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Façade biological colonisation assessment

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Abstract. With increasing number of thermally insulated buildings, the number of façade surfaces massively colonised by microorganisms is also rapidly growing. Such colonisation may occur even within a few years after the thermal insulation installation and evolve into a serious issue in a relatively short time. Perceived by the public as an aesthetic problem only, biofilms in fact represent rather significant technological and health risks. The aim of this case study is to show assessment and evaluation of the causes of biotic attack, including distinguishing between direct growth on the façade and mere pollution by surrounding spores. In addition, the impact of the façade biological colonisation on the building inner air microbial pollution was studied.

1. Introduction

Currently, the number of façades affected by the growth of microbiological biofilm is increasing. This phenomenon is directly related to the trend of building insulation. Biofilms on façades are perceived by the public as an aesthetic problem only, but in fact, they represent serious technological and health risks.

Microorganisms are transported onto the façade surfaces through the surrounding air. Under suitable conditions, they multiply and produce visible coloured coatings, so-called biofilms. The composition of a biofilm depends on climatic conditions and numerous other factors, the most important being humidity. Micro-particles of organic matter, supplied together with air dust, serve as nutrients. The possibility and extent of façade colonization by microorganisms depend primarily on the surface material, implementation of problematic details, location of the building, sunlight, presence and type of surrounding greenery, pH of the adjacent soil, and last but not least the purpose and way of using the building. A prerequisite for the growth and multiplication of microorganisms on facades in the outdoor environment is moisture. Particularly on insulated houses, the heat is prevented from escaping the building, the top layers of insulation remain cold and moisture occurs due to condensation. In European conditions, rain water also contributes to overall humidity on the northwest and northern sides of buildings, as there's no warming and drying sunlight on the surfaces and even the disinfecting effects of UV radiation are suppressed [1]. Research shows that the first organisms colonizing the surfaces are bacteria, followed by algae. Soon after algae, microscopic fibrous fungi, later mosses and lichens appear and prepare the soil for the emergence of higher plants. On building stone, the mostly occurring green algae genera are *Gloeocystis, Tetracystis, Cystomonas, Murielle, Chlorella, Stichococcus, Scenedesmus, Klebshormium, Apatococcus, Trebauxia*) [2]. Among the microscopic fungi, the degradation of the façades is mainly due to the representatives of the genus *Alternaria*. This genus is considered to be the main cause of brown and black stains on marble, sandstone, limestone and on facades of building structures. Another important genus is *Cladosporium*, which is very common on wet and cold building stone, including facades, and also soil moulds, such as *Acremonium, Mucor*, or *Penicillium*, naturally spread by the wind [2].

On the surface of facades, biofilm acts mechanically, but mainly chemically due to production of organic acids that react with the surface and damage it. Together with dust particles, biofilm retains water. During freezing in winter, the water converts into ice, plaster particles are released and thus the surface of the façade is degraded.

From moulds growing on the surfaces, a major amount of spores is released, spread through the air and enter the indoor environment of apartments and houses during ventilation. These microscopic reproductive particles settle in the respiratory system and cause allergic and consequently asthmatic seizures to many people. Some types of fungi may also occasionally cause other human diseases, such as skin diseases or inflammation of cornea or other internal tissues of the eye. The incidence of health problems always depends on the immunological condition of affected people and the amount of spores in the environment [3, 4].

In the atmosphere, up to several tens of thousands spores per cubic meter can occur, depending on the season and the vicinity of the spore source, such as the infested façade. In housing areas with more sources, the risk of bio colonization on wet spots rises. Higher concentrations of spores in the air also complicate the diagnosis of upper plaster surface attack, microbiological examination of the surface is distorted by air contamination and indication of actual mould infestation is difficult. For this reason, a combined sampling methodology called "swab-bulk-swab" was developed at the Klokner Institute, which takes into account the above-mentioned contamination. [5]

The aim of the paper is to show a way of assessing and evaluation of the biotic infestation causes, including the distinction between direct attack of the facade and mere contamination from the surrounding environment. The effect of the contact thermal insulation system colonization on indoor air microbial pollution is also monitored.

