CHAPTER 6

Heat, an age-old technology conquers insect pests in structures and buildings

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Environmental concerns and an emphasis on integrated pest management has led to increased interest in the use of heat as an alternative to chemical fumigation. Researchers at the CSIRO Stored Grain Research Laboratory have recently demonstrated the successful use of this age-old technology to control insect pests in work environments where fumigation would present serious practical problems.

The CSIRO Stored Grain Research Laboratory (SGRL) used heat in recent trials to disinfest two different types of facilities that store machinery, processing equipment, and seed and other plant material. These facilities are adjacent to offices and other functional areas that would have been unacceptably disrupted if chemical fumigation had been used. The operation was successfully undertaken over two days with minimal impact on adjacent areas.

The concept of heating machinery plant, materials and structure to control insect pests is not new. In the early 1900's several food processing companies in the United States used heat to successfully control pests. Flour mills and food processing plants in the United States and Canada now routinely incorporate heat disinfestation into their pest control strategy. In Australia, several cereal processing companies have also used 'plant bake-outs' as an alternative to fumigation but the process could be applied much more widely.

The process of heat disinfestation is not complex and provided a few simple guidelines are followed this method could be a useful alternative to chemical fumigation in many and varied situations. Heat is pervasive and insect kill is instantaneous when target temperatures are attained. To ensure effective treatment using heat there needs to be sufficient air circulation to achieve the desired temperature uniformity throughout the volume being treated.

Audit of treatment area

A temperature of 55 to 60 degrees Celsius (°C), maintained for 24 hours, is essentially all that is required to kill insects. Most industrial equipment and materials can cope with such treatment without damage. The important first step is to undertake a thorough audit of the area to ensure that the treatment temperature will not present a hazard to equipment, materials and structures in the area. In such an audit the possible presence of low flash-point materials is a particularly important consideration. CSIRO's experiences with heat treatments suggest it should be possible, in most circumstances, to complete such an audit quite quickly.

Insect susceptibility to heat

Insect pests of stored foods are killed within seconds when exposed to temperatures above 60°C. The exposure time required to kill insects increases with decrease in the treatment temperature, taking a few hours at 50°C and days at 45°C. The time taken at a given temperature to kill all insects infesting grain is shown in Table 1. At temperatures that are not instantly lethal, insects die through heat stress and dehydration. Heat can also make insects more susceptible to other methods of treatment.

Table 1: Temperature-time mortality relationship

99.9% mortality is reached in	at a temperature of
Less than one minute	60°C
5 minutes	57°C
20 minutes	55°C
29 hours	50°C
About 96 hours	45°C

Heat treatments

In the CSIRO trials, an initial heat treatment was undertaken within a research facility used for handling seeds and assorted plant material.

These premises had become heavily infested with the grain moth Sitotroga cerealella and associated mites. Chemical fumigation was unattractive because the facility was located adjacent to offices and other functional areas. A "bake-out" procedure was recommended to rectify the problem. After successfully completing this operation, another facility at an experimental research station was successfully disinfested. This building was substantially larger, less congested with materials and had walls insulated with polystyrene, which was a significant advantage.

The first seed and plant handling facility consisted of a main room about of 180 square metres area and 4 metres high, which housed large equipment, and several smaller storage rooms. The large amount of plants, grain and soil samples were kept "in-situ" so the heat treatment carried out also disinfested all stored material and the plant handling equipment that filled the area.

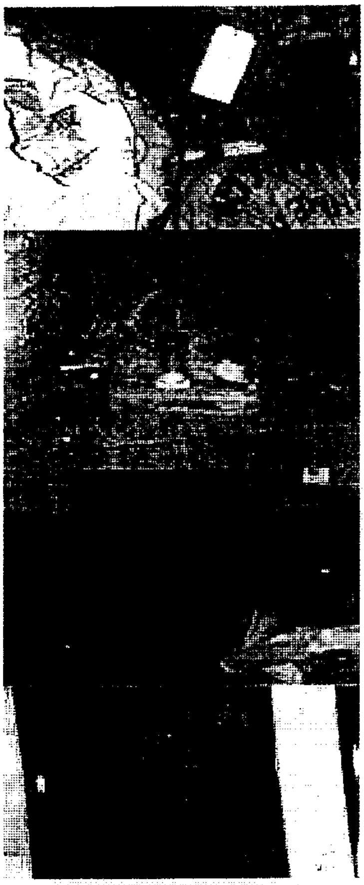


Figure 1. Containers with test insects were placed amongst stored bags of material in the plant handling area before heat treatment

Most of the plant samples were in small paper bags inside plastic bags, which were scattered across the whole area, on the floor and on and under tables (Figure 1). The equipment left in the area during heat treatment included an electronic balance, plastic fittings, power switches, two plant dryers, a steam generator, and the smoke alarms and the sprinkler system. The ancillary rooms were filled with seed and plant samples in sealed containers in plastic baskets. Figure 2 shows the floor plan of the area.

