Maria V. Korneykova[1*], Elena V. Lebedeva[2]
[1] Institute of North Industrial Ecology Problems – Subdivision of the Federal Research Centre "Kola Science Centre of Russian Academy of Science"Apatity, Murmansk region, Russia
[2] Komarov Botanical Institute of Russian Academy of Science, Saint Petersburg, Russia
[*]**Corresponding author:** korneykova.maria@mail.ru

OPPORTUNISTIC FUNGI IN THE POLLUTED SOILS OF KOLA PENINSULA

ABSTRACT. The species diversity and the structure of the opportunistic fungi complexes in the forest Albic Podzols under the impact of the Aluminum and Copper-Nickel Plants emissions, as well as in the Hortic Anthrosol contaminated by the oil products (diesel fuel, gas condensate, mazut) in the north-west region of Russia (the Kola Peninsula) have been investigated. The share of the opportunistic fungi increase up to 15% in the zones of the Aluminum and Copper-Nickel Plants emissions comparable to the background soil, and up to 20-25% in the soils contaminated by the oil products has been revealed. The majority of the fungi species belong to the following genera: Penicillium, Aspergillus, Mucor, Lecanicillium, Phoma and Cladosporium. The structure of the fungal complexes has changed in the polluted soil, that is, the species abundance and the frequency of the opportunistic fungi occurrence have increased. The strains of the fungi isolated from the contaminated soil reveal the potential pathogenicity in a greater degree, than the strains isolated from the clean soil. 55% of the total amount of fungi strains isolated from the soils contaminated by the Aluminum Plant emissions had the potential pathogenicity. The most dangerous for a human's health were Amorphotheca resinae, Aspergillus fumigatus, A. niger, Paecilomyces variotii, Penicillium commune, P. purpureogenum, Trichoderma viride isolated from the soils contaminated by the Aluminum Plant emissions; and P. aurantiogriseum, P. glabrum, P. commune, P. simplicissimum, Rhizopus nigricans isolated from the soils contaminated by the oil products. Those species revealed protease, phospholipase activity, as well as the growth ability at the temperature 37°C

KEY WORDS: opportunistic fungi, potential pathogenicity, soil, pollution, industrial plant, oil products, Kola Peninsula

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INTRODUCTION

All through our lifetime, we are in constant contact with the fungi which are present everywhere in the human environment. The main natural habitat of fungi is soil. Fungi migrate easily with air currents and are constantly present in the environment, mainly as spores, and sometimes as mycelium fragments. As decomposers, fungi grow on plant residues. They can also grow on the surfaces of different man-made facilities, such as buildings, roads, etc. Special hazard for humans may be represented by the fungi belonging to the group of opportunistic ones. The opportunistic fungi are the group of fungi that are able to provoke various mycotic diseases, allergic reactions for immunocompromised humans, and in the meantime retaining the ability to develop in other environments. Hoog et al. classified three groups of fungi according to their potential danger to the human health (BioSafety Level - i.e. fungi are related to a certain level of safety): BSL1, BSL2 and BSL3 (Hoog et al. 2011). The most dangerous mycoses are caused by the BSL3 group. Opportunistic fungi of the BSL2 and BSL1 groups can be found much more frequently in the environments, as most of them utilize a wide range of substrates. The important environmental factors for the growth of opportunistic fungi of these groups are: the availability of organics, the favorable range of moisture, the temperature, and the pH value in their habitat. The typical way of getting an infection by deep mycoses agents in the environment is breathing in their spores. In case of skin injuries the agents may get in also through wounds, often from soil.

Within recent years, more and more attention has been given to monitoring the fungi species in the environment, and the correlation between opportunistic fungi and the growth of diseases amount. The data of different scientific works confirm the increasing amount of the opportunistic fungi in the urbanized areas located close to the major industrial plants, oil products, motorways and agricultural areas. All these circumstances lead to the negative impact on human's health (Badiee and Hashemizadeh 2014; Evdokimova et al. 2013; Kireeva et al. 2005; Marfenina 2005; Pappas 2010). This can be explained by the opportunistic fungi habitat versatility, their wide range of tolerance towards unfavorable environment, as well as capability to utilize diverse substrata.

