Computational Simulation Prediction of Fungal Growth on Religious Building Materials

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Abstract

Religious building materials are often renovated with a high expenditure of time and money without investigating and considering the causes of either damages or deterioration. In many ways, religious buildings can only be maintained by changing their usage. This change of use may influence the interior climate enormously. To assess the effect on the risk of fungal mycelial growth on building parts or building materials, a predictive model has been developed recently, describing the hydrothermal behaviour of the spore. It allows for the first time to employ the changing surface temperatures and relative humidity for the computational prediction of fungal mycelial growth. The calculational assessment of fungal growth allows the handling of such problems which until now could not be solved with simple estimations or with reasonable metrological expense. The modified model generated predictions which agreed closely with experimental data on fungal mycelia growth on religious building materials, thereby supporting the assumptions on which the model was based.

Keywords: computational prediction, fungal, religious building, humidity, temperature

I. INTRODUCTION

India is a country known for its highly enriched heritage in the form of ancient monuments and highly valuable cultural material. It survives and thrives on its ever-lasting heritage embedded in the soul of this great country. Microbial defacement and degradation of artistic or historic artifacts is a worldwide problem affecting all countries regardless of their history, geographical location or economic conditions. Religious buildings and monuments are the most visible and important foundation of the Indian cultural heritage and contribute significantly to the attractiveness and identity of India for its citizens and visitors to all over world. Therefore, we must take care that these invaluable testimonies of our past are maintained and protected in a sustainable manner. Although, huge progress has been made with air conditioning and heating technologies while saving energy for modern buildings, most of the damages to collections of works of art in such buildings are still caused by unfavorable climate conditions and attack of microbial consortia like, bacteria, actinomycetes, moulds, fungi, termites etc. An increasing problem caused by the adaptation of traditional buildings to new uses is the proliferation of microbial mycelial growth. Knowledge of how to prevent microbiological attack is already needed in the planning stage of interventions. The problem of microbial growth will also gain further importance due to effects of climate change, since in various parts of Europe it will become warmer and more humid.

The microbiologist all over the world have studied the role of microbial colonization on the biodegradation of different cultural artifacts ranging from famous buildings to books, wall paintings, textiles, sculptures, currency notes, writings on Bhojpatra (Betula utilis, the Himalayan birch, the bark of which was used for preparing hand written manuscripts of sanskrit in ancient India) and glass; and the compounds utilized to control microbial invasion. According to Amoroso and Fassina (1983) salts are solubilized and migrate with the water in or out of the buildings followed by the drying out of the solution at the exposed surface. These results in the formation of deposits of crystallized salts in the surface called “efflorescences” (Amoroso and Fassina, 1983). The application of biocides is always accompanied by risks to health and also to works of art, especially when used indoors, and moreover can prevent the formation of mould fungus only over a limited period of time. A prerequisite for preventing mould fungus without the use of biocides is the knowledge of the boundary conditions under which fungus growth takes place. In reference to the boundary conditions for the growth of fungus it turns out that the decisive parameters of influence like relative humidity (Grant and et al.,1989) and temperature (Sedlbauer and et al.,2001; Smith and Hill, 1982) as well as the substrate (Ritschkoff and et al., 2000) have to be available over a certain period of time simultaneously in order to enable the formation of mould fungi. Therefore, the main focus of this scientific paper is the development of a planning instrument that aims at predicting the formation of mould fungus. This procedure consists of consecutive predictive models the Isopleth Model.

A. Microbes and Biodegradation:

The term biodegradation is generally used to describe the breakdown of culturally, historically or economically significant material in nature. In other words, biodeterioration refers to the decay of material that is caused by biological agents. Microorganisms frequently damage walls and even attack metals, however, as a rule, in buildings in nature it contains organic and inorganic material that suffer most from biological decay. Wood, ivory, paper, leather, textile, glues and sizes as well as
conservational material such as the saline compounds which are used to consolidate silicates, all are susceptible to biodegradation. Thus, in general, surveys have often been limited to fungi, actinomycetes, bacteria, cyanobacteria and eukaryotic algae (Ascaso et al., 1998; Tomaselli et al., 2000). The alterations that they provoke are mainly related to the formation of biofilms on the substrate and this is a precursor for several mechanisms of biodegradation of the underlying substrate (Gu, 2003). The existence of such biofilms indicate the continuous presence of water, a potential source of physical damage (Saiz-Jimenez, 1999) and the microorganisms themselves contribute to chemical deterioration because of metabolic products which excreted by microorganisms (Sand, 1997).

B. Health and Conservation Aspects of Microorganisms:

People are exposed to microorganisms spores in the air they breathe daily; however, sometimes moulds grow excessively in certain areas and can cause illnesses (Pasanen, 2001). The most prevalent effect of mould on human health is caused by the allergic impact of its spores (Hornak and et al.,1995). Some microorganisms are more hazardous than others. Different people show a different response to microorganisms exposure. In particular, those with allergies, existing respiratory conditions or suppressed immune systems are especially susceptible to illness. In addition, some moulds produce chemicals called mycotoxins, which can cause flu-like symptoms. It should be noted that the causes and effects of microorganisms exposure on people are not very well understood. For this reason the exposure to an environment contaminated by microorganisms should be restricted as far as possible by preventing conditions suitable for mould growth. Cultural heritage assets are affected by microorganisms both in regard to aesthetic and conservation aspects.

