Effects of fumigants on the water loss in *Periplaneta americana* (L.)

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**ABSTRACT**

Factors influencing water loss in *Periplaneta americana* (L.) treated with vapours of some selected fumigants have been investigated. Ventilation of fumigated roaches does not control transpiration. The enhanced duration of opening of the spiraeles causes an increased water loss in the fumigated insects. Water loss is also dependent upon the molecular weights of the compounds in a chemical series.

**INTRODUCTION**

In insects conservation of the vital body fluid is chiefly brought about by spiracles (Gunn; Mellanby², ³; Ramsay⁴, ⁵; Bursell⁶, ⁷, ⁸; Miller⁹ and Loveridge¹⁰) and to some extent also by the lipoid layer of integument (Wigglesworth¹¹, ¹², ¹³, ¹⁴, Alexander *et al.*¹⁵; Parkin¹⁶; Beament¹⁷; Ebeling¹⁸ and Loveridge¹⁹). Some inert insecticidal dusts are known to cause water loss by disrupting the lipoid layer of the integument (Wigglesworth¹¹, ¹², ¹³, ¹⁴; Alexander *et al.*¹⁵; Parkin¹⁶; Beament¹⁷ and Ebeling¹⁸). Although the effect of carbon dioxide on the rate of water loss in *Locusta migratoria migratorioides* R. and F. (Loveridge¹⁹), *Tenebrio molitor* L. and *Xenopsylla cheopis* Roth (Mellanby²) has been shown to be due to the changes in respiratory activity, the precise significance of the relationship between the effects of gaseous poisons and the transpiratory rate is yet to be fully appreciated.

**MATERIALS AND METHODS**

Adult *Periplaneta americana* (L.), reared in laboratory by techniques described by Wagner *et al.*²⁰ and Mehrotra *et al.*²¹ were used. A batch of cockroaches was taken from the same colony and was then starved for 24 hours. At the end of this period they were weighed in order to select insects of similar weight.
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The above insects were then fumigated to death with different gases at 28° ± 2°C and 40% R.H. The concentration of all the fumigants used except phosphine, was 0.0769% (V/V). In the case of phosphine the dose used was 0.0769% (Wt/V). The fumigants used in this study were ethylene dichloride (ED), trichloroethylene (TCE), dichloroethane (DCE), ethylene oxide (EO), carbon tetrachloride (CT), 1, 2, dibromo-3-chloropropano or Nemagon (O) (NEM), ethylene dibromide (EDB), nicotine (NIC), ortho-dichlorobenzene (OBD), phosphine (PH₃) and methyl bromide (MB). Water loss caused by the action of these fumigants was determined by weighing the insect before and after the treatment (Ramsay 4 and Loveridge 19, 10). The same procedure was adopted for the control specimens which were not subjected to fumigants.

Transpiration in insects has been shown to be directly proportional to ventilation (Loveridge 10) and to the open condition of the spiracles (Gunn 1). Hence, it was necessary to record the ventilatory and spiracular movements of the fumigated insects. For recording ventilation a suitable wire gauze cage, in which the test insect was restrained, was fixed in the plastic fumigation chamber. Before this, an aluminium foil, with a silk thread tied to it, was glued to fifth abdominal tergum of the insect. The thread passed through a capillary on the lid of the fumigation chamber and was tied to aluminium lever to record ventilatory movements on the rotating smoked paper. The lid was sealed by plaster of paris and capillary closed by an oil drop before testing with fumigants (Bhatia 22).

Microscopically observed spiracular movements were simultaneously recorded by tapping a key connected electrically to electro-magnetic marker recording on the smoked drum. Fumigation chamber was suitably modified for this purpose (Bhatia 22). Only first two spiracles were studied because they are the largest and hence play an important role in the control of water loss.

RESULTS

The ventilatory movements of the unfumigated control insects and the fumigated ones were recorded (figure 1). It was observed that the ventilation of insects fumigated with ED, TCE, DCE and EO increased while that in insects treated with CT, NEM, EDB, NIC, ODB, PH₃ and MB decreased.

Kymographic records of the movements of the first and second thoracic spiracles are shown in figures 2 and 3 respectively. Based on these figures, the duration of opening of the spiracles in the fumigated insects is represented in table 1. It was observed that the computed duration of opening of the
Figures 1–2. Figure 1. Kymographic records of ventilation of *Periplaneta americana* (L.) treated with different fumigants at the dosage of 0.2 ml/260 ml.

N, normal or in air; ED, ethylene dichloride; TCE, trichloroethylene; DCE, dichloroethane; EO, ethylene oxide; CT, carbon tetrachloride; NEM, Nemacon or 1, 2, dibromo-3-chloropropene; EDB, ethylene dibromide; NEC, nicotine; CDB, orthodichlorobenzene; PH₃, phosphine; MB, methyl bromide; C, contraction; and r, relaxation of the abdomen.

Figure 2. Kymographic records of valvular movements of the first thoracic spiracle of *Periplaneta americana* (L.) treated with different fumigants at the dosage of 0.2 ml/260 ml.

