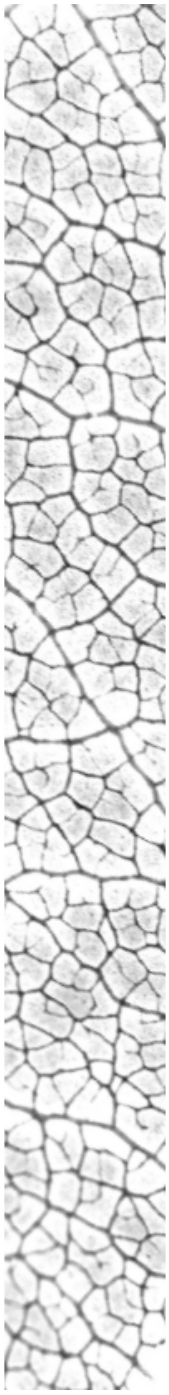

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Analyzing changes in elemental composition of ecosystems under man-induced impact

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Abstract

Background: With the modern trend of urbanization of areas, the question about its impact on ecosystems becomes quite urgent. In spite of positive aspects arising at the result of urbanization, there is a probability of elemental composition of ecosystems being changed. These changes can not only disrupt the internal exchange processes but also impair the population health.
Objective: The relevance of the research is associated with the necessity of studying the changes in elemental composition of soil – the ecosystem constituent impacting the human health. With regard to this, the paper is aimed at identifying any change in elemental composition of ecosystems and their influence on human diseases.
Materials and Methods: The methodology of this research is based on assessing the pollution of soils that is viewed from a twofold standpoint: the danger of negative consequences emerging for soil as the basic component of ecosystems due to its stability impaired and that for the population health. The leading method for studying this problem is the analysis of soil samples that ensures an integrated view of any change occurring in the elemental composition of soils.
Results: In the paper, the results of reconnaissance surveys are presented that allow confirming the process of rapid urbanization, changes in the main soil indicators such as pH, humus, nitrates, ammonium nitrogen, phosphorus and potassium, are identified, and grounds are given for the interrelation between the results obtained during laboratory studies and the impact on the human organism.
Conclusion: In this paper, the main methods of studying the elemental composition, the results and possible consequences for the population health are worded relying on the foreign and Russian literature sources. The materials of the paper are of practical value for researchers in the field of urban ecology, students of the ecology focus area, and scientists dealing with the impact of urbanization on the population health.

Keywords: ecosystem services, elemental composition, urbanization, man-induced impact, ecosystem goods, health of the population

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INTRODUCTION

The characteristics of the world's urban districts are incredibly diverse: about half of urban dwellers live in relatively small settlements numbering less than 500 000 citizens, while almost one in eight people lives in one of the 28 metropolises having the population of at least 10 million people. Since 1990, the quantity of metropolises has almost tripled, and according to forecasts, by the year 2030, 41 urban agglomerations will have counted 10 million dwellers each (World Urbanization Prospects 2014).

The world of today has a burning issue of the natural condition of ecosystems being changed due to various processes associated with human life activity. Among its aspects, one can list infill and housing development sprawl of forest areas and plough lands, stocking of MSW, emissions of various enterprises and motor transport, and a lot more. All this upsets the exchange processes having formed in an ecosystem bringing it to the status of an anthropogenically changed ecosystem, or an urban ecosystem (Goldstein et al. 2012).

Ecosystems have a direct impact not only on the environmental situation but also on the human health condition. Throughout their functioning, ecosystems produce goods that are necessary for people; these are called ecosystem services. The particular feature of natural ecosystems is preserving their biological

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diversity as well as full-fledged production of ecosystem goods (McGranahan and Marcotullio 2015).

Ecosystem services are defined as benefits people obtain from functions of the ecosystems or as the direct and indirect contribution of ecosystems into human well-being (De Groot, Wilson and Boumans 2013).

The loss of ecosystems in towns and cities can involve high long-term economic costs and grave consequences for social, cultural and insured values associated with ecosystem services (Schneiders et al. 2012). The economic costs associated with the loss of urban ecosystems are due to the necessity of restoring and preserving utility services and supplies via the constructed infrastructure, because the lost services which used to be rendered by the urban green infrastructure are no longer available. Further negative consequences follow from the consequences in social and cultural values, including the sense of place, identity and community, social cohesion and the local environmental knowledge (Santos-Martín et al. 2014). Restoration of urban ecosystems is a time-consuming and extremely costly process that includes assessing the condition of the ecosystem components (soil, quality of water resources, condition of biocenosis), developing an action plan for restoring them and fulfilling the plan (Gaponenko et al. 2018).

