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Fumigation Applications in Historical Buildings

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Abstract: Disinfestations of historical buildings by re – circulating of a gaseous fumigant through the building is a fumigation technique that was practiced. The building constructed from a mix of wood and stone is a historical palace, in Istanbul (Turkey), which is a volume of 40.000 m^3, composed of two floors and a basement. It contains extensive use of mother – of – pearl that covered almost all of its surfaces. There are also detailed painted landscapes on the ceiling. Valuable old sculptures of wood, paintings on wood or with wooden frames, as well as parquet floor material are all very susceptible to damage by wood boring insects. The main pest in that building was the furniture beetle. Damage was very serious on the wooden parts.

Methyl bromide was the only registered fumigant at 2005 in Turkey. So, fumigation was carried out using methyl bromide. Because of fire risk of fan electricity, re – circulation system was set up outside of the building and electricity was cut off during fumigation inside the building. Before fumigation, all sensitive and precious objects were kept in specially designed cube in the building to disinfest using modified atmosphere application.

The building was fumigated with methyl bromide at 20 – 32 g/m^3 for two days of exposure. Whenever gas concentration decreases, additional gases were added to keep desired concentration inside the building.

A piece of heavily infested wooden sample were kept inside the building during the fumigation. After aeration of the building, wooden sample were kept in glass cabinet for 3 months without any insect activity.

Key words: the furniture beetle, *Anobium punctatum*, wooden artifacts, historical buildings fumigation, methyl bromide

Introduction

There are many historical buildings including palaces in Istanbuln Turkey. Of these, 12 Ottoman palaces in Istanbul serve as museums under the administration of Department of National Palaces of Turkish Grand National Assembly. Artifacts made of wood and wood containing structures often suffer from extensive damage caused by wood-boring insects that over time can reduce large volumes of wood to hidden networks of sawdust-filled channels. The common furniture beetle, *Anobium punctatum* De Geer (Coleoptera: Anobiidae), is a widespread pest of wood in temperate regions, favored by high levels of relative humidity (Hansen and Jensen, 1998). Historical Palaces in Istanbul (Turkey) are infested with the furniture beetle (*Anobium punctatum*), because of the favorable conditions such as high humidity and temperature. Thus, it is a common pest of wooden objects and wooden parts of the Palaces. Precious old sculptures from wood, paintings with wooden frames as well as furs and skins in museums are very susceptible to damage by insects that are able to digest cellulose.

Wood-infesting beetles are difficult to control because their immature stages feed within wood, and usually remain undetected by conventional inspection methods. The larvae feed and grow within the wood creating a network of tunnels closely packed with frass (fine dust). The main sign of activity is fine dust of wood under the wooden objects, which was common in the palace.

Methyl bromide had been the most frequently used of the museum fumigats and many safe and effective treatments had been carried out all over the world (Bond, 1984). However, it is reactive and fumigation will produce chemical changes in objects. Objects such as wool and horsehair may give off a very strong smell after treatment. Methyl bromide has now been banned because it is an ozone-depleting gas. Thus, sulfuryl fluoride as an alternative to methyl bromide is now used for fumigating buildings.

The importance of the damage caused by the pests to Palaces has led to formation a project that financially supported by SPO (Turkish

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Republic Prime Ministry State Planning Organization) in 2003. In the context of that project the structure of the Ottoman Pavilion was fumigated. Below given fumigation was the last fumigation in Turkey for the museum disinfestations using methyl bromide.

Application Technique

The building constructed from a mix of wood and stone is a historical palace, in Istanbul (Turkey), which is a volume of 40.000 m^3, composed of two floors and a basement. It contains extensive use of mother-of-pearl that covered almost all of its surfaces. There are also detailed painted landscapes on the ceiling. Valuable old sculptures of wood, paintings on wood or with wooden frames, as well as parquet floor material are all very susceptible to damage by wood boring insects (Reichmuth et al., 1993). The main pest in that building was the furniture beetle. Damage was very serious on the wooden parts.

Fumigation of the building was combined with modified atmosphere application. All wooden artifacts and textile materials were confined in PVC cubes of 30m^3 volumes to apply with modified atmospheres composed of conditioned high nitrogen ((98.5%) in the palace. Modified atmosphere using nitrogen gas generator controlled by SCADA (supervisory control and data acquisition) system. At the end of application system were shut off and gas vent out of the cubes were closed, then fumigation of the building was started. During modified atmosphere application, building was sealed to improve the structure's fumigant retention properties. Doors and windows were sealed with methyl bromide proof polyethylene sheeting and tape. Particular attention was devoted to sealing of the building.

Because of fire risk of fan electricity inside the building, re-circulation fans outside of the building were used to gas introducing, sucking, distributing and also aeration. Thus, electricity was cut off inside the building during fumigation. Re-circulation system was consists of four pump (each 2 500m^3 per hour) and gas evaporation chamber (3 m^3). System sucks inside air and introduces it into the evaporation chamber, then extends mixed air to inside the building using PVC ductwork. Methyl bromide was released into the evaporation chamber using copper pipe connections.

For the sucking air from the building and introducing air mixed Methyl bromide PVC flexible pipe (40 cm diameter) were used outside of the building. Inside the building, sucking pipes (40 cm diameter) extended to each floor including basement. Main introducing main pipes inside the building extended to each floor including roof except basement. For each level, main pipe extended to each room using appropriate connection and pipe (10 cm or 20 cm diameter). When the re-circulation system was started to work, air was sucked mainly from the center of the each floor and basement using pipes (40 cm diameter). Sucked air pushed to the first and second floor and also roof. In each room, gas introduction was measured and tried to equalize according to the volume using sealing tape to the open end of the pipe. Before fumigation, gas distribution to everywhere inside the building was secured. Fumigant gas did not introduced to the basement, because methyl bromide heavier than air. So, it is expected that gas was naturally goes into the basement. Though, there were only sucking pipe in the basement to prevent accumulation of the fumigant.

