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TREATMENT OF WOOD-BORING BEETLES IN OXYGEN-FREE ATMOSPHERES

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Abstract The investigation showed lethal effects to development stades of three different wood boring insects commonly found in storages and exhibition rooms of museums. Hermetically closed chambers without floor sealing contained atmospheres < 1 vol.-%, the results of 100 % mortality could only be determined by examining test insects.
Key words Controlled atmospheres, museum pests, wood-boring, powderpost beetles.

INTRODUCTION

Caused by loans from all over the world, new acquisitions and changing exhibitions, a pest infestation occurred in the storage of the MMK Museum of Modern Art Frankfurt Main. All kinds of material and aspects concerning the collection are handled by the conservator of the MMK. Due to the active acquisition policy and ongoing projects, the storage is in constant motion. Beyond paintings and sculpture, artists may use any material or method in their artwork or installation and each has different parameters for preservation and conservation. Deterioration is determined by the art material's stability and its interaction with the environment. An accumulation of minor, often unnoticed events is usually only found when examining the entire collection over a long period of time. Changes in temperature or relative humidity may create varying stress levels in components or layers. We try to create an environment for the artworks that possibly does no harm. That includes light, temperature, moisture but also any gas that could lead to an uncontrolled chemical reaction. Acidic or other gases and vapours readily attack cellulose and other materials, and cause irreversible, cumulative damage to the appearance and supporting structure of works of art.

After previously finding beetles in the storage, they were examined by the Senckenberg Institute in Frankfurt to see whether they could survive or even breed in the acclimatized storage. Aware of the risk, we had implemented a constant monitoring. An early warning system with adhesive films, UV light traps and pheromone was installed. Still, a massive infestation was found in early 2011 in one spot probably brought in with a crate. A task force was founded with external specialists to find the most effective way to get rid of this pest. Thorough investigations showed that the beetles had already spread throughout. We learned that the powder-post beetle (*Lyctus brunneus*), and its life cycle is still part of scientific research.

It became clear that there was only one way to get rid of the pest: We had to remove everything from storage and redo the entire sapwood floor. For conservation reasons, we decided to use a sapwood-free oak floor. The Museum has a 20th Century collection of more than 4500 artworks comprised of more that 15.000 single pieces: they range from large convolutes of graphics and b/w photographs, colour prints, paintings, objects, installations, organic materials and technical equipment. We then tried

to separate the conifer from the hardwood to reduce the costs for the anoxia treatment. But it was a bigger effort to separate all endangered materials than tenting a whole heavy-duty shelf. All crates and packing had to be opened, bubble wrap foil had to be removed to allow oxygen to escape as quickly as possible. Because of special packing and the fragility of the objects, they could only be moved by trained art handlers.

Recommendations had called for oxygen levels in controlled atmospheres in museums at less than 1 Vol.-% (Gilberg, 1989). A lethal effect is more easily achieved on adult insects than on their eggs. (Gilberg, 1991) tested eggs of *Lasioderma serricorne*, *Stegobium paniceum*, *Anthrenus vorax* and *Tineola bisselliella* with a gas mixture of 0.4 % oxygen over a period of three weeks at 30°C. The eggs of all species showed 100% mortality after exposure. These results are not feasible for treatment of modern art in controlled atmospheres. Conservators only allow maximum temperatures of 20 to 22°C.

Few past studies have shown mortality results in eggs from wood borers at standard room temperatures of 20°C and applied oxygen levels at less than 1.0 Vol.-%. Frank (1991) tested inert gases to control powder-post beetles at 20 °C for more than 3 weeks treatment for 100% mortality. This paper will show the feasibility to eradicate different stages of wood boring species in controlled atmospheres under feasible conditions and at oxygen < 1vol.-%.

