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Possibility of micromycetes detected in dust to grow on metals (Al, Fe, Cu, Zn) and on polyaniline-modified Ni

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Studies performed in 2006–2007 have shown that dust particles present in the air of industrial and residential premises are constant pollutants of the environment. By their origin, they can be separated into technical (anthropogenic) and natural. Technical sources of dust are closely related to the character of the industrial operations, as well as on the chemical and physical properties of the raw materials used. Dust contains a great number of microorganisms; it makes a peculiar environment for microorganisms to survive and gives an impulse to begin developing under unfavourable conditions and to become active components of the ecological environment. So microorganisms find their way onto metals, attach to their surface and start to act forming chemical bonds, thus chemical processes set in. The surface of metals starts to exchange. The data obtained have shown that under conditions of natural environment, most of micromycete cosmopolites belonging to *Penicillium*, *Aspergillus*, *Alternaria*, *Ulacladium*, *Fusarium*, *Scopulariopsis*, *Paecilomyces*, *Rhizomucor*, *Rhizopus*, *Botrytis*, *Cladosporium*, *Chrysosporium* and more rarely to other genera can attach to metal surface. The strength of bonds and the course of attachment between various species of fungi and metals differ. Purposeful studies carried out with individual strains of micromycetes will help create methods to decelerate the corrosion of Al and other metals and to diminish the environmental impact on metal surfaces, thus preventing substantial economic losses.

Key words: dust, micromycetes, metals, corrosion, polyaniline film, environment, protection

INTRODUCTION

Studies on the ecology of living organisms are usually carried out on three levels: an individual organism, a population formed of individuals of one species, and an association formed by several to several tens of different populations. While studying the ecological peculiarities of individuals, it is important to determine how both abiotic and biotic factors of the environment affect the individual, as well as to elucidate the impact of separate individuals on the environment. Dust is a specific, variable substratum for the development of microorganisms. Microorganisms detected in dust can be considered as accidental individuals in this substratum. To investigate microorganisms at the population level in such a substratum is rather difficult methodically, as there are no possibilities to correlate the peculiarities of population with the main parameters of the environment, which are highly inconstant. The main exchange stream of energy, biological elements and other substances in dust occurs at the level of a colony. The stream can be investigated as a diversity of functional activities of species, in which correlations are not completely formed and well-established and at any moment can be strongly affected by the environmental factors, and *vice versa* – to determine the essence and direction of these factors. When studying dust, one encounters the initial moments of colonies formation and the peculiarities of their behaviour, as well as the prognostication possibilities of their influence on the environment (Bigon et al., 1989; Filtenborg et al., 2000).

In the past years, the growth of a pure culture on agar substrata, the peculiarities of colonies formation, structure, pigmentation and morphological evidences reflecting the character of conidiogenesis of fungi were the main criteria for species characterization. In recent years, the criteria have been amplified in increasing frequency with the following data: the protein content in a fungal cell, the composition of isoenzymes, the composition of ubichinones (derivatives of 5-methyl-2,3-dimetoxsi-1,4-chinone) as well as serological properties. At present, while describing a species, more and more often data on the capacity of taxons to synthesize various secondary metabolites (Frisvald et al., 1988) whose composition is characteristic of various strains of the same species separated from substrata of the different composition are used (Flannigan et al., 2001). The molecular–genetic methods, which allow specifying the species identification precision, are becoming increasingly important. For instance, it is possible to specify the propinquity of the genus *Aspergillus* by using the cytochrome B gene (Wang et al., 1998). The data obtained by these methods significantly replenish the data, enabling to characterize more precisely the ecological peculiarities of micromycetes of every species and population as well as to evaluate their potency in the environment.

While studying dust micromycetes accumulated indoors, attention should be paid to commonly encountered *Acremonium*, *Alternaria*, *Aspergillus, Chrysosporium*, *Cladosporium*, *Paecilomyces*, *Penicillium*, *Trichoderma* and to fungi belonging to other genera capable of a prompt adaptation to various substrates used industrially: metals, coatings, lubricants, polymeric substances. These fungi produce various organic acids, enzymes, antibiotics, mycotoxines, aminoacids and a multitude of other biologically valuable substances, therefore, they are active components of the ecological environment. Fungi of the *Aspergillus niger* species secreting citric acid, produced industrially, are especially active makers of such substances (Banik, 1976) – phenylacetilic, indolilacetilic, oxalic, formic acids, which play an important role in plants pathogenesis processes. Along with the acids mentioned, the fungi of this species are capable to synthesize and release into environment nigragiline, pentopeptide, malformine A, naphthoquinone, aspergilines, aspercilones (+aspercebrole), dehydroaflavines, flavioline, genisteines and a great deal of other compounds (Kozakiewicz, 1989; Frisvad, Samson, 1991; Lugauskas ir kt., 2002; Иванушкина, 2003). The physiological activity of this fungus and the abudance of metabolites allow them to attach to various metals: aluminium, iron, copper, zinc and polyaniline-modified nickel (Juzeliūnas et al., 2005, 2007; Ramanauskas et al., 2005; Mieczinskas et al., 2006, 2007; Binkauskienė et al., 2008).

