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The potential of pulse amplitude modulation fluorometry for evaluating the resistance of building materials to algal growth

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ABSTRACT

As a consequence of increased insulation levels, the growth of algae on façades has developed into a serious aesthetic problem over the past decade. Manufacturers of façade and coating materials are looking for strategies to avoid or at least delay the establishment of biofilms. Efficient product development, however, is complicated by the necessity of time-consuming free-weathering tests and a lack of objective measures to quantify the growth. In a two-year study the potential of pulse-amplitude modulation (PAM) fluorometry was tested for the quantification of algal growth on free-weathered specimens below the visual threshold. By using an imaging PAM in combination with a scanning device, surface colonization by algae was repeatedly visualized and analysed in detail. It was demonstrated that in the case of water saturation the resistance of a specific paint against algal growth can be quantified with sufficient accuracy by measuring the fluorescence yield after dark adaptation. The representative growth pattern identified, however, is not characterized by a linear accumulation of algal colonies but by a long phase of fluctuating biomass at a low level, followed by a steep increase. Only if the fluorescence yield rises significantly above the basic value does the specimen simultaneously show green discoloration. The duration of free-weathering tests, therefore, cannot be significantly shortened by using the more sensitive diagnostic tool.

1. Introduction

1.1. The problem of building physics

Within the past 15 years the growth of algae on thermally insulated façades has become a widely discussed phenomenon. Scientists agree that this primarily aesthetic problem is caused by the continuously increased standard of the insulation level required by law. As desired, the thermal insulation significantly reduces heat conduction through the building envelope, which leads to a significant drop of the outside surface temperatures (Fig. 1).

As the cold façades have a high disposition to undercooling and at the same time a reduced drying potential, these façades are exposed to long-lasting humidity films. The availability of liquid water is the most important precondition for algal growth (Häubner et al., 2006; Krus et al., 2006; Gladis and Schumann, 2011). For thermally upgrading existing buildings, external thermal insulation composite systems, or ETICS, for short, are very popular because of their cost-effectiveness. Their setup, however, makes them even more sensitive to algal growth than other insulation systems. As the insulation board applied to the outside of the exterior is covered only by a thin rendering layer, the system has a very small heat capacity. The exterior climate has, therefore, an immediate effect on the surface temperature of the façade. When it is exposed to direct radiation, its surface temperature rises within minutes. During the night the heat loss into the atmosphere leads to an undercooling of the façade temperature below the ambient temperature and sometimes even below the dewpoint temperature. Fig. 2 shows the surface temperature measurements compared to the ambient and the dewpoint temperature of a free-weathered sample facing northeast. The surface temperature dropped below the dewpoint temperature almost every night. In the morning hours the direct insolation leads to a rise of the surface temperature above the ambient temperature.

1.2. Avoidance strategies

Since algal growth constitutes a visual defect, the manufacturers of paints and rendering systems are competing to develop products with an enhanced resistance against algal growth. Basically there are two different strategies to avoid algal growth: the chemical and the hygrothermal strategy. The aim of the chemical strategy is to

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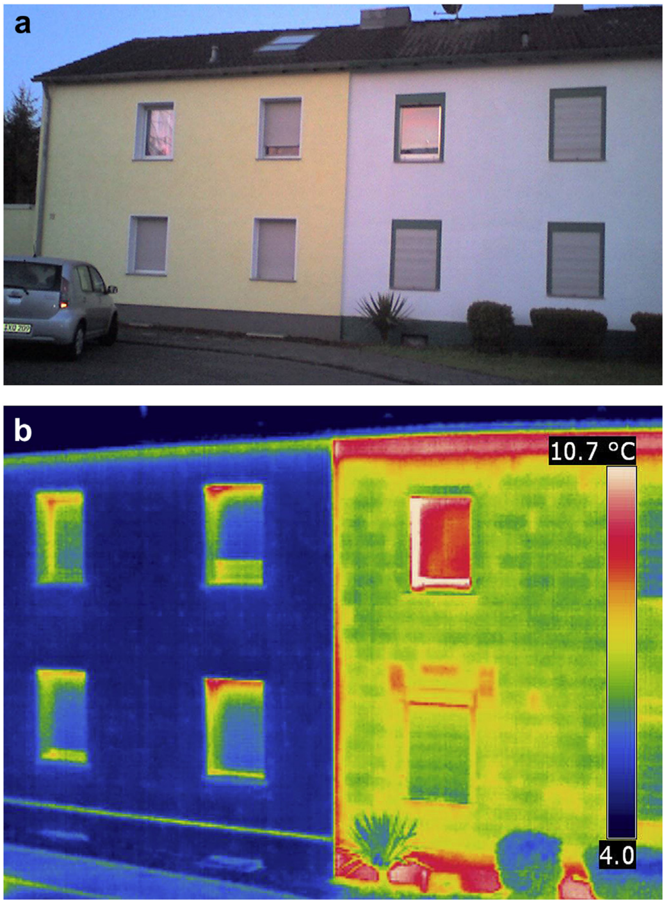