The opportunistic fungi are known to be characterized by certain properties: the growth ability at a temperature 37°C, as well as mycelia-yeasty dimorphism, cell melanism, capsule formation, the ability to adhesion and extra cell secretion of protease and phospholipase, etc. (Bogomolova et al. 2012; Fotedar and Al-Hedaithy 2005). Recently, much attention has been paid to the investigation of enzymatic fungi activity, which is considered to be human's clinical pathogens. However, there is lack of research dedicated to most likely pathogenicity of the fungi which are habitants in the soil, air and other environments. The protease activity makes possible the fungi to destroy the horny super layers of skin. As for the phospholipase fungi activity, it allows them to destruct the human's membranes of tissue cells and infest them extensively, that is, to promote deep fungal disease. At the same time, to determine the potential agents of the deep fungal disease, it is essential, first and foremost, to take into account their survival rate at the temperature 37°C.

The Murmansk region is a part of the onshore Arctic area of the Russian Federation (Fig. 1). The region under research is characterized by a unique combination of natural and anthropogenic factors: severe climatic conditions and intensive industrial development. The Kandalaksha Aluminum Plant and the Copper Nickel Plant «Severonickel» are known to be the industries in the Murmansk region which have the highest impact on the environment. The consequences of all the types of pollution – both on the environment and on human beings – have not been studied comprehensively yet. In the future, the development of oil and gas production in the Barents Sea in the Murmansk region may give place to additional risk of pollution with oil products on the terrestrial ecosystems of the Kola Peninsula. There is a necessity for studying the anthropogenic factors impact on the fungi accumulation in the environment. Anthropogenic changes of the fungal complexes can change this relationship, and cause negative impact on the plants, animals and human beings.

The goal of this research is to study the species diversity and the structure of opportunistic fungi communities within the industrially polluted soils of the Kola Peninsula, and to determine the potential pathogenicity degree of the fungi strains on the basis of proteasic and phospholipase activity, and the growth ability at the temperature 37°C.

MATERIALS AND METHODS

The ecosystems are pine forests with associations of moss/dwarf shrubs and lichens/dwarf shrubs and in the ground cover. The sample collection took place in the summer-autumn period: June, September in 2000–2011 along the gradient of the pollution by the Aluminum Plant emissions (88 samples on each plots); June, September in 1999-2010 along the gradient of the pollution by the Copper-Nickel Plant emissions (88 samples on each plots); June, July, September in 2006-2011 in the model experiments with oil products (45 samples on each plots). The type of soils is the Al-Fe-humus podzol (Albic Podzol according WRB) in the areas polluted by Aluminum and Copper-Nickel Plants emissions and the arable soil (Hortic Anthrosol according WRB) in the model experiment with oil product.

The objects of our research are (see Fig. 1): 1) soil located in the area contaminated by the Kandalaksha Aluminum Plant; 2) soil located in the area contaminated by the «Severonickel» Copper- Nickel Plant; 3) soil polluted by oil products in field model experiment near Apatity; 4) unpolluted soil of the Kola Peninsula.

Soil and vegetation characteristics are described in detail in previously published articles (Evdokimova et al. 2011, 2013).There have been identified three environmental impact area zones related to the Kandalaksha Aluminum Plant in terms of fluorine content in the organic horizon (0–3(7) cm) and the condition of vegetation, too. The definitions of these three zones were identified: the zone of maximum pollution at the distances up to 2.5 km from the pollution source (F >1200 mg/kg; pine trees were significantly damaged by pollutants as indicated by multiple dead branches in the lower and middle parts of tree crowns and ground