The overgrowth of metallic surfaces with fungus mycelium is closely related to electrochemical processes (Juzeliūnas et al., 2007; Mieczinskas et al., 2007). Studies of metal overgrowth in open natural environments show that fungi most intensively evolve in the places where the metal comes into contact with water and air. It has been stated that the electric characteristics of steel, aluminium, and titanium can be worsened by some species of fungi belonging to the genera *Aspergillus*, *Penicillium*, *Sporotrichum*, *Cladosporium*, *Paecilomyces* (Stokes, Lindsay, 1979; Коваль, Сидоренко, 1989).

Metal surface is a convenient basis for micromycete propagules to attach (Svidirenok et al., 1994). At the beginning, the attached fungus does not change the structure and composition of the metal surface. Most often fungi start to use the metal as a source of nourishment by involving it in the processes of fungal growth and metabolism occurring in the environment. The possibilities of some fungal species to grow on metal surface are determined by their secreted metabolites which enable fungi to adapt to new environmental and noushment conditions. In these cases, complicated processes take place in fungal organisms when the enzymatic systems are rearranged and directed towards performing a specific activity, namely assimilating new elements by their incorporation in the adaptive processes. Data on the capacity of micromycetes of individual species to adapt to metals are scarce. The reaction of aluminium and its alloys used in aircraft building to the influence of micromycetes and their metabolites has been studies somewhat wider (Герасименко, 1987).

Changes in the composition of the surface layer of metal or metal alloy are one of the evidences confirming that the fungus has penetrated the metal surface and uses it to satisfy its nourishment needs. The course of the process depends on the quantity of oxygen in the metal oxide layer. It has been noticed that formation of *Aspergillus niger* colonies and their colour are determined by oxygen concentration in the metal oxide layer. The pH of the surface of copper alloys decreases with an increase in oxygen quantity, which is especially pronounced in the zone where fungi start growing. Micromycetes of various kinds grow on metals and their alloys irregularly. Fungi isolated from organic substances or substrates rich in organic substances grow more intensively on metals. Nowadays, studies of the regularities of biofilm formation on conductive polymer surface have been carried out as polymers are widely used for a number of applications. Electroactive polymers are distinguished by their redox properties and a developed morphological surface structure (Тарасевич, Хрущева, 1990).

The aim of this work was to isolate and identify micromycetes capable to contaminate Al, Cu, Zn, carbon steel and polyaniline, as well as to search for the methods of increasing metal safety and to diminish losses from corrosion and environmental pollution.

MATERIALS AND METHODS

Dust settled on different surfaces in agricultural product storage and processing facilities was gathered with a sterile brush into sterile glass vessels. Two nutrient media were used for micromycete isolation: standard malt agar (DIFCO) and dicloran glycerol agar (DG–18, OXOID). The media were sterilized for 15 min by autoclaving at 121 °C. The cooled media were poured into sterile Petri dishes. The dishes were sterilized by autoclaving.

One gramme of dust was suspended in 100 ml of saline (0.85% NaCl) with the addition of 0.1% Tween 80 supplement. This suspension was used to prepare a dilution series of 1 : 100; 1 : 1000; 1 : 10000. Later, 0.1 ml of the suspension was set into a Petri dish, and 15 ml (45 ± 0.5 °C) of the medium was poured over it. The dishes were kept in a thermostat at a temperature of 26 ± 2 °C. The developed colonies of microscopic fungi were calculated after 3, 5 and 7 days. The number of micromycete propagules was expressed as colony forming units (cfu) per 1 g of dust (Krysińska-Traczyk et al., 2001; Šveistytė et al., 2005). The morphological peculiarities of fungi were studied employing a scanning electron microscope EVO 50 EP (Carl Zeiss SMT AG, Germany) and light microscope.

The isolates were ascribed to taxonomic groups following Ainsworth and Bisby's Dictionary of Fungi (Hawksworth et al., 1995). Micromycetes were identified according to various manuals (Charmichael, 1962; Chaverri, Samuels, 2003; Domsh et al., 1980; Gams, 1971; Ghosh, 1955; Hoog, 1983; Klich, 2002; Lugauskas et al., 1997, 2002; Nelson et al., 1983; Ramirez, 1982; Samson, Frisvad, 2004; Samson, 1974; Van Oórschot, 1980; Zabawski, Baran, 1998).

Plates (100 × 150 × 3 mm) of the four principal metals: Al (Al > 99.5%), Cu (Cu > 99.5%), Zn (Zn > 98.5%) and low carbon steel (LCS) (C 0.05–0.12%, Cu 0.003–0.10%, P < 0.07%) were used in these investigations. The exposured metal plates were cleaned with a fine suspension of $Mg(OH)_2$ and high purity acetone to minimize the initial contamination of the surface by nutritives from the environment. With the purpose to determine the capacity of micromycetes to adapt to metals, experiments were performed under laboratory conditions using a malt agar extract poor in nutritive materials (Lugauskas et al., 2004, 2005; Juzeliūnas et al., 2005, 2007).