Fig. 1. (A) Photography, and (B) thermal image of a twin house (© *H. Roeder*). The thermal insulation is restricted to the left building, thus leading to a significantly lower surface temperature compared to the original construction of the right building.

kill or limit the growth of façade algae by using chemical substances or by taking advantage of photocatalysis. The aim of the hygrothermal strategy is to create an algae-hostile environment by minimizing the humidity films at the surface. This can be achieved either by increasing the surface temperature, which leads to a reduction of dewpoint deficits, or by optimization of the hygric properties so that liquid water can be quickly transported from the surface into deeper material layers. A third option to minimize surface humidity is to favor roll-off of water droplets by improving the surface quality.

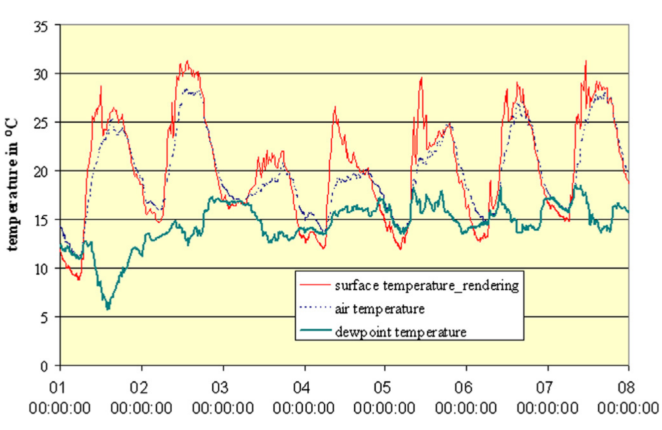

Fig. 2. Surface temperature measurements compared to the ambient and the dewpoint temperature of an ETICS facing northeast, 01.08–08.08.2009.

1.3. Diagnostic

For the enhancement of product development as well as for the impartial evaluation of existing products valid methods to assess the resistance of building materials to algal growth are urgently needed. Depending on the avoidance strategy there are two basic diagnostic methods to assess the algal resistance of a building material. The algal resistance can either be determined directly by evaluating the algal biomass present on the surface in the course of natural or artificial weathering tests, or it can be assessed indirectly using building component simulation.

The use of numerical simulation tools allows only the assessment of the efficiency of avoidance strategies based on adjusting the hygrothermal storage and transport parameters or the radiation properties of the building materials. Results strongly depend on the quality of the material and weather data and the parameter chosen for evaluating the algal resistance. Free-weathering tests fully depict the natural colonisation process and the complex interactions between the weather and the material data as well as their consequences: weathering, leaching, and soiling. These tests are very time-consuming and only representative for the local climate and the chosen orientation, but they can be used to evaluate all avoidance strategies. The setup of laboratory experiments has to be specifically designed for the tested strategy (Barberousse et al., 2007; Cerman, 2007; Borutzky and Junghannß, 2008). To date, however, there are no tests that have been successfully validated and officially approved. Weathering tests are therefore still the most reliable method for evaluating the algal resistance of new products.

An impartial diagnostic tool that would allow measuring algal growth that are below the visual threshold could significantly shorten the duration of the tests and would therefore be of great value for efficient product development.

The potential of pulse-amplitude modulation (PAM) fluorometry was evaluated during a weathering experiment designed to evaluate the algal resistance effectiveness of an admixture of microscopic glass bubbles in silicon paint.

2. Materials and methods

2.1. Setup of the free-weathering experiment

The measurement series included 18 ETICS samples with a surface area of 20 × 20 cm, all of which consisted of a ceramic mounting plate, 5 cm of expanded polystyrene insulation board, and a water-repellent mineral rendering system. On top of the rendering silicon paints from two different manufacturers (A and B) in three different variations were applied.

The paint for sample set no. 1 did not contain any biocides. The paint for sample set no. 2 contained biocides and the paint for sample set no. 3 had microscopic glass bubbles added to it. All six sets of ETICS samples were manufactured in triplicate (Table 1).

In September 2006 the specimens were mounted vertically, facing northwest on a free-weathering stand on the island of Poel, in the Bay of Wismar (Germany), in the Baltic Sea. For a period of two years they were examined every six months—in April and October 2007, and in April and October 2008.

2.2. Imaging PAM

To monitor and quantify the development of algal growth on the test specimens, an imaging PAM fluorometer was used (Standard IMAGING PAM, Heinz Walz GmbH, Germany). The instrument