Biological activity of forest litters in Ukhta City's Central Park soils (The Komi Republic)

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Abstract. Physicochemical properties and parameters of biological activity of forest litter horizons of illuvial-ferruginous podzols, formed the main part of soil cover of the largest recreational zone of Ukhta city, the G. A. Karchevsky Central Park, have been determined for the first time ever. In the park soils, a change in the basic agrochemical parameters (alkalinization and an increase in the content of available forms of the most important biogens with the exception of organic compounds carbon), the accumulation of heavy metals (up to moderately toxic level according to value of total pollution index) and petroleum hydrocarbons were indicated in comparison with background soils. An increase in soil enzymes (catalase, invertase) activity and a metabolic activity of soil microbial community was established. Based on the spectra of organic substrate consumption (multisubstrate testing method), a higher activity of all microbial functional (trophic) groups, with the exception of bacteria that consume alcohols, hexoses, and amino acids as an energy source, was revealed.

1 Introduction

Recently, special attention is paid to the study of urban soil properties - urban ecosystems. This is due to the growth of the areas of cities in today's world [1], and also the specific ecological state of the urban environment [2, 3]. All components of the urban ecosystems are strongly affected by anthropogenic impact, but the soils include the highest load. The urban soils are universal indicators and the most important stabilizers of the state of urban environment. The wellbeing of the entire urban ecosystem depends on their quality [4, 5]. Integral indices of the balanced functioning of soils are parameters of vital activity and functioning of soil microbial communities. [6, 7].

At present, microbial communities of urban soils are being actively studied in Russia. Such studies have been conducted in more than 30 cities [8]. But at the same time there are still regions where urban soils are still poorly studied in this aspect. The Komi Republic is among them. Under the high level of urbanization (the urban population is around 80%) and the developed industry, urban soils of the Komi Republic are still almost unexplored. Single publications are mainly devoted to the

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assessment of urban soil pollution by priority pollutants excluding the reactions of soil microorganisms on this pollution [9, 10].

The aim of this study is to assess the level of biological activity of forest litters of soils in the recreational zone of Ukhta city, one of the industrial cities of the Komi Republic.

2 Objects and methods

Ukhta is relatively young industrial city of the Komi Republic. It was founded in 1929 as a settlement of oil workers and currently known for the transportation and processing of hydrocarbon raw materials. In the second half of the 20th century, mechanical engineering, metalworking and the production of building materials were also developed here. The population of the city is currently about 90 thousand people, the area is 100 sq. km. The city is equated to the regions of the Far North of Russia.

The G. A. Karchevsky Central Park (Children's Park) located in the historical part of city. It is one of the largest recreational zones of Ukhta city. This is the oldest park of culture and recreation, found in 1937. Its area is about 10 hectares. The degree of greening of the park is 75%. The basis of green spaces is formed by a stand of Pinus sylvestris (crown density is up to 80%). The ground vegetation cover is strongly disturbed in some places– the projective cover is 20–30%. The ground cover is dominated by Pleurozium schreberi and herbaceous plants (Taraxacum officinale, Trifolium repens, Plantago media, etc). Detritus composed of cones, needles, twigs, and bark is slightly decomposed; the projective cover is up to 50%. In the park the natural soils developed on sandy deposits have been fragmentarily preserved. Their profile corresponds to the profile of illuvial-ferruginous podzols. Such soils, represented within the park, hold a great scientific value. These soils allow assessing the degree and the pattern of anthropogenic transformation of illuvial-ferruginous podzols under urban impact as compared to background soils of the same type [11]. The parameters of the forest litter horizon as the most dynamic soil horizon are especially informative in this regard [12].

To achieve this goal, in the summer of 2018, in the park areas with undisturbed illuvial-ferruginous podzols, small soil pits (10 pits) have been dug up (to a depth of 30 cm) to sample soils from upper organogenic (forest litter) and mineral (podzolic) horizons. For studies, a mixed sample of forest litter compiled from 10 individual soil samples was prepared. The soils of the specially protected natural territory of federal significance - Paraskiny Lakes Nature Reserve were used as the background soils. The Reserve is located 50 km southwest of Ukhta. Illuvial-ferruginous podzols are common on the territory of the Reserve, their forest litter samples were used to compare with the soils of the Karchevsky Park.