To study the relation between the organic substance and the metal, a peat substratum produced by Joint Stock Company

"Veiverita" and recommended for plant growing was used. Its pH was 6.8 and the atomic C/N ratio was 13.9. The duration of the experiment was 28 days at a temperature 26 ± 2 °C. The contact of the metal with fungi was investigated: metal plates were placed in Petri dishes filled with a sterile agar medium of malt extract supplied with chloramphenical (50 mg · l^{-1}). After the medium with metal had been sown up and cultivated in a thermostat at a temperature of 26 ± 2 °C, the intensity of fungi growth on the five-point scale and metal oxidation and surface changes were evaluated. The extent of fungal growth was assessed by the naked eye and by light microscopy in accordance with the scheme:

– no fungal growth observed on specimens under the light microscope – 1 point,

– mycelium with branched hyphae, and possibly sporulation, visible under the light microscope – 2 points,

– growth of fungi, spare but visible to the naked eye under the light microscope, sporulation clearly visible – 3 points,

– growth of fungi clearly evident, but covering <25% of the tested surface – 4 points,

– heavy growth of fungi visible to the naked eye and covering >25% of the test surface – 5 points.

Polyaniline films were electrodeposited on a Ni plate (10 μm thick, 0.5 cm wide and long). Potentiodynamic synthesis was performed within the potential limits of –0.1 and 1.3 V at a sweep rate of 50 mVs^{-1} in an electrolyte containing 0.1 M of the aniline monomer (purified by distiliation) in 0.3 M $H_2C_2O_4$ aqueous medium (Binkauskienė et al., 2008).

RESULTS AND DISCUSSION

Dust is part of the geochemical background of a natural environment. The background quantities of elements in dust are formed as a result of natural processes and global and regional transfers of technogenic and chemical elements.

The average quantities of elements, or clarks, which are detected in soil water, plants and other environmental objects could be referred to as background quantities of an element. It is important to take into account the average regional amount of an individual element whose value is determined by local natural peculiarities, as well as the number and quantity of technogenic elements and the peculiarities of their transfer. Evaluating the level of concentration of a certain element in an urbanised environment, the local background is calculated by mathematical statistical methods. A great deal of factors determines the background quantities of elements in dust. The solid phase of dust is composed of minerals and organic substances. The solid particles of dust can be coarse-grained (larger than 0.001 mm) and fine-grained (smaller than 0.001 mm). The background quantities of P, Mn, Ti, Ni, Zn and other elements in dust mainly depend on the mineral composition of coarse-grained particles.

Fine grained particles, which are mainly composed of clay minerals and decay products of organic substances, are the major part of a dust sorption complex. A fine-grained organic substance, which is rich in Cu, Fe, Ni, Ti, Zn, Co and other elements, is distinguished for its particularly high sorption capacity. All this allows microorganism propagules to retain in dust, not to perish, and given enough moisture to sprout and start functioning, and become an active source of mineral pollution on technical objects, metals, coatings and synthetic polymer substances.

The results of studies performed under laboratory conditions indicate that two fungi forming white colonies of white mycelia easily adapt to Al and Fe plates and contaminate them (Fig. 1, 1–3). A systematic dependence of these fungi has been determined by using an EVO 50 EP scanning electron microscope.

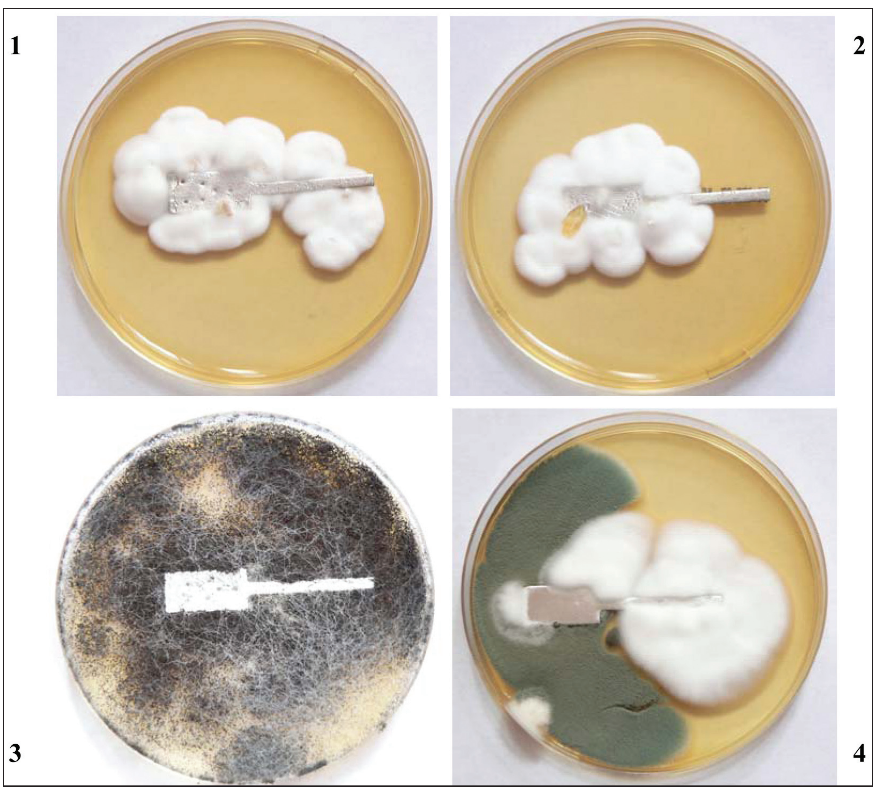


Fig. 1. General view of micromycetes' adaptation to metallic plates: 1. An Al plate overgrown by *Acremonium* spp. fungus. 2. A Fe plate overgrown by *Acremonium* spp. fungus. 3. An Al plate contaminated by various fungi. 4. A Fe plate contaminated by various fungi

