Urban soil mycobiota and its potential danger for human health in the Subarctic

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Abstract
The quantitative and qualitative parameters of cultivable microfungi communities in urban soils of Subarctic (Apatity, Murmansk region, Russia) were evaluated. In total, 21 species belonging to 11 genera, 10 families, 7 orders, 5 classes, and 2 divisions were distinguished. We determined the proportion of allergenic, toxigenic, and opportunistic microfungi and their potential pathogenicity for humans based on extracellular enzyme activity. The number of microfungi in urban soils varied from 1×10^3 to 9×10^4 CFU g^{-1} and was lower than in the forest soil (background) except in the recreational zone. In urban soils, there was a decrease in species diversity compared to forest soil and a significant change in species diversity, as evidenced by the low value of the Sørensen index (28%). Fungi that pose a threat to human health made up to 85% of the total number of isolated species. The most dangerous genus in urban soil was Aspergillus. An increase in their shares and frequency of occurrence in urban soils compared to the background was found as well. We noted the appearance of dangerous fungi belonging to the RG2 group, an increase in the number of toxigenic (by 15%) microfungi in urban soils. According to the mycological risk index (Im = 6.7-8.4), urban soils were classified as dangerous in Apatity. Microfungal strains with higher extracellular activity of proteinase and phospholipase enzymes than in the background soil were isolated from urban soils. These species also had the ability to grow at human body temperature. Regular monitoring of allergenic, opportunistic and toxigenic fungi in urban soils allows us to assess their potential impact on residents of Northern regions and recommend minimizing contact with the soil and hard road surfaces. This is especially important for preschool children, in order to reduce the likelihood of interaction with opportunistic fungi.

Key words: opportunistic, allergenic, toxigenic microfungi, mycological risk, enzymatic activity, northern region

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Introduction

Throughout our life, we are constantly in contact with microfungi, which are present everywhere in the environment (Barnes 2019). The main reservoir of fungi is the soil (Sabale et al. 2019, Sokol et al. 2022). Fungi are the most important groups of saprotrophic soil microorganisms, because of their leading role in decomposition of wide range of organic substances and high biomass content (Kaviya et al. 2019, Schmidt et al. 2019, Mayer et al. 2021). The microbial communities of urban soils differ from those in natural ones in the same zonal conditions by the functional and taxonomic diversity, morphological structure of fungal biomass (spore/mycelium ratio), dominating species, and the increasing portion of opportunistic fungi, yeast and bacteria (Delgado-Baquerizo et al. 2021, Bridget Gleeson 2022, Gómez-Brandón et al. 2022).

Due to the growing number of allergic and mycotic diseases caused by opportunistic fungi, special attention should be paid to microfungi (Gnat et al. 2021, Xu 2022). Opportunistic fungi can develop and persist in the environment for a long time and may cause mycoses in people suffering from immunodeficiency and other serious diseases (Kumar et al. 2019, Oliveira et al. 2023). Microfungi are also one of the most common sources of allergens in the environment. Over 300 species with allergenic properties have been reported (*see* e.g. Simon-Nobbe et al. 2008, Esch et al. 2020, Sztandera-Tymoczek and Szuster-Ciesielska 2023). A large number of microfungi are known to produce toxins, especially species of the genera *Aspergillus* and *Penicillium* (Perrone et al. 2020, Picková et al. 2020). Toxigenic fungi that often cause allergic symptoms in humans, such as allergic rhinitis, conjunctivitis, atopic dermatitis, or eczema are also dangerous, because they can lead to the development of severe bronchial asthma. Mycogenic allergies can be induced by microfungi of genera *Aspergillus, Aureobasidium, Chaetomium, Cladosporium, Phoma, Penicillium,* and others.