2. Sampling and determination methods

The studied object was a school building with different degree of façade infestation over the outer surface. The building is V-shaped with the arc part directed to north-west and surrounded by a park. The school is situated in urban area. Figure 1 shows the building floor plan, aerial photograph is shown in Figure 2.

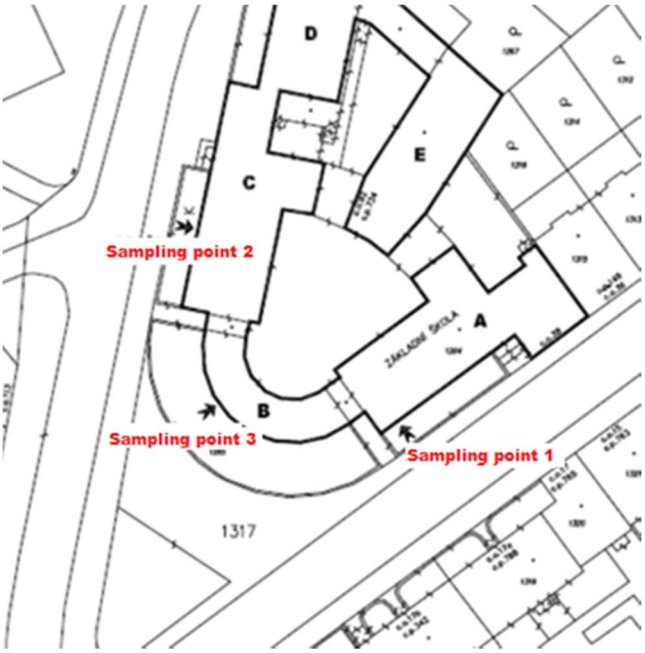

Figure 1. The building floor plan.

Figure 2. Aerial photograph.

To determine the biological colonization of the facade, 3 sampling points were selected, see Figure 1. Samples were taken from these sites by the "swab-bulk-swab" Method [5].

At first, a swab was taken from the surface of the sampling site with a sterile tampon soaked in sterile demineralized water. Subsequently, using a sterile stainless steel spatula, a sample of about 2 g of the plaster was taken. Finally, one more swab was performed on the abraded spot with a sterile tampon soaked in sterile demineralized water. Both swabs were immediately inoculated onto Sabouraud agar supplemented with chloramphenicol and cultured at 20–25°C in a thermostat for 5 days. From the plaster sample, 0.2 g was shaken in 1.8 ml of physiological saline solution and afterwards, 0.1 ml was inoculated on the surface of Sabouraud agar with chloramphenicol and cultured at 20–25°C in a thermostat for 5 days. After cultivation, the CFU value (colony-forming unit) per 1 g of plaster was determined. The bulk plaster sample was also cultured in the Bold Basal Medium [6] nutrient solution to detect green algae contamination. Swab cultures were assessed visually and individual colonies and genera were identified. Air sampling was also carried out to determine microbial air pollution at the sampling points 1 and 2, both inside the building in the room and outside the building in the immediate vicinity of the façade. The sampling was performed by an aeroscope, following the recommended standard procedures [7].

3. Results and evaluation

First, growth of colonies from both swabs (before and after the plaster was abraded) was visually evaluated. Cultivation dishes of swabs before abrasion are in Figures 3–5, those after abrasion in Figures 6–8.

Figure 3. Sampling spot 1.

Figure 4. Sampling spot 2.

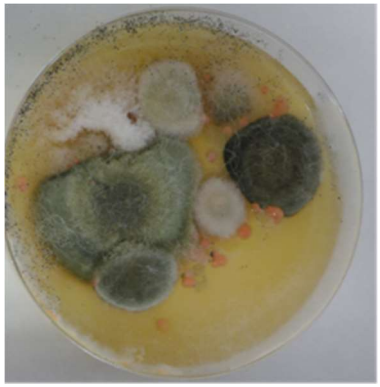

Figure 5. Sampling spot 3.

Figure 6. Sampling spot 1.

