APPLICATION OF ANOXIC TREATMENT FOR INSECT CONTROL IN MANUSCRIPTS OF THE LIBRARY OF MEGISTI LAURA, MOUNT ATHOS, GREECE

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INTRODUCTION

The library of the Great Lavra Monastery on Mount Athos, Greece, houses, in addition to some 30,000 printed books, 2,046 manus-cripts, 460 of which are on parchment. Many of the manuscripts date from the early part of this millennium and are quite rare.

Examination of the condi-tion of the library and the rare manuscripts of Great Lavra, Mount Athos, was undertaken by the authors in September 1993. The primary purpose of the visit was to ascertain the extent of an insect infestation in the manuscripts (samples of which had been received by RJK and examined at the Metropolitan Museum of Art, MMA) and to treat the most heavily infested ones. The secondary purpose of the visit was to suggest improvements in the library storage conditions.

Fig. 1 : The U-shaped library and treasury building of the Great Lavra Monastery

Initial examination of the manuscripts confirmed the findings from New York, in that live «book-lice» (similar to the North American psociids *Lepinotus* sp.) were found crawling on the cloth book covers recently used to encase the codices.

The shelves in the library rest directly against stone walls, either exterior or interior walls. The corners were deemed the areas of the library most at risk, as these sections had damp walls. On the walls could be observed probable fungal colonies, a prime attractant for book-lice. The cotton covers in which the codices were encased (a project recently completed) may have served to initiate the infestation, and at the least may perpetuate the infestation, as the cloth covers trapped moisture around the codices. This was apparent as many of edges of the parchment books were damp.

Live book-lice were discovered on the cloth book covers taken from a particularly damp corner, but the insects have probably traveled to many of the other codices. The codices in the dampest corner of the library were removed and treated, as described below, but it is recommended that all of the rare manuscripts (about 1950 more) be treated with argon.

TREATMENT CHOICE FOR INSECT ERADICATION

The choice of an appropriate treatment for control of insect infestation in art objects is naturally restricted to one that will minimize the alteration it causes. Over the past 25 years in the US, a succession of insecticides have been tried and rejected. These have included methyl bromide, ethylene oxide, and, most recently, sulfuryl fluoride. Sulfuryl fluoride is still in use by many museums in the US, but recent work (Koestler et al., 1993) clearly shows the danger of this insecticide to some kinds of art work.

Recent developments (Gilberg, 1989, 1990, 1991, 1992; Koestler, 1991, 1992, 1993; Valentin, 1990) offer a much safer method for insect control in objects. This method is the use of low-oxygen environments. The anoxic environment is usually achieved with nitrogen or argon gases (helium is currently being tested, separately and with argon, at the MMA).

Anoxic gases: background

The use of nitrogen for pest control is not new. Perhaps the earliest mention of its use was in the 1860s

(see Bailey and Banks, 1980; Sigaut, 1980; and Annis, 1986). Since the 1960s many studies have been performed using nitrogen to control insect pests in grain storage silos, with notable success (e.g., Navarro, 1991; Navarro and Jay, 1987). Studies on the use of inert environments in the museum field have blossomed over the past five years (e.g., Gilberg, 1989, 1990, 1991, 1992; Koestler, 1991, 1992, 1993; Koestler et al., 1993; Valentin, 1990; Valentin and Preusser, 1990 a,b).
The literature to date, and testing carried out at the Metropolitan Museum of Art (Koestler et al., 1993, and unpublished) have encouraged the abandonment of chemical fumigation and the adoption of inert gas fumigation procedures. In particular, argon gas is employed preferentially over nitrogen for several reasons: it is totally inert; it is heavier than oxygen and thus it pushes the oxygen to the top of the enclosure; and it kills insects 25-50% faster than nitrogen (Valentin, 1990, 1992, personal communication).
The aim of any suffocation treatment is to remove the oxygen without causing any deleterious – or too rapid – alteration in temperature, pressure, or humidity of the object being treated.

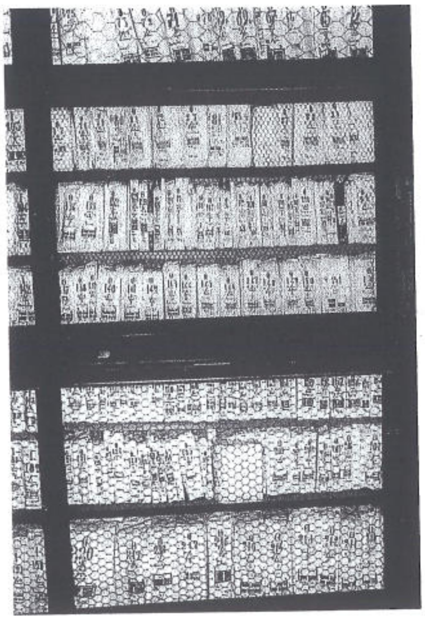

Fig. 2 : Storage shelves for the rare books and manuscripts.