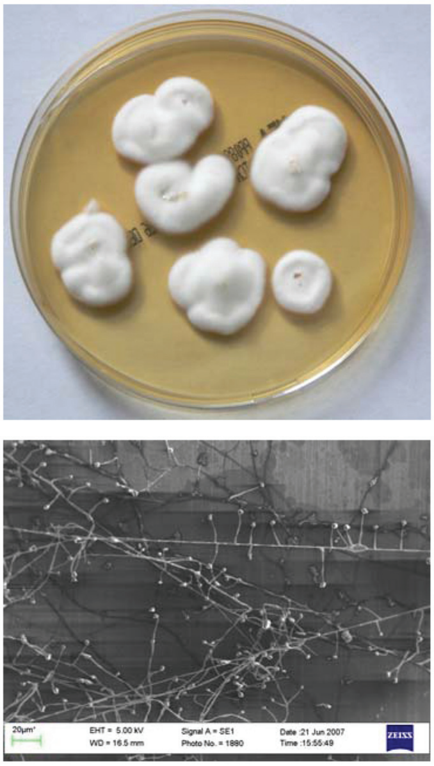
1
2


Fig. 2. *Acremonium* spp. Isolated from an Al plate exposed to natural environment in Vilnius: 1. Colonies on the malt agar after 10 days of growth. 2. A general view of conidia formation on an Al plate

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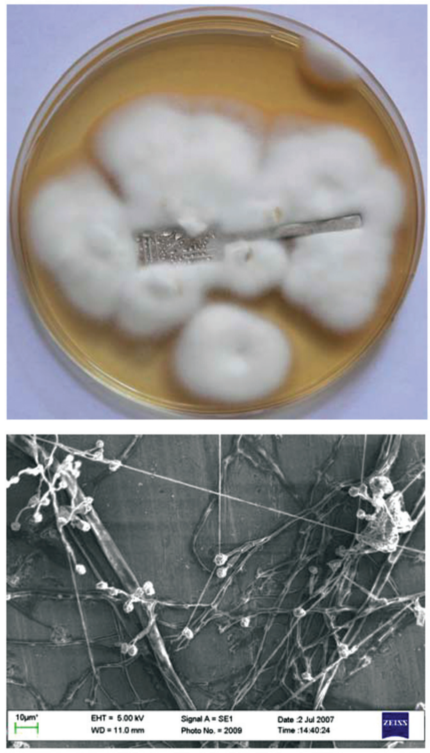

Fig. 3. Fungi of *Scopulariopsis parvula* spiecies: 1. Concentrated along a Cu plate; 2. A conidiogenesis view of the fungi obtained by scanning electron microscope

One of them (Fig. 2, 1–2) belongs to the genus *Acremonium* Link ex Fr. and resembles micromycetes of *A. fusidioides* (Nicot) W. Gams species. However, it should be mentioned that the colonies have retained their white colour in all the experiments. This fungus produces an antibiotic substance – fusidic acid and its sodium salt fusidin, both having a high specific activity against grampositive bacteria and being able to partially protect the metal surface from the negative effect of spore-forming bacteria.

The second micromycete developing on Al and Fe and producing white colonies has been assigned to *Scopulariopsis parvula* Marton et Smith (= Syn. Paecilomyces parvus Brown et Smith (Fig. 3). The fungus was isolated from metals in a natural environment. In the type culture of both species, the condiogenous cells elongate with age. The conidia have a truncate base. The physiological peculiarities of fungi of this species remain little investigated, notwithstanding the fact that specialists of medical mycology also take interest in them.

The studies carried out under laboratory conditions have shown that fungi of other genera can also contaminate Al, oxidize and damage the surface of the metal. One of the substances is *Aspergillus* (= *Eurotium*) *repens* de Bary (Fig. 4) capable of releasing into the environment a wide variety of metabolites of various composition as well as destroying such substances as hydrocarbons from fuel oil and using them as a carbon source, and transforming tryptamine into indole-acetic acid. *Exophiala jeanselmei* (Langeron) McGinnis et A. A. Padhye (Fig. 5) fungi also actively destroy nitrates, urine and other substances rich in nitrogen, as well as assimilate various sugars. Fungi of this spe-

1
2


Fig. 4. *Aspergillus* (= *Eurotium*) *repens* fungi: 1. A view of a colony on the malt agar after 10 days of growth. 2. The fungi starting to grow on an Al plate

cies were noted to be capable of a rapid adaptation on metal surfaces together with organic dust. As these fungi are resistant to various chemical compounds, they are difficult to remove from the surface even when fungicides are used.

The interaction of various micromycetes detected in the dust of enclosed spaces with Al, Fe, Cu and Zn has been investigated. The data obtained after 28 days of exposure are presented in Table.

