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Soils Assessment in Natural and Anthropogenic Landscapes for Environmental Management

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Abstract: *Environmental management of territories, as a system of relations between nature and society, should be based on the findings of landscape ecological planning (LEP). The article analyses two types of territories: anthropogenically - managed urban landscapes in the city of Kharkiv (Ukraine) and minimally altered landscapes of National park "Slobozhansky" (Ukraine). They represent one landscape zone – forest – steppe, which is characteristic of the region. Based on complex LEP of the two areas some cartographic models have been drawn using GIS software that included soil sampling and its analysis. The difference between the acid-alkaline conditions caused by anthropogenic factors has also been revealed. This is the basis for environment management optimization.*
Keywords: environmental management, landscape - ecological planning, urban landscape, national park, soil, geochemical indicators.

1. Introduction:

To improve environment management efficiency in different territories it is appropriate to use the results of landscape ecological planning, as they integrally characterize natural and socio - economic conditions. Furthermore, the supplements proposed by the authors [8] to the classical landscape planning procedures, including geochemical studies, can develop more informative models of the area. Applying modeling processes to landscapes and forecasting future changes depending on the selected model can significantly reduce the role of the subjective factor and increase the effectiveness of management decisions.

At present, there are several models of landscape planning [1, 2, 3, 4, 6, 7] which contain information about its structure and the procedure. In varying degrees, they all share common features with the model proposed by Smeets and Weterings [5] in the report for the European Environment Agency - DPSIR (Driving forces, Pressures, State, Impacts and Responses), confirming its popularity in Europe. For Ukrainian realities, the authors propose its extension and amendments [9], which should be supplemented by geochemical studies.

Modern geochemical classifications of landscapes (A. I. Perelman, M. A. Glazovskaya, V. A. Alekseyenko, A. G. Isachenko, G. I. Denysyk, L. L. Malysheva) are based on the study of external (landscape-geochemical) factors of elements' migration. Herewith, what all classifications have in common is that the peculiarities of chemical elements' migration in soils should be taken into account at certain taxonomic levels. The greatest intensity of geochemical processes with maximum of humus which acts as a kind of geochemical center is found in soils of natural and natural-anthropogenic landscapes. On the one hand, the flows of natural and technological migration of elements are interrelated in the soils, and on the other hand, soils are at the crossroads of migratory flows from bedrock, groundwater, surface air and living organisms.

Geochemical classification of the landscapes in Ukraine, developed within the landscape and geochemical analysis and evaluation of landscapes by L. L. Malysheva [11], is also based on the determination of certain properties of soil. According to L. L. Malysheva (1997), all taxa in geochemical classification of landscapes are associated with physical and chemical properties as well as chemical composition of a humus layer in soils, which is determined as a geochemical centre of landscape-geochemical systems. The factors of landscape-geochemical territorial differentiation are:

1) chemical composition of mobile and fixed elements in the upper humus layer of soils;
2) mineralogical composition of soils and soil-forming rocks
3) their physical properties.

2. Study area, materials and methods:

The choice of methods for landscape-geochemical analysis primarily depends on the landscape-geochemical conditions of the territory, the specific anthropogenic load, etc. The desired rates mainly include the following [11]: mineralogical composition of the soil, its physical and chemical properties (soils pH, redox potential, the content and composition of humus, carbonate, etc.).Our research is based on the comparison of two fundamentally different areas in terms of operation: nature protection object of territory National Park "Slobozhansky", located in Krasnokutskii district, Kharkiv region (Ukraine) and territory urban landscape, located in city Kharkiv (Figure 1).

