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Researhe Article ISSN 2658-5553

Received: December 01, 2022 *Accepted: December 03, 2022* *Published: December 09, 2022*

Microbiological contamination of reinforced concrete structures in the poultry complex

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Keywords:

Poultry complexes reinforced concrete structures; microbiological contamination; microbiological studies; destruction mechanics; biological corrosion; bacteria; Aspergillus; Alternaria; Penicillium; Cladosporium; Chaetomium; Fusarium; Paecilomyces; Stachybotrys; Mucor fungi

Abstract:

The object of research is a microbiological contamination of reinforced concrete structures of the poultry house. **Method.** The species composition of microorganisms settled on the selected samples of reinforced concrete structures was determined in laboratory conditions. The identification of microscopic fungi was carried out according to their morphological and cultural characteristics using determinants: K. B. Raper, C. A. Thorn, 1949; K.B. Raper, D.I. Fennel, 1965; N.P. Podopilchenko (1971); M.A. Litvinov (1967); A.A. Milko (1974); T.C. Кириленко (1977); K. Donch, V. Gams, 1980; A.U. Lugauskas, A.N. Mikulskene, D.U. Shlyauzhene (1987); V.I. Bilay, E.Z. Koval (1988). **Results**. Biodegradation processes in buildings with different service lives are considered. Biodegraders that affect biodegradation of concrete and reinforced concrete structures have been identified.

1 Introduction

Concrete and other cement composites are used in the construction of various buildings and structures. The results of studies of various authors show that cement concrete is exposed to various destroyers that act like ordinary chemicals, destroying concrete structure both inside and outside [1]-[7]. Internal corrosion is caused by the processes that occur inside the concrete body due to the interaction of cement alkalis with the amorphous silica contained in the aggregate. To minimize this type of corrosion, for example, in European standards, alkalis content in cements is limited to 0.6%, and the content of silica soluble in alkalis was not more than 50 mmol/l [8]. External destruction of concrete occurs during chemical interaction between the aggressive media and concrete components, followed by dissolution and washing of chemical reaction products from the structure surface. In this case, concrete destructive processes are combined into three groups [9, 10]: aggressive media dissolves and washes out components of the composite (1st group); aggressive media chemically reacts with composite components to form substances that dissolve and wash out with water (group 2); aggressive media chemically interacts with composite components to form slightly water-soluble substances of greater volume than the initial components leading to the formation of internal stresses and destruction of the material (3rd group).

Concrete has high surface activity and can adsorb a wide variety of aggressive substances [11]-[13]. Degradation process of cement materials is enhanced by microbiological corrosion, especially in conditions of high humidity, temperature, and difficult air exchange [14, 15].

According to the data, the most common of damaged objects are Ascomycetes, Basidiomycetes, Deuteromycetes, Zygomycetes fungi. Among the most numerous groups of fungi-biodestructors are such representatives as Aspergillus (A. fumigatus, A. terreus, A. niger, A. flavus, A. luteus), Penicillium (P. glaucum, P. chrysogenum, P. purpurogenum, P. funiculosum, P. citrinum, P. rugulosum, P. ochro-chloron), Trichoderma (T. viride, T. sp.), Cladosporium (C. cladosporioides, C. sphaerospermum), and Alternaria, Mucor, Scopulariopsis [15]-[19].

The main biodestructors of building materials are bacteria, mycelial fungi, actinomycetes and their metabolic products [20]-[23]. The development of biocorrosion under the influence of aggressive media leads to a gradual decrease in the operational reliability of products and structures [24]-[26].

Bio-resistance of cement composites is limited by their nature, since capillary-porous materials are prone to active interaction with microorganisms and their vital products. In many cases concretes with good physical and mechanical properties do not have resistance in organogenic media [27]-[30].

