Ecological State of Soils and Technogenic Superficial Formations in Perm City

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Abstract: Soil cover in Perm City is characterized by frequent interchange of soils and technogenic superficial formations (TSF). Soils of low-rise building area, industrial and agricultural zones along with transformed upper horizons in the lower part of the soil profile inherit characteristics of nature soils. In multistory building areas TSF prevail. Neutralization of acidity, increase of humus content and nutrients correlated with increase of biochemical activity of soils and TSF. Agrourbosoils and agrourbanozems of orchards and vegetable gardens have a thicker biologically active layer. In multistory building areas reduction of biochemical activity characteristics of root-inhabited soil and TSF layer was registered.

Key words: Urban soils · Enzymes activity · Land use · Ecological state of soils

INTRODUCTION

Soil investigation and mapping of urban areas is primary based on zoning according to zone functions and further description of the most representative soil profiles within each zone [1-3]. Land use type (functional zoning of area and the related types and degree of impact on soil) is the key factor of soil cover alteration. At the same time, in the city basic properties (granulometric composition, mineralogy, chemism, etc.) of nature soils and rocks are inherited when being transformed, fully destructed or TSF formed, that complicates soil cover structure. At present urban soils are regarded as renewable resources. Landscape planning and standardized anthropogenic impact technologies are being developed on basis of urban soil resources inventory [4].

At present soils and soil fertility are degrading due to anthropogenic impact. Depression of biochemical soil activity is registered when being polluted with heavy metals, in oil product contamination areas and in case of general lack of soil fertility. Influence of toxic wastes results in soil sterilization and plant and animal habitat impair [1, 5-9].

The objective of this research was to study soil and technogenic superficial formations (TSF) variety of various functional zones on the left bank of Perm city and to evaluate ecological condition of root-inhabited soil layers.

MATERIALS AND METHODS

Systematization of variety soil and TSF of functional zones on the left bank of Perm city was made on basis of field research data considering well-known classification approaches [3, 10-13].

In order to evaluate soil and TSF state a number of routine methods of biochemical and agrochemical values were used. Water pH was determined by pH-meter in 1:2.5 (w/v) soil:water suspension. Salt pH was measured in 1:2.5 (w/v) ratio of soil to KCl suspension, hydrolytic acidity (H_{pH}) by the Kappen and titrimetic method, base saturation by the Kappen-Gilkovits method, cation exchange capacity (CEC) by calculation method, in alkaline samples cation exchange capacity was determined by the Shmuck method. Soil organic matter was measured by wet oxidation and titrimetic method, available phosphates by photometric method using acid extract by the Kirsanov method, available potassium by photometric method.

Soil enzyme activities were assayed in air-dried samples. Briefly, catalase activity was measured using H2O2 as a substrate, shaked for 10 min and catalase activity was expressed as O_2 $cm^3/g/min$. Urease activity was determined using urea as substrate and the soil mixture was incubated at 37°C for 24 h, the produced NH3-N was determined by a colorimetric method and urease activity was expressed as mg NH3-N mg/100g/h.

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Phosphatase activity was measured using sodium phenolphthalein phosphate as a substrate, incubation at 37°C for 24 h and the liberated phenol was determined colorimetrically, phosphatase activity was expressed as phenol mg / 100g/h;

Soil respiration was evaluated by the quantity of carbon dioxide emitted by soil for 24 hours at 28°C temperature by adsorption method by the Sharkov method.

All the statistical analyses were performed using Statistica 8.0 software.

RESULTS AND DISCUSSION

Soils of natural system and soils of recreation purposes situated within the administrative boundary of the city were referred to natural recreation area of Perm city. Its total area in left-bank part of the city is 277 km^2 (59 %). In soil cover soddy podzolic soils on cover loams prevailed. Soddy soils of slopes on eluvium of Perm rocks and soddy and dark humus soils in the Kama basin valleys are represented in small areas.

In residential areas of low-rise (private) building of total area of 47 km^2 (10%) soil cover structure is significantly transformed. Urboagrosoils that are cultivated soils of private areas prevail among soil types. Urbanozems, urbosoils, replantozems and ecranozems are less widespread.

In medi- and multistory building zones of total area of 61 km^2 (13%) open areas are mainly occupied by various TSF on organic and mineral interbedding sediments, that are valley peat, sand, loamy soils, loams and carbonaceous rubble. Among them urbosoils buried under sediments were presented.

In industrial zone of total area of 58 km^2 (12%) near build-up objects and roads urbanozems and urbosoils contained many solid inclusions especially of industrial origin. Mineral formations without humus (TSF) were represented on recently formed covers that were cultivated by covering with valley peat layer. In areas distant from buildings natural soils were presented.

In agricultural zones of total area of 22 km^2 (6%) in Perm city soil cover was formed of agrozems and agrosoils that inherited some characteristics of nature soil composition.

Ecological-agrochemical and biochemical condition of root-inhabited soil layers were evaluated by application of statistical criteria. Minimal, maximal, average values, medians and quartiles of soil layer 0-25 cm and confidence interval of general medium for 5 % significance level are given in Table 1.

Taking into account the amount of soil cover research data in Perm city, it is recommended to take confidence interval as background level of root-inhabited soil layer condition. Phosphotase activity and pH distribution pattern was not determined, therefore median and quartile were taken as background level.

In case of any side deviation of values from background condition it can be stated that soil properties and biological functions are significantly disrupted. Evidently, this occurs due to high level of chemical pollution, degradation of physical properties, etc.