Humidity, temperature, and environmental contamination contribute to the growth and reproduction of microfungi, including opportunistic species (Bornehag et al. 2001, Abdolshahi and Shokrollahi Yancheshmeh 2020). There is clinical evidence that exposure to mold and other dampness-related microbial agents increases the risk of hypersensitive pneumonia, allergic alveolitis, chronic rhinosinusitis, and allergic fungal sinusitis (WHO 2009[10], Ahlroth Pind et al. 2017, Norbäck 2020). This is especially important in the northern regions (subarctic, arctic), where people are constantly under the influence of extreme climatic conditions and anthropogenic pressure, which can lead to a weakening of the immune system (Pirogov 2018, Shchegoleva et al. 2019, Gubkina et al. 2024). For example, there are many mining, metallurgical, and energy enterprises on the research territory (Murmansk region). The problem of dust pollution from apatite-nepheline tailings is particularly relevant in the region. Dust particles themselves pose a danger to human health, and also their surface may contain potentially dangerous microorganisms (Evdokimova et al. 2009).

Although the northern and mountainous regions are considered the most "mycologically pure", the presence of potentially dangerous fungi in the northern urban soils was observed in comparison with the anthropogenically undisturbed territories in same regions (Marfenina 2005, Korneykova 2018, Korneykova et al. 2018). According to Marfenina (2005), 0-1 species of fungi dangerous to human health were observed in the northern and mountainous regions, constituting 0-6% of the abundance of the total diversity. While 3-5 species of dangerous fungi were observed in urban soils, their abundance reached

20% of the total diversity. The reason is that urban soils are enriched with organic matter and have a neutral or slightly alkaline pH, which is usually typical of more southern soils (Bakhmatova et al. 2022). Indirectly, the soil microbial community can be affected by an urban heat island (Demin et al. 2016, Varentsov et al. 2018), which is especially important in the harsh climate. For example, the abundance of thermotolerant and opportunistic fungi of the genus *Aspergillus* in the Arctic Circle regions is much higher in cities in this area than outside of them (Marfenina et al. 2014).

Moreover, the conditions of the Subarctic are characterized by a peculiar clinical course and pathological manifestations of diseases. In particular, pathomorphoses of diseases in the population of the Subarctic are caused by excess moisture, low levels of insolation, violation of photoperiodicity (polar day from May 29 to July 14 and polar night from December 15 to December 28 at the latitude of Apatity), and a decrease in vitamins and important chemical elements (magnesium, calcium, iodine, fluorine, cadmium, molybdenum, boron) in food. These features make diseases caused by opportunistic microfungi quite dangerous in the circumpolar regions (Pirogov 2018).

There is an urgent need to monitor the number of opportunistic and allergenic fungi found in the northern regions. This monitoring will significantly reduce the risk of mycogenic sensitization of people, and, in some cases, the risk of fungal infections. This research aimed to study the quantitative and qualitative parameters of soil mycobiota in Apatity (Murmansk region), including opportunistic species and assess their potential danger to humans based on enzymatic activity. Enzymes are considered among the virulence factors of many human pathogenic fungi (Khan et al. 2010, Yike 2011, Brunke et al. 2016, Leitão 2020). An experimental approach based on visual testing of extracellular enzyme activities associated with pathogenicity is widely used in medical mycology (Bogomolova et al. 2007, Pandey et al. 2018, Erum et al. 2020, Gharaghani et al. 2022).

Material and Methods

Soil description and sampling

Apatity (67.567°N, 33.393°E) is the fifth largest city in the Arctic Circle and is located within the Murmansk region on the Kola Peninsula, Russia. Samples were collected in triplicate from topsoil horizon at five sites located in different urban functional zones according to the standard sampling procedure with possible measures to prevent contamination (ISO 18400-206: 2018[6]). Samples of background soils (Albic Podzols) were collected in the northern taiga zone. The site characteristics are shown in Table 1. The urban soils have a profile of natural ones but often the topsoil horizon(s) is missing and replaced with a newly formed anthropogenic horizon. Samples were stored at 4°C for 1 day. Mycological analysis was performed in fresh samples on the day after sampling.