As many scientists state, the destructive effect of mycelial fungi on concrete and other stone building materials is due to the aggressive effect of fungal metabolites (organic acids, redox and hydrolytic enzymes) on individual components. For example, it has been found that citric and oxalic acids can be accumulated by fungi in large quantities (up to 10%). For example, the Aspergillus niger strain produces gluconic and oxalic acids. After 11 months of contact these acids cause an increase in porosity of cement stone and a loss of binding capacity of the binder.

The mechanism of negative impact of microorganisms on concrete is presented as follows. As a result of hardening, concrete is covered with a protective film, which is formed by the action of calcium dioxide. If the film is intact, it prevents water diffusion into the internal structure of the product and thereby protects them from destruction. Thionic bacteria that are on the product surface with a carbonate film destroy it by changing pH of the contacting water due to the acid formed by them. In addition, they cause harm by producing sulfates, which form calcium hydrosulfoaluminate, which accelerates the destruction of the material [31].

Many years of research in the field of biological resistance of composite building materials indicate that from a large variety of microscopic organisms, fungi of Aspergillus niger and Penicillium chrysogenum species are the most harmful to industrial and building materials, products, and structures.

Protection from biodamage presents a global scientific and practical challenge. World damage from biodamage in the 1950s was estimated at 2% of industrial production. Losses from biodamage reach colossal proportions: more than 7% of the total cost of industrial production on a global scale, which amounts to hundreds of billions of dollars [32]-[35].

Intensive development of biocorrosion of concrete and reinforced concrete is observed in man-made environments at enterprises of agro-industrial complex - meat processing plants, dairy plants, bakeries, wineries, poultry farms and livestock farms [36, 37]. High air humidity and presence of various substances (proteins, fats, carbohydrates and products of their hydrolysis), urea, ammonia, carbon dioxide and salt solutions create favorable conditions for intensive development of corrosive microorganisms [35].

Environmental aspects of biodegradation by microorganisms of materials and structures are receiving increasing attention. The researchers' main focus is on ecological and biological component of the problem. Species composition, features of properties, the ability of microorganisms to populate materials are studied.

It should be noted that nowadays, features and regularities of damaging effect of biofactors have been studied much less than other environmental factors, such as temperature, mechanical stresses, light radiation, chemical media, etc. [38].

Low efficiency of biosecurity is largely due to the lack of knowledge of material science aspects of microorganisms damaging effect. A successful solution to the problem can be achieved by studying causes and mechanisms of biodamage of building structures, patterns of materials´ interaction with biodegraders.

Solving the problems in the field of biological protection increase of building structures requires the organization of their examination, conducting inspections to study the processes of materials´ biodegradation [39]-[41]. Special degradation conditions are created in poultry complexes. The specificity of poultry complexes is in the presence of rich media for microorganisms [42]-[45].

It should be emphasized that, as a rule, not one, but several species of fungi participate in biological-damaging action at the same time, which leads to the emergence of a qualitatively new damaging agent.

First, a visual examination is carried out when detecting biodamage center. Samples are taken from the most damaged area of the selected area in the group.

2 Materials and methods

To identify the presence and study of the nature of microbiological contamination, poultry buildings of Avangard LLC poultry farm in Ruzaevsky district were studied. The very first buildings were built more than 50 years ago. Samples were taken from various sections of inner surface of concrete bearing structures of the buildings of different years of construction (Fig. 1).

All collected samples were numbered.

Species composition of microorganisms settled on all selected samples was determined under laboratory conditions. Identification of microscopic fungi was carried out based on their morphological and cultural features using determinants: K. B. Raper, C. A. Thorn, 1949; K.B. Raper, D.I. Fennel, 1965; N.P. Podopilchenko (1971); M.A. Litvinov (1967); A.A. Milko (1974); T.C. Кириленко (1977); K. Donch, V. Gams, 1980; A.U. Lugauskas, A.N. Mikulskene, D.U. Shlyauzhene (1987); V.I. Bilay, E.Z. Koval (1988).

