutrients from soil and fertilizers.

Necessary volumes of mineral fertilizers application could be determined on the basis of:

- indices of compensation of nutrients taken away with harvest from soil;
- indices of nutrients absorption efficiency from soil and fertilizers;
- planned increase of vegetative output;
- planned output and desired change of phosphorus and potassium mobile forms content in soil.

Various calculation methods are more expedient to use to verify the correctness of the fertilization system developed on the basis of experimental and regulatory doses under certain cultures and for the estimation of potential increase of the accepted standards of organic and mineral fertilizers. On the whole, to increase the productivity of urban vegetative associations volumes of mineral fertilizers application must be 0,5–2,5 time over the standard ones.

Conclusions

Accumulation of elements, including heavy metals, by plants from soil depends on presence of sufficient quantity of mobile forms of basic nutrient compounds and reaction of environment. Under the conditions of urban territories soil testing to define the content of nitrogen, phosphorus, and potassium, and also actual acidity of soils is the basis for defining the need in additional volumes of nutrients application for prevention of hazardous elements accumulation in plants or for stimulation of their selective absorption.

The evaluation of nutrients content in soil enables controlling general geochemical situation at urban territories, that is predefined by their influence on mobilization, inhibition, assimilation or formation of complexes with heavy metals.

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