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Fumigant recirculation in Aynalikavak pavilion

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ABSTRACT

Aynalikavak Pavilion (Istanbul, Turkey) holds a special place among 18th century architectural works with its Audience Hall, its gesso mozaic windows, interior walls inscribed with fine examples of Ottoman calligraphy and other decorations such as the imperial monogram of Selim III, 28th Sultan of Ottoman Empire. Aynalikavak pavilion is one of the last and outstanding buildings of classical Ottoman Structure with its two storey facing the sea and one storey body facing the land. The building constructed from a mix of wood and stone has a volume of 5,000 m^3. Valuable old sculptures of wood, furniture, paintings on wood or with wooden frames, as well as parquet floor material are all very susceptible to damage by wood-boring insects. Wooden materials used both structure and furniture heavily infested with wood-boring common furniture beetle, *Anobium punctatum* (De Geer). It was decided to fumigate the building after restoration. Disinfestation of historical building by re-circulating of a gaseous fumigant through the building— fumigation technique. Before fumigation, the building was covered with PE film to make more gas tight structure. Unique re-circulation system was set up outside of the building. To verify the efficacy of the application, several pieces of heavily infested wooden samples were kept inside the building during the fumigation. Additionally, vials including mix cultures of *Rhyzopertha dominica* (Fabricius), *Lasioderma serricorne* (Fabricius), *Tribolium confusum* Jaquelin Du Val, and *T. castaneum* (Herbst) were also placed at different locations ofthe building during the fumigation. Fumigation was carried out using sulfuryl fluoride for three days. At the end of exposure, the concentration × time product (ctp) reached to 3,800 ctp. Then, the building was aerated using recirculation system. After aeration, wooden samples were taken and kept in glass cabinets for 3 months to observe any insect activity in the laboratory. Both wood samples and test insect results showed that sulfuryl fluoride successfully eradicated the furniture beetle.

Key words: *Anobium punctatum*, Furniture beetle, Pavilion fumigation, Sulfuryl fluoride

The architecture of Istanbul describes a large mixture of structures, which reflect the many influences that have made an indelible mark in all districts of the city. The architecture inside the city proper contains buildings, statues, and functional constructions which came from Byzantine, Genoese, Ottoman, and modern Turkish sources. The city has many architecturally significant entities. Throughout its long history, Istanbul has acquired a reputation for being a cultural and ethnic melting pot. As a result, there are many historical mosques, churches, synagogues, palaces and pavilions in the city. 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, favoured 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 favourable 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

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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
Lasioderma serricorne	1-3 d (50) *	Mature (25)	1-3 d (20)	5-10 d (25)
Tribolium castaneum	1-3 d (50)	Mature (25)	1-3 d (20)	5-10 d (25)
Tribolium confusum	1-3 d (50)	Mature (25)	1-3 d (20)	5-10 d (25)
Trogoderma granarium	1-3 d (50)	Mature (25)	1-3 d (20)	5-10 d (25)
Rhyzopertha dominica	1-3 d (50)	Mature (25)	1-3 d (20)	5-10 d (25)

* Test individuals number; figures in parentheses indicate numbers

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 fumigants 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 been banned because it is an ozone-depleting gas. Thus, sulfuryl fluoride as an alternative to methyl bromide is now being 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 Turkish Republic Prime Ministry State Planning Organization (SPO). In this context, the structure of the AynalikavakPavilion was fumigated. Below given fumigation was the example of the fumigation with recirculation in Turkey for the museum disinfestations using sulfuryl fluoride.

MATERIALS AND METHODS

Aynalikavak Pavilion building constructed from a mix of wood and stone is a historical Palace in Istanbul (Turkey), with a volume of 5.000 m^3, composed of two floors. Valuable old sculptures of wood, furniture, 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 of this building was the furniture beetle, *Anobium punctatum*. Damage was very serious on the wooden parts.

Fumigation of the building was carried out with the re-circulation system. Building was sealed to improve fumigant retention properties of the structure. In order to seal the building steel frame were set-up from the outside. There was gap of one meter between the frame and the building wall. Two sheets of polyethtlene material were used to seal the buildings. Sleeves were closed with the sand snakes.

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 the fumigation. Recirculation system consisted of two pumps (2,500 m^3/h) and a gas evaporation chamber (3 m^3). System sucks inside air and introduces it into the evaporation chamber, then extends mixed air inside the building using PVC ductwork. Sulfuryl fluoride was released into the evaporation chamber using steel-pipe connections.

