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Original Research Article

BIODETERIORATION DUE TO IMPROPER EXPLOITATION OF EXTERNAL FACADES

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Abstract

Unaesthetic stains and deposits often form on external facades (especially those facing the north) in places where barriers were installed on them. Such places include, for example: fragments of facades in which external window sills were mounted, canopies, downspouts, boxes, advertising billboards, flags holders, lightning conductors, aerials as well as facade steps, and many others. During exploitation, elevations are exposed to water retention. In places were barriers are installed, moisture occurs with greater intensity than in other parts of the facade. Over time, in addition to the aesthetic problem, this results in biodeterioration (biological corrosion), induced by the deposited biological factors. The article presents the issue of placing barriers on external facades, on the example of buildings developed in Zielona Góra.

Keywords: facades, buildings, facade exploitation, biodeterioration, deposits, stains

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1. INTRODUCTION

External facades are exposed to water retention. Moisture occurs within varying degrees of severity, depending on the absorption properties of the used material, weather conditions (insolation, the direction and speed of wind, precipitation) and proximity to greenery [1- 4, 6, 9, 10, 21]. Biological infestation is usually observed on facades in the shade, especially facing the north, in which moisture persists. Nowadays, a lot of attention has been paid to the thermal protection of buildings. All buildings are designed in such a manner as to limit the heat losses through building partitions as much as possible. Meanwhile, the most frequently colonised facades are facades with additional insulation on the surface of which water vapor is present for a longer period of time. According to observation, in places where various types of barriers were installed on the facade, such as sills, downspouts, canopies, boxes, lightning rods, handles, advertising billboards, aerials etc. and in places where there are facade steps, there is a great possibility of creation of unaesthetic discoloration and stains (Fig 1.).

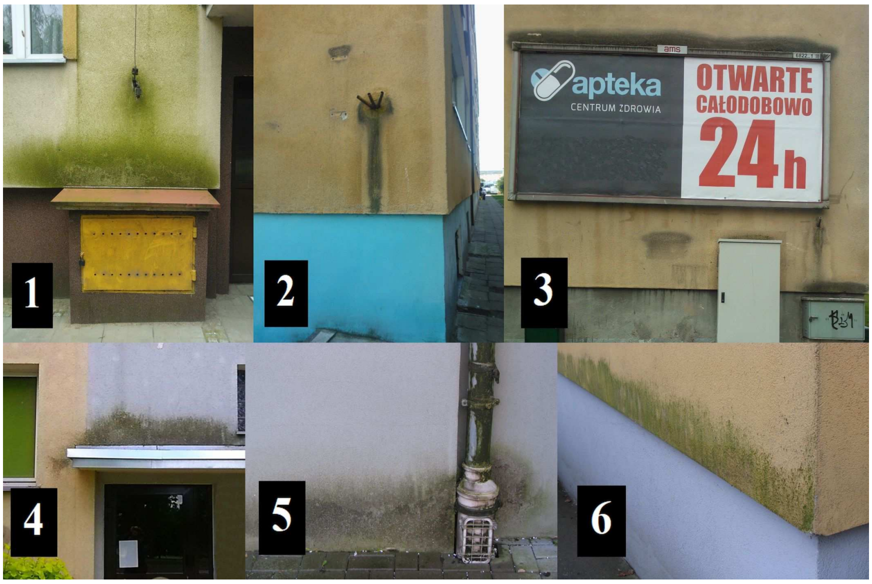

Fig. 1. View (1-6) on places in northern facades with visible discoloration and deposits

The phenomenon is caused by moisture which persists with higher intensity than in other parts of the facade and is the main factor contributing to the formation of biological corrosion [3, 4, 6, 8-11]. Over time, it can lead to the formation of biodeterioration (biological corrosion). With the increase of water content within the material, its coefficient of thermal conductivity grows as well, thus leading to reduced durability [8-10, 18]. Microorganisms, depending on the species, cause degradation in the structure of the occupied material with varying effects and intensity [2-4, 8, 11, 13-18]. Once accustomed to the surface, they begin to proliferate and produce polymeric substances. Thanks to them the organic and mineral compounds as well as particles of other micro-organisms are adsorbed, serving as the source of food for the micro-colonies. The biodegradation process begins due to the secreted metabolic waste products. The most common organisms found on elevations include: bacteria, myxophyta, and actinomycetes, algae, fungi and protozoa [1-4, 6, 10, 11, 17, 19]. Thanks to drought resistance and unfavorable UV, blue-green algae, fungi, and algae constitute the majority of biomass found on the facade deposits more often than other organisms [4]. During the metabolic processes they produce alkali and aggressive acids (sulfuric, nitric and others) and surfactants [2], which enter into the chemical reactions with the background and thus cause irreversible changes to its structure, allowing for the micro-organisms' penetration into the technical material.