(a)

(b)

Fig. 1 - The examined poultry complex. a - main facade of the building; b - structural fragments (wall panel and half frame)

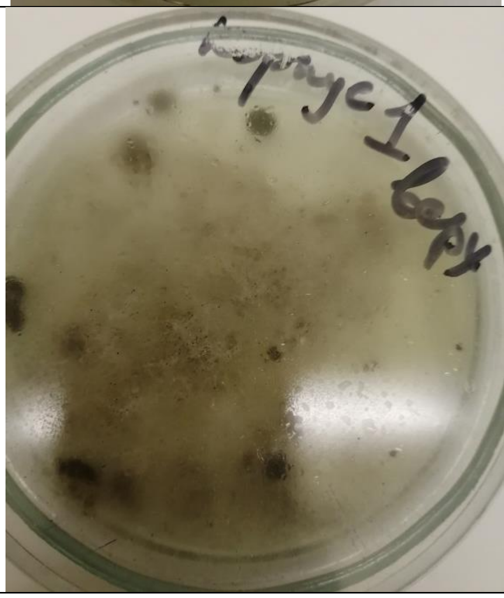
3 Results and discussion

The results of taken samples are shown in Tables 1-5.

The tables show the species composition of microorganisms isolated from samples taken from the surface of reinforced concrete structures with different service life and from various high-altitude points.

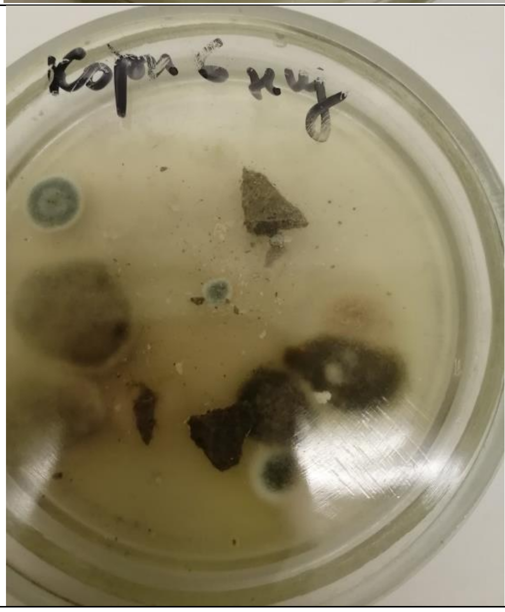
Table 1 shows obtained data from structures maintained for 11 years.

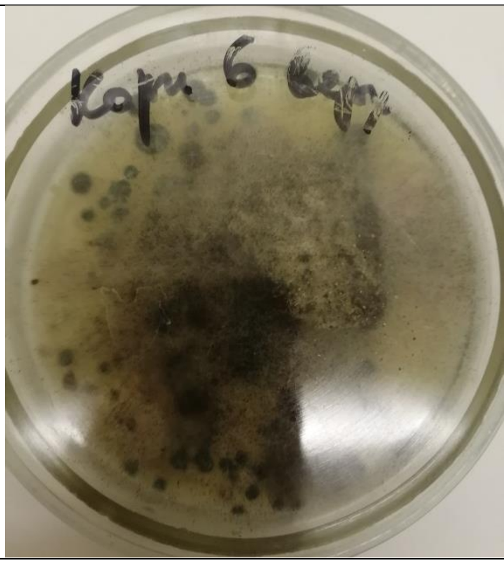
Table 1. Species composition of microorganisms isolated on the surface of structures after 11 years of maintenance

No.	Sample number	Species composition of microorganisms isolated from the surfaces of taken samples	Photos of fungi from concrete surface
1	Sample 1 (wall)	*Alternaria alternata, Penicillium chrysogenum, Penicillium claviforme, Penicillium notatum, Penicillium lanosum, Paecilomyces variotii, Fusarium moniliforme*	
2	Sample 1 (bottom)	*Alternaria alternata, Alternaria solani, Penicillium chrysogenum, Penicillium notatum, Penicillium lanosum, Fusarium moniliforme, Cladosporium elatum, Mucor corticola*	
3	Sample 1 (top)	*Aspergillus oryzae, Alternaria alternata, Alternaria* brassicae, *Fusarium moniliforme, Penicillium lanosum, Cladosporium* herbarum, *Cladosporium elatum,* Chaetomium dolichortrichum, *Mucor corticola*	