II. MATERIALS AND METHODS

- Substrate category 0: Optimal culture medium.
- Substrate category I: Biologically recyclable building materials like wall paper, plaster, cardboard, building materials made of biologically degradable raw materials, material for permanent elastic joints.
- Substrate category II: Biologically adverse recyclable building materials such as renderings, mineral building material, certain wood as well as insulation material not covered by I.
- Substrate category III: Building materials that are neither degradable nor contain nutrients.

A. Conditions for the Growth of Microorganisms:

For the construction sector, German literature often states a relative humidity of 80% at wall surfaces as the decisive criterion for microbial growth, independent from temperature. Sometimes it is mentioned that many types of mould can also thrive at lower humidity (Ayerst, 1969). Other growth conditions, namely a suitable nutrient substrate and a temperature within the growth range are usually taken for granted on all types of building elements.

B. Results and Discussion:

The growth conditions for microorganisms may be described in so-called isopleth diagrams (Ayerst, 1969). These diagrams describe the germination times or growth rates. Below the lowest line (isopleth) every microorganism activity ceases. Under these unfavorable temperature and humidity conditions spore germination or growth can be ruled out. The isopleths are determined under steady state conditions, i.e. constant temperature and relative humidity. The three factors required for growth – nutrients, temperature and humidity – must exist simultaneously for a certain period of time. This is the reason why time is one of the most important influence factors. It can be assumed that germinable spores are present in most cases. This means that mould growth will occur when hygrothermal growth conditions are fulfilled.

C. Isopleth Systems:

Significant differences exist among the various fungus species. Therefore, when developing common isopleth systems, all known fungi were included that can be detected inside buildings. Quantitative statements on the growth preconditions of temperature and humidity have been set up for more than 250 species that fulfill both features, as far as they are given in the literature (Sedlbquer, 2001). Within the Isopleth Model the prerequisites for the growth of microorganisms of temperature and relative humidity are given at first for the optimum culture medium. These isopleth systems are based on measured biological data. The resulting lowest boundary lines of possible microorganisms activity are called LIM (Lowest Isopleth for Mould). In order to include the influence of the substrate, that is the building materials or possible soiling, on the formation of mould fungus, isopleth systems (Fig. 1, left side) for 4 categories of substrates are suggested that are derived from experimental examinations:
On the right, the isopleth system for the so called critical microbial species (Class K, on optimum culture medium). It was also planned to hang canvas paintings on the thinner sections of the exterior wall of rooms which had been unused until then. If the wooden frame of a picture is fixed flat against the wall, it can be assumed that because of the feeble air exchange, the air layer behind the picture functions as an additional insulating layer, resulting in lowered wall surface temperatures. The positive influence of the interior insulating layer is obvious. During winter time the surface temperature is increased about 2°C and the RH is lowered about 10 to 15 %. Figure 4 shows the result of the mould growth prediction. Whereas with the interior insulation no mould growth is predicted, without additional insulation, increasing problems have to be expected after the planned change of use.

III. Future work

The WUFI Bio software is freely available through the internet and is already being used as a post-processing model for various building simulation systems. The growth model is not yet validated for cultural heritage materials but further research is planned for identifying the growth conditions for micro-organisms on different historic materials used in both movable and immovable cultural heritage. The results will be incorporated into the existing analysis software for modern buildings (WUFI Bio) for improved risk assessment for cultural heritage assets.
The course of the relative humidity is strongly influenced by the buffering effects of the building envelope materials and the inside furniture, as well as by the transient outdoor conditions. For the development of suitable ventilation and heating strategies these effects also have to be taken into account. Recently a whole building model for the simulation of the heat and moisture transfer effects which influence the indoor climate has been developed and validated. A combination of this model with the innovative model for the determination of the risk of mould growth makes it possible to assess different temperature and humidity regulation strategies for the preservation of indoor cultural heritage.

IV. CONCLUSION

This newly developed model, describing the hygrothermal behaviour of the spore, allows for the first time to employ the changing surface temperatures and relative humidity for the prediction of microorganisms growth. The calculational assessment of microorganisms growth allows the handling of problems which until now couldn’t be solved with simple estimations or with reasonable metrological expense. Therewith the effectivity of refurbishment measures on behalf of the elimination of the risk of microbial growth can be determined. The optimization of building constructions may now be performed in an easy way. The biohygrothermal model additionally is of great use for determining the necessary rate of ventilation (Krus, 1996). The use of the hazardous class K enables to assess the actual call for action. As a consequence of ongoing problems with mould growth especially in retrofitted old houses with new tighter windows a sensor-free ventilation system has been developed at the IBP (Krus & Sedlbauer 2002).

REFERENCES