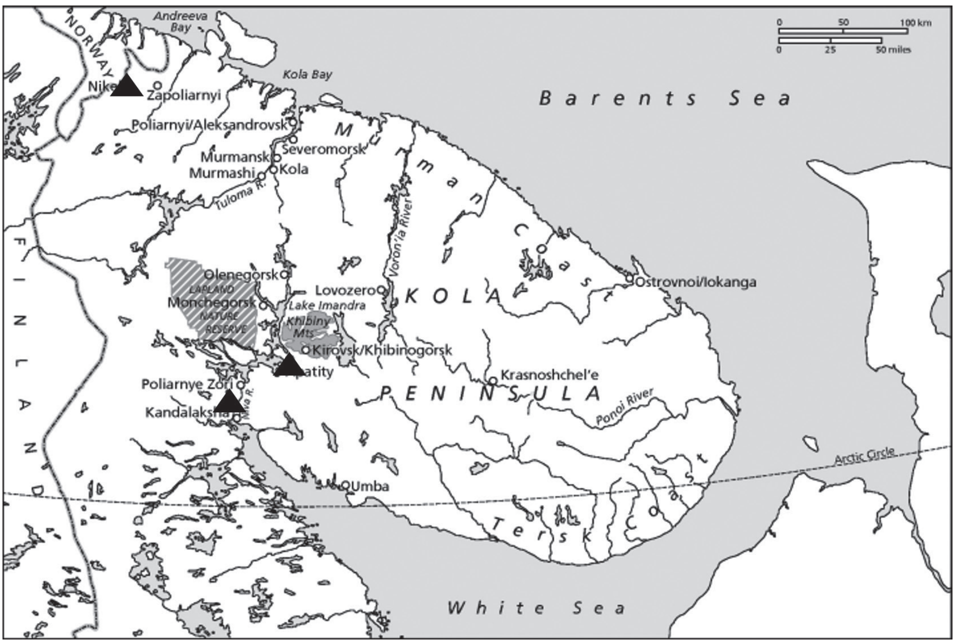

Fig.1. The investigated sites

cover was presented by crowberry), the zone of intensive pollution – up to 13 km (F – 400–1200 mg/kg; pine trees were slightly damaged and no visible changes in the ground cover were recorded) and the zone of temperate pollution – up to 20 km (F – 200–400 mg/kg; vegetation had no visible features of the adverse effect of contamination). At the distances more than 20 km, the pollution did not affect the content of soil biota. In the area of the Copper - Nickel Plant, the influence zones were revealed: the maximum pollution was up to 5 km from the Plant (Cu – 600–1000, Ni – 1700–2600 mg/kg; vegetation was presented by sparse horsetails growing on sands, and crowberry located only at the bases of birch trees; wild rosemary, cowberry, and bilberry were represented by single plants), and the strong pollution was up to 15 km from the Plant (Cu –200–400, Ni – 500–1000 mg/kg; tree layer consists of pine and birch; dwarf shrubs are represented mainly by cowberry, bilberry, and bearberry; wild rosemary and crowberry are less frequent). The background plot was located at 50 km from the source of emissions (Cu – 40, Ni – 80 mg/kg). The pH water suspension of the organic horizon in the area of maximum pollution by the Copper-Nickel Plant was 4.0–4.1, for the Aluminum Plant, it was 5.6–5.7.

The soil samples for the mycological analysis were taken from the organic horizon of the Albic Podzol and layer 0-10 cm of the Hortic Anthrosol. The number of fungi was estimated by the plating method on the wort agar media with adding lactic acid. The fungal biodiversity analysis was carried out on the basis of cultural-morphological characteristics with the use of keys (Raper and Thom 1968; Domsh et al. 2007; Seifert et al. 2011). We have used three literature sources (Hoog et al. 2011; Satton et al. 2001; Sanitary… 2008) to determine whether the fungus belongs to the group of opportunistic.

The fungi protease activity was fulfilled on the nutrient media with the bovine serum albumen adding; the phospholipase activity was determined on the nutrient media with the egg yolk addition (Fotedar and Al-Hedaithy 2005). The Petri dishes were incubated for 10 days after the inoculation. Then the measurements of the colony diameter and the zone of lucid interval round the colonies (proteasic activity), as well as precipitation zone (phospholipase activity) took place. The activity ratio counting was carried out using the formula: I=1-Dc/(Dc+3p), where I is an index of proteasic/phospholipase activity; Dc is a colony diameter, 3p is the zone of lucid interval/precipitation. The fungi growth capability was determined at a temperature 37°C against the 7th day (Bogomolova et al. 2007).

RESULTS

In total, 62 species of fungi (from 29 genera), which belong to the opportunistic ones, were identified in the polluted soils of the Kola Peninsula (Table 1). The largest number of the opportunistic fungi species belonged to the following genera: Penicillium (11), Aspergillus (8), Mucor (4), Phoma (4), Lecanicillium (3) and Cladosporium (3). Most fungi belong to the group BSL1, only 7 fungi species belong to the group BSL2. We did not isolate the fungi belonging to the BSL3 group. Also 17 species belong to opportunistic fungi according to (Satton et al. 2001) and (Sanitary… 2008).

Opportunistic fungi in the area of the Aluminum Plant emissions

In the polluted soil of the Aluminum Plant emission 34 opportunistic fungi species were revealed. In the polluted soils, the share of the opportunistic fungi increased up to 50% compared to the background soil, where it made 35% of the total number of the identified species. Among them, there are agents of mycoses and also the fungi causing diseases of respiratory and digestive systems from genera Acremonium, Alternaria, Amorphotheca, Aspergillus, Aureobasidium, Cladosporium, Fusarium, Mucor, Myxotrichum, Paecilomyces, Penicillium, Phoma, Rhizopus, Sarocladium, Scopulariopsis, Stachybotris, Trichoderma. The largest number of species belonged to g. Penicillium (6) (see Table 1). Some changes were noticed in the species composition of the opportunistic fungal complexes. Trichoderma viride and Penicillium canescens dominated in the polluted soil, and rarely

