Algae and their biodegradation effects on building materials in the Ostrava industrial agglomeration

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Abstract. Microorganisms cause changes in the building stone, which reduce its usable life and reliability. Microalgae make important parts of the biodegradation consortia of microorganisms on the surface of building materials. Via their metabolites, microalgae affect the stability of mineral components and thus lead to the material destruction. The aim of the paper was to identify aerophytic microalgae on the surface of engineering structures in the Ostrava agglomeration, and to describe the basic interactions between such microorganisms and the building materials, which may lead to the destruction of the materials.

1. Introduction
The investigations of microflora abundant on the building materials show that microbial communities of bacteria, algae, blue-green algae and microscopic fungi develop on the surfaces of structures, which may form more complex consortia (biofilms) and form symbionts of higher orders (lichens). The colonisation of structures by such organisms is in opposition with the human efforts to maintain structures free of damage, either from the constructional or aesthetic point of view. It has been established that the action of microorganisms with the building materials leads to biodeterioration changes that reduce their lifespan and reliability [1,2].

Microalgae represent polyphyletic microorganisms that have adapted to wide spectra of the environments, in which in dependence on various conditions these alter their morphology and physiological strategy of survival. Despite the fact algae are primarily aquatic organisms, they have managed to well adapt to aerobic conditions on the morphological as well as physiological levels [4]. Aerophytic algae are able to grow in different environments, for example in sites with extreme pH values or temperatures – algae have been documented for their capacities to tolerate temperature changes in the range from 0 to 85 ºC [5], [6]. Urban agglomerations with built-up areas may be, to a certain extent, considered extreme environments where algae find habitats with extreme temperature conditions resulting from large artificial structures, especially in the summer. However, the pH value is also important for the occurrence of algae on manmade structures. In dependence on the species, its optimal value may range from 3.5 to 9 [7]. In general, algae find pH over 12 difficult to tolerate. In case of accelerated carbonation of the building materials due to surplus of CO₂ in the atmosphere, the pH value falls below 9, and the onset of algae on the structure surface is very probable. As a result, green algae may
be found particularly on older, wet facades with pH around 7, while cyanobacteria grow better on alkaline surfaces.

The major danger for the building materials caused by the abundance of algae lies in their photosynthetic production of carbon dioxide that chemically affects the components of the building material. At increased amounts of aggressive carbon dioxide in the environment due to the industrial emissions, CO₂ reacts with calcium hydroxide from cement sealant under the formation of CaCO₃ and water; the action of water causes the dissolution of CaCO₃ and in the reaction with other molecules, CO₂ forms hydrogen carbonate complexes [8]. It has been established that microalgae also produce organic acids that disturb the building substrate and thus enable the development of other microorganisms responsible for biodegradation – bacteria and fungi. These are often sources of changes in the aesthetic and mechanical properties of building materials. Algae as organisms that combine water cause physical corrosion of such materials via penetrating into the porous systems of building materials and contribute to the formation of micro-fissures. Under higher moistures, microalgae increase their volumes and erode the surrounding material by swelling pressure. Along with the impurities from the atmosphere in towns (soot, dust particles, microorganisms, etc.) they form a mucous bio-layer of the material surface that further supports the retention of water. In addition, algae may also participate in the formation of a crust as they produce the so-called extracellular polymer substances (EPS), which have been identified on the surfaces of a range of urban structures [9,10]. These substances significantly affect the physicochemical properties of materials, e.g. building stone, and support the bacterial growth and activity leading to the release of inorganic substances useful for organisms in the same environment.

2. Methods and experimental
The samples were repeatedly drawn using sterile Pasteur pipettes (Fisher Scientific Inc., USA) from the surfaces of building materials of residential buildings within the City of Ostrava. The basic identification and determination were made using an Olympus CX41 light microscope and expert literature [11].

| Phylum Chlorophytae                  | Samples |
|-------------------------------------|---------|
| * species – name is currently accepted taxonomically [14] | 1 | 2 | 3 | 4 | 5 | 6 |
| Apatococcus lobatus (Chodat) Petersen | + | + |   |   |   |   |
| Chlorella vulgaris Beyerinck [Beijerinck] | + | + | + | + | + | + |
| Chlorococcum infusionum (Schrank) Meneghini | + | + | + | + | + | + |
| Cosmarium undulatum Corda ex Ralfs | + |   |   |   |   |   |
| Desmococcus vulgaris Brand |   | + |   |   |   |   |
| Klebsormidium flaccidum (Kützing) Silva, Mattox & Blackwell | + | + |   |   |   |   |
| Monoraphidium griffithii (Berkeley) Komárková-Legnerová |   |   |   |   |   |   |
| Pleurococcus vulgaris Meneghini | + |   | + | + |   |   |
| Protococcus nivalis (Bauer) Agardh |   | + | + |   |   |   |
| Scenedesmus quadricauda (Turpin) Brébisson |   |   |   |   | + |   |
| Scotiellopsis terrestris (Reisigl) Puncochárová & Kalina | + |   |   |   |   |   |
| Stichococcus bacillaris Nägeli | + |   | + | + | + | + |
| Trebouxia decolorans Ahmadjian | + |   | + |   |   |   |
| Trentepohlia umbrina (Kützing) Bornet | + | + | + | + | + | + |
| Ulothrix tenuissima Kützing | + |   | + |   |   |   |