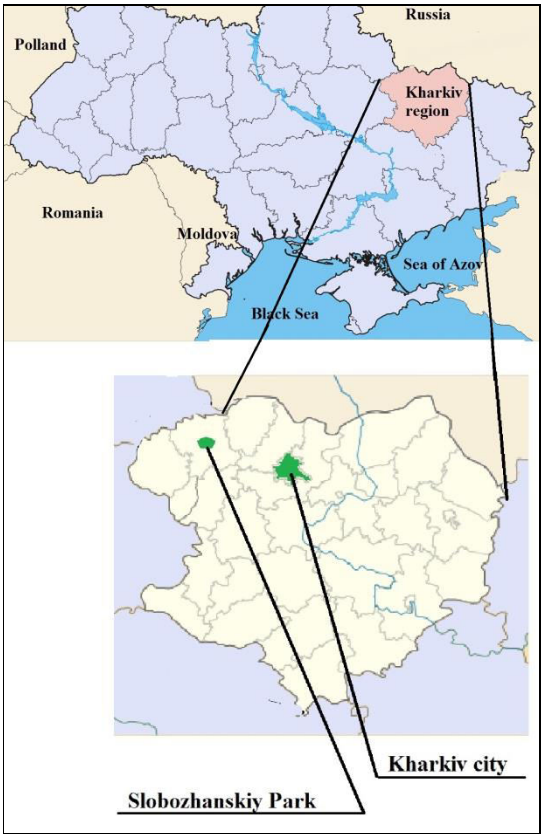

Figure 1: Location of Experimental Areas on the Map of Ukraine and Kharkiv Region

The first research area is the territory of the city of Kharkiv, characterized by a complex landscape structure due to the development of indigenous natural-territorial systems and the formation of natural and anthropogenic complexes of the city.

Within the city, a uniform network of research points identified by the characteristics of the landscape structure covering all functional zones of the city has been established. Experimental sites are located at the nodes of conventional regular lattice and are 2 km apart. The experiment included 105 model samplings: 83 - in the city, 22 - in the territories adjacent to the city (Figure 2).

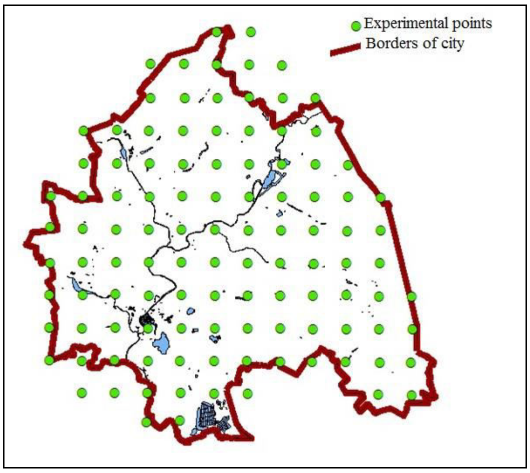

Figure 2: Network of Model Areas in Kharkiv

The second area of research is the National Park "Slobozhansky" where human pressure priori is the lowest and untouched nature areas have been still preserved (Figure 1). In the administrative boundaries of the park there is a uniform monitoring network covering all the natural landscape complexes inherent to it. Overall 73 pilot areas were incorporated (Figure 3).

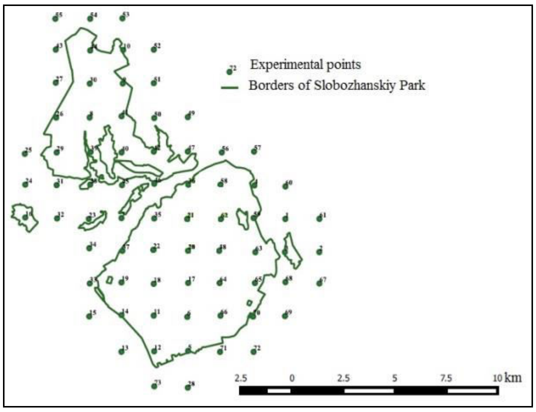

Figure 3: Network of Model Areas in Slobozhansky National Park

Complex reconnaissance and field work on the research and experimental plots certification were conducted from 2014 to 2016. PH was determined according to generally accepted certified techniques carried out by the potentiometer via electrodes EVL - 1M4 15-11 and ECL-connected digital ionometer pH-150.

The humus content was studied using a titration method for determining organic carbon by Turin's wet burning. Chemical analysis was conducted in the laboratory of analytical ecological studies at the

School of Ecology, V.N. Karazin Kharkiv National University.

