CASE STUDY: DETERMINATION OF MOISTURE DAMAGES ON ITEMS OF ART IN EXHIBITIONS BY THE USE OF MICROBIAL ANALYSIS

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ABSTRACT

The described case studies concerning the distinctive features and demands of investigations of mold growth on art and other objects of exhibition. The surfaces and materials used in this objects, pose a special challenge for sampling and analysis. In the microbiological assessment of damages of art objects, the conservation of the value of the object, the search for the cause and the age determination of the damage and the minimization of the damage were the primary targets, as well as attending to the interests of museums, artists and insurances.

KEYWORDS: mold, art, object of exhibition, microbiologic analysis

INTRODUCTION

Inaccurate storage and transportation can cause moisture damage on art objects.

As soon as microbiological damage occurs, many interest groups, like artists and museums, but also insurances, are concerned about the conservation of the value of the damaged objects. The often very delicate surfaces of these objects pose the particular difficulty and only allow for limited sampling and restoration. In some cases, only a minimization of the damage, instead of an elimination of the damage, can be achieved. Microbiologists, restorers and artists have to work together closely to decide on and carry out the options of sampling and removal of the damage. The preservation of art and other objects of exhibition as well as safety and health of restorers, employers and visitors should always be the crucial factor of decision, even if financial considerations have a strong influence on all work carried out.

MATERIALS AND METHODS

The investigations were carried out together with a German laboratory which is specialized on mold and bacterial analysis of moisture damaged building materials, but lately investigations were carried out in museums and exhibitions. After a case of water leakage in a storage building microbiologists worked as team workers closely together with restorers, conservators, directors and insurances experts. With the accurate microbial analysis, correct estimations of the damage could be accomplished, further microbial growth prevented and the objects with mold growth restored.

Before items are sent to other museums and after they are returned it is of great importance to investigate their microbial status. To detect the microbial status of items, the age and activity of microbial growth or contamination on surfaces are

evaluated. The investigation of the microbial status of items can also confirm the storage standards at museums and let them prevented self made microbial damages depending on incorrect storage.

The samples were analyzed by using different methods:

Adhesive tape direct microscopy, sterile cotton swab samples, material samples, i.e. wood or paper, if possible without destroying objects, and air sampling were accomplished in the building to estimate microbial health hazards. Adhesive tape samples are analyzed using a microscope. Mold spores and mycelia are examined and counted and the number per cm^2 was calculated.

All material samples, including swab samples, were analyzed using a three-level method of analysis in order to get as much information as possible about the microbiological infestation. Following, the three levels (Palmgren, 2004) are defined:

1) Determination of the total number of cells (Tnc)
Using the Camnea method², all mold and bacteria are made visible with a fluorescent dye and an epifluorescence microscope. The microorganisms are microscopically detected, counted, categorized and defined as the total number of mold and bacteria cells.

2) Determination of the number of biochemical active cells (Nbac)
Using the fluorescent dye and an epifluorescence microscope, the microorganisms, with active metabolisms, are made visible. The active microorganisms can be divided into bacteria and mold. They are counted separately and therefore deliver crucial data for the age determination of the microbiological damage.

3) Determination of the number of colony forming units (NCFU)
Colony formed units (CFU) are assessed on three standard media (Holah, Betts, Thorpe, 1988) (TGE for bacteria, DG18 and Malt agar for mold), incubated at 25 °C and counted, as well as differentiated, after seven days.

Air samples are made with the filtration method (Camnea method, (Palmgren et al. 1986)). Polycarbonate filters with a pore size of 0.4µm and a diameter of 37mm are placed on support pads in sterilized filter cassettes (Millipore). With an air flow of 2 liters per minute over 4 hours, air is sucked through the filter holder with an air sampler (SKC). After the sampling, the filter is removed out of the cartridge and washed with a sterile washing liquid. 100 mµ of the sample is dyed with acridine-orange (fluorescent dye) and filtrated through a black polycarbonate filter. Thereafter, the microorganisms on the filter surface are counted under a fluorescence microscope. In the next step, colony formed units (cfu) are plated out on three standard media, incubated at 25 °C and counted, as well as differentiated, after seven days. Total number of cells (tnc) of microorganisms stained with fluorochromes, such as acridine orange, has been used for a long time in different environments, such as marine research (Zimmerman, Meyer-Reil, 1974), rapid determination in

food samples (Holah, Betts, Thorpe, 1988) and counting of airborne microorganisms in highly contaminated environments (Palmgren et al., 1986).