Site	Functional zone	Coordinates	Soil, according to WRB*
S-R	recreational	67.56978 33.40082	Umbric Leptic Entic Podzol (Arenic, Neocambic, Technic)
RZ-O	residential external courtyard	67.56506 33.41000	Umbric Leptic Entic Podzol (Arenic, Neocambic, Technic)
RZ-I	residential, inner courtyard	67.56139 33.41057	Umbric Leptic Entic Podzol (Arenic, Neocambic)
AR	agricultural	67.57959 33.30014	Plaggic Entic Podzol (Arenic)
FT	forest (background)	67.56139 33.41057	Umbric Leptic Entic Podzol (Arenic, Neocambic)

Table 1. Site characteristics. *Note*: * WRB – World Reference Base.

Number and taxonomic diversity of cultivable microfungi

The number of fungi was determined by the plating method on Czapek-Dox's agar with the addition of lactic acid (4 ml l^{-1}) to inhibit bacteria (Zvyagintsev 1991). The Petri dishes were incubated in two temperatures: at +27°C and +37°C for 7–14 days. The fungi were identified based on morphology (Klich 2002, Domsch et al. 2007, Seifert et al. 2011). The species name and systematic position were found in the CABI Bioscience Databases (Index Fungorum 2024[12]). For five species isolated as sterile mycelium, identification was performed based on the analysis of the ITS1–5.8S–ITS2 rDNA site. DNA was isolated using the method described in Glushakova et al. (2011).

Mycological risk index

Microfungi were classified as opportunistic fungi according to two different approaches. The first approach (state approach) was based on sanitary standards of different countries: the European Union (Directive 2000/54/EC 2000[5]), the United Kingdom (Advisory Committee on Dangerous Pathogens 2023[1]), the USA (National Institutes of Health 2019[8], Centers for Disease Control and Prevention 2020[3]), Canada (Public Health Agency of Canada 2024[13]), Russia (Sanitary-and-epidemiological rules SR 3.3686-21 2021[9]), China (National Health Commission of the People's Republic 2023[7]), India (Department of Biotechnology 2021[4]), Australia and New Zealand (AS/NZS 2243.3:2010 2010[2]). The second approach (international approach) used an international scientific classifications of opportunistic fungi based on Satton et al. (2001), de Hoog (2020) and German Collection of Microorganisms and Cell Cultures (DSMZ 2024[11]).

Fungi were classified as an allergenic group based on Gaskell et al. (1997), Brito et al. (2003), Esch (2004), Vijay et al. (2005), Shen et al. (2007), Simon-Nobbe et al. (2008) and Weikl et al. (2015), and toxigenic group – Frisvad and Filtenborg (1989), Pitt and Leistner (1991), Jarvis et al. (1998), Reddy et al. (2015), Perrone and Susca (2017), Skóra et al. (2017), López-Díaz et al. (2018) and Guruceaga et al. (2020).

To assess the mycological hazard of the region, which implies the presence of dangerous (opportunistic, allergenic, or toxi-

genic) species of microfungi in quantities exceeding the natural fluctuation level in this habitat, the index of integrated assessment of mycological risk (Im) was used (Marfenina 1999). This index was calculated by the following formula:

$$Im = D \times C \qquad Eqn.\ 1$$

Im – mycological risk index;
D – change in the diversity of opportunistic microfungi compared to the background;
C – change in the abundance of opportunistic microfungi compared to the background.

Index values greater than 4 allow us to classify regions as "mycologically dangerous."

Extracellular enzyme assay

Eighteen strains of microfungi were tested for enzymatic activity. The isolated strains were tested for proteinase activity on a nutrient medium with the addition of bovine serum albumin (Fotedar and Al-Hedaithy 2005), phospholipase activity on a medium with egg yolk (Price et al. 1982). After inoculation, the plates were incubated for 7 days at +27°C, after which the diameter of the colonies and the light/muddy zones around them were measured. Enzyme activity index (EAI) was calculated by the following formula:

$$\text{Enzyme activity index (EAI)} = \frac{\text{Diameter of the colony (D)}}{\text{(D + Light/Muddy Zones (Z)}} \qquad Eqn.\ 2$$

The value of the coefficient EAI = 1 indicates that the strain is proteinase/phospholipase negative (Fotedar and Al-Hedaithy 2005). The survival of fungal cultures at 37°C was determined on the Chapek's medium after 10 days (Bogomolova et al. 2012).