Mycobiota of the surface of reinforced concrete structures of poultry building 1, maintained for 11 years (Table 1), is represented by 14 species from 8 genera: 3 species of Alternaria (Alternaria alternata, Alternaria brassicae, Alternaria solani), 1 species of Aspergillus genus (Aspergillus oryzae), 4 species of Penicillium (Penicillium lanosum, Penicillium claviforme, Penicillium chrysogenum, Penicillium notatum), 1 1 species of Paecilomyces genus (Paecilomyces variotii), 1 species of Fusarium genus (Fusarium moniliforme), 2 species of Cladosporium genus (Cladosporium herbarum, Cladosporium elatum), 1 species of Chaetomium genus (Chaetomium dolichortrichum), 1 species of Mucor genus (Mucor corticola). The results of the studies showed that among the fungi contaminating the surface of the presented concrete samples, fungi of Alternaria, Penicillium, Cladosporium, Fusarium and Mucor genus are the most common. Dominant species identified from various sections of reinforced concrete structures of poultry building 1 are such fungi as Alternaria alternata, Penicillium lanosum, Penicillium chrysogenum, Fusarium moniliforme.

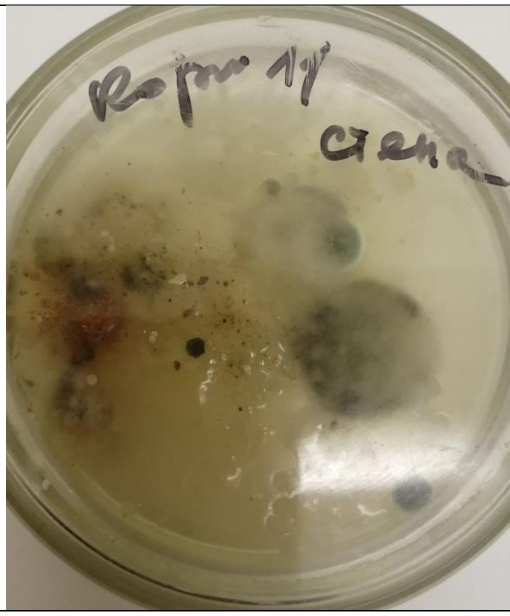
Table 2. Species composition of microorganisms isolated on the surface of structures after 16 years of maintenance