Crysosporium merdarium and *Fusarium proliferatum* fungi were determined to affect aluminium more markedly, but less than *Rhizomucor pusillus*. Other fungi did not grow on Al and did not oxidize its surface. Fungi of *Alternaria alternata*, *Aureobasidium pullulans*, *Fusarium proliferatum*, species heavily affected Fe under similar conditions, and fungi of *Chrysosporium merdarium* affected Fe slightly less. The micromycetes of *Rhizomucor pusillus* and *Trichoderma harzianum* fungi did not grow on Fe at all. On the Cu surface, only a weak growth of *Fusarium proliferatum* species was observed. Fungi grew rather weakly on Zn surface as well. A continuous greyish deposit of uncertain origin and a weak superficial fungal growth were observed on Zn plates under the action of *Chrysosporium merdarium* and *Rhizomucor pusillus*. There was no pronounced relation between the intensity of fungal growth on metal surface and the degree of damage.

Table. **Reaction of Al, Fe, Cu, Zn metals to the impact of various micromycetes**

Fungal species	Changes in metal surface	Intensity of deterioration in points (1–5)
1	2	3
Aliuminium (Al) after 28 days of exposure to fungi		
1. *Alternaria alternata* (Fr.) Keissl.	Fungi did not grow on metal surface	0
2. *Aureabasidium pullulans* (de Bary) G. Arnaud	Fungi did not grow on metal surface, moisture accumulated intensively	0
3. *Chrysosporium merdarium* (Link ex Grev.) J. W. Carmich.	The metal surface is covered by a layer of mycelia (denser at the edges, thinner in the centre), moisture accumulates intensively	3.0
4. *Fusarium proliferatum* (Matsushima) Nirenberg	The fungus grew on metal surface in the form of a thin, prostrate mycelia	2.0
5. *Rhizomucor pusillus* (Lindt) Schipper	Only the edges of a metal plate and the holder are covered by mycelia	1.0
6. *Trihoderma harzianum* Rifai	Fungi did not grow on metal surface	0
Iron (Fe) after 28 days of exposure to fungi		
1. *Alternaria alternata* (Fr.) Keissl.	The metal surface is corroded, scaled, crumbly, discontinuous	4.0
2. *Aureabasidium pullulans* (de Bary) G. Arnoud	The metal surface is covered by a film and is discontinuous	4.0
3. *Chrysosporium merdarium* (Link ex Grev.) J. W. Carmich.	Fungi intensively grew on the edges of a metal plate, less intensively in the centre, the mycelia are yellow	3.0
4. *Fusarium proliferatum* (Matsushima) Nirenberg	The metal surface is corroded, covered with the fungi mycelia, forming a dense fuzzy coating	4.0
5. *Rhizomucor pusillus* (Lindt) Schipper	Fungi did not grow on metal surface	0
6. *Trihoderma harzianum* Rifai	Fungi did not grow on metal surface	0
Copper (Cu) after 28 days of exposure to fungi		
1. *Alternaria alternata* (Fr.)Keissl.	Fungi did not grow on metal surface	0
2. *Aureabasidium pullulans* (de Bary) G. Arnaud	Fungi did not grow on metal surface	0
3. *Chrysosporium merdarium* (Link ex Grev.)J. W. Carmich.	Fungi did not grow on metal surface	0
4. *Fusarium proliferatum* (Matsushima) Nirenberg	A thin fungi mycelium prostrates over the metal surface, moisture accumulates	1.0
5. *Rhizomucor pusillus* (Lindt) Schipper	Fungi did not grow on metal surface	0
6. *Trihoderma harzianum* Rifai	Fungi did not grow on metal surface	0
Zinc (Zn) after 28 days of exposure to fungi		
1. *Alternaria alternata* (Fr.) Keissl.	Fungi did not grow on metal surface	0
2. *Aureabasidium pullulans* (de Bary) G. Arnaud	The metal surface remains unchanged, moisture accumulates intensively	0
3. *Chrysosporium merdarium* (Link ex Grev.) J. W. Carmich.	A thin net of mycelia hyphae prostrates over metal surface	1.0
4 *Fusarium proliferatum* (Matsushima) Nirenberg	The metal surface is corroded and covered with almost continuous grayish fur	2.0
5. *Rhizomucor pusillus* (Lindt) Schipper	A thin layer of fungi is observed on the edges of the metal plate	1.0
6. *Trihoderma harzianum* Rifai	Fungi did not grow on metal surface	0

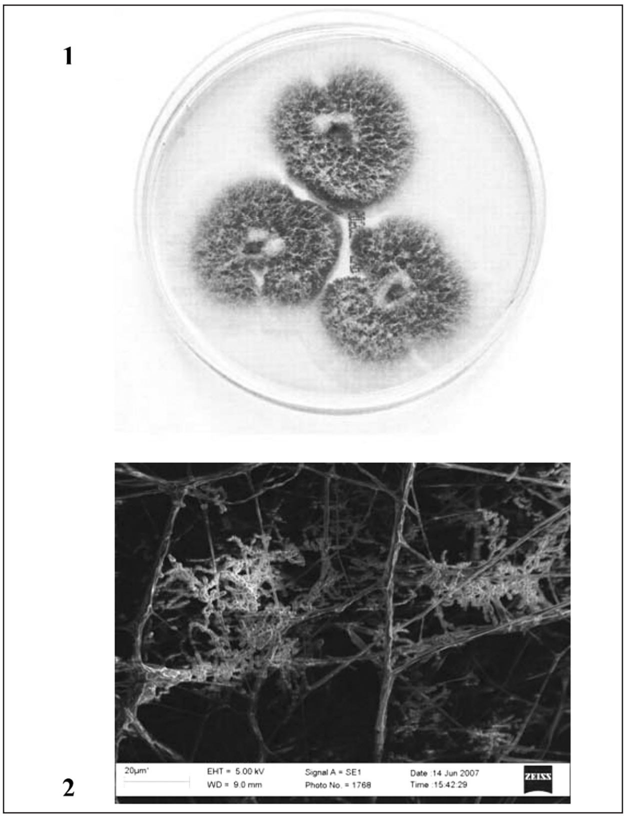

Fig. 5. *Exophiala jeanselmei* species micromycetes: 1. Colonies formed on malt agar. 2. A microscopical view of conidia formation on Al surface