As it is known, agrochemical values indicate soil fertility and there are soil valuation scales according to these values. Ecological-agrochemical condition is also important for urban soils which provide stability of planted lands. Biochemical properties of soils, particularly

Table 1: Results of statistical analysis of ecological state variables of soils in industrial, residential and agricultural areas of Perm city (layer 0-25 cm)

Variables	Number of samples	Mean	confidence interval	minimum	maximum	median	higher quartile	lower quartile
Organic matter content, %	40	2.4						
1.9-2.8	0.4	5.7	2.2	1.2	3.3			
CEC, meq/100 g	35	24.3	20.2-28.4	1.3	47.4	20.7	16.7	33.9
pH (1:2.5 soil: water suspension)	47	-	-	4.4	8.3	7.2	6.5	7.5
pH (1:2.5 soil: KCl suspension)	42	-	-	3.7	7.6	6.8	5.6	7.1
Available P$_2$O$_5$, mg/100 g	28	2.5	1.7-3.3	0.1	8.9	1.8	1.2	2.9
Available potassium, mg/100 g	28	17.0	13.3-20.7	3.5	35.2	14.2	9.5	27.0
Catalase activity, Î$_2$ cm^3/g/min	45	3.8	3.3-4.3	1.0	8.0	3.0	3.0	5.0
Urease activity, N-NH$_3$ mg/100 g/h.	45	3.3	2.4-4.2	0.2	18.0	2.3	1.9	3.6
Phosphotase activity, P$_2$O$_5$ mg/100 g/h.	41	-	-	0.1	1.3	0.3	0.2	0.6
Soil respiration, CO$_2$ mg/ 100 g/24 h.	45	30.0	25-35	2.0	64.0	29.0	18.0	37.0

Table 2: Correlation coefficient between values of ecological state of soils and TSF in Perm city (layer 0-25 cm)

	Organic matter content	CEC	pH_{h2o}	pHkcl	Available P_2O_5	Available potassium
Catalase activity	0,63*	0,64*	0,22	0,22	0,10	-0,20
Urease activity	0,58*	0,33*	0,09	0,16	0,33*	0,36*
Phosphotase activity	0,08	0,21	0,21	0,19	0,38*	0,37*
Soil basal respiration	0,47*	0,73*	0,63*	0,66*	0,53*	0,46*
Soil substrate-induced respiration	0,30	0,62*	0,66*	0,67*	0,58*	0,53*

* - significant at 5 % level

Table 3: Factor influence on soil ecological state values (layer 0-25 cm) of industrial, residential and agricultural zones in Perm city

Values	Factors	
	Acidity neutralisation	Humus accumulation
Organic matter content	0,05	0,83*
Basal saturation	0,75*	0,42
H_{pH}	-0,89*	0,03
pHh_2o	0,95*	0,09
pHkcl	0,94*	0,15
Available P_2O_5	0,40	0,56
Available potassium	0,49	0,45
Catalase activity	0,53	-0,24
Urease activity	0,13	0,77*
Phosphotase activity	0,14	0,03
Soil basal respiration	0,70*	0,54
Soil substrate-induced respiration	0,70*	0,46
Factor influence, %	40%	21%

* - significant impact.

urban soils are less studied. At the same time biochemical activity of soils is considered as biological soil function value as enzymes are generated by all living organisms and their activity depends on soil properties. Due to that fact, the correlation between ecological-agrochemical and biochemical values of root-inhabited soil layer condition was studied (0-25 cm). Mathematical treatment showed average correlation dependence between organic carbon, basal saturation, available phosphates on the one part and catalase and urease activity, "respiration" values on the other. Phosphatase soil activity correlated with the content of available mineral nutrients of plants (Table 2).

Consequently, less acid soils with concentration of humus and available mineral nutrients had higher enzyme activity and produced carbon dioxide more intensively ("respiration"). In general, taking into account the complex of ecological-agrochemical and biological values, one can adequately evaluate the ecological function property of urban soil and TSF.

In transformed soils and TSF of green fields, industrial and agricultural zones values of background, increased and reduced biochemical activity of root-inhabited soil layers were equally presented. In low-rise building areas almost half of the values of root-inhabited soil layer condition were higher than the background values. The worst ecological state is registered in multistory building area where along with deep transformation of soil layer, 60 % of biochemical values were lower than the background and only 11 % of values were higher than the background level, that is the evidence of disruption of soil cover ecological functions.

The results of mathematical data treatment by PCA (principal components analyses) showed (Table 3) that in upper layers of soils and TSF in residential, industrial and agricultural zones in Perm city 40 % of soil property variability were determined by actual and exchange acidity factors. Under the influence of the factors integral values biochemical activity, that are basal and substrate-induced respiration were significantly varied.

CONCLUSIONS

According to soil cover organization of Perm city and the objects of landscape planning the following functional zones were distinguished: greenfield (nature-recreational), residential with low-rise building, residential with multistory building, industrial and agricultural.

Soils in low-rise building areas, industrial and agricultural zones along with transformed upper horizons ('urbic', arable) often inherited characteristics of nature soils, especially in the lower part of the profile. In multistory building areas due to mechanical disruption or total destruction of soil cover, technogenic superficial formations prevailed.

In urban conditions amelioration of soils was registered in low-rise building areas, where in private areas agrourbosoils and agrourbanozems with a thicker biologically active layer had been formed.

There was correlation dependence between values of agrochemical and biochemical condition of root-inhabited

soil horizons. Acidity neutralization, increase of humus content and nutrients correlated with increase of biochemical soil activity.

In multistory building areas reduction of biochemical activity values of root-inhabited soil layer and TSF was registered that evidently reflects disruption of soil cover ecological functions.

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