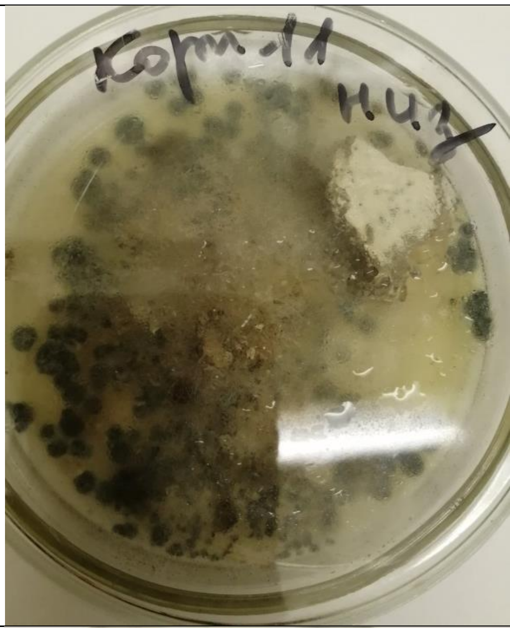
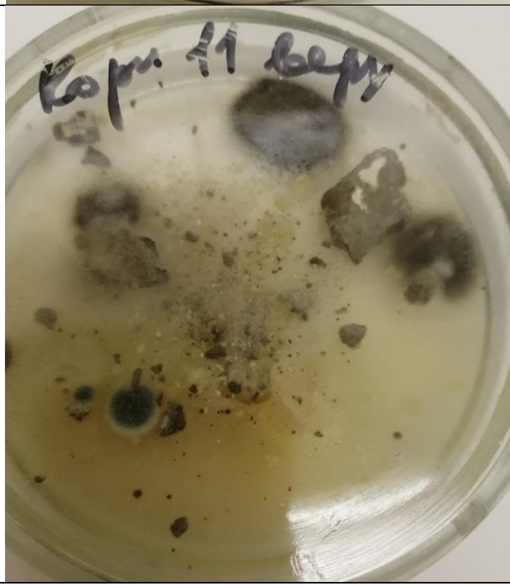
No.	Sample number	Species composition of microorganisms isolated from the surfaces of taken samples	Photos of fungi from concrete surface
1	Sample 6 (wall)	*Aspergillus niger, Alternaria alternata, Alternaria brassicae, Penicillium corylophilum, Penicillium lanosum, Penicillium chrysogenum, Penicillium cyclopium, Cladosporium elatum, Chaetomium dolichortrichum, Fusarium moniliforme*	
2	Sample 6 (bottom)	*Aspergillus terreus, Alternaria alternata, Penicillium chrysogenum, Penicillium corylophilum, Fusarium moniliforme, Chaetomium dolichortrichum, Mucor corticola*	

3	Sample 6 (top)	*Aspergillus niger, Alternaria brassicae, Penicillium chrysogenum, Penicillium corylophilum, Penicillium lanosum, Penicillium urticae, Penicillium notatum, Cladosporium elatum, Chaetomium dolichortrichum, Mucor corticola*	

Mycobiota of the surface of reinforced concrete structures of poultry building number 6, maintained for 16 years (Table 2), is represented by 14 species from 7 genus: 2 species of Alternaria genus (Alternaria alternata, Alternaria brassicae), 2 species of Aspergillus genus (Aspergillus niger, Aspergillus terreus) , 6 species of Penicillium genus (Penicillium lanosum, Penicillium corylophilum, Penicillium chrysogenum, Penicillium urticae, Penicillium cyclopium,Penicillium notatum), 1 species of Fusarium genus (Fusarium moniliforme), 1 species of Cladosporium genus (Cladosporium elatum), 1 species of Chaetomium genus (Chaetomium dolichortrichum), 1 species of Mucor genus (Mucor corticola). Among the fungi contaminating the surface of concrete structures of building 6, the most common fungi are the genera Aspergillus, Alternaria, Penicillium, Chaetomium, Cladosporium, Fusarium and Mucor. The dominant species isolated from the reinforced concrete structures of poultry building 6 are micromycetes: Aspergillus niger, Alternaria alternata, Penicillium chrysogenum, Penicillium corylophilum, Chaetomium dolichortrichum, Fusarium moniliforme.