Statistical analysis

The significance of differences in number of microfungi in the urban and forest soils was evaluated by one-way ANOVA tests, with preliminary testing of options for normality of distribution (Shapiro–Wilk normality test) and the Dunnett test was used for post-hoc comparisons ($p \leq 0.05$, control group – forest soil). Statistical analysis was performed using the R 4.3.1 software package (R Core Team, Vienna, Austria) and in the Microsoft Office Excel software.

Results and Discussion

Number and taxonomic diversity of cultivable microfungi

The number of cultivable microfungi in urban soils was found much lower than in forest soils, with the exception of recreational zone area. Their number in the topsoil horizons ranged from 1×10^3 to 9×10^4 CFU g^{-1} of soil (Fig. 1). The minimum number was observed in the residential zone, where the soil was maximally compacted due to trampling. This finding was supported by the correlation coefficient between the number of fungi and soil density (r = 0.7). The maximum number of fungi was found in the recreational zone. The number of cultivable microfungi in the forest soil was 2.3×10^4 CFU g^{-1}, which is lower than in the recreational

zone (p = 0.0012), apparently due to the lack of anthropogenic substrates specific to the development of atypical microfungi in this natural zone (Marfenina et al. 2002).

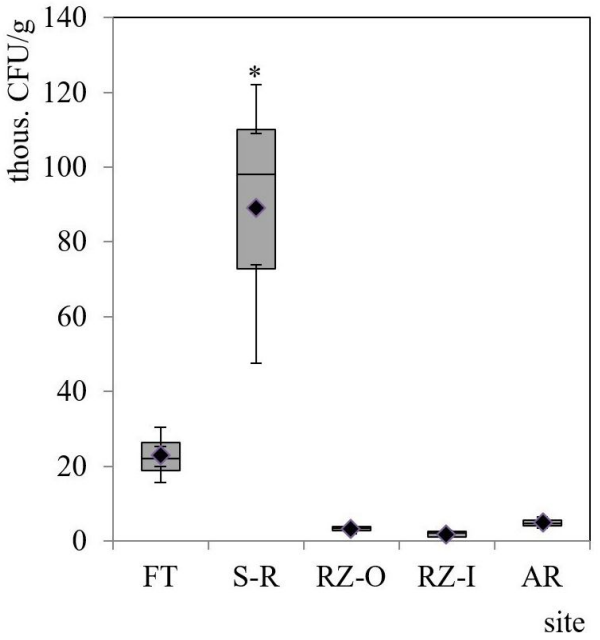

Fig. 1. Number of microfungi in the urban and forest soils.

The species diversity of cultivable soil microfungi was represented by 21 species belonging to 11 genera, 10 families, 7 orders, 5 classes, and 2 divisions (Table 2). The *Mucoromycota* division was represented by the genera *Mortierella* and *Umbelopsis*. The *Ascomycota* division included 8 anamorphic genera (*Acremonium, Aspergillus, Berkeleyomyces, Fusarium, Penicillium, Stachybotrys, Torula, Trichocladium*). There was also one sterile mycelium isolate of uncertain systematic position due to complex cultivation. In general, the above-specified set of genera is typical for background biotopes of the Murmansk region (Korneykova 2018, Korneykova et al. 2018).

The species composition of urban soil microfungal community differed significantly from the forest soil (background), as evidenced by the low value of the Sørensen coefficient (28%). In urban soils, there was also a decrease in the diversity of microfungal community in all functional zones. The maximum number of fungal species was isolated from the soils of forest and recreational zones, which may be due to the maximum similarity to the background biotopes (Ivanova et al. 2015).