In order to reveal the response of micromycetes developing in substrata rich in organic substances, Al, Fe, Cu and Zn plates were kept in a close contact with peat compost prepared for agricultural needs. The results are presented in Fig. 6.

The data obtained suggest that micromycetes developing in the environment actively participate in the process of surface damage and destruction. The intensity of these processes is determined by the peculiarities of the environment, the kind of metal and the adaptation capacity of microorganisms, the latter being dependent on the biological peculiarities of the micromycetes taking part in the processes, the abundance of their populations, as well as the physiological peculiarities and interrelation of the associations formed.

While studying dust formed in premises where commercial production was performed, attention was given to a peculiar diversity of micromycetes present in dust in herb-drying rooms and industrial potato storehouses. In these temporarily formed premises resistant to the external impact, the domination of fungal associations of *Chrysosporium merdarium*, *Gymnoascus reessii* and *Botrytis cinerea* species was observed (Fig. 7).

Studies of the capacity of the mentioned fungi to contaminate Ni surface modified with polyaniline revealed the activity of *Chrysosporium merdarium* species and close to them *Gymnoascus reessii* fungi, and their ability to damage the conductive polymeric coating (Fig. 8, 3).

Chrysosporium merdarium shows a good adhesion of a polyaniline film synthesized in an oxalic medium on Ni surface. After 15 days of exposure, the influence of *Ch. merdarium* on polyaniline was assessed by 4.5 points (from 5).

Micromycetes and their functional capacity are important ecological factors of the environment, which often determine the duration of the effective usage of metals and their ware. Propagules of micromycetes along with dust find their way onto metal surface under the action of adhesion forces, and they start to function even at the lowest moisture. In such a manner they form chemical bonds with the metal. Intensive chemical processes of metabolism start, and the medium changes.

It has been noted that not all micromycetes and their population species can survive on a metal surface. Most of them die from severe, unfavourable conditions on the metal surface, such as alternating moisture, temperature, physical, chemical and technical parameters. Only micromycetes able to incorporate the metal as a link into their activity chain connecting them with the environment and whose functioning helps minimize the tension between the metal and their vital needs can survive.

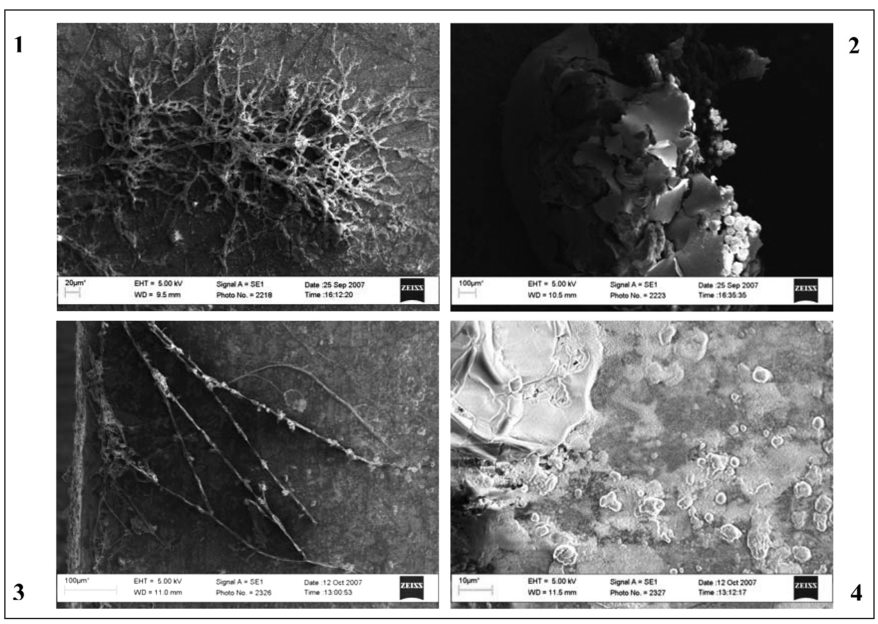

Fig. 6. Results of close contact of peat compost mass with various metals: 1. Fungal growth on Al surface. 2. Fe surface deteriorated, abundance of conidia fungi. 3. Hyphae of hifai fungi on Cu surface. 4. Deteriorated Zn surface contamined by micromycetes