Ecosystem services produce an impact on various areas of the human life activity (Alcamo 2015). In particular, 4 categories are singled out among ecosystem services (McGranahan and Marcotullio 2015). The first category is the resource services, it is responsible for providing the production of goods and services with any natural resources required (Daily 1997). The second category is the regulatory services – they not only have a direct impact on the internal exchange reactions of ecosystems but also together with other categories influence the quality of atmospheric air and condition of the human health. The changes in these services are interrelated with those in human health, which is expressed in the elemental composition of human foods being compromised as a total by the elemental composition of soils, water, and air being disturbed, in their turn. Among the main tasks of the benefits obtained from regulatory services, there are regulation of micro-climate, reserves and purification of water, and possible diseases of plants, animals and people.

The cultural service is quite an important one for the functioning of ecosystems and human life; it is responsible for the development of the population's spiritual enrichment, cognitive activity and the like. Lacking socially important objects in the environment of living, people can experience altered state of their psychological health, which later affects their physiological state, too.

The category of supporting services includes ones that are necessary for producing all services. For instance, the processes of elements circulation, soils formation, photosynthesis etc. can be referred to supporting services (Kubiszewski et al. 2017).

As it was mentioned above, during urbanization, there arise a number of problems, the severe shortage of natural and spatial resources being one of them. This, in its turn, affects the ecology of the environment negatively and, consequently, the population's quality of life (Santos-Martína et al. 2019). New residential areas, roads and other development types tell on such an important element of each ecosystem as soil. First of all, man-induced impact on soil is characterized by disturbance of the soils profile structure, over-consolidation of soils, fertility fall, pollution with heavy metals and oil products, and salinification (Santos-Martína et al. 2019).

The relevance of the work consists in analyzing the changes in elemental composition of the ecosystem constituent, soil, in order to find out its impact on the human health.

The objective of the work is to analyze the changes in elemental composition of ecosystems and regularities of their transformations.

In order to study this range of problems in detail, the changes in elemental composition of ecosystem constituents have to be analyzed and the effect of these changes on the human health and life activity has to be forecast. In this paper, the changes in indicators of elemental composition of soil, the fundamental part of the ecosystem.

LITERATURE REVIEW

Changes in the land use take place worldwide and influence the human well-being by having an impact on provision of the numerous ecosystem services (Lawler et al. 2014). There are several processes that can identify the nature of land use type change (Bennett 2017). One of the main types is intensifying the land use in order to enhance the efficiency of foods production that takes place due to diminishing most ES (Lawler et al. 2014). The second type, quite an important one, is organizing the housing construction which is associated with having to provide the population with accommodation.

When studying the process of urbanization, the vexed question arises as for what scenario of its development will save the natural characteristics to the highest extent and reduce the impacts on the goods provided by various ecosystems (Eigenbrod 2016). It should be noted that the process of urbanization implies changing the types of land use and the structure of goods obtained from that in general, which impacts the condition of the population health (Hamann et al. 2015).

The excess of pollutants can tell on the diverse spheres of the human life activity. Everyone has their own response to various pollutants of the atmosphere.

For instance, the response cases may range from allergic and asthmatic conditions, reproductive problems in women to general weakening of the immune system.

Livestock can have a negative impact on the quality of air locally, especially due to emissions of ammonia (NH3). Excessive ammonia emissions can indirectly (through food and water) cause caries-related and non-carious diseases in people (fluorosis, enamel hypoplasia etc.).

Agriculture and livestock husbandry are heavy users of water while also having a strong impact on regulating the water runoff. Organizing the agricultural type lands can contribute to disruptions of the water balance and affect the regulation of water flows at the regional level (Hauck et al. 2015).

Agricultural wastewater is a large source of water pollution. Livestock husbandry produces wastewater and can cause water pollution, too. The impact of livestock husbandry on the quality of water is associated either with concentrating the water supply in one of the points where the animals are gathered or with pollution occurring due to manure and mineral fertilizers used for forage crops. Disruption of the qualitative composition of products for human consumption (due to pollution by the agricultural and livestock breeding areas (Hamann et al. 2015) can provoke such diseases as hyperesthesia of teeth or toxic damage of dental tissues.