MATERIAL AND METHODS

To investigate the efficiency in oxygen-free atmospheres, a XXL-tent with a volume of 600 cbm was applied to eradicate a powder-post beetle infestation. A total package with floor-foil was impossible because all infested objects in heavy boxes were stored on industrial storage shelves and wrapped in Vacupac made up of HDPE, aluminium and PET. For reversible fixation, the aluminium foil was stuck together with gas-tight aluminium tape and fixed to the industrial storage floor.

For humidity control, a humidifier and a dehumidifier were placed inside the tent and connected via an electronic control unit (INVAN4) outside. The unit records oxygen, humidity and temperature levels and regulates the humidity inside the tent. To reduce oxygen below 1 Vol.-%, nitrogen was flushed first and a nitrogen generator used to maintain the oxygen concentration inside the tent. Figure 1 shows the exposure data for humidity, temperature and oxygen levels.

To evaluate the efficacy in terms of mortality, house longhorn beetle (*Hylotrupes bajulus*), furniture beetle (*Anobium punctatum*), and powder-post beetle (*Lyctus brunneus)* contained in 20 pieces of softwood, were placed into the tent. Control organisms of the same batch were stored beside the tent and samples of the same batch were also tested at the laboratories of Materialprüfungsamt Eberswalde. The different stages of test organisms used are described below.

Exposure of Larvae

Six living larvae of the powder-post beetle *Lyctus brunneus* were applied to a suitable specimen that could fit seamlessly into the sampling block. For comparison, six larvae of the common furniture beetle *Anobium punctatum* and three larvae of the house longhorn beetle *Hylotrupes bajulus* were introduced into the specimens, and these subsequently inserted into sampling blocks. The silicon-sealed sampling blocks were then placed into the fumigation tent. Post-fumigation, the sampling blocks were removed to study the larvae. Identically fitted sampling blocks were placed simultaneously outside of the tent and not subjected to the treatment with oxygen low atmosphere.

Exposure of Eggs

Insect species used: 2–9 days old eggs of the common furniture beetle *Anobium punctatum* and 1 – 4 days old eggs of the powder post beetle *Lyctus brunneus* from the MPA lab. Material for the egg deposit: Incubation medium, predominantly consisting of oak formed into a cube of approx. 1 cubic meter. See Table 1 and 2. The beetle pair was placed on a semi-synthetic diet of compressed nutrient as a breeding ground. The female deposited eggs within two to three days for *Anobium* and 24 hours for *Lyctus*. It was not possible to determine the number of eggs as some were deposited deeply into

the nutrient media. Each of these nutrient media was then placed inside a glass vessel, tightly closed off with air-permeable gauze and taken to the fumigation tent. The nutrient media were removed after fumigation and checked daily for larvae hatching. After finding the first hatching the investigation ended. Larvae that hatched later were not taken into consideration. Egg deposits for the control study, were prepared and transported in the same way as the fumigated samples but kept outside of the fumigation tent. Egg deposits post-fumigation were stored at the breeding room at 20 °C and 80% RH for *Anobium* and breeding room at 26°C and 70% RH for *Lyctus* at MPA Eberswalde.