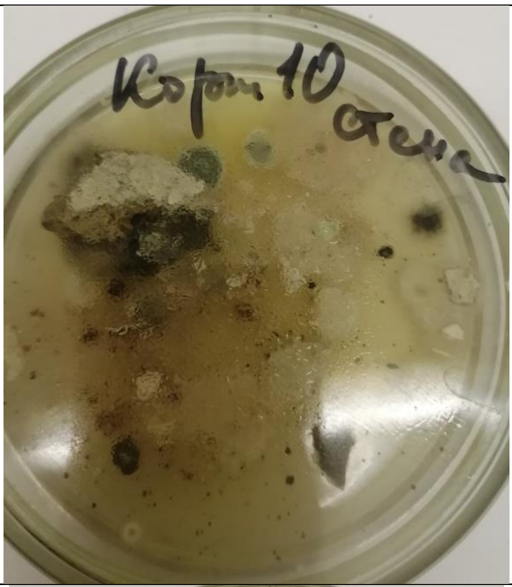
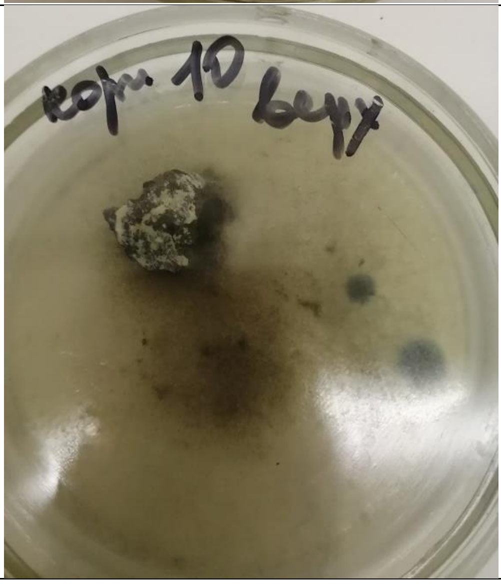
Table 3. Species composition of microorganisms isolated on the surface of structures after 31 years of maintenance

No.	Sample number	Species composition of microorganisms isolated from the surfaces of taken samples	Photos of fungi from concrete surface
1	Sample 11 (wall)	*Aspergillus ustus, Aspergillus terreus, Alternaria brassicae, Penicillium chrysogenum, Penicillium corylophilum, Penicillium lanosum, Penicillium expansum, Fusarium moniliforme, Paecilomyces variotii, Cladosporium elatum, Chaetomium dolichortrichum*	

2	Sample 11 (bottom)	*Alternaria brassicae, Penicillium notatum, Penicillium corylophilum, Penicillium lanosum, Fusarium moniliforme, Cladosporium elatum, Mucor corticola*	
3	Sample 11 (top)	*Aspergillus oryzae, Alternaria brassicae, Alternaria alternata, Penicillium chrysogenum, Penicillium claviforme, Penicillium lanosum, Cladosporium elatum, Chaetomium dolichortrichum, Fusarium moniliforme*	

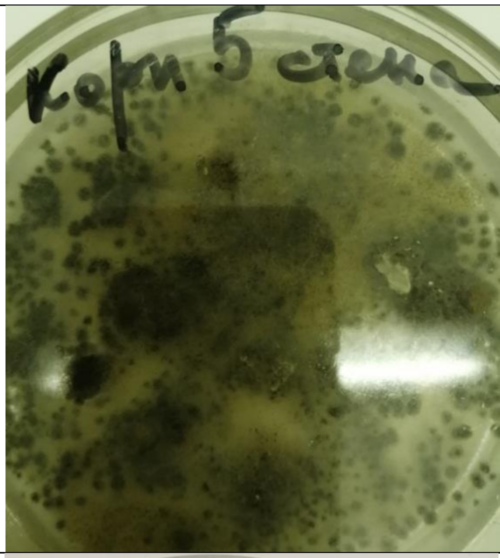
The species composition of micromycetes isolated from the surface of reinforced concrete structures of poultry building 11 maintained for 31year (Table 3) is represented by 16 species from 8 genus: 2 species of Alternaria genus (Alternaria alternata, Alternaria brassicae), 3 species of Aspergillus genus (Aspergillus ustus, Aspergillus oryzae, Aspergillus terreus) , 6 species of Penicillium genus (Penicillium lanosum, Penicillium corylophilum, Penicillium chrysogenum, Penicillium claviforme, Penicillium expansum, Penicillium notatum), 1 species of Paecilomyces genus (Paecilomyces variotii), 1 species of Fusarium genus (Fusarium moniliforme), 1 species of Cladosporium genus (Cladosporium elatum), 1 species of Chaetomium genus (Chaetomium dolichortrichum), 1 species of Mucor genus (Mucor corticola). Among the fungi contaminating the surface of concrete structures of building 11, the fungi of Aspergillus, Alternaria, Penicillium, Cladosporium, Fusarium genus are the most common. Dominant species isolated from reinforced concrete structures of poultry building 11 are micromycetes: Alternaria brassicae, Penicillium lanosum, Cladosporium elatum, Fusarium moniliforme.