Quantitative chemical analysis, biochemical and microbiological studies were carried out on the basis of the Soil science department and the Ecoanalytical Laboratory of the Institute of Biology of the Federal Research Center of the Komi Scientific Center of the Ural Branch of the Russian Academy of Sciences (Syktyvkar). Agrochemical indices, as well as the content of priority pollutants (heavy metals and petroleum hydrocarbons) were determined according to the

classical methods of soil science. The biological activity of soil forest litters was assessed based on its enzymatic activity (enzymes catalase and invertase) and metabolic activity (functional diversity) of microbial communities. The catalase activity was determined by the gasometric method and the invertase activity by the photocolorimetric method [13, 14]. The functional diversity of microbial communities and the level of their metabolic activity were determined by the multisubstrate testing method based on the assessment of the optical spectra of consumption of organic substrates (47 test substrates) using the 96-well "Eco-log" test plates and the automated data processing system [15]. The total wellbeing of microbial communities was assessed using the indicator of the rank distribution of substrate consumption (d) on the following scale: 0,01–0,1 - sustainable system with a maximum safety margin, 0,1–0,4 - sustainable and stable system; 0,4–0,8 – resource-depleted system (oppressed state); 0,8–1 – destabilized system (crisis state); more than 1 –system is irreversibly broken (catastrophic state).

3 Results and discussions

The data of quantitative chemical analysis are shown in Table 1. Apparently, the properties of forest litter horizons of illuvial-ferruginous podzols represented in the city park (urban soils) are slightly different from those of background soils. For urban soils (podzols), it was noted (i) a decrease in acidity (the reaction of medium changes from very strongly acidic to slightly acidic compared to the background), (ii) an increase in exchangeable bases (calcium 2,9 times, magnesium 1,5 times) and (iii) a slight increase in mobile forms of phosphorus and potassium (1,3 times). A decrease in soil acidity under urban impact is the specific feature of urban ecosystems [2, 3, 9, 11, 16]. In urban soil, a slight decrease in the organic carbon content in forest litter horizon (1,2 times) may be due, on the one hand, to recreational load [16], and on the other hand, to the activation of the vital activity of the microbiota under conditions of decreasing acidity, increasing biophilic elements and increasing role of herbaceous plants in the structure of ground cover.

Assessment of heavy metal content and arsenic in urban and background soils showed the following. In the forest litter horizon of urban soil, the total content of nearly all kinds of heavy metals is higher compared to background soil. The elements are most intensively accumulated in the forest litter of the urban park are as follows: Fe, V, Zn, Co, As. The concentration factors for them range from 3,8 (Fe) to 4,5 (As). An exception is manganese, which a higher content (1,4 times) was indicated in the forest litter of illuvial-ferruginous podzol in the Reserve, compared to podzol studied in the Ukhta City park. The calculation of the complex index of total pollution, including the geometric mean of concentration factors of heavy metals relative to both the background and toxicity of heavy metals [17], showed that its value corresponds to the moderately hazardous level of pollution (Z = 22). The sanitary and hygienic standard (Sanitary Rules and Normative 1.2.3685–21) for the approximate permissible concentration (APC) was exceeded only for single heavy metal, zinc (by 2.4 times).

In the central park, the content of petroleum hydrocarbons in the forest litter is significantly lower the regulated values of acceptable level of soil pollution with oil

and petroleum products (1000 mg/kg) [18]. However, the values obtained for the park soil exceed 5 times indices for the background (Table 1) that may be the result of urban impact on hydrocarbon accumulation not just for soils of the transport and industrial zones of the city, but for the soils of the recreational area.