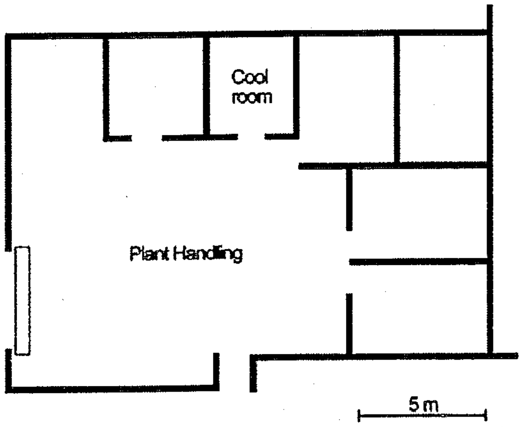


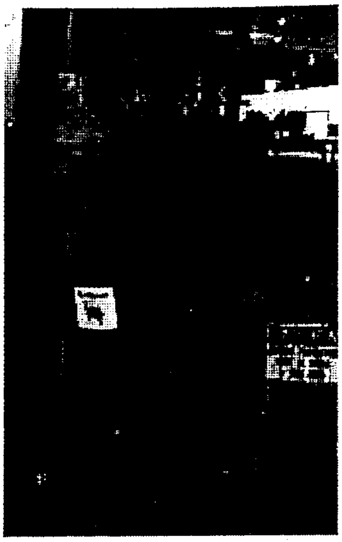
Figure 2. Floor plan of initial facility treated. Unmarked rooms were used for storage. Office and laboratory facilities were above and adjacent to treatment area.

To prepare for the fumigation the researchers used a heat treatment check list that was presented at the 1999 Heat Treatment Workshop in Manhattan, Kansas, USA (Pedersen, J.R. 1999). Rather than disable the fire sprinkler system, the heads were replaced with units set to trip at 93°C, well above the planned disinfestation temperature. The doors, windows and a ventilation duct had to be reasonably sealed, but essentially only to control the hot air flow. The injection of hot air into the room using large gas burners required controlled escape of air during the treatment.

The layout of the second facility was more open (Figure 2a), and seeds and other plant material were packaged onto shelving. The building was about 430 square metres in area and 4 metres high.

Equipment and monitoring

No exotic equipment, materials or processes are required for heat disinfestation operations. All of the necessary equipment is readily available from hire contractors.



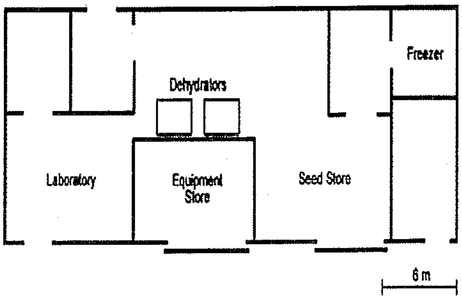


Figure 2a. Floor plan of second facility treated. Unmarked rooms were used for storage. Office facilities and work areas were adjacent to treatment area.

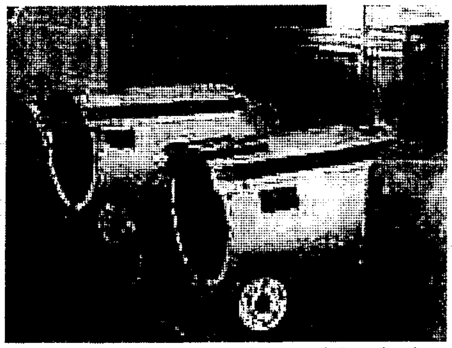


Figure 3. Gas burner units used for the heat disinfestation.

Two industrial gas burners, with capacity variable from 17 to 70 kW, were hired and positioned outside the building to blow hot air into the main area (Figure 3). One burner was run at full capacity and the other one was used to control the heat so the ceiling temperature would remain between 63°C and 70°C. The second burner was not brought into operation until six hours into the heating operating. Six large commercial fans were used to circulate the hot air and to direct the air into the ancillary rooms.

Computer-monitored thermocouples were used to monitor the temperature at eleven points in the area. These were located in heat-sensitive areas (near sprinkler heads), in places difficult to heat (eg. under bags of plant material beneath tables) and in representative locations from floor to ceiling and in the ancillary rooms.

The aim of the trial was to raise the whole volume to a sufficient temperature and for a sufficient time to kill all the insects. The lowest average temperature was 48°C (max. of 52°C) inside one of the ancillary rooms; there the temperature was maintained above 45°C for almost 22 hours.

Not surprisingly, the maximum temperatures were near the ceiling, reaching close to 70°C, so there was a considerable temperature range across the volume treated. The temperature profiles obtained from sensors placed at different points in the premise are shown in Figure 4.