2. METHODS AND MATERIALS

2.1. Sampling location

Samples for microbiological analysis were colledcted from 3 selected locations in the northern facades of buildings in Zielona Góra (Figure 2) on which barriers were placed and visible discoloration and deposits have formed. All objects underwent thermomodernization. Warming was made according to ETICS (from the English name: External Thermal Insulation Composite System) - or in other words: seamless insulation system. The section of a two-layer wall of buildings, that is, the connection of the wall with the thermal insulation material includes about 9 components: 1. hollow bricks, 2. optional substrate priming, 3. adhesive for fixing panels, 4. thermal insulation made of Styrofoam, 5. additional fixing - connectors for Styrofoam, 6. adhesive for the reinforced layer, 7. reinforcing mesh, 8. plaster base, 9. thin-coat plaster. Nearby the selected elevations one can find greenery, shrubs, and trees, which increase the emission of biological agents on the surface.

Fig. 2. View of the sampling areas on the northern facades of buildings in Zielona Góra: A- multifamily building developed at Podgórna Street, B - multifamily building developed at Batorego Street, C- facade of the buildings of the Environment Engineering Institute of the University of Zielona Góra.

2.2. Research methods

Biological material was scraped from the facades showing visible deposits and placed in sterile containers and afterward sent to the laboratory for analysis. Part of the collected deposit was intended for direct microscopic observation with the use of a stereomicroscope and scanning electron microscope (SEM) found in the Faculty of Mechanical Engineering of the University of Zielona Góra. The remaining part of the material was seeded on biological substrates.

- malt agar: brewing malt diluted 1:1 50 cm^3, agar 10 g, distilled water 500 ml;
- enriched agar (pepton K 5.4 g peptone 4.0 g yeast extract 1.7 g meat extract 0.4 g, sodium chloride 3.5 g agar 15.0 g pH 7.2 ± 0.2 in 25°C after sterilization);
- gelatin medium (500 ml of distilled water and 30 g of gelatine);
- liquid medium with an addition of mineral salts (500 ml of distilled water, 0.1 g of NH_4 NO_3, 0.05 g $CaCl_2$, 0.05 g H_2HPO_4, 0.05 g $MgSO_4$, a drop of 1% Fe_2Cl).

The plating was incubated in a breeding enclosure at a room temperature ranging from 18 to 22°C while maintaining the circadian rhythm of day and night. Breeding time was 7 days. Clean (axenic) cultures were isolated from the starting cultures mixed by passage on malt agar (MEA). The screening, breeding and observation time for an isolated species was approximately 21 days. The isolated strains were tested in order to identify their taxonomic affiliation.

Measurements were performed with hygrometer Hygropen, designed to measure the relative humidity of wood, building materials, air as well as measure the ambient temperature. Relative humidity determines the ratio of the mass of vapor present in a given volume of air to the mass of vapor which saturates this volume at the same temperature. Relative humidity is expressed as a percentage. The maximum moisture content corresponding to relative humidity of 100%, in other words the maximum amount of vapor in a given amount of air, depends on the temperature of air. The higher the temperature of air, the more water vapor can be found within.

Moisture measurement was based on the measurement of resistance (electrical resistance) by inserting needles in the concrete structure. Table 1 presents the results of the measurements. According to the manufacturer's instructions it can be approximately assumed that in case of concrete the density moisture equals 1/8 of indications by Hygropen hygrometer. For example: an indication of 24.0 indicates concrete of a humidity of 24.0:8= 3.0%.

3. RESULTS

Thanks to the laboratory analysis it was possible to identify representatives of clusters of organisms: fungal spores, aerofit cyanobacteria, algae, moss and lichens. The organisms' membership to species was defined macroscopically and microscopically based on their morphological and physiological properties using keys [5, 7, 12, 20].

