Resistance is Futile: The increasing use of heat treatment in urban pest control

- Heightened regulation of chemical insecticide use in the developed world
- Fewer insecticides have entered the market over the last 40 years
- Less differentiation in chemical control methods between pest management companies have lead an increase in insect resistance
- Industry shift towards non-chemical and integrated pest control methods
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Background

Increasing regulation of chemical insecticide use in the developed world has meant that fewer novel insecticides have entered the market over the last 40 years than have left due to human and/or environmental safety concerns (Ollinger & Fernandez-Cornejo, 1995). This has resulted in less differentiation in chemical control methods between pest management companies, leading to increased reports of insect resistance and a move towards non-chemical and integrated pest control methods (Field, 1992; Greene & Breisch, 2002).

The use of physical methods in urban pest control has developed rapidly in the past decade, particularly to target the ever increasing prevalence of bed bugs (Pinto et al, 2007). Space treatments such as heating, cooling and removing oxygen from their environment are all ways of controlling insect pests, without having to legally register a chemical insecticide. Of these methods heat treatment technology is the most mature and has arguably the broadest range of application.

The effect of heating on insects and arachnids

Pest insects and arachnids have differing tolerances to heat, however at high temperatures many of the common basic building blocks and metabolic processes of living animals will be affected with lethal results. The effectiveness of a treatment is determined by both the temperature and the treatment time – for example, an insect that will be killed by exposure to 56°C for 20 minutes may also die at 49°C for 2 hours. Humidity also has a bearing on efficacy but to a lesser extent.

Proteins molecules form enzymes, which only function efficiently within certain temperature ranges. Enzymes are essential to metabolic processes which in turn are essential to life. Proteins are destroyed at high temperatures, usually referred to a ‘denaturing’ effect. This occurs in many ways but a change in molecular shape is most common. Denaturing of many common proteins will occur at 55°C and is irreversible.

Table One: Common pests, treatment times and upper lethal temperatures (redrawn from Strang, 1992, and Olsson et al, 2013 and Kells & Goblirsch, 2011 timescales vary).

<table>
<thead>
<tr>
<th>Common Name</th>
<th>Scientific Name</th>
<th>Lower Lethal Temperature °C</th>
<th>Upper Lethal Temperature °C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Furniture beetle</td>
<td>Anobium punctatum</td>
<td>-16</td>
<td>48</td>
</tr>
<tr>
<td>Cigarette beetle</td>
<td>Lasioderma serricorne</td>
<td>-12</td>
<td>49</td>
</tr>
<tr>
<td>Biscuit beetle</td>
<td>Stegobium paniceum</td>
<td>-18</td>
<td>49</td>
</tr>
<tr>
<td>Varied carpet beetle</td>
<td>Anthrenus verbasci</td>
<td>-20</td>
<td>&gt;40</td>
</tr>
<tr>
<td>Larder beetle</td>
<td>Dermestes lardarius</td>
<td>&lt;-2</td>
<td>54</td>
</tr>
<tr>
<td>Confused flour beetle</td>
<td>Tribolium confusum</td>
<td>-20</td>
<td>54</td>
</tr>
<tr>
<td>Warehouse moth</td>
<td>Ephesia elutella</td>
<td>-16</td>
<td>64</td>
</tr>
<tr>
<td>American cockroach</td>
<td>Periplaneta americana</td>
<td>-15</td>
<td>45</td>
</tr>
<tr>
<td>Bed Bug</td>
<td>Cimex lectularius</td>
<td>&lt;-13</td>
<td>48</td>
</tr>
</tbody>
</table>

At high temperatures, insect spiracles will open and fats in their exoskeleton will start to melt with the resulting
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loss of water and nutrients leading to death. Some species of insects, such as those that have robust exoskeletons, are less prone to death in this way. Others such as moths have relatively thin exoskeletons and will succumb at much lower temperatures through water loss. A drier treatment environment (lower humidity) will require slightly lower temperatures and/or shorter treatment times for lethal effect (Thompson & Leaf, 2011).

Example 1: The graph (right) shows the temperature versus time plot during a standard Entotherm treatment.

The temperature zones are:

**Sub-Lethal Zone:** The temperature is below the target treatment temperature.

**Entotherm Zone:** The temperature of air and all items in the treatment area are above the minimum specified treatment temperature, but below the maximum allowed temperature. The recommended temperature range for Entotherm treatments is between 56°C and 60°C (133°F to 140°F).

**Damage Zone:** The temperature is above the target treatment temperature and there is a serious risk of damage to items in the treatment area. Manual intervention is required immediately to correct the temperature by adjusting thermostats or moving heaters and circulation fans.