Table 1. The list of opportunistic fungi isolated from the contaminated soils of the Kola Peninsula, and diseases caused by them

Species	Caused diseases	KAP[1]	Severo-nickel	Oil roducts
According to (Hoog et al. 2011)				
BSL1 group				
Acremonium rutilum W.Gams	Onichomikosis, ulcer of a cornea of an eye, endophthalmitis, meningitis, endocarditis	+	+	+
Alternaria alternata (Fr.)Keissl.	Keratomikoz, onichomikosis, sinusitis	+		+
A. botrytis (Preuss) Woudenberg & Crous	Onichomikosis	+		
Amorphotheca resinae Parbery	Onichomikosis, skin infections	+		
Aspergillus glaucus (L.) Link	Onichomikosis, otitis, orofacial infection	+		
A. niger Tiegh.	Infections of respiratory system, inhalant aspergilloma, otomycosis, onichomikosis, peritonitis, endophthalmitis, endocarditis	+	+	
A. flavus Link	Onichomikosis	+		
A. sydowi (Bainier et Sartory) Thom et Church	Onichomikosis, aspergillosis, keratomikoz	+		
A. versicolor (Vuill.) Tirab.	Onichomikosis, osteomielitis	+		
A. ustus (Bainier) Thom et Church	Infections of respiratory system, skin infections, middle otitis, disseminated and burn infections		+	
Aureobasidium pullulans (de Bary et Lowenthal) G.Arnaud	Infections of respiratory system, keratitis, peritonitis, alveolitis	+	+	+
Cladosporium cladosporioides (Fresen.) G.A. de Vries	Infections of respiratory system, skin infections		+	

C.oxysporum Berk. Et M.A. Curtis	Ceratit cutaneous infection	+		
C. herbarum (Pers.) Link	Asthma, keratomikoz, keratitis, rhinitis	+		
Gongronella butleri (Lendn.) Peyronel et Dal Vesco	Asthma, keratomikoz		+	
Mucor circinelloides Tiegh	Skin infections			+
M. plumbeus Bonord.	Skin infections			+
M. racemosus Fresen.	Infections of respiratory system, skin infections	+		
Penicillium aurantiogriseum Dierckx	Asthma, rhinitis, alveolitis	+	+	+
P. canescens Sopp	Asthma, rhinitis, alveolitis	+	+	+
P. citrinumThom	Asthma, rhinitis, alveolitis		+	
P. commune Thom	Asthma, rhinitis, alveolitis		+	
P. chrysogenum Thom	Keratitis, endophthalmitis, otomycosis		+	
P. decumbens Thom	Alveolitis	+		
P. glabrum (Wehmer) Westling	Alveolitis	+	+	
P. miczynskii K. M. Zalessky	Asthma, rhinitis, alveolitis			+
P. purpureogenum Stoll	Asthma, rhinitis, alveolitis		+	
P. spinulosum Thom	Asthma, rhinitis, alveolitis	+	+	+
Pseudogymnoascus pannorum (Link) Minnis & D.L. Lindner	Onichomikosis			+
Purpureocillium lilacinum (Thom) Luangsa-ard, Houbraken, Hywel-Jones & Samson	Onichomikosis, infections of respiratory system		+	
Rhizopus stolonifer (Ehrenb.) Vuill.	Dermatomycosis, rhinocerebral mycosis	+	+	+
Rhodotorula sp.	Fungemia, endocarditis meningitis, pyocephalus, peritonitis			+
Sarocladium kiliense (Grütz) Summerb.	Noduloso hyalohyphomycosis, keratitis	+		
S. strictum (W. Gams) Summerb	Skin mycosis, onichomikosis	+	+	