METHODOLOGICAL FRAMEWORK OF THE RESEARCH

In this paper, the research results are presented that were obtained when analyzing the soil structures in the part of Moscow undergoing the stages of rapid urbanization – the area of Troitskiy and Novomoskovskiy Administrative Districts.

First of all, the work on creating the research structure was performed. It was decided to conduct works in four stages for completing the research.

At the first stage, the reconnaissance survey research method was applied. The first stage covered the time from November 2017 through May 2018 and consisted in collecting and analyzing graphic maps concerning the research object. While digitizing the maps, the authors identified the main locations exposed to rapid urbanization rates. Identification of these areas allowed finding out the main points for collection of soil samples for the subsequent stages.

For the second stage, the field survey method was opted for. The stage was characterized by going out to the sampling points determined during the first stage in June and July 2018, on-site investigation and identification of the soils morphology, as well as drawing the soil samples for further physical and chemical laboratory tests.

The third stage took place from August through November 2018 and was represented by the laboratory research method. The study for finding out the elemental composition and physical characteristics of the samples collected was conducted on the basis of the natural sciences laboratory of the RSSU.

During the fourth stage (December – March 2018), the obtained results were evaluated using the analytical method and conclusions were compiled.

RESULTS AND DISCUSSION

All the results obtained are presented within the framework of the work stages described.

The first stage. During this stage, three main regions were selected: the villages of Kommunarka, Sosenki, and Filatov Lug gardeners' non-commercial partnership (adjacent to Ulyanovskiy forest area); the villages of Vatutinki and Babenki, the town of Troitsk; Maryino, Malinki, and Fominskoe villages. In each of the three regions, the land use types that are the most characteristic of the region are presented: forests, plough lands, and residential areas. In some places, for example, in Ulyanovskiy woodland park (Filatov Lug GNCP), they have the transition status. There is a trend for converting the forest area into the park area status as well as expansion of Grad Moskovskiy residential complex; this is also associated with the underground station being constructed.

When digitizing the land use maps of Novaya Moskva, it was found out that during the time span from the year 1978, the greater part of the area was made up by forests (84.4 thousand hectares or 59.3% of the total area under study) where the completely natural ecosystem was preserved except in the belts adjacent to motor- and railways – with minor pollution observed there due to exhaust gases.

The ecosystem in which man-induced impact not disrupting the exchange of elements was observed was located on the plough lands (38.8 thous. ha or 28.5% of the total area under study). Any man-induced impact on the soil was compensated by the timely introduction of elements removed during growing the agricultural crops. The ways of purifying the waste water generated during the production, however, are unknown.

Alongside with that, in the region, there are areas where the change in the internal elemental composition of ecosystems does not imply any compensation, in particular, this is the residential development area (540 ha or 1.9% of the total area under study).

When comparing the above data with the current situation, what is important is that the main changes fell for areas having the natural ecosystems (forests 83,4% of the total area of changes) and anthropogenically replenished ones (plough lands 15,1% of the total area of changes). The summarizing conclusions for this stage are given in **Table 1**.

The table presented lists the area characteristics of the land use category changes. The data were obtained

Table 1. Land use categories, thous. ha

Land use categories	1978	2018
Forest	84.4	68.47
Plough land	38.8	24.32
Residential area	0.54	30.95

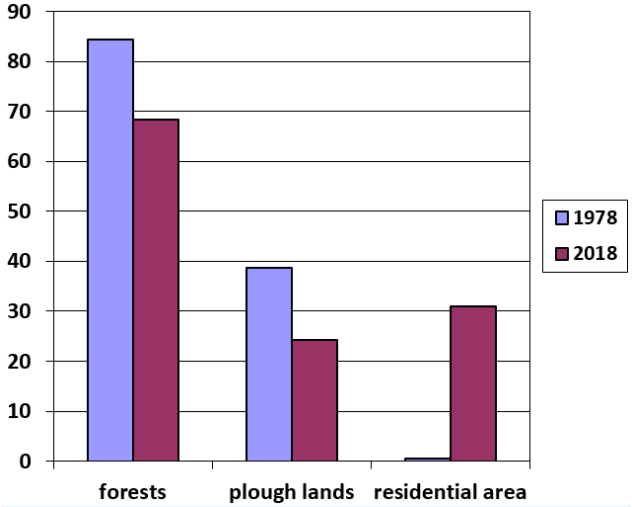

Fig. 1. Area change of the lands used, %. 1978 – 2018
Source: authors

by digitizing the maps using QGIS software, in May 2018.