N, normal or in air; ED, ethylene dichloride; TCE, trichloroethylene; CCE, dichloroethane; EO, ethylene oxide; CT, carbon tetrachloride; NEM, Nemacon or 1, 2, dibromo-3-Chloropropane; EDB, ethylene dibromide; NIC, nicotine; CDB, orthodichlorobenzene; PH₃, phosphine; MB, methyl bromide; O, opening of the spiracle; and C, closing of the spiracle.

Two spiracles is more in fumigated insects than in the normal ones. The only exception is found in the insect treated with NEM, where the second thoracic spiracle closes. The reason for this unusual response, which was also observed in earlier studies (Tonapi³) is, that the closure of this spiracle is due to the flight posture of the insect. After flight there is a high frequency of impulses to the spiracular muscles (Miller⁴). Nicotine
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Table 1. Duration of opening of first and second thoracic spiracles of *Periplaneta americana* (L.) as obtained from the kymographs in figures 2 and 3.

<table>
<thead>
<tr>
<th>Fumigant</th>
<th>Duration of opening of I thoracic spiracle sec. per min.</th>
<th>Duration of opening of II thoracic spiracle sec. per min.</th>
<th>Total duration of I and II thoracic spiracles sec. per 2 min.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air</td>
<td>15.2</td>
<td>44.8</td>
<td>60.0</td>
</tr>
<tr>
<td>Ethylene dichloride (ED)</td>
<td>60.0</td>
<td>46.8</td>
<td>106.8</td>
</tr>
<tr>
<td>Trichloroethylene (TCE)</td>
<td>56.0</td>
<td>56.8</td>
<td>112.8</td>
</tr>
<tr>
<td>Dichlorethane (DCE)</td>
<td>57.2</td>
<td>39.2</td>
<td>96.4</td>
</tr>
<tr>
<td>Ethylene oxide (EO)</td>
<td>56.8</td>
<td>46.4</td>
<td>103.0</td>
</tr>
<tr>
<td>Carbon tetrachloride (CT)</td>
<td>60.0</td>
<td>60.0</td>
<td>120.0</td>
</tr>
<tr>
<td>Nemagon (NEM)</td>
<td>52.4</td>
<td>0.0</td>
<td>52.4</td>
</tr>
<tr>
<td>Ethylene dibromide (EDB)</td>
<td>40.8</td>
<td>60.0</td>
<td>100.8</td>
</tr>
<tr>
<td>Nicotine (NIC)</td>
<td>60.0</td>
<td>60.0</td>
<td>120.0</td>
</tr>
<tr>
<td>Orthodichlorobenzene (ODB)</td>
<td>20.0</td>
<td>60.0</td>
<td>80.0</td>
</tr>
<tr>
<td>Phosphine (PH₃)</td>
<td>60.0</td>
<td>60.0</td>
<td>120.0</td>
</tr>
<tr>
<td>Methyl bromide (MB)</td>
<td>60.0</td>
<td>60.0</td>
<td>120.0</td>
</tr>
</tbody>
</table>

also has been found to induce simulated flight (Raffy and Portier, 1931 See p. 122, Roeder25) and the first reaction of the insect to nicotine is to close the spiracles (Kitchel and Hoskins26).

Water loss caused by the action of different fumigants is given in table 2. Unit water loss, unlike the rate of water loss, increases with the molecular weight of the fumigant.

**DISCUSSION**

Gunn1, Mellanby2,3, Ramsay4,5, Davies and Edney27, Bursell6 and Loveridge10 have pointed out that in an insect whose spiracles are open when treated by carbon dioxide, water loss is more than that in the normal insect. As the computed duration of opening of the two anterior thoracic spiracles of the fumigated *Periplaneta americana* (L.) is always more than that of the normal insect (table 1), the water loss by the insect is also more, irrespective of the fumigant used. Effect of ethylene dibromide (EDB), which is the only exception, is dealt with in the following discussion.
Figures 3-4. Figure 3. Kymographic records of valvular movements of the second thoracic spiracle of *Periplaneta americana* (L.) treated with different fumigants at the dosage of 0.2 ml. 260 ml.

N, Normal or in air; ED, ethylene dichloride; TCE, trichloroethylene; DCE, dichloroethane; EO, ethylene oxide; CT, carbon tetrachloride; NBM, Nemagon or 1, 2-dibromo-3-chloropropane; EDB, ethylene dibromide; NIC, nicotine; ODB, orthodichlorobenzene; PH₃, phosphine/MB, methyl bromide; O, opening of the spiracle; and C, closing of the spiracle.

Figure 4. Relationship between molecular weights of fumigants and water loss (mg/g) in *Periplaneta americana* (L.) treated with different fumigants at the dosage of 0.2 ml/260 ml.

- Compounds having bromine in their molecules;
- Compounds without bromine in their molecules;
- Aromatic compounds.