Scopulariopsis communis Bainier	Pulmonary infection	+		
Talaromyces purpurogenus (Stoll) Samson, Yilmaz, Frisvad et Seifert	Infections of respiratory system		+	
Trichoderma koningii Oudem.	Infections of respiratory system, keratomikoz, rhinitis		+	+
Tr. viride Pers.	Infections of respiratory system, keratomikoz, rhinitis	+	+	+
BSL2 group				
Aspergillus fumigatus Fresen.	Asthma, alveolitis, rhinitis, aspergillosis, which leads to infections of respiratory, nasal, bone systems	+	+	+
A. terreus Thom	Bronchopulmonary aspergillosis, optic disseminated mycosis, keratitis, otitis, arthritis		+	
Codaphora melinii Nannf. Conant	Phaeohyphomycosis, chromoblastomycosis		+	
Fusarium oxysporum Schltdl.	Keratomikoz, keratitis, peritonitis	+		+
F. solani (Mart.) Sacc	Keratomikoz, keratitis	+		
Paecilomyces variotii Bainier	Pneumonia, asthma, keratomikoz, nephritis, rhinitis, endocarditis, alveolitis	+		
Scopulariopsis brumptii Salv.-Duval	Pulmonary infection	+		
According to (Satton et al. 2001; Sanitary… 2008)				
Collariella bostrychodes (Zopf) X.Wei Wang et Samson	Onichomikosis, skin infections, peritonitis		+	
Clonostachys rosea (Link) Schroers, Samuels, Seifert & W. Gams	Keratitis	+		
Fusarium fujikuroi (Sawada.) Wollenw.	Disseminated mycosis, keratitis, endophthalmitis			+
Humicola grisea Traaen	Infections of respiratory system, mycosis			+

Lecanicillium sp.	Keratitis		+	
L. lecanii (Zimm.) Zare et W. Gams	Keratitis			+
L. psalliotae (Treschew)Zare et W. Gams	Keratitis			+
Mucor hiemalis Wehmer	Infections of respiratory system, skin infections			+
Myxotrichum deflexum Berk.	Skin infections	+		
Oidiodendron flavum Svilv.	Neurodermatitis		+	
O. griseum Robak	Neurodermatitis		+	
Penicillium. simplicissimum (Oudem.) Thom	Asthma, rhinitis, alveolitis	+	+	+
Phoma eupyrena Sacc.	Skin mycosis			+
Ph. glomerata (Corda)Wollenw. et Hochapfel	Skin mycosis			+
Ph. herbarum Westend	Skin mycosis	+	+	
Ph. medicaginis Malbr. et Roum.	Skin mycosis	+		
Stachybotrys chartarum (Ehrenb.) S. Hughes	Dermatomycosis	+	+	

[1]*Kandalaksha Aluminum Plant*

in the background soil. On the contrary, Aureobasidium pullulans was rarely revealed in the polluted soil, but prevailed in the background one. Aspergillus fumigatus, P. glabrum are related to the group of occurrence frequency in the soils of all the plots. It should be noted that the opportunistic fungi species, such as A. niger, Cladosporium herbarum, Fusarium oxysporum, Paecilomyces variotii, P. simplicissimum and Phoma medicaginis were found only in the soil of the polluted plots.

Opportunistic fungi in the area of the Copper-Nickel Plant emissions

In the polluted soil of the Copper-Nickel Plant emissions, 30 fungi species belonging to opportunistic fungi were isolated. Their share in the polluted soil is 45%, and in the background soil is 30% of the total number identified species. In the soils of both plots, the opportunistic fungi group is represented with the following genera Acremonium, Aspergillus, Aureobasidium, Collariella, Cladosporium, Gongronella, Lecanicillium, Oidiodendron, Penicillium, Codaphora, Phoma, Purpureocillium, Rhizopus, Sarocladium, Stachybotris, Talaromyces and Trichoderma. Most species belong to Penicillium (9), Aspergillus (4), Oidiodendron and Trichoderma (2); the rest of the genera have only one (see Table 1). One can observe the increase in the number of g. Aspergillus species in the soil polluted by the emissions from the Copper- Nickel Plant in comparison with the background soil. Most species of this genus belong to opportunistic ones, and take place mainly in the soils of the southern regions. At the same time, different authors speak about the increase in the number of "southern" fungi in the polluted soils of the Northern part of Russia (Kireeva et al. 2005; Marfenina 2005; Evdokimova et al. 2013). The changes in the structure of the opportunistic fungi complexes were also noticed. Such species as Penicillium simplicissimum, Trichoderma koningii and T. viride dominated, and P. glabrum also often occurred in the polluted soil, but in the background soil all of them belonged to rare species. It should be noticed that the opportunistic species, such as Aspergillus fumigatus, A. terreus, A.ustus, P. aurantiogriseum and Codaphora melini were not found in the background soil, but they were revealed in the polluted one.

Opportunistic fungi in the soil contaminated by the oil products

The increase of the opportunistic fungi share in the soils contaminated by different types of oil products in various concentrations was revealed. In the clean soil, the share of opportunistic fungi was 45% of the total number of species; in the soils both with low and high diesel fuel content, the share amounted to 65%; in the soils with gas condensate it was 70%; and in the soils with the mixture of mazut and diesel fuel, the amount reached 55%.

