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THERMAL TREATMENT FOR BED BUGS

[1]ANTON HASENBÖHLER AND [2]ALEXANDER KASSEL

[1]Gupfenstrasse 33, CH-8166 Niederweningen, Switzerland
[2]APC AG, Ostendstrasse 132, D-90482 Nürnberg, Germany
ahasenboehler@gmx.ch; kassel@apc-ag.de

Abstract It is the challenge of every thermal treatment to achieve the lethal temperatures in inaccessible harborages. With thermal treatments hot air is the heat transfer medium. This medium has a low heat capacity and the heat transmission rate from hot air on a solid body is relatively poor, especially if there is a small temperature difference between the heat transfer medium and the surface of the body. It is necessary to move big volumes of hot air with a turbulent flow. The resulting rise in temperature is not more than 5°C per hour and this slow rise prevents damage of the surrounding materials. The operating band to kill bed bugs without damaging materials is 15-20°C and lies between 45°C and ~60°C. Holding a constant high temperature after heating up is necessary to penetrate cracks, crevices and hollow spaces. A permanent temperature control at many measuring points with a hand-infrared measuring device followed by corrections through newly positioning the heater/ventilator are necessary. Not all cold spots were detected before the treatment and that the thermocouples were not always placed at the critical points. The movement of bed bugs to cooler areas begins above temperatures of 30-35°C. This escape is interrupted through applying physical and /or chemical barriers.
Key Words Heat transmission, *Cimex lectularius*

INTRODUCTION

Bed bug infestations are increasing worldwide. The lost know-how first had to be aquiered and spread along the PCO. This knowledge was elaboured, collected and published by Dogget (2010) and today is considered as standard for the control of bed bugs. In this guide thermal treatment is mentioned in four lines, although the classic chemical methods several show deficits, for example: resistance against many insecticides; strong exposition of people to insecticides because of necessary multiple-applications in close surroundings. Some objects like televisions and other electronic devices, textiles and matrasses can't be treated with insecticide formulations and have to be removed from the room for alternative treatment, which can lead to the danger of spreading bed bugs to other rooms or accomodations.

The development and improvement of alternative methods to control bed bugs are therefore a must. The use of high temperatures to kill insects is not new and is used successfully against stored products pests in the food industry for many years (Adler, C. 2002; Adler et al. 2004). In practice mainly the ThermoNox®-technique has proven to be effective and convenient (Hasenböhler, A. 2006; Hofmeir, H. 2000; Hofmeir, H. 2002; Hofmeir, H.2005). The research on the bed bugs *Cimex lectularius* capability of resistance against heat treatments have been conducted at the UBA in Berlin (Schrader et al., 2009).

MATERIALS AND METHODES

Heat Characteristics of Different Materials

What can go wrong during heat treatment? Various physical processes may occur during a thermal treatment, namely: Reversible / irreversible deformation due to unequal temperature (homogenous material); Reversible / irreversible deformation due to unequal extension (different material); Evaporation of components: water, softeners; Reduction of strength: modules of draw, pressure; Initiation of phase transitions; Initiation of chemical reactions. In order to avoid damages due during warming of different materials, their respective coefficients of extension have to be regarded. Some important coefficients are: Concrete $10 \cdot 10^{-6}$ K^{-1}; brick 6, wood 15, steel 12, aluminium 24, glass 9, plastics 80-200.

It is vitally important that combined materials with differing extension coefficients are capable of extending independently – care should be taken to separate (e.g. loosen or remove locks, screws) such materials wherever possible.

Concrete. The deformation of a slab of concrete due to difference in temperature is shown in the following: Thickness: 30 cm, Difference in temp.: 40 K, a = 10. 10^{-6} K^{-1}, Length: 10 m; Difference in extension: 4 mm; Radius of curvature: 750 m; Strength: 14 N / mm^2 << compressive strength (30 – 50 N / mm^2). Differences in temperature are not critical: No cracking; No inacceptable deformation; Time too short for dehydration.

Wood. Wood behaves in a characteristic way when heated, in general it can be stated that: wood is very temperature resistant; thermal extension is anisotropic (natural wood); wood warps below 30% RH; wood is strongest deformed by dehydration >> thermal deformation; thermally occurring forces << compressive strength; the necessary humidity close to wooden installations is: RH.> 30%.

Plastic. Different plastic materials display the following behaviour: Duroplastics: non soften, non melt, decompose only at T > 100 °C (epoxy, polyester, Teflon, "Bakelite"); Thermoplastics: can soften, glass point, melt only at T > 100 °C (PU, PE, PVC); Elastomers: are already soft elastic, decompose only atT > 100 °C (gum, caoutchouc). Some thermoplastics have a softening temperature in the range of between 50 – 60 °C (heat treatment). They can soften: Permanent impressions by resting vertical load; Susceptible to shear stress: particular adhesives, soft-PE, soft-PVC; Duroplastics, elastomeres and most thermoplastics do not pose a problem below 60 °C.