Temperatures and treatment times are accurately recorded in real-time as proof of achieving the heat exposure requirements.

Insect pests such as bed bugs and cockroaches can be difficult to eliminate as they can hide in the deepest recesses of infested objects and wood boring insects are very challenging to treat within a materials with a high heat capacity that is often finished with varnishes or paints that do not react well to heat (Kells & Goblirsch 2012). Heat capacity is the quantity of thermal energy required to increase the temperature of a material by a given amount. Materials with a higher heat capacity require more thermal energy to reach the same temperature as materials with a lower heat capacity.

All objects contain some thermal energy and may lose it or retain it as different rates depending on the material. Heat is defined as the transfer of thermal energy between two objects. This is usually measured as a difference in temperature between the objects.
The transfer of energy between the two will stop when both objects achieve the same temperature.

Raising a room or container to a uniform temperature high enough to kill all life stages of insects and arachnids within requires the conversion of energy (chemical fuels or electrical current), into a rise in air temperature. How this is achieved varies with the cost of fuel in the location the service is offered. For example, propane heaters may be more cost effective in areas where this fuel is readily available; whereas thermally conductive gels run from grid-generated electrical supply may be favoured in others.

On a smaller scale heating clothes in an electrical dryer is sufficient to kill bed bugs on or in clothing/bedding and hand-operated wet steam cleaners are useful for treating furniture and fixed objects in situ (again, bed bug treatments are the most frequent application of the technology in urban pest control) (Naylor & Boase, 2010). Equally, microwave treatment of timber will raise the temperature of water within the timber (Mõlder et al, 2013; Novotny, 2013). Whilst the principles are the same, these methods are not considered in this paper.

Risks of heat treatment and alternatives

These risks and hazards include those associated with flammable materials, extremes of temperatures, electricity and heat-conducting liquids, but these can be managed by the strict controls and procedures.

- **Re-infestation.** Articles and areas are susceptible to re-infestation due to an absence of residual effect. Used as part of an integrated pest management program other risk reduction measures can be used in tandem with heat treatments. Otherwise—this is generally ‘by design’.
- **Cost varies with fuels sourcing.** Heat treatments are price-linked to the availability of fuel which may fluctuate.
- **Encumbrance.** Articles need to be placed within a container or else the heating system needs to be capable of heating a large (room-sized) area. Difficulties arise when insect activity is within the fabric of the building, e.g.: timber bearings embedded within walls.
- **Accuracy of monitoring.** Without accurate monitoring equipment and training, pockets of cool air or material can remain.
- **Damage.** Warping and cracking of plastics and organic material through water loss is a serious hazard that must be mitigated by thorough risk assessments, particularly with unique artefacts and museum pieces.

Benefits of heat treatment

Heat treatments for the sanitation of items and enclosed areas are a relatively mature technology having shown a steady increase in use since the phase out of methyl bromide nearly a decade ago. It has significant benefits over other non-chemical remediation:

- **Minimal business disruption.** Quick, efficient treatment. All life stages can be killed in a single service visit.
- **Protects business reputation.** Pest problems are solved rapidly and thoroughly.
- **Multiple treatment areas.** Versatile to offer simultaneous treatment, hence saving time.
- **No prospect of resistance.** Not even the most resilient of insects can survive the levels of heat generated by commercial service treatments.
- **Minimises overall cost.** Replacing items such as mattresses that are difficult and expensive to treat by conventional methods.
- **High quality service.** All treatments are conducted by specialists that are fully trained.
Physical pest control alternatives to heat include:

- **Rapid cooling.** Movement of compressed gas poses a number of logistical problems for this treatment as does the risk of insect diapause (rather than death) at low temperatures.
- **Anoxia.** Reducing oxygen levels inside a container to as close to 0% as possible for as long as is required to kill all the insects in or on the treated article. However, best results are achieved with a raised temperature (up to 30°C) to increase the rate of insect respiration which in turn increases mortality. This is a useful treatment for delicate or wooden objects (Rust et al. 1993).

**Summary**

The science of heat treatment is not so much in the generation of heat as in the uniform distribution of hot air and the careful monitoring of the environment being heated.

Ensuring uniformity of the treatment with respect to penetration and distribution of heated air is critical for effective pest control, more so given that many of the insects targeted by this treatment occur in situations where multi-visit treatments are not ideal.

Many objects which possess varying thermal properties will be found within and surrounding the treatment area and an understanding of thermodynamic principles and properties is necessary to ensure consistent results. Higher temperatures will speed up the heating process but increases the risk of damage to the articles or area.

Ensuring a uniform treatment with accurate monitoring is paramount to success.

**References**