Table 1. Characteristics of forest litter in podzols under urban park and background area

Indices		Unit of measure	Urban	Background
The hydrogen index of the salt extract, pH (KCl)		pH unit	5,4±0,1	3,5±0,1
Organic carbon content, Corg		%	24±1,2	29±1,5
Content of exchangeable bases	Ca2+	cmol kg-1	38±2,8	13,3±1,0
	Mg2+	cmol kg-1	5,1±0,4	3,5±0,3
Content of mobile forms	P2O5	mg kg-1	382±57	285±43
	K2O	mg kg-1	723±72	568±57
Petroleum hydrocarbons content		mg kg-1	90±40	18±8
Total index of heavy metal soil pollution, Z (calculated according to [17].)			22	–

It is known that parameters of biochemical and microbiological activity of soils are closely associated with their physicochemical properties and pollution levels [7, 8, 19]. Our data indicate a relatively high level of enzymatic activity of urban soils (Figure 1). According to Zvyagintsev [13], in the forest litter, a degree of enrichment for catalase corresponds to an average value, and for invertase to a high one. These indices are significantly higher ones for the background: for catalase activity – 5.6 times, for invertase activity – 10 times. In background soil, the enzyme activity of both is low. In forest litter horizon of background soils, invertase activity corresponds to low level, and catalase activity to very low level, which is basically typical for podzolic soils of the taiga zone.

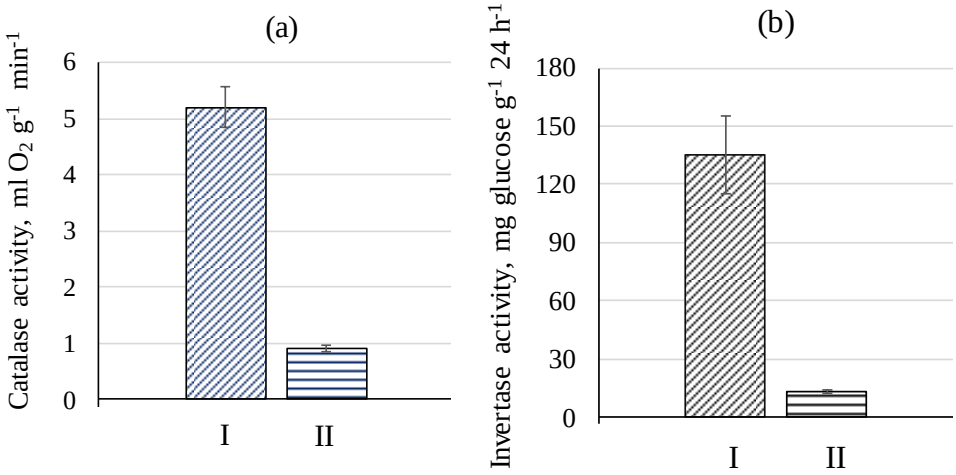

Fig. 1. Enzyme activity indices for catalase (a) and invertase (b) in forest litter horizons of illuvial-ferruginous podzols under urban park (I) and background area (II).

Lately, during urban soil quality assessment both in Russia [19] and abroad [20, 21], the parameters of the functional diversity of soil microorganisms are used. We studied the functional activity of soil microbial communities for the soils of two sites (the city park and the background area) using the multisubstrate testing method. The

results showed the trophic structure of microbial communities is very diverse for both studied sites (Table 2). Of the 47 substrates, in urban podzol, forest litter microorganisms did not utilize only starch, and in background podzol, dulcite, acetate and treonin. The Shannon (H) and Pielou (E) indices, which characterize the diversity and evenness of microbial communities, are almost identical for both studied sites: the H index is more than 5, and the E index is close to 1. However, the specific metabolic work (W) of microbial communities in forest litter of urban soils is 1.4 times higher than background soils (Table 2). This indicates a higher trophic activity of microbial communities in urban podzol, compared to background podzol, which is free of anthropogenic impact. This may be due to both a change in the basic agrochemical parameters of topsoil (first of all, neutralization of the reaction of the medium), and an increased content of certain heavy metals and hydrocarbons. It is important to note that under certain conditions, they can not only depress [22, 23] but also encourage the biological activity of the soil [24, 25, 26].

Table 2. Parameters of biodiversity and metabolic activity of microbial communities of forest litters of podzols under urban park and background area (according to results of the multisubstrate testing method).