For the sucking air from the building and introducing air-mixed sulfuryl fluoride PVC flexible pipes (40 cm diameter) were used outside of the building. Inside the building, sucking pipes (40 cm diameter) extended to each floor including ground. Main introducing 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 or 20 cm diameter). When the re-circulation system was started to work, air was sucked mainly from the ground floor using pipes (40 cm diameter). Sucked air pushed to the first 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 introduce to the basement, but all openings between each floor including the roof-stair door were kept open during the fumigation. So, it was expected that gas was naturally moved into the basement, though there was 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

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

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

the building. For the effectiveness tests, heavily infected wood piece collected from exchanged parts in carpenter's workshop were placed at different locations of the building. For laboratory-reared test insects, eggs, larvae, pupae and adult stages of *Trogoderma granarium* Everts, *Rhyzopertha dominica* (Fabricius), *Tribolium castaneum* (Herbst), *Tribolium confusum* (Jaquelin Du Val) and *Lasioderma serricorne* (Fabricius) were used for evaluate of the effectiveness of the application (Table 1).

After preparation of the re-circulation system, fumigation was started with sulfuryl fluoride at between 70 and 45 g/m^{3}during the fumigation for 82 h of exposure. At the beginning, 350 kg sulfuryl fluoride was introduced in two hours of application. The measured gas concentration was reached to 70 g/m^{3}sulfuryl fluoride. Whenever gas concentration decreased to 45g/m^3, additional gases was introduced to keep desired concentration during fumigation inside the building. Re-circulation system was kept working during gas introduction and equalization inside the building. When the concentration of fumigant inside the building equalized after introduction, system was kept switched off till another gas introduction.

After 82 h exposure period, sucking pipes were separated from re-circulation system and extended to elevated level for the aeration. Though, air from inside was sucked from the building through the gas introducing pipes to the aeration pipe. System was kept

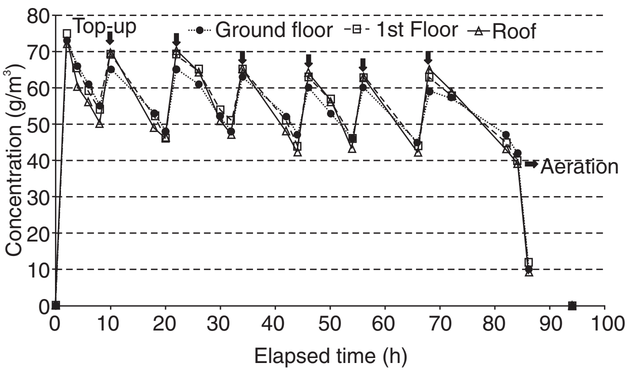

Fig 1. Sulfuryl fluoride concentrations (g/m^3) during fumigation of the Aynalikavak Pavilion

working for 2 h, the gas concentrations inside were decreased to 10 g/m^3. Then, the cover of the building was opened as well as windows and door opened during the aeration for the night. After 8 h, aeration system was restarted for an hour and the building was checked and secured to re-entry.

RESULTS AND DISCUSSION

During the last decades methyl bromide was used to eradicate pests in artifacts in museums. After the phase out of methyl bromide, sulfuryl fluoride is used in controlling wood-boring insects, mainly *Anobium punctatum* (Bess and Ota, 1960; Meikle and Stewart, 1962; Binker, 1993). Thus, we used sulfuryl fluoride for the fumigation of structure of the historical building.

With passive application of sulfuryl fluoride, gas build-up started slowly in structure, and it reached the maximum level and then decreased because of leakage. The rate of decrease varies depending on gas leakage for the structural fumigation. With forced-air re-circulation, gas introduction into the structure can be increased and there will not be much difference in concentration between each floor. In our study, the gas release into the structure was very quick, and gas concentration between each level in the building was not different from each level, because of unique re-circulation. The temperature during fumigation was around 24^{o}C. In the present study, recorded gas concentration values were plotted against the exposure period (Fig 1). Concentrations built up to a maximum in 2 h of the treatment as gas added (Fig 1). The decay in gas concentration in the structure was 27% between 8 and10 h of the fumigation. 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.

After fumigation, heavily infected wooden pieces were kept in a ventilated class enclosure for 3 months. Visual observation 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 observation showed that fumigation was successful. After fumigation, test insect samples were kept for a week in controlled condition of the laboratory, and mortality was determined. The results showed complete mortality (Table 2).

Wood for construction, as artifacts and other purposes can be infested and attacked by insects being capable to digest wood. Our study showed that wood pests can be controlled by using sulfuryl fluoride.

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