ANOXIC TREATMENT FOR INSECT CONTROL IN PANEL PAINTINGS AND FRAMES WITH ARGON GAS

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Abstract

The only technique for eradication of insects in fine art currently used at the Metropolitan Museum of Art is a low-oxygen, or anoxic, treatment, using argon gas. The reason for using argon rather than nitrogen, currently the most widely publicized gas in controlled-atmosphere treatments, is four-fold: Argon is totally inert; it gives faster "kill rates" than nitrogen (25-50% faster); argon will not encourage anaerobic microorganisms; and, being heavier than oxygen, it will preferentially sink to the bottom of an enclosure, thus displacing the oxygen and producing lower-oxygen environments over time where the art usually rests.

More than 1000 fine art objects, including dozens of panel paintings and frames, have been treated with argon over the past five years, with no deleterious effects to the art.

Outlined herein is a brief review of the suffocation procedure, including determination of length-of-treatment time based on detection of actual insect presence in art, using a prototype Fourier transform infrared spectroscopy respiration detection system.

Introduction

The choice of an appropriate treatment for control of insect infestation in art objects, especially panel and easel paintings, is naturally restricted to one that will minimize any potential alteration to the object. The choice of treatments until about 1990 for our paintings collection was restricted to a fumigant.

A fumigant is defined as a volatile material that forms vapors that destroy insect pathogens and other pests. All fumigants are therefore reactive. They actively interfere with some aspect of the pests' life processes. The interference may be specific to one life process, e.g., respiration or digestion, or nonspecific (affecting many aspects of the insect). The reactive ability of the fumigant to kill the pest has a detrimental side to it, which is that it can also react with the art object, and if they are not careful, with personnel handling the art. Fumigants are harmful to the environment and harmful or even lethal to humans in the dosages used to control insects. Also, residues from them may pose a problem if they become absorbed into the art.

The most recently used fumigant for our collection was sulfuryl fluoride (Vikane^{R}). Testing undertaken in 1990 at the MMA (Koestler et al., 1993) clearly showed the danger of this insecticide to some kinds of artwork. The poor performance of sulfuryl fluoride on tests of our painting material caused us to discontinue the use of this fumigant on any artwork within our collection.

The choice of an alternative process is limited by the desire to reduce the risk of collateral damage as much as possible. For art collections this means selecting a treatment that will not be reactive with the art or significantly alter its temperature, humidity, or pH, but that will still be effective at killing any stage of any of the insect pests that might infest the object. Such a treatment is found in the use of a low-oxygen or anoxic environment. An anoxic gas is one that is essentially inert, e.g., helium, argon, or, for most purposes, nitrogen. It is nontoxic, nonflammable, and nonreactive. The anoxic gas serves to replace the oxygen-rich environment with one that insects cannot use. Many studies have shown that the use of anoxic gases is effective in eradicating insect infestations in museum objects (see for example Daniels et al., 1993; Gilberg, 1989, 1990, 1991, 1992; Koestler, 1991, 1992, 1993, 1994; Koestler and Mathews, 1994; Koestler et al., 1993; Valentin, 1990; Valentin and Preusser, 1990a,b). Koestler et al., (1993) has shown that nitrogen does not visually alter test samples of easel painting materials (unpublished work in our laboratory has shown a similar lack of effect for argon).

Nitrogen gas has been used by agricultural services and governmental agencies around the world to control insects in granary silos for decades. Helium gas has been used for some 40 years to protect one of the most important historical documents in U.S., the Declaration of Independence. Argon gas has been employed in museums around the world to control insect attack in fine art with no damage to the art.

The anoxic procedure

The procedure for anoxic treatment is at first glance very simple, as noted below (this procedure is the same regardless of the anoxic gas used):

1) Isolate the object from the oxygen-rich environment;

2) replace the oxygen-rich air with an anoxic (oxygen-less) air; and

3) wait until the insects die, and then remove the object from its anoxic environment.

While simple in concept, each step requires an understanding of environmental, physical, and biological factors that may affect the procedure (Koestler, 1992).

Isolating an object from the oxygen-rich environment

There are two ways to isolate art from the environment: either in a hard-walled chamber or a soft-walled bag system.

A chamber offers the advantage of being able to treat a large number of objects at one time, month after month, year after year. It has the disadvantages of requiring that the objects be brought to the treatment site, and restricting treatment to the specific commencement times (i.e., no object can be added during the chamber treatment cycle.) Chambers are expensive to build, so if they are to be cost-effective large numbers of objects per year must be treated. In addition, the chamber must be able to maintain, actively or passively, a very-low-oxygen environment (at the MMA we currently recommend on the order of 0.05%, or 500 ppm).

A soft-walled, or bag system, on the other hand, enables one to build an enclosure around any infested object(s), at the collection location or at the conservation facility, thus reducing the risks of damage or spreading of infestation by transporting the art to a chamber location. Heat-sealable plastics materials with suitably low oxygen leakage rates can be obtained readily from plastic suppliers.

Replacing the oxygen-rich air with an anoxic (oxygen-less) air

Replacing the oxygen-rich air with an anoxic gas can be accomplished by a gas-flushing and replacement process or by scavenging the oxygen out of existing air.

The gas-flushing and replacement process uses simple gas displacement to gradually flush the oxygen-rich air out of the container. This procedure permits selection of any of a number of different gases or gas combinations as the replacement choice, depending on the delicacy of the material to be treated.

The scavenging process using a chemical reaction to actively remove oxygen from air, leaving a high-nitrogen environment. Use of a nitrogen generator would fall under this category.