The results obtained are shown in **Fig. 1** for clarity.

Proceeding from **Table 1** and **Fig. 1**, it is seen that in these areas the 18.88% reduction of forests, the 37.32% reduction of plough lands and the 57.5 times increase of the quantity of residential areas are observed. Finding out the urbanized areas allowed identifying the required sampling points. There were 17 points of sampling selected that were located southwards along the Kaluzhskoe highway (from the village of Kommunarka up to Troitsk, and from the town of Troitsk up to Babenki village). Points 1-9 were chosen in residential areas (1-5 – multi-storied development, 6-9 – villa development), points 10-13 – in the areas of the present-day plough lands (points 10-11 – former forests, points 12-13 – plough lands since 1978), and points14-17 – in the forest areas.

The second stage. The soil samples were collected in June 2018. In the prevailing part of the land plot, there are combinations of soddy-podzolic soils with different extents of podzolic soils presence that formed on the mantle of clay loams with underlying moraine or glaciofluvial clay loams. Soddy and low-podzolic soils occupy the top part of catena in the better drained conditions of peak plains or sloping surfaces, moraine hilly surfaces and interfluvial plains of various origin. These soils are one of the best ones of the region according to their agrotechnical properties because they contain quite a lot of humus (up to 3.5%) and nutritive substances and they have a better structure than the more podzolic soils. The depth of humus horizon in soddy and low-podzolic soils reaches 15-20 cm under forests.

This type of soils has a high capacity for physical and biological self-purification, provided that the tree vegetation is preserved.

In the course of morphological study of the soil samples selected from each described area, the following changes were registered. In the morphological structure of samples 14-17, a large quantity of inclusions in the top horizons (A, AE, AB) are observed. The coloring and quantity of horizons were changed pro rata depending on the urbanization extent of the areas.

In plough horizons of the soil, light clay loam, medium clay loam, and sandy loam prevail – P_MT_2. As for soils of this land use type, their particularity is a large quantity of inclusions of roots in the top plough layers of each area, except the residential one.

The third stage was conducted on the basis of the natural sciences laboratory of the RSSU from August through November 2018. Using the generally accepted methods, such indicators as pH, humus, the content of nitrates, ammonium nitrogen, phosphorus and potassium were identified (**Table 2**).

As the distance away from the industrial areas, locations of MSW deposits and collection points, as well as the main motor- and railroads diminished, the higher content of heavy metals and chlorides in the soil was observed. Deterioration of some agrochemical indicators of the soils that are essential for the normal functioning of ecosystems was also registered: from 2014 through 2018, there was the 10.9% decrease of carbon (humus content reduction) in the forest area, with the 59.6% one in the plough lands area, and the soils acidity went up. **Table 3** lists the changes of fluorine content in the soils as compared to the year of 1978.

The results of the research described confirm that there is a trend for the lower content of fluorine in the soil, with the decrease being essential in residential areas and in plough lands.

In all open plots of soils (not paved up in the course of urbanization), over-consolidation of soils is observed, its extents varying. This can compromise water transmissivity and migration of nutrition elements in the

Table 2. Some agrochemical indicators of the land plots under study. Source: authors

Points	pH	Humus	Nitrates	Ammonium nitrogen	Phosphorus	Potassium
Norm (standard sample)	6.39	6.51	19.95	3.71	232.45	225.19
1-5	3.96	2.8	19.96	1.05	79.23	105.36
6-9	4.56	3.56	12.18	1.88	106.21	110.25
10-11	6.02	6.01	19.94	2.2	106.25	155.0
12-13	4.85	3.5	19.6	2.57	106.32	107.9
14-17	5.06	3.5	12.05	2.45	142.83	224.8

Table 3. The content of fluorine in the sampling areas

Reduction in residential areas		
Norm	**deviation from the norm registered*	
fluorine, mg/kg	2018, mg/kg	reduction %
35.5±-3.5	30.4±1.1	4.7
Reduction in the plough lands area		
Norm	**the lower threshold of the norm*	
fluorine, mg/kg	2018, mg/kg	reduction %
35.5±-3.5	33.9±1.3	2.9
Reduction in forest areas		
Norm	**within the norm*	
fluorine, mg/kg	2018, mg/kg	reduction %
35.5±3.5	34.95±1.1	1.3

Source: authors

horizons, which contributes to disruption of water exchange and full-fledged functioning of soils in general.