Humidity

Gases useful in suffocating insects, e.g., nitrogen, argon, or helium, are available in pressurized cylinders. The moisture content of these cylinders is low, <10% RH. Direct application of unconditioned gas into a closed environment surrounding an object will cause a reduction in the humidity of the object, possibly resulting in cracking of the object. To avoid this, it is necessary to condition the gas to an appropriate humidity level by bubbling it through a water bath.
Relative humidity measurement of the conditioned gas is easily carried out by insertion of a hygrometer at the exit hose from the water bath. Tests carried out have shown that argon or nitrogen, when bubbled through water, become conditioned to about 58% RH (at about 68°F or 20°C) at a flow rate between 10 and 100 ml/min. Lower RH levels can be achieved by mixing dry and conditioned gases; higher levels would require either a glycerol and water mixture (maximum level achieved is 68% RH [Jay, et al., 1971]), or humidification of the bag enclosure system by silica gel or other means (Note: use of glycerin may not be appropriate, especially if it is carried along with the water vapor and interacts with the object).

Temperature

Generally a constant temperature is required for treating objects (in a museum context this is usually about 68°F or 20°C). Equilibration of temperature from a gas cylinder to the ambient level is readily accomplished by a combination of the water conditioning method mentioned above and the use of long hose leads between the gas cylinder and the water container. The water bath could also be heated or cooled to achieve other desired temperature conditions.

Pressure and flow rate

Rapid pressure changes, positive or negative, or high gas flow rates may be harmful to objects and are to be avoided. The pressure and flow rate within a closed system can be easily monitored and regulated, with consideration given to the delicacy of the object within the environment. Pressure regulation can be controlled easily by increasing the exit hole in the bag, while flow rate is adjustable at the tank valve.

Length of Treatment

Length of treatment is the single most important factor in anoxic treatments. It is also usually the most difficult factor to determine precisely. Laboratory studies may give an approximate idea as to the ability of different insect species to resist a low-oxygen environment. This length of treatment (LOT) will vary considerably, not only from species to species, but also with life-cycle stage – egg, larval, pupal, or adult – and with age within each cycle, among other factors (Jay, 1984; Navarro and Jay, 1987). In addition, the nutritional and ecological state of the insect in the object will affect the LOT, as will the ability of the gas to penetrate the object, or conversely, the ability of the insect to trap oxygen around it.
In the absence of *in vivo* data, the conservative approach is to pattern LOT after the most difficult insect life stage we are likely to encounter: for example, the LOT suggested by Navarro (1991) for *Trogoderma granarium*, the khapra or grain storage beetle, in 99.5% nitrogen, 20°C, and about 60% RH, is 20 days; Gilberg (1991) gives a LOT of 21 days for *Tineola bisselliella* (Hummel), webbing clothes moth; *Lasioderma serricorne* (Frabicus), cigarette beetle; *Stegobium paniceum* (Linnaeus), drugstore beetle; and *Anthrenus vorax* (Linnaeus), carpet beetle, in 99.5% nitrogen, 30°C, and 60% RH. Since higher temperatures generally produce higher mortality rates, lowering the temperature in Gilberg's studies should increase the LOT. This would imply a treatment time in excess of 20 days for nitrogen, for common museum pests.
Methods to decrease the LOT, such as increasing the temperature or lowering the humidity, are not safe for museum pieces; therefore one must seek alternatives.

Fig. 3 : Measuring the oxygen level in a book-filled argon-flushed bag (left to right, , T. Mathews, R.J. Koestler, D. Cacharelias and Fr. Nicodemos; helper in background).

The use of argon gas is one alternative, as it has been shown to be faster at killing insects than is nitrogen as already mentioned. Given that we are generally restricted to a room temperature of around 20°C, a conservative estimate of LOT in 99.5% argon at about 60% RH is 20 days.

Assessing effectiveness of LOT values

There are two methods of assessing a LOT value for argon of 20 days: Treat objects and wait to see if the infestation continues, or devise a measurement system to determine the presence or absence of insect activity. Both the empirical and the instrumental testing methods have been employed.

Empirical testing: From 1991 to 1993, approximately 600 art objects, comprising the main organic categories of leather, paper, parchment, textiles, and wood have been treated with ≥99.5% argon for at least 20 days at 20°C and about 58% RH. In all but one case, no renewed insect activity was discovered. This sole exception may have resulted from re-infestation.

Instrumental testing: A Fourier transform infrared spectrometer (FTIR) has been used to measure the CO_2 produced by insects (Koestler, 1993). The system has proven capable of measuring a 10-ppm change per day as insect-derived respiration by product. Using this system, measurements have been taken before and after treatment of selected objects. Results so far have demonstrated that a 16-day treatment in ≥99.5% argon, 20°C, and 58% RH, have been effective in eliminating measurable insect-produced CO_2.