While adding diesel fuel to soil, the richest diversity of the opportunistic fungi group was observed: 21 species out of 24 were isolated in the soils polluted with different oil products, in the soil with gas condensate there were 9 species and in the soil with a mixture of mazut and diesel fuel were 13 species. The following genera belonged to the opportunistic fungi group; they were isolated from the soil contaminated with diesel fuel: Acremonium, Alternaria, Aspergillus, Aureobasidium, Fusarium, Humicola, Lecanicillium, Mucor, Penicillium, Phoma, Rhizopus, Pseudogymnoascus, Rhodotorula, and Trichoderma. The species gg. Fusarium, Mucor, Penicillium and Trichoderma occurred in soils both with low and high diesel fuel concentrations; while the species g. Lecanicillium was isolated only from the soil with high diesel fuel doses. The genera Alternaria, Aspergillus, Aureobasidium, Humicola, Phoma, Pseudogymnoascus and Rhizopus occurred only in the soil with low concentration of diesel fuel. Most species belonged to Penicillium (5), Mucor (3), Lecanicillium, Phoma and Trichoderma (2), while other genera were presented by one species.
In the soil polluted with gas condensate, the opportunistic fungi group was represented by such genera as Acremonium, Lecanicillium, Mucor, Penicillium, Pseudogymnoascus, Rhizopus, Trichoderma. In the soil with the mixture of mazut and diesel fuel, gg. Acremonium, Aureobasidium, Mucor, Penicillium, Phoma, Pseudogymnoascus, Rhizopus, Rhodotorula, Trichoderma were found. Genera Mucor, Penicillium, Trichoderma occurred at both low and high oil product concentrations; while the fungi of gg. Acremonium, Aureobasidium, Rhodotorula, Phoma were isolated only at high concentrations. As for gg. Pseudogymnoascus, Rhizopus, they were revealed only at low concentrations.

Some changes in the structure of opportunistic fungi complexes in the polluted soil compared to the background soil were revealed. The increase of these species abundance and frequency of occurrence in the polluted soil were observed. That can be explained by good adaptability of opportunistic fungi to the environmental conditions. The fungi of Fusarium oxysporum, Penicillium simplicissimum, Phoma eupyrena, Trichoderma koningii and T. viride were identified as a group of rare species in the background soil. They were frequent and abundant in the soil polluted with diesel fuel. P. miczynskii became the dominant species at high diesel fuel concentrations. This type is the most resistant species of fungi with respect to all studied opportunistic fungi types. In the soils with gas condensate, such species as P. canescens and T. koningii became dominant, and Rhizopus stolonifer was frequent, while in the background soil they were rare. P. canescens was identified as frequent species in the background soil. It became the dominant species in the soils polluted by the mixture of diesel fuel and mazut. Mucor hiemalis was a frequent species in the background soil, but it became a rare species in the soils under contamination by all types of oil products, and that indices its sensitivity to this type of pollution.

Potential pathogenicity of the opportunistic fungi

41 fungi strains (55%) revealed the protease activity among the fungi isolated from polluted soil by Aluminum Plant emissions. The protease activity coefficient changed from 0 up to 0.4. 16 strains displayed the

most significant coefficient values (0.2-0.4). The most active strains were Aspergillus fumigatus, A. versicolor, Cladosporium herbarum, Penicillium commune. 20 isolates (27%) revealed the phospholipase activity. The phospholipase activity coefficient value changed from 0.1 up to 0.3. Such strains as Aspergillus fumigatus, A. niger, Paecilomyces variotii, Penicillium decumbens, P. commune, P. purpurogenum, Rhizopus stolonifer, Lecanicillium lecanii exhibited the most coefficient values. 31 strains (41%) out of 75 tested, indicated the growth activity at a temperature 37°C.

The protease activity was discovered in 17 isolates (49%) among the strains, isolated from the soil contaminated with oil products. The following species Mucor circineloides, Penicillium decumbens, P. glabrum, P. simplicissimum, Trichoderma viride revealed the greatest protease activity coefficient value. Only 8 cultures (23%) testified their phospholipase activity. The isolates of this group belonged to such species as Penicillium aurantiogriseum, P. decumbens, P. glabrum, P. commune, P. simplicissimum, P. spinulosum, Rhizopus stolonifer. All the rest cultures did not exhibit their phospholipase activity. Consequently, they are not able to penetrate deep into the tissues and provoke considerable mycosis. The growth activity was marked within 21 species (60%) out of 35 tested ones, at the temperature 37°C.