Site	Consumed amount of substrates (N)	The Shannon index (H)	Pielou evenness index (E)	Specific metabolic work (W)	Destabilization level of bacterial community (d)
Urban	45	5,37	0,98	2500	0,05
Background	44	5,23	0,96	1766	0,25

Differences in the biological properties of the studied soils can be traced not only in the level of metabolic activity of soil microorganisms, but also in the consumption intensity of certain types of organic substrates (Figure 2). Apparently, in the structure of microbial communities functioning in the forest litters of urban soils, the share (% of total numbers) of bacteria consumed oligosaccharides, polymeric and nitrogen-containing organic compounds is slightly higher. In background soils, there is slightly higher share of microorganisms utilized hexoses, alcohols, and amino acids. This may also indicate a change (i) in urban soils, even as they retain the morphological structure of natural undisturbed soils, and (ii) ecological conditions for the vital activity of soil microorganisms.

Assessment of the general condition and level of wellbeing of microbial communities using the parameter of rank distribution of the substrate consumption (d) revealed the following shown at Table 2. Forest litter bacterial complexes of urban and background areas correspond to the state of stable and sustainable systems ($d<0.4$). Despite the increased content of certain heavy metals and hydrocarbons in urban soils, the vital activity of microbial communities in ones is not disturbed.

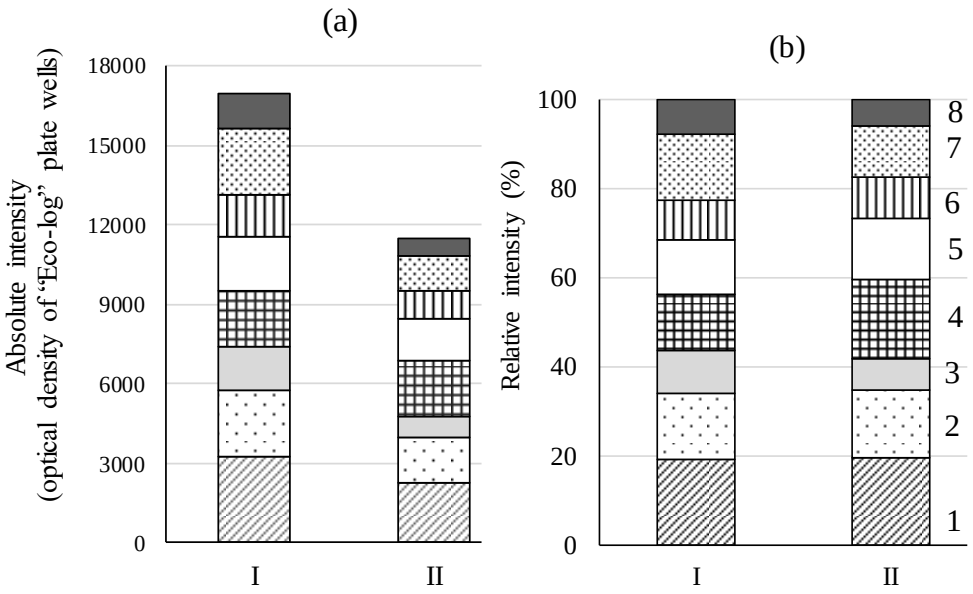

Fig 2. Absolute (a) and relative (b) intensity of consumption of organic substrates by microbial communities in litter horizons of soils under urban park (I) and background area (II). Substrates: 1 - pentoses, 2 - hexoses, 3 - oligosaccharides, 4 - alcohols, 5 - amino acids, 6 - low molecular weight organic acids, 7 - polymers, 8 - nitrogen-containing organic compounds.

4 Conclusions

Therefore, these studies allow making the following conclusions. The forest litters of urban soils (podzols of the recreation zone of Ukhta City's Central Park) is characterized by higher biological activity compared to background indices. This is expressed in the activity of soil enzymes and the metabolic work of microbial communities. With the similarity of the trophic structure of microbial communities of urban and background soils, the consumption activity of organic substrates by microbial communities is higher under urban conditions. Differences in microbial communities inhabiting the forest litters of podzols are also revealed in some activation of consumption of oligosaccharides, polymer and nitrogen-containing substrates under urban conditions. Share of microorganisms, consumed hexoses, alcohols, and amino acids, is higher in background soils. More favorable conditions for the functioning of microbial communities in urban soils are due to a neutralization of the soil medium and an increase in the number of chemical elements and carbohydrates (hydrocarbons) in soil capable to encourage the vital activity of soil microbial communities.

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