3. Results:

The main factors that determine the nature of migration processes in soils are: acid-alkaline conditions, humus soil and environment migration ability to absorb and retain elements. The research enables to compare these factors in the conditions of natural and anthropogenic complexes of the city and protected areas to optimize environmental management of them.

The forms, in which a particular item migrates, and, correspondingly, its migration intensity are closely associated with pH. The reaction of the medium is an important indicator because this figure mostly characterizes migration ability of various chemical elements and compounds. Thus, the stability of the complexes formed by the interaction of humic substances with metal ions, depends primarily on the pH and ionic strength. These conditions determine possible binding of heavy metals with soils and separate components. It is known that rise in pH from 4 to 5.5 leads to increased adsorption of zinc on iron and aluminum hydroxide. When pH 7.5 zinc solubility increases complexes with organic matter form [12]. Thus, a variation in pH changes the role of soil components in heavy metals sorption.

Changes in pH also affect the activity of microorganisms through activation of some groups and oppression of others. The level of soil's enzyme activity connected largely with microbiological processes depends on concentration of hydrogen ions. This, in turn, affects the mineralization and humification rates, as well as a rate of humus accumulation.

It is known that the reaction of the soil environment depends on the balance of free ions H^+ and OH^- in it and is caused by the combined action of water-soluble substances (salts, acids, bases) of inorganic and organic origin, colloids, specific and non-specific nature (humic and fulvic acids, oxalic citric, acetic, formic, etc.). acids and clay minerals. Moreover, the reaction of the soil environment is affected by the secretion from plant roots which together with organic acids contain ions H^+, OH^-, NSO^{3-}, SO_3^{2-} [13]. A significant contribution to the formation of soil environment's reaction is made by the products of soil microorganisms' metabolism.

The reaction of the medium also directly affects the mobility of elements. One reason for this is that at higher pH redox potential of oxidation reactions reduces, i.e. at higher pH the element may be in the oxidized, while at a lower value - in the reduced state at the same meanings Eh of environment [14].

As pointed out by some researchers [15, 16], elements mobility, i.e. their ability to migrate, is the highest for Co, Cd, Mn, Fe, Ni, Zn in weakly reduced conditions (Eh is about +400 mV), Cu - in oxidizing conditions (Eh reaches 700800 mV). The lowest mobility of all these elements is in strongly reducing conditions (at lower Eh -50 - -150 mV) and in alkaline environment (up to pH < 8.5 - 9).

In the acidic environment the majority of cationic elements actively migrate, while increasing pH leads to a drastic reduction in the intensity of their migration through the formation of weakly soluble compounds of these elements. Hydroxide precipitation pH is often cited as the limit of a sharp decline in the intensity of a migration element.

To determine the acid - alkaline conditions of elements' migration in the research areas pH of soil water and salt extraction was measured [17].

The majority of the studied soils in the city of Kharkiv (for samples from depths of 0 - 30 cm) have a reaction close to neutral and slightly alkaline (Figure 4).

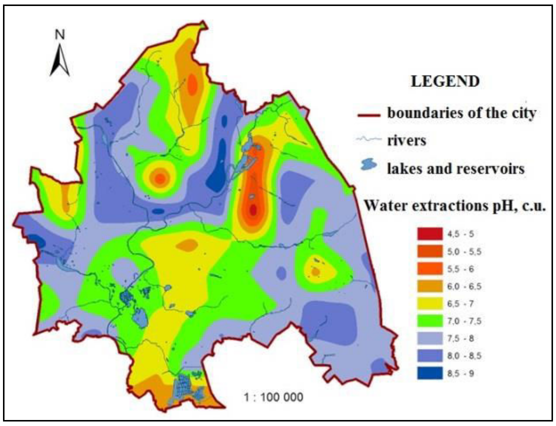

Figure 4: Distribution of water extraction pH within the study area (city Kharkiv)

The surface layer of urban soils under study has a relatively large amplitude fluctuation of pH $_{H2O}$ - from 5.36 to 8. 81. Average pH value in the studied soils in the city is 7.20. Standard deviation is - 1.22, variance - 1.28. Soil - forming rocks in the area (according to NSC IAA) have a slightly alkaline reaction. It should be noted that according to the results of agrochemical soil survey in Kharkiv region in 2010 – 2013 the average soil pH in the region (on average, without division into types) was 6.02; minimum - 5.5; maximum - 6.6; standard deviation - 1.68; dispersion - 0.06. Thus, by comparing values of the soils reaction in Kharkiv region and the city of Kharkiv, we see significant changes in the alkaline-acid balance with the shift to the alkaline one.