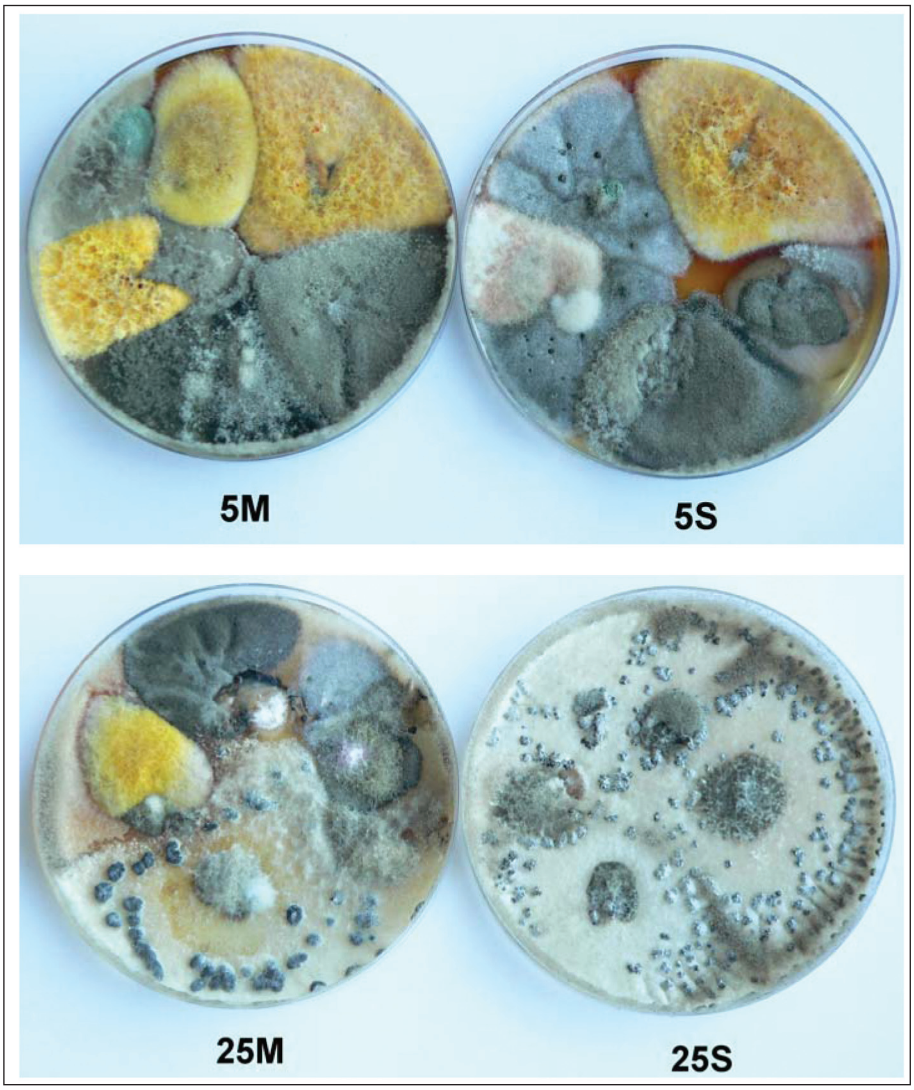

Fig. 7. Micromycetes obtained from dust, collected: 5. In industrial potato storehouse. 25. In herb dryer. Fungi grown on two agar media: M – malt extract, S – Sabouroud's

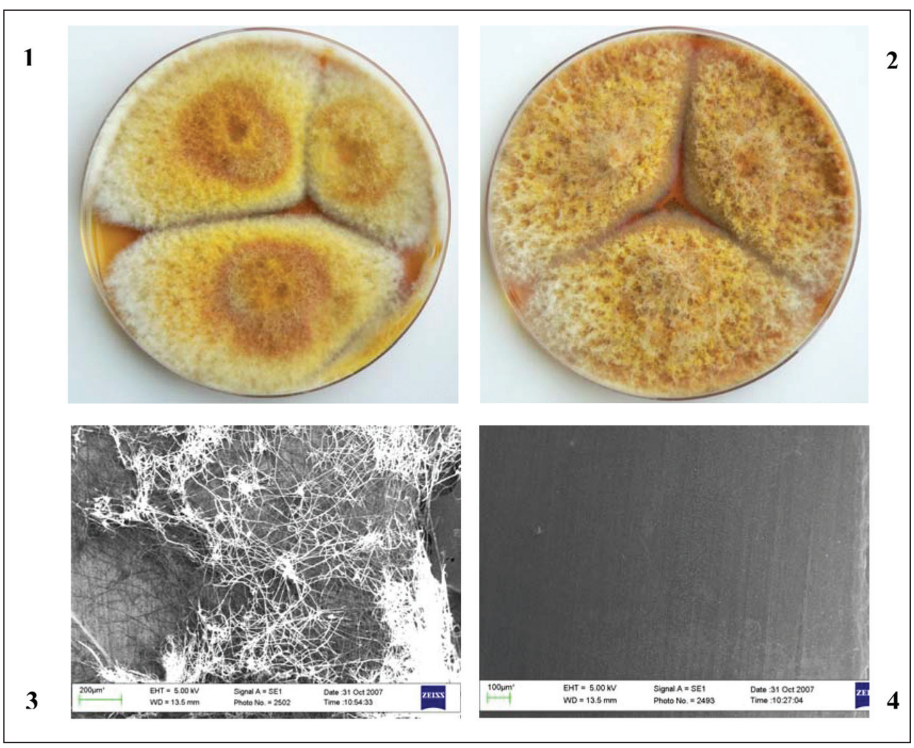

Fig. 8. Micromycete colonies on standard malt agar 1. *Chysosporium merdarium*. 2. *Gymnoascus reessii*. 3. *Chysosporium merdarium* on the surface of a conductive polyaniline film. 4. The surface of Ni covered with a polyaniline film (reference)