The fourth stage. The analytical method based on the data of literature and results of laboratory tests allows supposing the possible effect on the human organism. Given the lack or excess of some elements in soils of an ecosystem, people using goods of the ecosystem can develop a number of conditions. For example, as it has been mentioned above, within the area under study, a reduced content of fluorine is observed. With the downward trend remaining, a shortage of this element increases the probability of development of dental caries in the population consuming the goods of this urban ecosystem. Meanwhile, if an incorrect approach to solving the problem is opted for and the excess of this element is provoked, the damage of the bone tissue structure is possible.

It is heavy metals and radionuclides that pose the greatest hazard for the human health; according to the research data, they tend to get accumulated in soils but they still remain within the permissible limits. Higher acidity of soils renders them more accessible to plants. Substances entering soils as a result of motor and other equipment exhausts have quite a strong impact on the soils. Removal of these impurities from the soils is a long-standing and quite expensive process, so one has to keep in mind the environmental safety associated with this sector so early as at the stage of designing the area. Creating protective belts and barriers as well as selecting the environmentally friendliest layout of roads and industrial enterprises can mitigate considerably their impact on the elemental composition of urban ecosystems.

CONCLUSION

As there are numerous chemical elements and compounds in the human organism, and various microelements that have the effect on the functions of organs and systems, individual cells etc., the volumes of different elements entering the environment have to be controlled. The greater part of microelements is taken in with food and water, so the quality of soil on which the products are grown or livestock is out grazing has to be monitored.

Proceeding from the materials obtained during the study, it can be stated that with the course of time there is a trend for changing the land use, which is confirmed by the reconnaissance method. Reducing the areas of forests in favor of forming the agricultural and livestock breeding sector (formation of plough lands), mass and infill development is characteristic. It has been found out that it is the increment of residential area expressed in the formation of new residential districts with multi-storied development and in the formation of villa communities that is the most essential.

In this research, changeability of the content of chemical elements in the soil is confirmed, which can not only contribute to altering the ecological condition of the system but also bring essential changes to the chemical composition of the human organism.

During the on-site investigation, newly formed and transition soil horizons were found in the area of plough lands and in the residential area. They are associated with abundant inclusion of human life activity wastes and pollution due to construction. Over-consolidation of soils in the residential area and in ones located near the main motor- and railroads was observed, too. This can contribute to upsetting the water balance, which in its turn will lead to a number of diseases. They can include the general weakening of the immune system, allergic and asthmatic conditions, reproductive problems in women, caries-related and non-carious dental illnesses (fluorosis, enamel hypoplasia etc.).

It is the excessive content of radioactive elements and heavy metals in the soil that is a particular hazard. They can provoke the onset of serious illnesses such as malignant tumors. The main source of oil products entering the ground in the urban conditions is the emissions of motor transport, polluted fill-up earth, as well as carbohydrates permeating into the soils with the rainfall and snowmelt runoff.

The strong negative impact of the urban environment on the soil is expressed in polluting it with human activity wastes. Compounds of Cd, Co, As, Pb, nitrogen and sulfur dioxides disrupt the biological balance in the soil and produce a toxic impact on vegetation and the human organism. In Moscow, the main pollution sources are emissions of industrial enterprises, combined heat and power plants, and motor transport. Among the

pollutants, heavy metals (HM), chloroorganic compounds and other toxic agents are considered to be the most dangerous ones.

Against the background of a number of problems associated with changes in elemental composition of ecosystems possibly emerging, the possible disruptions of ecosystems have to be assessed at the design stage. In particular, environmentally friendly materials have to be used in construction, and protective barriers along highways have to be built. Various kinds of waste have to be recycled, too, with monitoring of adherence to the maximum permissible concentrations to be enhanced, and purification systems in agricultural and livestock breeding areas have to be set up, among similar measures.

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