A large percentage of bacteria and mold in buildings do not growth under laboratory condition. The total amount of microorganisms can be detected by the total cell count analysis. In regard to air samples the amount of the total number of cells can deviate from the number of cfu up to 100 times1.

Additional staining of material samples with flourochromes shows the metabolic activity of microorganisms and gives the researcher information that makes a determination of the age of the mold growth on building materials possible. Labor Urbanus GmbH, Duesseldorf Germany for example, invented this extended method of investigation to confirm if more than just one water damages have caused particular mold damage to a building.

The microbial damages on surfaces and materials of art were estimated with rating of Labor Urbanus GmbH publicized 20041. The evaluation and the rating of the results by these extended microbial material investigations depend on the experience and classification of > 200.000 microbial samples in 25 years. The classification of the degree of microbial damage is based on normal back ground concentrations found on materials without additional water damage. The critical values are not defined as sterile material samples; on the contrary a certain contamination with microorganisms on all surfaces is ubiquitary existent. Background values state that no abnormal numbers of microorganisms were detected in the samples.

TABLE 1: background or critical value of bacteria depending on reference parame-

Bacterial classification / Microbial method of investigation	Background values in cm²	Background values in gram
Total number of bacteria (Tnb)	< 100.000	< 1.000.000
Number of biochemical active bacteria (Nbab)	< 10.000	< 100.000
Share of Nbab in Tnb	< 10%	< 10%
Number of colony forming units (NCFUb)	< 10.000	< 100.000
Share of NCFUb in Tnb	< 10%	< 10%

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Mold classification Microbial method of investigation	Background values in cm^2	Background values in gram
Total number of molds (Tnm)	<10.000	< 100.000
Number of biochemical active molds (Nbam)	<1.000	< 10.000
Share of Nbam in Tnm	< 10%	< 10%
Number of colony forming units (NCFUm)	< 1.000	< 10.000
Share of NCFUm in Tbn	< 10%	< 10%

TABLE 2: Background or critical value of mold depending on reference parameter

Classification of microbial damage	Assessment
Up to background values	No abnormal microbial growth
Slightly increased numbers	Up to 10 times higher than background
Increased numbers	Up to 100 times higher than background
Strongly increased numbers	More than 1.000 times higher than background

TABLE 3: Classification of microbial damage

If one of the described microbial methods of investigations show an increased number or strongly increased number of microorganisms in the sample the sample is assessed as microbial damaged.

The age determination of microbial damages by microbiological analyses is based on microbe's lifecycles and the metabolic activity of bacteria and mold. The expanded analysis including total cell count, biochemical activity and cfu has to be carried out. The rates of tcc / ba and cfu / ba serve as a basis of decision. Table 4 sums up the simplified basis of this method. For the final age determination the overall picture of the analysis, the biochemical activity, the composition of the microorganisms and experiences play a major role.

TABLE 4: Basis of a simplified age determination of microbial damages

Rate of CFU/Tnc	Approximate age
~ 1%	> 1 year
~10%	> 6 month
~25%-50%	about 3 month
>50%	< 3 month

RESULTS AND DISCUSSION

In these case studies, different cases the laboratory worked on will be examined and presented. Each case is distinct, regarding to varied questions, protagonists and difficulties. For the case studies objects and examinations were chosen to illustrate the diversity and the specific characteristics of mold infestation of art objects. The delicate structures, sensitive materials and the uniqueness of many objects are some of the challenges that need to be met at these appointments. The diverse interest groups also have to be regarded and accounted for. Often, the artist, who wants to preserve his art object and conserve its value, is in opposition to the insurance experts, who want to keep the cost of the damage low. Initially, it is important to thoroughly debate the question in each case and then to plan and execute the sampling and analysis as well as the possible measures with all experts involved.