Table 2. ► Taxonomic diversity of soil microfungi. *Note*: I – Opportunistic species according to the state approach; II – Opportunistic species according to the international approach; III – Allergenic species; IV – Toxigenic species; * – fungi, identified by molecular-genetic method.

Species	Location	Classification			
	C (city) / F (forest)	I	II	III	IV
Ascomycota, Pezizomycotina, Dothideomycetes, Pleosporomycetidae, Pleosporales, Torulaceae					
Torula sp.	C	+			
Eurotiomycetes, Eurotiomycetidae, Eurotiales, Aspergillaceae					
Aspergillus fumigatus Fresen.	C	+	+	+	+
Penicillium aurantiogriseum Dierckx	F	+	+	+	+
P. canescens Sopp	C	+	+		+
P. decumbens Thom	F	+	+	+	
**P. dierckxii* Biourge	C	+	+		
**P. melinii* Thom	C/F	+		+	+
**P. miczynskii* K.W. Zaleski	C	+			+
P. nalgiovense Laxa	C	+	+	+	
**P. simplicissimum* (Oudem.) Thom	C	+	+	+	+
P. spinulosum Thom	C	+	+	+	+
Sordariomycetes, Hypocreomycetidae, Hypocreales, Hypocreaceae					
**Trichoderma koningii Oudem.*	C	+	+	+	
Incertae sedis					
Acremonium felinum (Marchal) Kiyuna, K.D. An, R. Kigawa & Sugiy.	F	+	+		
Acremonium sp.	C	+	+	+	
Nectriaceae					
Fusarium oxysporum Schltdl.	C/F	+	+	+	+
Stachybotryaceae					
**Stachybotrys echinatus* (Rivolta) G. Sm.	C	+	+		+
Microascales, Ceratocystidaceae					
Berkeleyomyces basicola (Berk. & Broome) W.J. Nel, Z.W. de Beer, T.A. Duong & M.J. Wingf.	F				
Sordariomycetidae, Sordariales, Chaetomiaceae					
**Trichocladium griseum* (Traaen) X. Wei Wang & Houbraken	C/F	+	+	+	
Mucoromycota, Mortierellomycotina, Mortierellomycetes, Incertae sedis, Mortierellales, Mortierellaceae					
Mortierella alpina Peyronel	C	+			
Mucoromycotina, Umbelopsidomycetes, Incertae sedis, Umbelopsidales, Umbelopsidaceae					
Umbelopsis isabellina (Oudem.) W. Gams	C/F		+		
U. longicollis (Dixon-Stew.) Y.N. Wang, X.Y. Liu & R.Y. Zheng	C/F				
Incertae sedis					
Mycelia Sterilia	C/F				

The greatest species diversity was characterized by the genus *Penicillium*, prevailed in the urban soils (40–70% of the total number of species). It is known that representatives of this genus are soil saprotrophs and dominate in northern taiga soils (Marfenina et al. 2002, Domsch et al. 2007, Seifert and Gams 2011). The exception was arable soil, where the portion of *Penicillium* was 16%. The taxonomic composition of microfungal complexes in this soil is probably greatly influenced by the type of plant associations.

Classifications of opportunistic fungi

All fungi mentioned in the medical literature as potential etiologic agents are classified into two categories: risk groups (RG) or biosafety levels (BSL). The classification of fungi into risk groups is based on their association with disease in humans and the resulting severity of disease. Whereas the classification by biosafety levels is related to occupational health risk and is actively used in clinical practice. RG and BSL are not always congruent because almost all clinical fungi are environmental and opportunistic abilities may not correspond infection routes and laboratory distribution. For example, *Aspergillus fumigatus* is a harmless saprobe in nature but is easily transmitted to susceptible hosts (de Hoog et al. 2020). The abundance of opportunistic fungi of the RG1 and RG2 groups in the environment is significantly wider because they can assimilate a wide range of substrates.