The active scavenging process used by the product Ageless®, is an exothermic reaction. This product, when used without flushing with anoxic gas, results in a rapid reaction that can produce surface temperatures, on the scavenger packets, in excess of 110°F. If a packet is placed on or near a painted surface, melting or flowing could result.

Nitrogen generators have been recommended by some for use with hard-walled chamber systems. This has at least two drawbacks: the necessity of a hard-walled chamber system--an expensive proposition, and the fact that nitrogen must be used as the suffocation gas.

Flushing systems based upon hard- or soft-walled enclosure systems provide the greatest flexibility and the least amount of cost. A soft-walled enclosure system permits a capsule to be built around any size infested object or group of objects. This permits reducing the volume of treated space to a minimum and uses less gas than a hard-walled system would. In addition, a flushing system is easily transported to the site of treatment, reducing the risk of spread of infestations, and reducing handling and movement of the art. With this type of system, any anoxic gas or combination of gases may be used. 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.

Choice of anoxic gas

Much literature has been published about nitrogen gas. It is effective in suffocating insects, it is relatively inexpensive, and it is believed to be safe for the objects. What is generally overlooked in nitrogen use, though, is the ability of humidified nitrogen to support growth of anaerobic microorganisms. The microbiological literature is replete with studies about the ability of anaerobic microorganisms to "fix" nitrogen. What this means is that some microbes, when oxygen is absent, can convert the normally inert nitrogen gas to other nitrogen-containing compounds that are far more reactive and available for further use by organisms. Work performed at the Getty Conservation Institute clearly demonstrates the ability of anaerobic bacteria to grow in humidified nitrogen gas (Valentin and Preusser, 1990). This study reports that even at humidities as low as 33%, in 99.99% nitrogen, microbial activity was still present. The higher the humidity, the higher the activity of the microbes.

Microbes are often associated with insect presence. These can be protozoa or bacteria living in the guts of termites and wood borers, or fungi feeding on wood or the waste products of insects. Microbial deterioration affects virtually any material (c.f. the bibliography by Koestler and Vedral, 1991). What this means for art objects stored in or treated with nitrogen, especially in high-humidity environments and for long-term storage, is that there is a real risk of deterioration of the art caused by the actions of anaerobic microbes.

To eliminate the potential risk associated with the use of nitrogen, another anoxic gas should be used. Other choices are helium and argon. Helium was the gas of choice for storing the Declaration of Independence, some 40 years age. Argon is another possibility and is easier to retain in a bag enclosure than is helium.

Argon has other advantages over nitrogen besides discouraging anaerobic growth: It is faster at killing insects than nitrogen (25-50% faster, Valentin et al., 1992); it is inert; and, since it is heavier than air, it will displace any residual oxygen from the bottom of the bag where the painting usually resides.

Length of Treatment

After inertness of the gas, length of treatment (LOT) is the most important factor in anoxic treatments. It has also been the most difficult factor to determine precisely, until recently.

Laboratory studies give an approximate idea as to how long it takes different insect species to resist a low-oxygen environment. The LOT will vary considerably, not only from species to species, but also within one species, from one life-cycle stage--egg, larval, pupal, or adult--to another and age within each cycle to another, among other factors (Jay, 1984; Navarro, 1991; 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, and the ability of the insect to trap oxygen around it.

In the absence of <u>in vivo</u> 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 <u>Trogoderma granarium</u>, the khapra or grain storage beetle, in 99.5% nitrogen (0.1% O_2), 20°C, and about 60% RH,is 20 days. Gilberg (1991) gives a LOT of 21 days for <u>Tineola bisselliella</u> (Hummel), webbing clothes moth; <u>Lasioderma serricorne</u> (Frabicus), cigarette beetle; <u>Stegobium paniceum</u> (Linnaeus), drugstore beetle; and <u>Anthrenus vorax</u> (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. Rust and Kennedy (1993) suggest that shorter treatments are effective for all stages of the common museum pests (although they lump instars together as one lifestage when they may in fact be composed of up to 12 instars.) A reasoned assumption for length of treatment would be 2-3 weeks. We have found that this LOT is too short for wood borers in some kinds of art.

Is there life in art?

How effective are the LOT values derived from laboratory studies in practice?

There are two methods of assessing the effectiveness of any treatment: 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 in our studies.

Empirical testing is not satisfactory for a number of reasons: It is not always apparent that an object is infested, let alone still infested; the object may become re-infested if put back into an unaltered infested environment; and if still infested the object then is still undergoing damage and perhaps infesting other pieces.

There are a number of approaches one can take in using an instrumental technique to detect life in art. Some that have been attempted (Street and Bruce, 1976) include sound, temperature, and gas.

The most successful approach we have employed is detection of gas byproducts from infestation. A prototype system for measurement of insect respiration byproducts was constructed using a Fourier transform infrared spectrometer (FTIR) system 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 byproducts. Using this system, measurements have been collected from insects: in vitro and in vivo and before and after treatment of infested paintings and panels.

Using this system, it is possible to prove that the selected LOT times have infact killed all the insects within the art. To reliably eradicate all wood borers, a LOT of 4 weeks, in argon (O_2 ≤700 ppm) at 70°F and 58%RH is necessary. If nitrogen is used, Valentin's (1990, 1992) data suggests an increase of 25-50% in the LOT, that is 6-8 weeks, not the 2-3 weeks given in the literature for insects in test tubes.

Insects living on the surface of an object are more readily suffocated then those living within--here the in vitro data will probably match the in vivo results.

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1995
AIC PAINTINGS SPECIALTY GROUP POSTPRINTS

Papers Presented at the Twenty-Third Annual Meeting
of the American Institute for Conservation
Saint Paul, Minnesota
June 9-10, 1995

Compiled by Joan H. Gorman