Case 1: Water damage in a museum

In a museum, there was water entry due to a leaking roof. The entire wall structure, composed of plastered and painted drywall as well as mineral rock wool insulation, was completely saturated with moisture. Material samples of the drywall and the mineral rock wool showed a strong, microbiological infestation with a high fraction of the toxic fungus *Stachybotrys chartarum*. The wall was part of an exhibition hall that contained several pieces of art. However, the artwork was not directly affected. The goal was to remove the wet wall material, to ascertain whether or not the artwork had microbiological damage and, if possible, to continue the exhibition during the clean-up operations without endangering the employees and visitors of the exhibition. The extent of the damage was defined using material samples of the wall and then the clean-up area was shielded with dust-tight walls, behind which the work was performed in under negative pressure. All contaminated material was removed and transported outside through air-locks. The artwork was checked for contamination by using swab samples and, if necessary, was cleaned with Hepa filter protected vacuum cleaner. While the clean-up operations were going on, the air in the exhibition hall was regularly checked via air sampling to ensure that there was no hazar-

dous exposure to microbial contamination. The negatively pressurized dust tight walls were a successful strategy: the hazard for the employees and visitors in the exhibition hall was controlled by air samples. No higher microbial concentration could be found. In this way, the museum could carry out the clean-up operations without endangering the artwork and without closing the exhibition.

Case 2: Water damage in the storage area of a museum

The origin of the damage was the failure of the climate control unit in the storage area of a museum. The storage area did not have an alarm function and therefore there was a high temperature and humidity in the area for two weeks before the malfunction was detected. Most of the objects were stored in especially fabricated wooden boxes, but some of the objects were only covered with plastic foil sealing. The objects showed varyingly potent visible microbiological infestation. A new storage area was rented to assess the extent of the damage. The area was divided in three zones: a black area for infested objects, a gray area for examination and a white area for unsoiled and cleaned objects. Each object and each box was examined and assessed using adhesive tape and direct microscopy. At first, the boxes were divided into „no infestation", „to be cleaned" and „to be reassessed" groups and placed in the black or white area. The boxes that were to be cleaned, were sanded and then checked again and were then either discarded or placed in the white area, depending on the new result. The examination of the art work was performed in collaboration with the restorers. Depending on the material and the surface, swab samples or adhesive tape samples were used to decide which adequate methods for cleaning and conservation to choose.

With all the additional security measures and the extensive analysis, more serious damage to the objects could be prevented. Despite the additional cost for specialists and measures, the insurance companies saved millions of Euros in compensation claims from the artists.

Case 3: Mold damage on borrowed objects

A private collector lent his icons collection to a museum for 12 months and regulated the correct storage of the objects by contract. Icons are religious art work most commonly a painting on wooden board. After the return of the items, the collector examined the art work and detected a microbiological infestation in the form of a white coating. The allegation towards the museum was of microbial damages depending on incorrect storage resulting in a loss in value of the icons. The storage rooms were professionally examined and neither differences in room temperature or humidity nor structural damage of the rooms could be detected. The icons were investigated, using adhesive tape samples and swab samples. The adhesive tape samples confirmed the microbiological infestation. The wipe samples were used to determine the age of the microbiological infestation. Some icons had been chemically treated and were therefore not suited for the age determination. Consequently,

an untreated infestation was chosen and examined in the laboratory for the total number of cells, the biochemical activity and the CFU. The analysis cleared showed, that the infestation had occurred more than one year ago. Therefore, the museum was cleared of all compensation claims. In the future, the condition of borrowed objects is to be checked before these objects are accepted into the museum.

Every case in this study and every problem to solve were different, therefore a standard recommendation cannot be given. However, in many cases the microbiology can help to understand the damage and provide solutions for decontamination. If the microbiological status of museum objects is assessed before the items go for loan the claim of damages can be evaluated. In another case the analysis could help to define compensation for an artist after water damage affected his objects of art in a storage room. There was also a case where a total damage of an entire exhibition could be prevented because the spread of the microorganisms in an entire museum was prevented. The microbiological analysis can help to understand and deal with microbiological damages on items of art or the museum itself. The items are sensitive and microbiology is just one part of a close collaboration between artists, restorers and microbiologists that is essential to solve the damage of art in a professional way.

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