Table 1. The biodeteriogenic organisms identified in the deposits on northern facades of buildings

Lp.	Cluster	Species
1.	Moulds (spores)	1.*Acremonium strictum* ***W. Gams*** 2.*Alternaria alternata* ***von Keissler*** 3.*Aspergillus flavus* ***Link*** 4.*Aspergillus versicolor* ***(Vuill.) Tiraboschi*** 5*Aureobasidium pullulans (De Bary) Arnaud* 6.*Cladosporium cladosporioides* ***(Fres.) de Vries*** 7.*Cladosporium herbarum* ***Link ex Gray*** 8.*Cladosporium macrocarpum* Preuss, 9. *Epicoccum nigrum Link* 10.*Mucor racemosus* ***Frescenius*** 11.*Penicillium chrysogenum* ***Thom*** 12.*Penicillium brevicompactum* ***Dierckx*** 13.*Rhizopus stolonifer* ***(Echrenb.) Lind*** 14.*Scopulariopsis brevicaulis* (Sacc.) Bain 15.*Trichoderma viride* ***Pers.*** 16.*Ulocladium chartarum* ***(Preuss) Simmons***
2.	Cyanobacteria	1. *Asterocapsa sp.* 2. *Gloeocapsa fusco lutea* Kutzing

		3. *Gleocapsopsis chroococcoides* Novacek 4. *Heteroleibleinia kuetzingii* Schmidle 5. *Oscillatoria sp.* 6. *Tolypothrix byssoidea* Kirchner
3.	Algae	1. *Pleurococcus vulgaris* Meneegh
4.	Lichens	1. *Hypogymnia physodes* 2. *Lecanora dispersa* 3.*Xanthoria candelaria*
5.	Mosses	1. *Funaria hydrometria Hedw.* *2. Hypnum cupressiforme Hedw.*

Identification of isolated molds showed the presence of species commonly found in the environment. In addition, an increase in the numerous colonies of bacteria and actinomycetes was noted as well.
Humidity measurement results are shown in Table 3.

Table 3. Measurements of temperature and humidity of a wall with molds of the Environment Engineering Institute of the University of Zielona Góra

Measurement	Air	Air	Humidity of	Humidity of	Humidity of
The north facade of building A					
07.04.2018	18.5	54.5	LO DRY	29.3 WET	62.1 WET
11.04.2018	16.0	26.0	LO DRY	25.8 WET	47.2 WET
25.04.2018	17.5	32.0	LO DRY	6.4 DRY	38.4 WET
The north facade of building B					
07.04.2018	18.0	47.0	LO DRY	24.1 WET	42.1 WET
11.04.2018	16.5	24.0	LO DRY	LO DRY	27.2 WET
25.04.2018	16.5	33.5	LO DRY	6.4 DRY	36.4 WET
The north facade of building C					
07.04.2018	17.5	57.5	LO DRY	34.1 WET	52.1 WET
11.04.2018	15.5	24.0	LO DRY	LO DRY	29.6 WET
25.04.2018	17.0	32.0	LO DRY	4.8 DRY	36.1 WET

DRY (< 17) - dry background, WET (> 20) - wet background, LO - scope exceeded beyond the minimum limit of detection, HI - scope exceeded beyond the maximum limit of detection

RH (Relative Humidity) e.g. (1) of an air-water mixture is defined as the ratio of the partial pressure of water vapor (H_2O) (e_w) in the mixture to the equilibrium vapor pressure of water (e^*_w) at a given temperature.

$$\phi = \frac{e_w}{e^*_w} x\ 100\% \qquad (1)$$

Humidity measurements have shown that with the increase of air humidity its content within the biological deposit on the technical material grew as well. The thicker the deposit layer, the more moisture it is able to retain.

SEM photos showed (Fig. 3) the presence of biological agents in deposits found on the facades. Their presence results in the emergence of unsightly deposits and formation of degradation processes. Photos made with the use of the nanometer technology revealed the complex structure of the deposits.