RG1 (BSL1) includes saprobes or plant pathogens occupying non-vertebrate ecological niches, or commensals. Infections are coincidental, superficial, and non-invasive or mild. RG2 (BSL2) includes species principally occupying non-vertebrate ecological niches, but with a relatively pronounced ability to survive in vertebrate tissue (de Hoog et al. 2020). They may cause deep, opportunistic mycoses in severely immunocompromised patients. The pathogens causing superficial infections belong to this category as well.

Some classifications, in addition to RG and BSL, use pathogenicity groups (PG). In Russia and China, the classification of fungi by pathogenicity groups is reverse numbered (I–IV in descending order of danger).

Opportunistic, allergenic, and toxigenic microfungi

More than half of the species isolated from urban soil (19) belonged to the groups of opportunistic, allergic, and toxigenic fungi. The largest number of them belonged to the genus *Penicillium* (9); the genus *Acremonium* was represented by two species and the remaining genera by one species. Seven species belonging to the opportunistic, allergenic, and toxigenic groups were isolated from the forest soil and 16 species from urban soils. Only 4 species (*Penicillium melinii, Fusarium oxysporum, Trichocladium griseum, Umbelopsis isabellina*) were found in both urban and forest soils. Other species belonging to the genera *Acremonium, Aspergillus, Mortierella, Penicillium, Stachybotrys, Torula* and *Trichoderma* were found only in urban soils.

In urban soils, according to the state approach, an increase of 20% in the proportion of fungi belonging to RG1 (PG IV, BSL1) was noted, and fungi belonging to RG2 (PG III, BSL2) also appeared, which were not identified in background soils. According to the international approach,

the proportion of opportunistic fungi in urban soils increased by 7%. Most opportunistic fungi belonged to the RG1 group (PG IV, BSL1), and only *Aspergillus fumigatus* and *Fusarium oxysporum* belonged to RG2 (PG III, BSL2). In urban soils, the same proportion of allergenic fungi was observed as in the background soil (50%), but the proportion of toxigenic fungi increased by 15% (Fig. 2).

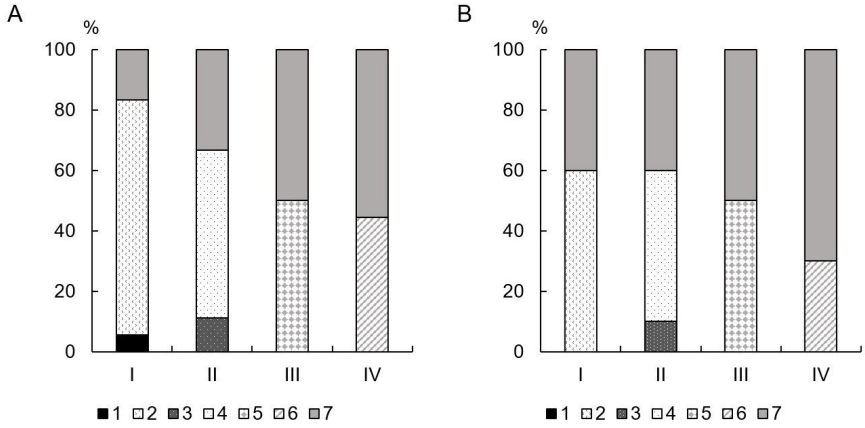

Fig. 2. The portion of opportunistic, allergenic, and toxigenic species in the urban (A) and forest soils (B). *Note*: I – According to the state approach: (1) opportunistic microfungi (RG2), (2) opportunistic microfungi (RG1); II – According to the international approach: (3) opportunistic microfungi (RG2), (4) opportunistic microfungi (RG1); III – Allergenic species: (5) allergenic microfungi; IV – Toxigenic species: (6) toxigenic microfungi; (7) – microfungi that are not marked as opportunistic, allergenic, or toxigenic species.

The species *Aspergillus fumigatus, Fusarium oxysporum, Penicillium aurantiogriseum, P. simplicissimum,* and *P. spinulosum* were classified as dangerous in all classifications (Table 2), while *Mortierella alpina*, *Torula sp.,* and *Umbelopsis isabellina* were classified as allergenic, toxigenic, or opportunistic in only one of the classifications.