Table 4. Species composition of microorganisms isolated on the surface of structures after 43 years of operation

No.	Sample number	Species composition of microorganisms isolated from the surfaces of taken samples	Photos of fungi from concrete surface
1	Sample 10 (wall)	*Alternaria alternata, Alternaria brassicae, Penicillium chrysogenum, Fusarium moniliforme, Cladosporium elatum, Chaetomium dolichortrichum*	
2	Sample 10 (bottom)	*Alternaria alternata, Alternaria brassicae, Penicillium lanosum, Penicillium chrysogenum, Fusarium moniliforme, Cladosporium elatum, Mucor corticola, Stachybotrys chartarum*	
3	Sample 10 (top)	*Penicillium chrysogenum, Penicillium lanosum, Fusarium moniliforme, Cladosporium elatum, Chaetomium dolichortrichum, Stachybotrys chartarum*	

Mycobiota of reinforced concrete structures of poultry building 10, maintained for 43 years (Table 4), is represented by 9 species from 7 genus: 2 species of Alternaria genus (Alternaria alternata, Alternaria brassicae), 2 species of Penicillium genus (Penicillium lanosum, Penicillium chrysogenum), 1 species of Fusarium genus (Fusarium moniliforme), 1 species of Cladosporium genus (Cladosporium elatum), 1 species of Chaetomium genus (Chaetomium dolichortrichum), 1 species of Mucor genus (Mucor corticola), Stachybotrys chartarum. Among the fungi contaminating the surface of concrete structures of building 10, the fungi of Alternaria, Penicillium, Stachybotrys, Cladosporium, Fusarium genus are most often found. Micromycetes of such species as Alternaria alternata, Penicillium chrysogenum, Penicillium lanosum, Stachybotrys chartarum, Fusarium moniliforme are dominant.

Table 5. Species composition of microorganisms isolated on the surface of structures after 51 years of maintenance

No.	Sample number	Species composition of microorganisms isolated from the surfaces of taken samples	Photos of fungi from concrete surface
1	Sample 5 (wall)	*Aspergillus oryzae, Alternaria alternata, Penicillium urticae, Penicillium corylophilum, Penicillium chrysogenum, Penicillium notatum, Penicillium lanosum, Cladosporium elatum, Cladosporium herbarum, Mucor hiemalis, Stachybotrys chartarum*	
2	Sample 5 (bottom)	*Alternaria brassicae, Alternaria alternata, Penicillium chrysogenum, Fusarium moniliforme, Cladosporium elatum, Chaetomium dolichortrichum, Mucor corticola*	

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Microbiological contamination of reinforced concrete structures in the poultry complex;
2022; *AlfaBuild;* **25** Article No 2501. doi: 10.57728/ALF.25.1

3	Sample 5 (top)	*Alternaria alternata, Alternaria brassicae, Penicillium corylophilum, Penicillium chrysogenum, Penicillium tardum, Penicillium urticae, Penicillium lanosum, Penicillium notatum, Fusarium moniliforme, Chaetomium dolichortrichum, Mucor corticola, Stachybotrys chartarum*	