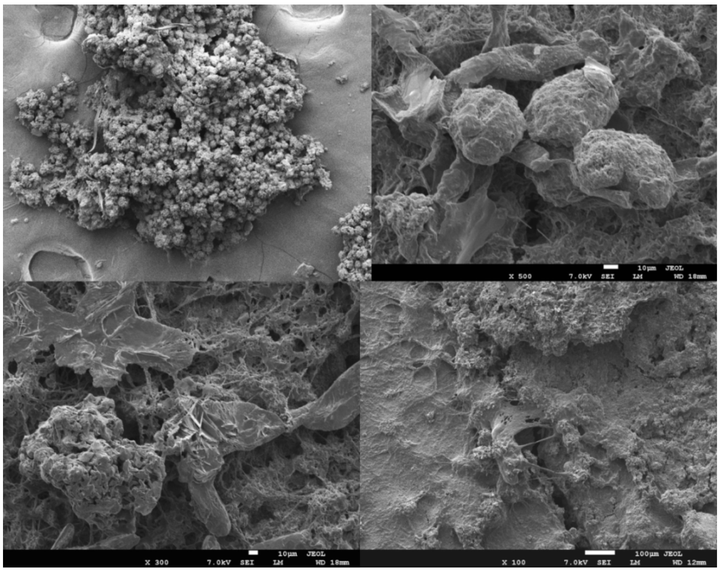

Fig.3. Exemplary SEM photos of the biological material collected from northern elevations of buildings with deposits

4. CONCLUSIONS

The presence of organisms (mainly algae and cyanobacteria) on the surface of the façade impairs its aesthetics. However, with the passage of time it also results in long-term retention of moisture, which leads to damages to plaster and paint layers, and thus transfer of moisture into the partitions. Particularly susceptible to colonization by micro-organisms are ETICS elevations insulated with a layer of a highly effective insulation. Reducing heat dissipation by the partition impairs, and in the case of northern and western facades - completely prevents - drying of the surface in periods from late autumn to the end of winter. In insulated northern and western facades one ought not to create spaces that maintain a high level of moisture for a long time, allowing for the development of micro-organisms. Organisms within the deposits destroy the technical material with varying intensity. Mold spores often make use of the mineral and organic compounds of the technical material, which enable them to develop and multiply. In the course of metabolic processes they produce aggressive organic acids (citric, gluconic and oxalic). The result of the metabolic activity of fungi can be processes of digestion and recrystallisation [3]. On inorganic substrates they commonly occur in symbiotic relationships with algae, hence forming lichens. During the respiration proces they produce carbon dioxide, which in combination with water, causes the formation of acid calcium carbonate ($CaCO_3$). The produced organic acids contribute to crumbling of mortar and bricks as well as cause deterioration of technical materials (marble, limestone, basalt and granite). Algae also produce a number of organic acids that either digest stone components or increase their solubility in water. In addition, they support the growth of other biodeteriogens, such as mosses or lichens. An important role in the biodeterioration process is played by lichen thallus, which penetrates into the slots of the material and causes their deepening and reduction of strength. Another destructive activity is based on the production of corrosive organic acids. Oxalic acid, which is one of the metabolic products, by reacting with calcium causes the precipitation of calcium oxalate, even up to 2-3 cm below the surface [8]. Mosses indicated similar degradation effects.

Cases described in the article confirm that mounting barriers on shaded facades (especially facing the north) may contribute to changes in the distribution of moisture on the surface, and hence lead to its increase in such places. This, in turn, may lead to biodeterioration. Biological deposits were formed in their places of installation. Therefore, there were favorable conditions to subsidence and multiplication of biological agents. Improper exploitation of façades leads to the biodeterioration of construction and finishing materials and damping of partitions in spite of the thermomodernization treatments.

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BIODETERIORACJA WYWOŁANA NIEWŁAŚCIWĄ EKSPLOATACJĄ ELEWACJI ZEWNĘTRZNYCH

S t r e s z c z e n i e

Na elewacjach zewnętrznych (szczególnie północnych) w miejscach wystąpienia barier pojawiają się nieestetyczne zacieki lub naloty. Miejsca, o których mowa w artykule to np.: fragmenty elewacji, w których zamontowano parapety zewnętrzne, daszki, rury spustowe, skrzynki, bilbordy reklamowe, uchwyty na flagi, piorunochrony, jak również uskoki elewacji i inne. Podczas eksploatacji elewacje narażone są na retencję wodną, a miejscach usytuowania barier zawilgocenie występuje z większym nasileniem, niż na pozostałych fragmentach elewacji. Z czasem oprócz problemu estetycznego dochodzi do powstania biodeterioracji (korazji biologicznej), wywołanej przez osadzające się czynniki biologiczne. W artykule przedstawiono problem związany z umieszczaniem barier na elewacjach zewnętrznych, na przykładzie budynków w Zielonej Górze.

Słowa kluczowe: elewacje, budynki, eksploatacja elewacji, biodeterioracja, nalot, zacieki

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