Most fungi that represent a threat to human health are characterized by a high spatial frequency of occurrence. Thus, *Trichocladium griseum*, which belongs to the opportunistic group as well as being a phytopathogen and cellulolytic (Domsch et al. 2007), was isolated from urban soils of all sites. Its spatial frequency of occurrence in urban soils was 100%. The frequency of occurrence of *Penicillium spinulosum*, also according to different classifications related to opportunistic, allergenic, or toxigenic groups, was 75%, and for the species *P. miczynskii* and *P. simplicissimum*, 50%.

We revealed differences in the dominating structure of soil microfungi communities in the urban soils compared to background territories. *P. decumbens* dominated in the forest soil. *Trichocladium griseum* prevailed in abundance in the urban soils. The species was previously isolated in the regional soils but belonged to the group of accidental and rare. We attributed the active development of *T. griseum* to the abundance of plant residues in individual biotopes (Domsch et al. 2007, Seifert et al. 2011) and the warming of climate in recent years in the area of Apatity (Demin et al. 2016). Microfungi of the genus *Fusarium*, which dominated in the

arable soil, are also not characteristic of the the Kola Peninsula. Species of this genus are often plant parasites (Domsch et al. 2007), and this probably explains their large numbers in arable soil (Meng et al. 2019).

According to mycological risk index, urban soils can be classified as dangerous, because the index value was 6.7 according to the international approach and 8.4 according to the state approach. This value is significantly lower than for the soils of Moscow, for which the index was 13–18, and, at the same time, it is comparable with the value of the mycological hazard index for the soils of Pushchino, Serpukhov, and Labytnangi, for which the index value was 5.7–7.7 (Marfenina 1999).

Extracellular enzyme activity of microfungi

Opportunistic fungi have a number of pathogenicity factors, such as the ability to grow at a temperature of 37°C, mycelial–yeast dimorphism (especially fungi of the RG3 group), the ability to produce melanins, encapsulation, increased ability to adhere, and extracellular secretion of proteases and phospholipases (Bogomolova et al. 2012). Fungal cells have constitutive and induced hydrolytic enzymes that are involved in the process of pathogen invasion in the host tissue and in the destruction of the host cell membranes. Lipids and proteins, as the main components of cell membranes, are targets for attack by two main types of enzymes: proteinases, which act on peptide bonds, and phospholipases, which hydrolyze phospholipids (Karpunina et al. 2006). Also, important hydrolytic extracellular enzymes for fungi are α-amylases, responsible for breaking down starch, and studied for Arctic strains (Krishnan et al. 2018, 2022; Pankova et al. 2023). Catalases are markers of virulence and allow fungal cells to avoid damage caused by reactive oxygen species (Sav et al. 2016, Sazanova et al. 2019). The ability to produce extracellular enzymes depends on the characteristics of the isolates. In some cases, the profiles of enzymatic activity of the isolates differed for the same species (Korneykova and Lebedeva 2016, Kirtsideli 2019).

Phospholipase activity was found in all species isolated from urban soils and in 86% of strains isolated from forest soils. The phospholipase activity index for different strains varied from 0.4 to 1.0 (*see* Fig. 3). The coefficient equal to 1, characteristic of phospholipase-negative strains, was noted only in two species. The portion of species with strong phospholipase activity with an index lower than 0.6 in urban soils was 36% and in forest soils slightly less at 29%. Strains that showed increased phospholipase activity belonged to the following species: *Umbelopsis isabellina, Mortierella alpina, Trichocladium griseum, Stachybotrys echinatus,* and *Acremonium sp*. Other strains showed weak phospholipase activity.