In the studied automorphic soils pH of aqueous extract is primarily caused by Ca^{2+} and NCO_3^- content. In hydromorphic soils the impact of water-soluble salts on pH is not so clear, and unlike automorphic soils, Cl^- and Mg^{2+} ions play a more important role. The inverse relationship between water-soluble calcium carbonate content and pH is found in alkaline soil which is constantly fed with capillary moisture almost to the surface due to the proximity of groundwater. Maximum water soluble carbonates content in the top layer of the soil for the landscape in general is explained by their deposition on a steamy barrier. Such precipitation was not registered in the black soils meadow where groundwater is much deeper, and there are no conditions for the loss of calcium carbonate.

The alkali soil area is mainly localized in the central part of the study area, confined to the floodplain and terraces of the river Lopan. This is the territory of densely located old private houses and infrastructure. Many researchers associate general tendency to alkalinization of urban soils with the arrival of compounds containing carbonate dust in the emissions [18, 19, 20]. The duration and regularity of such pollution is the cause of soil resistance to alkalinization.

The obtained pH_{H2O} and pH_{KCl} values indicate widespread alkalinization of urban soils. In most cases it is due to the presence of alkali and alkaline earth metals carbonates. Real contribution of different anions in alkaline soil formation depends both on the basicity constant, and the concentration of these ions in soil extracts. Urban soils with alkaline reaction are dominated by carbonates. It has been also established that pH_{H2O} has a fairly close negative and positive correlation with hydrocarbonates but always positive, and in some cases close - with calcium.

Thus, possible acidification of soils in urban areas due to intensive S_xO_y, NO_x and other substances emissions that can affect the pH value of the soil acidity is unlikely to happen in the area. This can be explained by several factors. First, bicarbonates, which are hydrolytically alkaline salts, form in the soils under the influence of sediments with a large amount of dissolved carbon dioxide. They can change the soil environment reaction to alkaline. Secondly, because of the atmospheric transfer soil acidification does not happen in the vicinity of the pollution source (1 - 1.5 kilometers). Thirdly, free oxygen is bound to the soil, and it cannot be detected by analyzing aqueous extract. Hydrogen ions from aqueous extract make up a fraction of the total number of hydrogen ions in soil.

The phenomenon of wide spread alkalization of urban soils has been found by various researchers for the towns with different industrial specialization located in different natural areas. It has been noted that in more acidic soils, such as the sod-podzolic soils, this pattern is clearly expressed than in naturally neutral soils, but the alkalization process is inherent to them as well.

The presence of man-made alkaline surface geochemical barrier creates a situation in which the processes of surface accumulation dominate and inhibit the processes of vertical and horizontal migration. Thus, in most parts of the investigated valley alkalization of urban soils surface layers leads to decrease in migration ability of various pollutants, including heavy metals.

Research of pH_{H2O} in the soil samples from park “Slobozhansky” (Figure 5) showed a range from 4.0 to 8.81, and the average value was 6.18. Indicators of pHKSl in soil samples from the park "Slobozhansky" ranges from 3.17 to 7.84, and the average value is 5.36. This indicates significant acidification of soils.