Before fumigation, gas-monitoring lines were extended to the outside from different locations of the building. For the effectiveness tests, heavily infected wood piece collected from exchanged parts in carpenter's workshop were placed different locations of the building. For laboratory reared test insects, eggs, larvae, pupae and adult stages of *Trogoderma granarium* Everts (Coleoptera: Dermestidae), *Rhyzopertha dominica* (F.) Coleoptera, Bostrichidae, *Tribolium castaneum* Herbst and *Tribolium confusum* (DuVal) (Coleoptera: Tenebrionidae) were used to evaluation of the effectiveness of the application (Table 1).

Table 1. Numbers and the ages of laboratory reared test insect species according to the developmental stages used for fumigation.

Insect species	Developmental stages			
	Eggs	Larvae	Pupae	Adult
Tribolium castaneum	1 – 3 d (50)*	Mature (25)	1 – 3 d (15)	5 – 10 d (25)
Tribolium confusum	1 – 3 d (50)	Mature (25)	1 – 3 d (15)	5 – 10 d (25)
Trogoderma granarium	1 – 3 d (50)	Mature (25)	1 – 3 d (15)	5 – 10 d (25)
Rhyzopertha dominica	1 – 3 d (50)	Mature (25)	1 – 3 d (15)	5 – 10 d (25)

Test individuals number

After preparation of the system, fumigation was started with methyl bromide at 25 – 32g/m^3 for two days of exposure. Whenever gas concen-

tration decrease to 25 g/m^3, additional gases which is necessary because of the inevitable losses of gas were added to keep desired concentration during the first day inside the building. For the second day, gas concentrations inside the building were tried to keep 20 g/m^3. Re-circulation system were kept working during gas introduction and equalization inside the building. When the concentration of fumigant inside the building equalize after introduction, system were kept switched off till to another gas introduction.

After 48 – hour exposure period, sucking pipes separated from re-circulation system. Though, air from outside was pushed to the building through the gas introducing pipes. System were kept working for 24 hours, then windows and door opened for the aeration. After 6 hours, building was checked and secured to reentry.

Results and Discussion

During the last decades Methyl bromide was used to eradicate pests in artifacts in museums. In some countries, sulfuryl fluoride is used for the control of wood boring insects mainly *Anobium punctatum* and *Ptilinus pectinicornis* (Bess and Ota, 1960; Meikle and Stewart, 1962; Binker, 1993). But, available fumigants on the market were only methyl bromide and phosphine during our study in Turkey. Thus, we used methyl bromide for the fumigation of structure of the historical building.

With passive application of methyl bromide, gas build – up starts slowly in structure, and then it reaches maximum level and then, decreases because of leakage. The rates of decrease will vary depending upon gas leakage for the structural fumigation. With forced air recirculation, gas introduction into the structure can be increased and there will not be big difference on concentration between each floor. In our study, we observed that gas release into the structure was very quick, and gas concentration between each level of height in the building was not high, because of unique recirculation. The temperature during fumigation was around 22℃. In the present study, recorded gas concentration values were plotted against the exposure period (Fig 1). Concentrations built up to a maximum in a 6 h of the treatment as gas continuously added (Figs 1). The decay in gas concentration in the structure was 25% between 6 to 8 h of the fumigation. This can be attributed predominantly to (a) gas circulation was not enough to evenly distribution at that time of exposure in the building, so recirculation system was kept working, and (b) leakage. In the present study because of our strategy to keep the gas concentration stable, gas addition to the building was repeated till to end of fumigation. Thus, we could not calculate half loss time.

Table 2. Mortality of the life stages of test insects after fumigation (%)

Insect species	Developmental stages			
	Eggs	Larvae	Pupae	Adult
Tribolium castaneum	100	100	100	100
Tribolium confusum	100	100	100	100
Trogoderma granarium	100	100	100	100
Rhyzopertha dominica	100	100	100	100

After fumigation, heavily infected wooden pieces were kept in a ventilated class enclosure for 3 moths. Visual investigation showed there was no fine dust of wood under the wooden pieces. Moreover, mortality was also determined by cutting the wood piece to find larvae. Both indications shoved that fumigation was successful. After fumigation, laboratory test insect samples were kept a week in controlled condition, and mortality were determined. It was found that mortality was complete (Table 2).

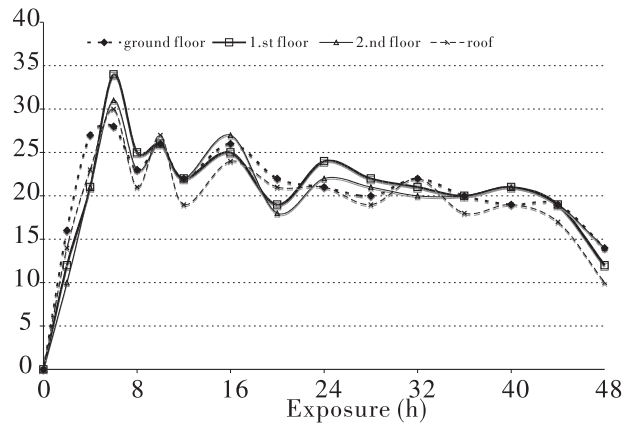

Fig 1. Methyl bromide concentrations (g/m^3) during fumigation of the historical building

Wood for construction, as artifacts and other purposes can be infested and attacked by insects being capable to digest wood. Our study showed that museums and palaces the aspect of keeping the structural stability and preservation of artifacts may be combined by using modified atmosphere and fumigation at the same time.

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