Conclusions for heat treatments: Most of the widely used materials can be heated to 55 – 60 °C without problems; the duration of 24 – 48 h is too short for causing structural damage; as a precaution preceding tests can be helpful; the presence of wood requires humidification

Equipment for Heating

The ThermoNox® procedure is based on the principle that only the air inside the building has to be heated and high air temperatures are not necessary. The heater causes a circulating airflow inside the room and this results in a very low energy consumption. During the heat treatment the temperature is controlled directly. Each heater automatically monitors and controls the temperature of its airflow and consequently that of the room. The treatment can work with lower temperatures and a lower energy consumption. This is very important in rooms with sensitive electrical components or electronic devices.

Owing to the construction of the heater, the air movement and the heat transfer are at floor level. This is a big advantage because bed bugs will emerge from beds and other furniture, cracks and crevices, fall onto the floor and try to flee but are not able to escape to cooler areas. The heater (Figure 1) is equipped with an axial quite fan. Air is sucked into the unit through the bottom sides and fed through the damper registers. Warm air leaves the heater unit horizontally at the top. The temperature of the circulated air is controlled by integrated thermostats. The heater is fitted with two wheels and a handle which makes it easy to transport and to remove it during the heating period.

Preparing for thermal treatment. The first step is to remove all items, which do not tolerate heat and are not usually infested with bed bugs. Objects that have to be removed from the room: Medicine, pharmaceuticals, perfumes, cosmetics; candles, colors, varnish, glues; Pressure tanks like sprays and fire extinguishers; food, plants, cleaning supplies.

After this further preparation is necessary. In order to treat all remaining objects of the room effectively it is important that they can be heated with warm air from all sides. This doesn't essentually have to happen at the same time, but can be accomplished in following steps.

All items should be lifted from the floor, turned 180° during the treatment or moved horizontally, if possible.

Barriers have to be installed at all gaps and break-throughs of walls, ceilings and floors, at windows and at doors, to prevent the evasion of escaping bed bugs to cooler areas or neighbouring rooms and to prevent their return after the treatment. Barriers can be adhesive tape, silicone mass, insecticide-coating or applied silica dusts. Bigger voids should be opened, because they are not heated enough in the normal heating time and then can be used as a refuge for the escaping bed bugs.

Measures to be taken before thermal treatment. Disconnect refrigerator and TV; Switch off air conditioning; Open bedstead; Remove headboard and cover plates; Put sheets, blankets and bath towels in a plastic bag for bringing out or hang them over a hat stand for thermal treatment in the room; Disconnect fire sprinklers or change the bulbs' opening > 90°C; Sealing of the treating room due to escaping bed bugs. The walls, ceilings and floors of the neighboring rooms will heat up to temperatures of about 30°C. Blocking these rooms is recommended.

Heating Procedure

Thermal treatments follow three phases: heating, maintaining target temperature and cooling.

Heating phase. Energy requirements are highest during the heating phase because all materials of a building including everything inside have to be heated up to the target temperature. During this phase heat is carried exclusively by the air inside the building. Room air is heated not once but is recycled through the heating apparatus, thus kept at the maximum achievable temperature. Since the specific warmth in air is relatively poor high volumes of air have to be circulated. Heat transmission from air on a solid body (i.e. building material, furniture, equipment) is described with this formula:

$$Q = \alpha\ A\ t\ \Delta\delta \text{ (air on smooth surface, v< 5 m/s) } \alpha = 5.6 + 4\ v$$

The amount of heat transmitted Q on the surface A is directly dependent on the heat transmission coefficient **α,** the duration of transmission **t** and the temperature gradient **Δδ** between the heated airflow and the surface of the object to be heated**.**

On the right of the equation two values appear given: A the surfaces and Δδ the temperature difference. Since the temperature of the room air must not exceed 60°C, the maximum temperature difference can be regarded given. Adjustable are only **α** and **t.** The heat transmission coefficient **α** contains the air velocity **v**, and the time **t** for heating is derived from the other parameters.

The limiting factor by the heat transfer through a solid body is normally the heat transmission on the surface of the body and not the following heat conductivity in the body. Buildings, furniture and other equipment are made from different material, taking up, storing and conducting heat at different rates. This means that there could be a variation in “heat demand” in different rooms, as well as within a single room. The warm air current of the ThermoNox®-oven is directed towards the highest heat demand. To ensure a regular heating of the room an additional fan is installed in the “shadow “of the oven. Both the heating phase and the maintaining phase have to be monitored on site. Surface temperatures of floor, ceiling and walls can be checked with an infrared thermometer. Deviations of the target temperature can be adjusted by repositioning of the heater and/or the fan.