Loveridge¹⁰ has observed that in *Locusta migratoria migratorioides* R. and F. water loss by transpiration is more in 50% carbon dioxide than in 80%. There are rapid ventilating movements along with opening of the spiracles in 50% concentration of carbon dioxide while in 80% carbon dioxide ventilation ceases but the spiracles are open. Due to absence of ventilation in the insect in 80% carbon dioxide there is reduced water loss from the spiracles. In this context, the logical conclusion from the contri-
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In the study, it was observed that fumigants increasing ventilation in the insect cause more water loss than those decreasing the rate of ventilation. However, it was noted that fumigants like CT, NIC, ODB, and MB cause more water loss even when the ventilation is reduced and the spiracles are open. On the other hand, the loss of water due to the action of fumigants such as ED, DCE, and EO is less even though these fumigants increase ventilation of the insect and cause the opening of its spiracles. Therefore, it seems that the water loss due to fumigation must be due to factors other than those mentioned by Loveridge.

It is important to note here that physical properties of the fumigants have a direct bearing on the water loss. It may be appreciated that the fumigants used in this study belong to three categories of compounds (Table 2). The first group of fumigants comprising of EO, DCE, ED, TCE, and CT are aliphatic compounds which have no bromine atom in their molecular structure; the second category, viz., MB, EDB, and NEM are aliphatic compounds having bromine in their molecular structure; the third group consists of aromatic compounds like ODB and NIC. When insects are

<table>
<thead>
<tr>
<th>Compounds</th>
<th>Fumigants</th>
<th>Molecular weight</th>
<th>Water loss mg/g</th>
<th>Rate of water loss mg/g/h</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inorganic</td>
<td>Phosphine (PH₃)</td>
<td>34</td>
<td>4.74</td>
<td>16.73</td>
</tr>
<tr>
<td>Aliphatic</td>
<td>Ethylene oxide (EO)</td>
<td>44.05</td>
<td>8.835</td>
<td>35.34</td>
</tr>
<tr>
<td>without</td>
<td>Dichloroethane (DCE)</td>
<td>98.97</td>
<td>17.429</td>
<td>34.85</td>
</tr>
<tr>
<td>bromine</td>
<td>Ethylene dichloride (ED)</td>
<td>98.97</td>
<td>19.35</td>
<td>24.17</td>
</tr>
<tr>
<td></td>
<td>Trichloroethylene (TCE)</td>
<td>131.4</td>
<td>28.8</td>
<td>115.2</td>
</tr>
<tr>
<td></td>
<td>Carbon tetrachloride (CT)</td>
<td>153.84</td>
<td>30.64</td>
<td>73.55</td>
</tr>
<tr>
<td>Aliphatic</td>
<td>Methyl bromide (MB)</td>
<td>94.95</td>
<td>3.8</td>
<td>79.56</td>
</tr>
<tr>
<td>with</td>
<td>Ethylene dibromide (EDB)</td>
<td>187.88</td>
<td>14.56</td>
<td>10.53</td>
</tr>
<tr>
<td>bromine</td>
<td>Nemagon (NEM)</td>
<td>236.5</td>
<td>16.57</td>
<td>8.279</td>
</tr>
<tr>
<td>Aromatic</td>
<td>Ortho dichlorobenzene (ODB)</td>
<td>147.01</td>
<td>98.09</td>
<td>41.45</td>
</tr>
<tr>
<td></td>
<td>Nicotine (NIC)</td>
<td>162.23</td>
<td>137.68</td>
<td>82.53</td>
</tr>
</tbody>
</table>

Table 2. Relationship between molecular weights of the fumigants and the water loss in Periplaneta americana (L.) fumigated with different fumigants at the dosage of 0.0769%.

Transpiratory rate of unfumigated control insects at 28° ± 2° and 46% R.H. was 13.34 mg/g/h.
fumigated with compounds of one of the above groups the loss of water increased with the increase in molecular weights of the different compound (table 2 and figure 4). In insect chemoreception also the stimulative efficiency of the compounds has been found to be proportional to their molecular weights (Dethier, 28, 29). Chemoreception and effects of fumigants are comparable because reactive nervous system is involved in both the phenomena (Dethier, 28, 29; Glover and Richardson, 30; Brown, 31; and Bhatia and Tonapia, 32). Pyrethrum has been shown to cause water loss by its neurotoxic action on the secretory activity of the epidermal cells (Ingram, 33). Thus it appears from the above observations that increased or decreased loss of water during fumigation is largely dependent upon the chemical nature of the compounds used. Incidentally this also explains the reduced water loss caused by ethylene dibromide.

ACKNOWLEDGEMENTS

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SUMMARY

1. Water loss in the insects fumigated with ED, TCE, DCE, EO, CT, NEM, EDB, ODB, PH₃ and MB is not so much related to the rate of ventilation.

2. Increased duration of spiracular opening causes increased water loss in the fumigated insects.

3. Water loss in the fumigated insects is directly proportional to molecular weight of each fumigant within the same chemical category.

REFERENCES