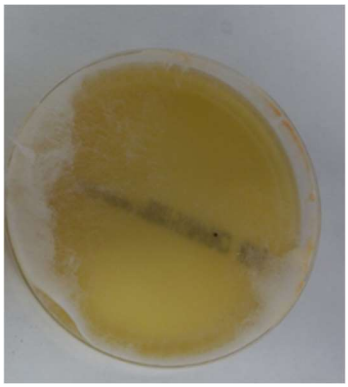

Figure 7. Sampling spot 2.

Figure 8. Sampling spot 3.

For both the first and the second sampling points, the difference between the two swabs cultivation is evident. The contamination of the second sampling point after abrasion was minimal, indicating a fast

growing species. The difference between findings at individual sampling points confirms high contamination only on the surface of the façade, under the surface the infestation is lower.

At the third sampling point, a relatively strong colonization through the entire layer of plaster occurs, biofilm was evident even during sampling. Identification of microbiological genera is presented in Table 1.

Table 1. Identification of microorganisms found in swabs.

Sampling spot	**1**	**2**	**3**
Genera identified before plaster abrasion	*Rhizopus sp., Cladosporium sp., Ulocladium sp., Aureobasidium sp.*	*Rhizopus sp., Cladosporium sp., Acremonium sp., Stachybotrys sp., Ulocladium sp., Aureobasidium sp.*	*Cladosporium sp., Stachybotrys sp., Chrysonilia sp., Trichoderma sp.*
Genera identified after plaster abrasion	*Rhizopus sp., Cladosporium sp., Epiccocum sp., Chrysonilia sp.*	*Chrysonilia sp.*	*Cladosporium sp., Ulocladium sp., Acremonium sp., Stachybotrys sp*

Table 2 presents the average number of moulds and yeasts in the plaster bulk, their identification and also the degree of algae contamination. The microbial image of the plaster bulk corresponds with the results obtained by swabs.

Table 2. Plaster bulk genera identification and algae contamination.

Sampling spot	**1**	**2**	**3**
Average mould and yeast CFU/g of plaster	$1.1 \cdot 10^3$	$7 \cdot 10^2$	$1 \cdot 10^5$
Genera identification	*Ulocladium sp.*	*Cladosporium sp., Ulocladium sp., Stachybotrys sp., Phoma sp.*	*Cladosporium sp., Ulocladium sp., Acremonium sp., Auerobasidium sp., Penicillium sp., Phoma sp., Stachybotrys sp., Chaetomium sp.*
Algae contamination	infested	not infested	strongly infested

The results show that the façade was least infested at sampling point 2, where the contamination under the plaster was minimal and the green algae contamination unproved. However according to literature, a healthy plaster contains up to 1×10^2 CFU/g [8] only, so the sampling spot must be considered infested by mould growth. On the other hand, at the sampling point 3, the façade was massively colonized, which corresponds with its location. Sampling point 3 is found in the northwest arc of the object, adjacent to the park, where vegetation of bushes closely surrounds the building.

As a supplement to the analyses, microbial contamination of air was determined outside and inside the building at sampling points 1 and 2. The outdoor sampling results corresponded with the condition of the plaster as at sampling point 1 and 2 the airborne contamination was higher than 600 CFU/m^3 and 237 CFU/m^3, respectively. The indoor air contamination in the classes adjacent to the sampling points exhibited only small variability between each other which was most certainly caused by different use of space and cleaning. Slightly higher occurrence of colonies was observed in sampling spot 2, 230 CFU/m^3, while 180 CFU/m^3 were found in sampling spot 1. Monitoring of the remediation and repair impact on contamination of the indoor environment will be the subject of further research.

4. Conclusions

The analyses prove infestation of the façade through the plaster at all sampling points, i.e. on the surface, in the plaster bulk and also under the top layer. Among the sampling spots, spot 2 was the least colonized, while spot 3 was massively infested and therefore created a new source of further air contamination. These findings correspond with the location of the sampling spots, as spot 3 is located on the north-west side of the building and surrounded with adjacent park vegetation. Based on the analyses, replacement of the contact insulation system layer was recommended together with elimination of trees and bushes from the closest vicinity of the building.

The results confirm contamination of the plaster surface by airborne spores and the factual microbial infestation of the plaster layer is represented by samples from plaster bulk and the second swab.

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