Judging by the research results, 7 fungi strains were the most dangerous for a human. They were revealed from the soils contaminated by the Aluminum Plant emissions: Amorphotheca resinae, Aspergillus fumigatus, A. niger, Paecilomyces variotii, Penicillium commune, P. purpureogenum, Trichoderma viride, and 5 species revealed from the soils contaminated by the oil products Penicillium aurantiogriseum, P. glabrum, P. commune, P. simplicissimum, Rhizopus stolonifer. Those species revealed all the investigated factors of the potential pathogenicity. They possessed both the proteasic and phospholipase activity, as well as the growth capability at the temperature 37°C.

To compare and estimate the degree of the fungi strains potential pathogenicity, 22 species (44 strains) of fungi revealed from the clean and contaminated by the Aluminum Plant emissions soils were tested (Table 2). Five species (23% of the total number) Penicillium glabrum, P. simplicissimum, Pseudogymnoascus pannorum, Rhizopus stolonifer, Trichoderma koningii did not reveal the difference in 3 specifications under test, depending on the presence of contamination in the soil. The strains of 11 species (50% of the total number) Amorphotheca resinae, Aspergillus fumigatus, A. versicolor, Cladosporium herbarum, Lecanicillium lecanii, Mucor hiemalis, Paecilomyces variotii, Penicillium aurantiogriseum, P. miczynskii, Phoma glomerata, Trichoderma viride isolated from the contaminated soil revealed either the appearance or intensification of one of the specifications, characterizing the potential fungi danger for a human being.

Thus, under the human's activity impact, the share of opportunistic fungi in soil has increased. In the Albic Podzol soils, in the impact areas of the Aluminum and Copper-Nickel Plants the number of opportunistic fungi increased up to 15%, as compared to that in the background soil. The share of the opportunistic fungi increased up to 20-25% in the Hortic Anthrosol polluted by the diesel fuel and gas condensate. That can be caused by the habitat versatility of the opportunistic fungi and their wide range of tolerance towards the unfavorable environmental conditions, as well as better capability to utilize diverse substratum. Most of them found in the polluted soils of the Kola Peninsula belonged to gg. Penicillium, Aspergillus, Mucor, Lecanicillium, Cladosporium and Phoma. Such species as Acremonium rutilum, Aspergillus fumigatus, Aureobasidium pullulans, Penicillium aurantiogriseum, P. canescens, P. simplicissimum, P. spinulosum, Rhizopus stolonifer, Trichoderma viride were found under all types of pollution. Penicillium miczynskii proved to be the most resistant species to all studied oil products, while Mucor hiemalis appeared to be the most sensitive one. The common tendencies for all types of studied pollutions in the fungi species composition have been identified: drifting of species from the rare group in the

Table 2. The results of the fungi cultural testing, isolated from the soils of the Kola Peninsula

Fungi species	Activity		Grow ability at t=37°C
	Proteasic	Phospholipase	
Amorphotheca resinae Parbery	+/–[1]	+/+	+/–
Aspergillus fumigatus Fresen.	+/–	+/–	+/+
A. versicolor (Vuill.)Tirab.	+/–	+/+	–/–
Cladosporium herbarum (Pers.)Link	+/–	–/–	+/–
Clonostachys rosea (Link) Schroers, Samuels, Seifert & W. Gams	–/+	–/–	–/+
Lecanicillium lecanii (Zimm.) Zare et W. Gams)	–/–	–/–	+/–
Mucor hiemalis Wehmer	+/–	–/–	–/–
Myxotrichum cancellatum W. Phillips	+/–	–/–	–/–
Paecilomyces variotii Bainier	+/–	+/–	+/+
Penicillium aurantiogriseum Dierckx	+/–	+/–	–/–
P. canescens Sopp	+/+	–/+	–/–
P. decumbens Thom	+/+	–/+	–/–
P. glabrum (Wehmer) Westling	+/+	–/–	–/–
P. miczynskii K.M. Zaleski	+/–	+/+	–/–
P. simplicissimum (Oudem.) Thom	+/+	–/–	–/–
P. spinulosum Thom	+/+	–/+	–/–
Phoma glomerata (Corda) Wollenw. et Hochapfel	+/–	–/–	–/–
Pseudogymnoascus pannorum (Link) Minnis & D.L. Lindner	+/+	–/–	+/+
Rhizopus stolonifer (Ehrenb.) Vuill.	+/+	–/–	+/+
Scopulariopsis communis Bainier	+/+	–/+	–/–
Trichoderma viride Pers.	+/+	+/+	+/–
T. koningii Oudem.	+/+	–/–	+/+

[1] *in contaminated soil/in uncontaminated soil*

background soil to the frequent group in the contaminated one.