Maintaining phase. During the maintaining phase it is ensured that the target (kill) temperature is reached in all parts of the treatment area and maintained throughout the duration of the treatment. The longer the temperature can be maintained in that phase, the better heat dissipation is guaranteed and a higher treatment efficacy can be achieved. During this phase heaters cut back automatically to 50% capacity and alternate between on/off, because only heat loss hast to be compensated.

Cooling phase. Towards the end of the maintaining phase doors and windows are opened, the heaters are switched off but the axial fans are left running. The effect is a “reversed” heat transmission supporting the cooling of building and installations.

Conclusions for a safe thermal treatment: Room air max. 60°C, heated through recirculation move heated air with a high velocity to increase heat transmission and to reduce overall heating time; Distribute heated air evenly throughout the treatment area to ensure a synchronous, slow and therefore secure heating of everything inside the area; Avoid local overheating (possible damage), this requires a adequately exact temperature control in the heat generating equipment.

RESULTS

Over 150 heat treatments against bed bugs with the ThermoNox® method have been performed in Switzerland and in Germany up to the present. A typical heating curve of a thermal treatment of bed bugs in a hotel room is shown in Figure 2.

The temperature was monitored with a data logger placed near the window. The first 24 hours are the so called heating (up) phase. At the beginning, the curve rises steeply because of a big temperature difference between heated airstream and object. Then it becomes flat and nears asymptoticaly the desired temperature value. After 24 h the maintaining phase begins and the thermostat switches off the heating elements. As soon as the temperature falls the heating element is reactivated to maintain the desired temperature in the room between 55°- 60°C. The specific energy consumption is 2 – 3 kW/m^3 treated room.

DISCUSSION

The heat characteristics of the different materials in a room prohibit a thermal treatment above 60°C, because the risk of heat damage increases strongly. As laboratory trials show (Schrader and Schmolz, 2009) higher

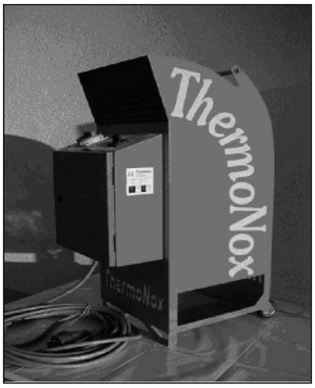

Figure 1. ThermoNox® heater WEO 4.5/9 (kW)

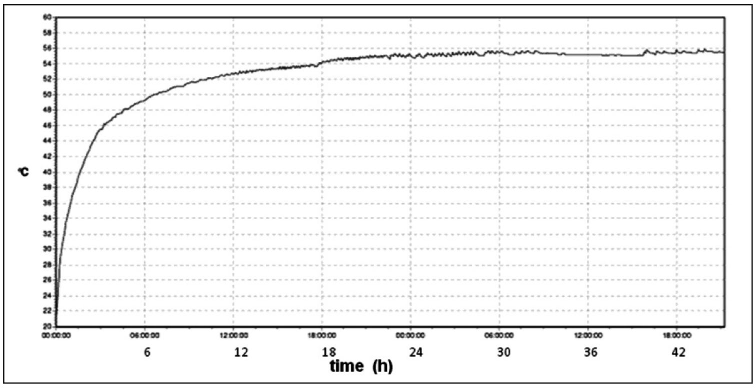

Figure 2. Heating curve of a thermal treatment in a hotel room.

temperatures are not necessary to kill the bed bugs. An extinction in one single application demands killing all developmental stages including the temperature tolerant eggs, particularly as thermal treatments have no longtime effect. Usually the female bed bug sticks its egg on surfaces in hiding places. For the thermal treatment this means that the lethal heat has to reach all these hiding places. The difficult fact is that these surfaces often lie in cracks and crevices and are made up of poorly conctive materials like wood, (wall) paper, cloth and textiles.

Already at the beginning of the heating phase at 30-35°C the bedbugs start leaving their hiding places and purposefully look for cooler and more humid hiding places. Here there is the danger that they escape to neighbouring rooms through pipe or cable shafts and disperse. It is also possible that they find cooler zones, “cold spots” and accumulate there. Through applying barriers in the preparation phase the dispersal has to absolutely be prevented. Likewise the room has to be searched for likely existing hot spots.

As infested items are largely treated in the room, the risk of dispersal is eliminated and there are no additional costs for external treatments.

It is a small band of the temperature scale, which is reserved for an effective thermal treatment of bed bugs and where no heat damage occurs on the object. Herefore we need a heat production that warms air in a air circulation process and revolves the air rapidly. The heat transfer under these circumstances takes time – physics sets these limits. Thermic treatments of bed bugs under damage preventive conditions can therefore not be performed within 3-6 hours. The longer treatment time (30- 40 h) demands reliable working equipment, because they can’t always be surveyed.

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