Anoxic bag systems

The most successful and most commonly employed bag system at the MMA involves the use of a heat-sealable low-oxygen-permeable plastic (P869, a co-extruded EVA/nylon/EVA side seal pouch 44 x 90" in size, 3.0 mil thick, from the Cryovac Div., W.R. Grace Co., Simpsonville, SC, USA, with O_2 permeability of 30-50 cc/day/m^2 at 20°C and 1 atm). The oxygen environment inside the bag is flushed out with the humidified inert gas to less than 0.1% O_2 level, an oxygen scavenger and oxygen indicator (Z-2000 Ageless^R and Ageless Eye^R indicator, respectively, Mitsubishi Gas Chemical America, Inc., 520 Madison Ave., New York, NY, USA, products available through Cryovac) are placed in the bag, and the bag is sealed. The oxygen scavenger functions to absorb any oxygen that diffuses out of the object or leaks into the bag (effective to about the 0.1% level). The O_2 indicator provides a quick passive monitoring method to ensure that O_2 levels within the bag are maintained at the desired level (≤0.1%); the tablet is pink when the O_2 level is <0.1%, and usually turns blue >0.5%.

The pouch system is portable, reasonably inexpensive, quick to set up, effective, and reusable, provided the sides of the pouch have not been pierced. All of the materials, except the argon cylinders, were transported to Mt. Athos.

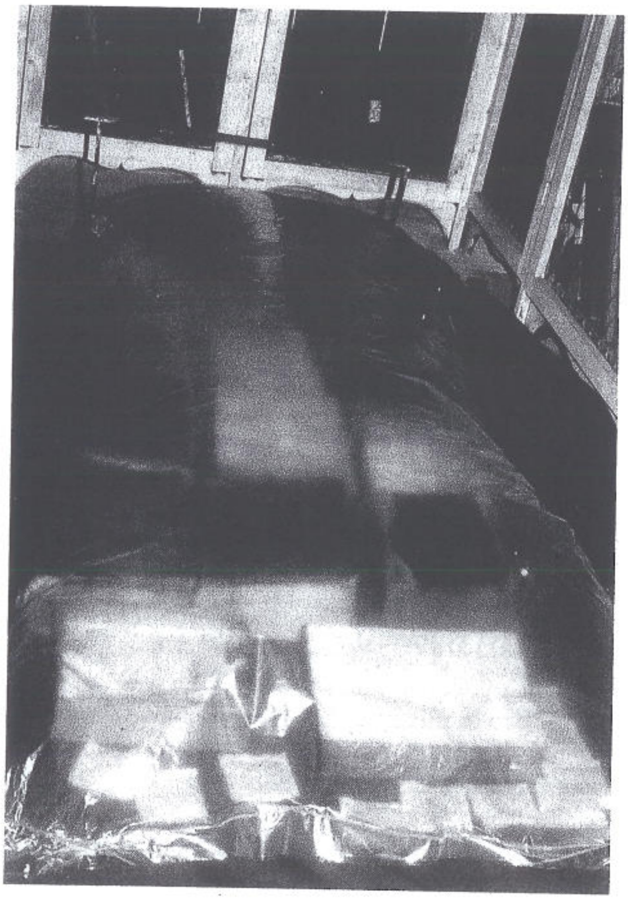

Fig. 4 : One completed treatment bag.

Treatment of manuscripts

Fifteen to 20 manuscripts were placed in each bag. Humidified argon gas was flushed into the bag at one end, and the oxygen-containing gas was pushed out of a hole in the opposite end of the bag. The oxygen monitor sampled the air at the exit hole of the bag. When the oxygen level decreased to under 1000 ppm (or 0.1%) the oxygen scavenger was placed in the bag. In addition to the oxygen scavenger, an oxygen indicator was also inserted. The level of oxygen was then reduced to about 700 ppm. The bag exit hole was sealed up and the bag allowed to inflate until a bubble shape was achieved, at which point the entrance hole was heat-sealed.

Examination of the bag shape and the oxygen indicator on the day after treatment is initiated is usually sufficient to determine if the system will hold for the duration of the desired treatment. The bag should remain inflated and the oxygen indicator should remain pink to light blue. These conditions were observed.

Enough supplies were available to make four bag systems. Seventy manuscripts were treated as described above. Normally, in a controlled museum environment, 20 days would be sufficient to ensure insect mortality. Given the variable temperature conditions at Mt. Athos, a minimum of 30 days was recommended. In actuality, the books will probably remain within their bag until the library storage conditions have been improved.

CONCLUSIONS

Suffocation treatments are very efficient at eradicating insects with the lowest possible risk for the art objects of any method currently available. However, this method does not provide any protection from re-infestation. Therefore, in order to ensure that the treatment of the important documents and manuscripts in the library of Great Lavra, Mount Athos, Greece, will have a lasting effect, the conditions within the library must be improved to avoid re-infestation.

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