Proteinase activity was revealed for all tested strains. There was no difference in the proteinase activity of the strains isolated from forest and urban soils. Fluctuations in the proteinase activity index values were insignificant, varying from 0.8 to 1.0 in all strains (Fig. 3). The highest proteinase activity was found in *Penicillium miczynskii,* and *Stachybotrys echinatus* isolated from urban soils, and *Berkeleyomyces basicola* isolated from forest soil. The remaining strains were proteinase positive but showed very little activity.

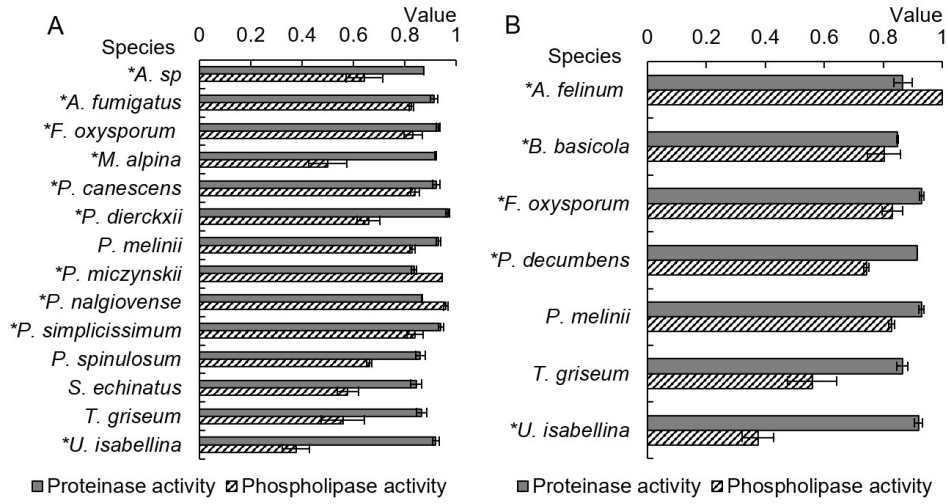

Fig. 3. Extracellular enzyme activity of microfungi in the urban (A) and forest soils (B).
Note: * – fungi, which can grow at 37°C.

Fourteen strains of fungi (77%) had the ability to grow at 37°C, 10 strains were isolated from urban soils, and 5 strains from forest soil. In urban soils, only 1 strain of *Acremonium sp.* showed high proteinase and phospholipase activity and also had the ability to grow at 37°C. It should be noted that *Trichocladium griseum* and *Stachybotrys echinatus* strains that had high phospholipase and proteinase activity in urban soils are not able to grow at a temperature of 37°C. Species *P. miczynskii, P. nalgiovense, Mortierella alpina,* and *Umbelopsis isabellina* showed high activity of only one of the enzymes and the ability to grow at human body temperature. These species pose a potential danger to human health. However, since most of the tested isolates have demonstrated the presence of two types of activity and the ability to grow at 37°C, it can be concluded that there is a risk of allergic and mycotic diseases caused by microfungi.

Conclusion

In our study, we revealed significant differences in quantitative and qualitative parameters of fungal complexes in urban soils compared to background forest soils, including fungi that pose a threat to human health. The decrease in the total number and diversity of microfungi in urban soils was found, but at the same time, the proportion of opportunistic and toxigenic species increased. The soils of Apatity are classified as mycologically dangerous, probably due to the appearance of dangerous, as well as an increase in the portion of toxigenic fungi. Potentially dangerous fungi had a high frequency of occurrence and abundance in urban soils. We identified particularly dangerous species *Acremonium sp., P. miczynskii, P. nalgiovense, Mortierella alpina, and Umbelopsis isabellina* using the assessment of their phospholipase expressions and proteinase activity. The species have potential risk to human health. As a recommendation, we can suggest monitoring of opportunistic and allergenic fungi in places frequently visited by city residents, especially chil-

dren (parks, playgrounds, *etc*.) in order to identify potentially dangerous species, and also recommend minimizing contact with soil in order to reduce the likelihood interactions with opportunistic mycobiota. These measures will reduce the risk of people mycogenic sensitization, which will improve the quality of life and work in the Arctic region.

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