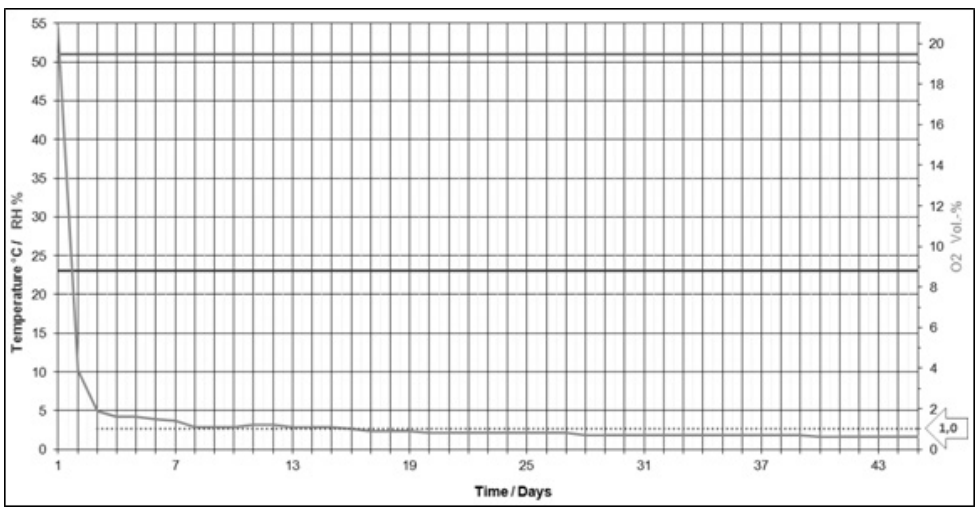

Figure 1. Graph showing RH, temperature and oxygen levels of the treatment.

Determining Mortality

Mortality was determined by examining the insects microscopically for any perceptible movement. Larvae and eggs were held for subsequent development. Unexposed controls. On the day of exposure, the same species and stadia were set up as unexposed control samples. These were placed beside the tent in identical basins and at identical RH and temperature as the insects being exposed.

Table 1. Eggs of *Anobium punctatum* post-exposure.

Type of Eggs	Sample No.	Maximum age of eggs at exposure (days)	Period of exposure (days)	Hatching of larvae after exposure (days)
Treated	1	9	12	-
	2	6	12	-
	3	5	12	-
Control	8	6	-	22
Treated	4	6	19	-
	5	5	19	-
Control	9	6	-	22
Treated	6	5	26	-
	7	2	26	-
Control	10	5	-	

RESULTS AND DISCUSSION

Oxygen-free atmospheres were achieved in an in-situ chamber with gas-tight sealing and purging nitrogen from a generator. Figure 1 shows the data for oxygen level and climate conditions with RH and temperature inside the chamber.

The efficacy of oxygen-free atmospheres for art and cultural heritage has been investigated for many decades. In this investigation we found that hermetically closed mobile ´chambers´ without floor seal could be used to control major wood boring beetles. Exposure time for eradication of three species of wood boring insects in different stages represented a range for practical application. Controlled atmosphere of < 1 Vol.-% O_2 (Figure 1) resulted in 100 % mortality of larvae of *Hylotrupes bajulus*, *Lyctus brunneus* and *Anobium punctatum* after 43 days. 100 % mortality of eggs from *Anobium punctatum* and *Lyctus brunneus* were achieved in a controlled atmosphere of < 1 vol.-% O_2 at 22°C temperature after an inspection of 12 days (*Anobium*) and 11 days (*Lyctus*).

The usual recommended oxygen levels of 0.1 to 0.3 % could be higher, as in cases with XXL-tenting, but should always be controlled by using test insects of the target species. More scientific investigations and technical standards are needed to have safe data for different parameters of higher oxygen levels (1.0 to 1.5 %), exposure time, temperature and different insect species.

Table 2. Eggs of *Lyctus brunneus* post-exposure.

Type of Eggs	Sample No.	Maximum age of eggs at exposure (days)	Period of exposure (days)	Hatching of larvae after exposure (days)
Treated	5	2	6	4
	6	2	6	6
	9	1	6	4
	10	1	6	4
Control	15	2	-	12
	17	1	-	17
Treated	1	4	11	-
	7	2	11	-
Control	16	2	-	10
Treated	3	3	18	-
	11	1	18	-
Control	18	1	-	20
Treated	2	4	25	-
	8	2	25	-
Control	13	4	-	8

After inspecting every single piece, we were able to confirm that the *Lyctus brunneus* only got as far as the stretchers and into some crates. All measures are now implemented as we have to guarantee to the insurance carrier that everything is being done to avoid future pests. We built a vast double door system within the outer storage, connected to an anoxia chamber. Every artwork or crate that is not guaranteed to be free of hardwood will have to go through our anoxia chamber before entering a storage area. Knowing that the *Lyctus brunneus* is gaining ground wherever factory-made wood is in use, we allow only conifer to be used for construction and in crates, bases, temporary walls.

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