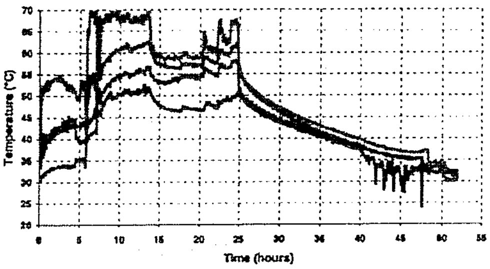


Figure 4: Sample temperature profiles during heat treatment of the first store facility. The highest temperatures were at the ceiling and the lowest were in an ancillary room.

Figure 5. Burner and fans used during the trials

The heaters were shut down after 22 hours. The heat treatment was followed by removal of all plant material, grain and soil samples, and steam washing of the floor. During this process the area was checked for live insects but none were found anywhere in the treated area.

There was no evidence of damage to any of the equipment that was left in the area during heat treatment, and there was no damage to doors, windows, glass, ducts and seals. Figure 5 shows the fans and the burners used during the heat treatment process.

In the second operation at the experimental research station, much better temperature control was achieved. Several ceiling fans installed in the facility were used in conjunction with two industrial gas burners positioned at ground level. The ceiling fans effectively achieved a more uniform vertical temperature distribution than just using the larger horizontally-directed fans that were used in the first operation.

The temperature profiles obtained from sensors placed at different points in the second building are shown in Figure 6. The maximum temperature was about 60°C and the average treatment temperature was 52°C.

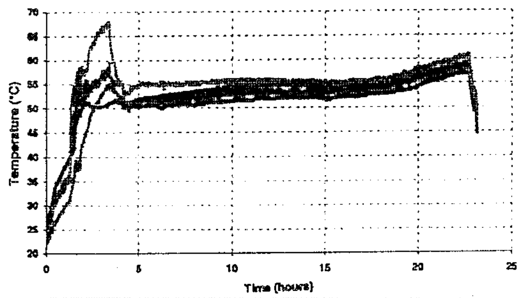


Figure 6: Sample temperature profiles during heat treatment of storage shed at an experimental research station

Insect bioassays

In the first trial, known test insects - mixed ages of the lesser grain borer, Rhyzopertha dominica, in grain and adults and larvae of the rust-red flour beetle, Tribolium castaneum - were placed in containers near several temperature monitoring points. For comparison, one sample of each species was placed in a controlled environment of 30°C and 65% relative humidity. Many of the locations chosen for the containers were considered likely to be those more difficult to heat.

The adult and larval flour beetles were checked immediately for surviving insects. However, the containers containing the borers were removed and placed in a controlled environment (30°C, 65% relative humidity). No surviving flour beetles were observed, and during the subsequent five weeks required for full immature development of the borers in grain, no evidence of the presence of any live insects was observed.

In the second trial, mixed age borers, and adult and larval flour beetles were again placed into the treatment area. Bioassays carried out after the treatment showed no insects survived the heat treatment.
Cost of heat treatment

What did it cost? The cost items were labour, electricity, gas, equipment rental, and the economic cost of down-time in the area. The last factor was balanced by the increased efficiency and reduced personnel hazard in the clean-up of the area.

The direct costs for the initial treatment were:
Gas burner rental for 2 days $100
Energy: 150kg of gas (total energy input 4130 kilowatthours)
plus 2400kWh of electrical energy to drive the fans $712
32 hours of labour ~$2,800
Total cost ~$3,612

The cost of the second operation was less due to fewer hours of labour to install the gas burners, and audit and prepare the premise for treatment.

Summary

A conclusion from these and other CSIRO trials is that there can be considerable advantage by disinfesting using heat rather than chemical fumigation. A major advantage is that shut-down of adjacent areas is not required as it would be for fumigation for safety reasons.
When heat is used the down-time in the treated area is only the period of direct heat treatment, plus fairly brief periods to set-up and disassemble the treatment equipment. As soon as the temperature is brought back to normal, the area can be occupied as normal. Chemical fumigation can require a lengthy further shut-down while the area is thoroughly ventilated to remove all fumigants.

The logistics involved in closing down a facility for a minimum of three-days to undertake a fumigation add considerable cost to the treatment. In addition, careful attention to gas distribution and leakage points is necessary to ensure that the fumigation will successfully kill target insect pests. The premises may need to be sheeted with gas-proof film to ensure effective treatment.

The cost savings through reduced logistical organisation and operation down-time make heat an attractive option to control insect pests in facilities associated with food handling, processing and warehousing.

Further information is available from Stephen Beckett (02 6246 4196) or Rashid Qaisrani (02 6246 4176) of the Stored Grain Research Laboratory, CSIRO Entomology in Canberra.

References

Pedersen, J.R. (1999). 1994 Heat treatment of Kansas State University Flour Mill/Cleaning House. Proceeding of the 199-Heat Treatment Workshop, Manhattan, KS: August 4-6, 1999.