The data obtained suggest that under natural conditions most micromycetes called cosmopolites, belonging to the *Penicillium*, *Aspergillus*, *Alternaria*, *Ulacladium*, *Fusarium*, *Scopulariopsis*, *Paecilomyces*, *Rhizomucor*, *Rhizopus*, *Botrytis*, *Cladosporium*, *Chrysosporium* and more rarely to other genera can attach to metal surface. The rates of bond formation between separate species and metals differ. Separate metals are sensitive to the impact of certain micromycetes, while others are inert to the metabolites of other fungi or this impact is insignificant. In the latter case, a weak growth of fungi on a metal surface is observed only when there is an additional source of nourishment, otherwise the metal remains untouched, no clear changes are seen, oxidation processes are very slow or completely stop.

At the same time, other micromycetes develop on a metal rather intensively: the hyphae of mycelium spread over the surface, covering the latter with a thick layer of fungi. This was established while observing the contacts between *Aspergillus niger* and Ni or a polyaniline film; *Chrysosporium merdarium* and Al; Ni or polyaniline coatings, *Acremonium* spp. and Al or Fe, *Scopulariopsis parvula* and Al or Cu.

The results of the initial studies have shown that it is possible to elaborate the technological procedures enabling to slow down the corrosion of Al and other metals and thus to prevent big losses and to protect the environment from pollution.

CONCLUSIONS

1. The fungi of *Chrysosporium merdarium*, *Fusarium proliferatum* and slightly less *Rhizomucor pusillus* affected aluminium plates markedly. After 28 days the surface of a plate was covered with a layer of mycelia and oxidized. The other fungi did not grow on aluminium plates and did not oxidize its surface.

2. The fungi of *Alternaria alternata*, *Aureobasidium pullulans*, *Fusarium proliferatum* species heavily affected iron. The metal surface was corroded, scaled, crumbly, covered with fungal mycelium and chapped. The micromycetes of *Rhizomucor pusillus* and *Trichoderma* did not grow on iron at all.

3. Fungi grew rather weakly on the zinc surface as well. A continuous grayish deposit of uncertain origin and a weak superficial fungal growth were observed on zinc plates under the action of *Chrysogenum merdarium* and *Rhizomuca pusillus*.

4. Studies of the capacity of fungi to contaminate the surface of polyaniline-modified nickel revealed the ability of *Chrysosporium merdarium* species to damage a conductive polymeric coating.

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DULKĖSE APTIKTŲ MIKROMICETŲ VYSTYMOSI ANT METALŲ (Al, Fe, Cu, Zn) IR POLIANILINU MODIFIKUOTO Ni GALIMYBĖS

Santrauka

2006–2007 m. atliktais tyrimais nustatyta, kad uždarose gamybinėse ir gyvenamosiose patalpose oro skraidinami dulkių mišiniai yra pastovūs aplinkos teršėjai. Pagal kilmę juos galima suskirstyti į techninius-antropogeninius ir gamtinius. Dulkių sklaidos techniniai šaltiniai glaudžiai siejasi su vykdomų industrinių operacijų pobūdžiu bei jų žaliavos cheminėmis ir fizikinėmis savybėmis. Dulkėse visada gausu mikroorganizmų. Jos sudaro savitą aplinką mikroorganizmams išgyventi, suteikia impulsą pradėti vystytis net ir nepalankiomis aplinkybėmis ir palaipsniui tapti aktyviu aplinkos ekologiniu veiksniu. Mikroorganizmai, su dulkėmis patekę ant metalų, čia įsitvirtina ir pradeda funkcionuoti. Tarp mikroorganizmų ir metalo užsimezga cheminiai ryšiai, prasideda metalo paviršiaus kaitos procesai.

Atliktų tyrimų rezultatai parodė, kad natūraliomis aplinkos sąlygomis ant metalų paviršiaus gali įsitvirtinti dauguma kosmopolitais vadinamų *Penicillium*, *Aspergillus*, *Alternaria*, *Ulacladium*, *Fusarium*, *Scopulariopsis*, *Paecilomyces*, *Rhizomucor*, *Rhizopus*, *Botrytis*, *Cladosporium*, *Chrysosporium,* rečiau kitoms gentims priklausančių mikromicetų. Nustatyta, kad ryšių tvirtumas ir prasidėjusi cheminių procesų eiga tarp atskirų rūšių grybų ir skirtingų metalų yra nevienoda.

Atliktų tyrimų rezultatai teikia galimybes pamatyti, kad kryptingai vykdant tyrimus su atskiromis mikromicetų padermėmis galima sukurti metodus, įgalinančius sulėtinti Al ir kitų metalų korozijos procesus ir sumažinti aplinkos poveikį metalų paviršiams bei išvengti dėl šių procesų patiriamų didelių ekonominių nuostolių.

Raktažodžiai: dulkės, mikromicetai, metalai, polianilino danga, korozija, sauga, aplinka