The species composition of micromycetes isolated from the surface of reinforced concrete structures of poultry building 5, maintained for 51 years (Table 5), is represented by 16 species from 8 genus: 2 species of Alternaria genus (Alternaria alternata, Alternaria brassicae), 1 species of Aspergillus genus (Aspergillus oryzae), 6 species of Penicillium genus (Penicillium corylophilum, Penicillium chrysogenum, Penicillium tardum, Penicillium urticae, Penicillium lanosum, Penicillium notatum), 1 species of Fusarium genus (Fusarium moniliforme), 2 species of Cladosporium genus (Cladosporium herbarum, Cladosporium elatum), 1 species of Chaetomium genus (Chaetomium dolichortrichum), 2 species of Mucor genus (Mucor corticola, Mucor hiemalis), 1 species of Stachybotrys genus (Stachybotrys chartarum). Among the fungi contaminating the surface of the concrete structures of building 5, fungi of Alternaria, Penicillium, Cladosporium, Stachybotrys, Mucor genus are the most common. Dominant species isolated from reinforced concrete structures of poultry building 5 are such micromycetes as Alternaria alternata, Penicillium chrysogenum, Penicillium lanosum, Cladosporium elatum, Stachybotrys chartarum.

The surface of reinforced concrete structures of poultry buildings of various years of construction of Avangard LLC poultry farm of Ruzaevsky district of Republic of Mordovia is contaminated with micromycetes of such genus as Aspergillus, Alternaria, Penicillium, Paecilomyces, Cladosporium, Chaetomium, Fusarium, Mucor, Stachybotrys.

Such fungi as Aspergillus, Alternaria, Penicillium, Cladosporium, Chaetomium, Fusarium, Mucor were found on reinforced concrete structures of all examined poultry buildings with different service lives. The similarity of mycobiota composition of reinforced concrete structures of buildings is due to the specifics of technological regime, technological process associated with the use of various substrates, many of which are easily absorbed by micromycetes.

Sample species composition is somewhat different depending on the terms of their operation, sampling points of materials that differ in the degree of biological damage. In buildings No. 1 and No. 11, Paecilomyces variotii is also identified, in buildings No. 5 and No. 10 Stachybotrys chartarum is identified; in building No. 10 there are no fungi of Aspergillus genus.

The most common are Aspergillus, Alternaria, Penicillium, Fusarium, Chaetomium genus.

Isolated types of micromycetes are typical destructors of various industrial and building materials. However, in addition to destructive effects on materials, buildings, structures, micromycetes can have a negative impact on human and animal health.

Among the fungi isolated from the surface of reinforced concrete structures of poultry buildings, opportunistic species of micromycetes were found. These fungi can cause various human and animal diseases (mycoses, mycoallergoses and mycotoxicoses), such species as Alternaria solani, Aspergillus niger, A. terreus, A. oryzae, A. ustus, Fergillus usarium moniliforme, Paecilomyces variotii, Penicillium notatum, P. cyclopium, P. chrysogenum, Cladosporium herbarum, Stachybotrys chartarum, Mucor corticola.

4 Conclusion

Mechanisms of concrete degradation and other cement composites, which are caused by internal and external factors, are shown. One of the aggressive factors affecting structures in agricultural buildings is biological. At the same time, the greatest destruction is due to the negative impact of microorganisms and products of their metabolism. Studies were carried out to establish the presence of microorganisms on the surface of reinforced concrete structures of the poultry complex. At the same time, buildings with different service life were considered, and samples for testing were selected from different elevations at the height of elevation's location.

The surface of reinforced concrete structures of poultry farms of all examined buildings of various years of construction of Avangard LLC poultry farm of Ruzaevsky district of Republic of Mordovia is contaminated with micromycetes of Aspergillus, Alternaria, Penicillium, Paecilomyces, Cladosporium, Chaetomium, Fusarium, Mucor, Stachybotrys genus.

The most common are Aspergillus, Alternaria, Penicillium, Fusarium, Chaetomium genus.

Such micromycetes genus as Aspergillus, Alternaria, Penicillium, Cladosporium, Chaetomium, Fusarium, Mucor are isolated from the surface of reinforced concrete structures of poultry complex buildings (various service life).

These studies will make it possible to substantiate scientific and methodological approaches to objective, reliable assessment, and prediction of biological resistance of building materials, buildings and structures and will contribute to the development of effective means and methods of protection against biological damage

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