The fungi isolated from the soil can be dangerous to human health, since many of them exhibit potential pathogenicity, to some extent. The strains of the fungi isolated from the contaminated soil reveal the potentially pathogenicity in a greater degree, than the strains isolated from the clean soil. 55% of the total amount of fungi strains isolated from the soils contaminated by the Aluminum Plant emissions had the potentially pathogenicity. It is necessary to conduct regular monitoring studies to identify potentially dangerous microscopic fungi species.

REFERENCES

Badiee P. and Hashemizadeh Z. (2014). Opportunistic invasive fungal infections: diagnosis and clinical management. The Indian journal of medical research, 139(2), pp. 25-195.

Bogomolova E., Minenko E., and Kircideli I. (2007). Potential virulence of micromycetes isolated from museum premises. Mycology and phytopathology, 41(2), pp.113-119 (in Russian with English summary).

Bogomolova E., Velikova T., Goryaeva A., Ivanova A., Kirtsideli I., Lebedeva E., Mamaeva N., Panina L., Popihina E., Smolyanitskaya O., and Trepova E. (2012). Microfungi in the air of Saint-Petersburg. Sankt-Peterburg: Himizdat, 215p. (in Russian).

Domsh K., Gams W., Anderson T. (2007). Compendium of soil fungi. 2nd ed. IHW Verlag Ehing.

Evdokimova G., Korneykova M., and Lebedeva E. (2013). Complexes of potentially pathogenic microscopic fungi in anthropogenic polluted soils. Journal of Environmental Science and Health, Part A, 48(7), pp.746-752.

Evdokimova G., Kalabin G. and Mozgova N. (2011). Content and toxicity of heave metals in soil of the zone affected by aerial emission from the Severonikel Enterprise. Eurasian Soil Science. 44(2), pp. 237-244.

Evdokimova G., Korneikova M., and Mozgova N. (2013). Changes in the Properties of Soils and Soil Biota in the Impact Zone of the Aerotechnogenic Emissions from the Kandalaksha Aluminum Smelter. Eurasian Soil Science. 46(10), pp. 1042-1048.

Fotedar R. and Ai-Hedaithy S. (2005). Comparison of phospholipase and proteinase activity in Candida albicans and Candida dubliniensis. Mycoses, 48, pp. 62-67.

Hoog de G. C., Guarro J., Gene J., and Figueras M. J. (2011). Atlas of clinical fungi. Electronic Version 3.1.

Kireeva N., Miphtakhova A., Bakaeva M., and Vodopyanov V. (2005). Complexes of soil microscopic fungi under technogenic conditions. Ufa: Gilem, 360p. (in Russian)

Marfenina O. (2005). Anthropogenous ecology of soil fungi. Moscow: Medicina dlya vseh (in Russian).

Pappas P. G. (2010). Opportunistic fungi: a view to the future. The American journal of the medical sciences, 340(3), 253-257.

Raper B. and Thom C. (1968). Manual of the Penicillia. London: Hafner Publishing Co.

Sanitary-and-epidemiologic rules SR 1.3.2322-08 (2008). «Safety of work with microorganisms of the III-IV groups of pathogenicity (danger) and causative agents of parasitic diseases», 185-186 (in Russian).

Satton D., Fotergill A., and Rhinaldi M. (2001). Key pathogenic and conditionally pathogenic fungi. Moscow: Mir (in Russian).

Seifert K., Morgan-Jones G., Gams W., and Kendrick B. (2011). The genera of Hyphomycetes. Utrecht: CBS.

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AUTHORS

Maria Korneykova is a PhD (Biology), an employee of the Institute of North Industrial Ecology Problems – Subdivision of the Federal Research Centre "Kola Science Centre of Russian Academy of Science". She is the head of the Laboratory of microorganisms ecology. She has 15 years of experience in ecology of microorganisms, soil and air mycology, bioremediation. Her work is devoted to the study of qualitative and quantitative indicators of microorganism communities in background and polluted areas of the Kola Peninsula, as well as the study of the physiological and biochemical properties of microorganisms under changing environmental conditions (reveal of microorganisms -bioindicators of pollution, microorganisms-destructors of pollutants et al.)

Elena Lebedeva is a PhD (Biology), an employee of the Komarov Botanical Institute of Russian Academy of Science. She is the Senior Researcher of the Laboratory of systematics and geography of fungi. Her research area is soil mycology, ecology of fungi, biodegradation.