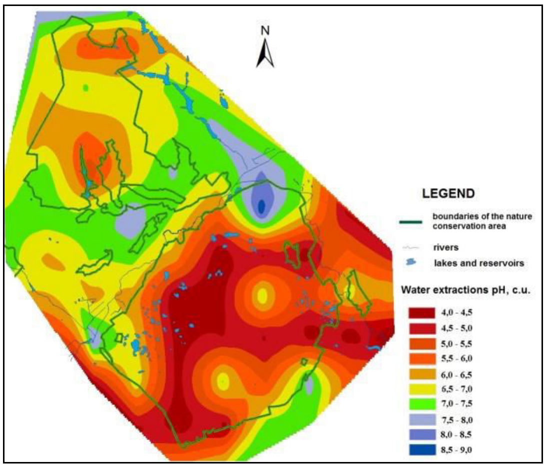

Figure 5: Distribution of water extraction pH within the study area (park “Slobozhansky”)

Spatial analysis of a cartographic model (Figure 4 and 5) shows that most of acidified soils are concentrated on the forest terrace with about 200 lakes and wetlands. Acidic soils are typical for this area. Such soils are characterized by deficient mineral nutrition, low fertility and the appearance of specific plant communities (such as insectivorous plants).

Different soil geochemical associations (with acidic soil pH < 5.5, with slightly acidic and neutral soil pH 5.5- 7.5, with alkaline and highly alkaline soils at pH 7.5 - 9.5) have significantly different degree of element mobility.

4. Conclusions:

Redox conditions were evaluated based on the assessment of indirect indicators. Automorphic soils of forest-steppe are in predominantly oxidative environment conditions, while hydromorphic soils of the floodplain are formed at a constant or sporadic domination of reducing conditions, as indicated by signs of gley soil in the meadow and meadow-marsh soils of the landfill in a bluish-black color, rusty – yellow spots and carbonaceous grains of divalent manganese. According to [21] redox potential of soil depends (in decreasing order of importance factor) on:

1) wetting regime;
2) the amount of decomposing organic matter and its material composition;
3) microbiological activity;
4) soil aeration due to its density.

In turn, automorphic soils of forest-steppe can renew under conditions of sporadic overwetting in the early spring. The lowest Eh values for steppe zone soils are observed in the spring, through creation of favorable conditions for the development of anaerobic biochemical processes and high soil moisture.

Redox conditions are replaced in the landscape both in space (from oxidation in soils of eluvial and transeluvial landscapes to weakly reduced in superaquatic and reduced in aquatic landscapes), and in time - from weakly reduced in early spring to oxidizing at other times of the year.

These conditions promote emergence of bilateral gley-oxygen geochemical barrier at the contact border of oxygen surface and groundwater on the slopes and gley water of flooded soils, as well as manganese deposition in the upper layers of automorphic soils on oxygen barrier.

Mobility of chemical elements is caused by geochemical conditions prevailing in natural and natural-anthropogenic complexes of the river valley. Thus, pH of heavy metals hydroxides precipitation is growing in number: Fe^{3+} << Fe^{2+} < Cu < Zn < Ni < Co = Pb < Mn < Cd. Assuming that heavy metals in a model system are present only in the form of simple compounds and there is no physical and chemical absorption, all the processes are chemical deposition-dissolution. Also the average depth of alkali barrier is more than 50 cm and the average pH of 50 cm layer of soil is 6.6. - 7.2. Then in the conditions of the studied natural and natural-anthropogenic landscapes deposition on the alkaline barrier is possible mainly for Ni, Co, Pb and Cd, and in reducing conditions - even and Mn. Unlike them, Fe, Cu, Cr and Zn are deposited in the upper soil layers.

Changes in pH from neutral to slightly alkaline at the lower boundary of automorphic soils profile leads to the emergence of alkali barrier. That is, soil forming rocks with pH about 8 form alkaline barrier for almost all of these elements; only Cd^{2+} with hydroxide sedimentation within pH 8-9.5can theoretically be mobile in these rocks.

In backwater weakly reduced conditions elements such as Mn and Fe can be increasingly mobile due to somewhat lower pH. However, in Eh > 200 mV almost all formed Fe^{2+} oxidizes Mn^{2+} to Fe^{3+} [21]. Therefore, iron mobility in weakly reduced conditions is low. Cd, Co, Pb, Ni and Zn are more mobile in hydromorphic soils of the floodplains than in slope soils.

Thus, the conditions of chemical elements' migration in the city are less contrasting relative to the soil profile and the surface (for pH and the content of humus) than in protected areas of national park "Slobozhansky".

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