The samples come from the surface of the facades (plaster) of the panel buildings in the city districts of Ostrava (Ostrava-Poruba, Ostrava-Zábřeh, Moravská Ostrava.) The monitored buildings underwent revitalization in 2010-2012; within the framework of their modernization, the defects of the sealing
between the panels were removed, the damage of the panel parts and the thermal insulation of the perimeter skin was remedied. Although the external thermal insulating system (ETICS) with the use of facade polystyrene, mineral fiber boards and plasters on based of silicates and acrylate, at present, there is already an apparent growth of cyanobacteria and algae on the plaster of these buildings. Algae microorganisms were identified using genomic DNA based on the DNA of a target DNA region of 18S rRNA gene [12] using eukaryotic standard primers 20F (5’-GTAGTCATATGCTTGTCTC-3’) and 18L (5’-CACCTACGGAAAACCTTGTTACGACTT-3’); according to the methodology published in Hamby et al. [13].

3. Results and Discussion

In the four samples of materials from building surfaces, there were identified 27 taxa, namely 8 taxa of Cyanobacteria, 15 taxa of Chlorophyta, and 4 taxa of Chrysophyta. The green algae Chlorella vulgaris, Chlorococcum infusionum and Trentepohlia umbrina were identified in all sampling sites (table 1).

The genus Chlorella was the most widespread, occurring on all buildings reported, represented by two subspecies and occurring on four different substrata.

The members of Chlorococcum genus were identified in all examined building substrata, including the newly insulated concrete-panel houses. Other abundant algae were the representatives of Stichococcus genus, and thus it may be assumed that Chlorella, Chlorococcum and Stichococcus are green algae that colonise the buildings in the Ostrava Region the most. This is in agreement with Ortega-Calvo et al. (1995), who state that the occurrences of Chlorella, Chlorococcum, Klebsormidium, Pleurococcus and Trentepohlia (figure 1) may be observed in the monuments in Europe, America and Asia, but due to their cosmopolitan distribution it is not possible to correlate the genera and specific substrata or climates [15,16].

![Figure 1](path_to_image1)

**Figure 1.** The progressive biodeterioration processes on the surface of building materials: algae constitute the medium for the growth of fungi that pass through the building material by means of their hyphae. The hyphae of microscopic fungi on the base comprising of Trentepohlia sp. algae (figure on the left); the figure on the right shows the hyphae penetrating the eroded building material (SEM coloured microphotography, photo by author).

Microalgae of the genera Chlorella and Trentepohlia are also represented among the Chlorophyta genera that colonise stone substrata in the Mediterranean Basin. The occurrence of Trebouxia and Trentepohlia indicates that these microalgae may be involved in the lichenisation leading to colonisation by lichens [17]. In fact, the genus Trebouxia occurs in approximately 20% of all lichens and has rarely been found free-living. Regarding the endolithic growth of green algae, Trentepohlia, Chlorella and Klebsormidium, they were found growing in monuments of Portugal [18].
Cryptoendolithic growth of Stichococcus bacillaris was also observed in granite of the Cathedral of Toledo, Spain [19].

4. Conclusion
Microalgae make significant parts of the biodegradation microbial consortia on the surfaces of building materials, which influence the stability of mineral components via their metabolites, and thus reduce their lifespan and reliability. Among the major determinants of the type and extent of microbial colonisation there are the mineral composition of the building substrata and their physicochemical properties. Nevertheless, the surrounding atmosphere contains high amounts of pollutants of different origins (especially air pollutants related to the industry and transport), which largely influence the course of the biodegradation process. The investigations of the microflora on the surface of building materials have shown that even in the conditions of industrial agglomeration communities of aerophytic microorganisms thrive, particularly bacteria, algae, blue-green algae and microscopic fungi that form biofilms and crusts on the surfaces.

In the environment of the Ostrava industrial agglomeration, there were identified microalgae on the building material surfaces, among which the species Chlorella vulgaris, Chlorococcum infusionum, Stichococcus bacillaris, Pleurococcus vulgaris and Trentepohlia umbrina may be considered to be ubiquitous colonisers of building materials. The industrial environment of Ostrava City, with its increased level of pollutants, is not a factor that determines algal growth on the structure surfaces. On the contrary, it may be a factor inhibiting their diversity, which needs to be confirmed by further expert studies.

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