Worldwide studies on aircraft disinsection at “blocks away”

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During 1971 worldwide experiments on the disinsection of passenger cabins at “blocks away” (as the aircraft starts taxing for take-off) were conducted in several types of jet aircraft. A procedure was developed whereby the high capacity Boeing 747 could be disinfected by four stewardesses in less than 1 minute. The favourable results of these and previous trials indicate that this method is suitable as a standard procedure for aircraft disinsection for international quarantine purposes.

The biological effectiveness against resistant and non-resistant mosquitoes of a 2% concentration of a pyrethroid, resmethrin, in Freon 11+Freon 12 (1:1) (without kerosine) and a favourable passenger response make it suitable as a standard formulation for aircraft disinsection.

The prevention of the spread of insect vectors of disease by aircraft travel is of great importance for the health and well-being of the people of the world. The mosquito is of overriding importance in this respect. In 1961 and 1962, the World Health Organization conducted a series of aircraft disinsection trials in temperate and tropical areas (Sullivan et al., 1962, 1964) that demonstrated that disinsection of passenger cabins at “blocks away” with single-use (one-shot) aerosol dispensers is suitable as a standard procedure for aircraft disinsection for international quarantine purposes. Based on the recommendations of the WHO Expert Committee on Insecticides (1957, 1961), this method was recommended for the disinsection of aircraft in the International Health Regulations (World Health Organization, 1971).

The International Air Transport Association (IATA) has expressed the view that more detailed instructions and guidance on the proper application of the “blocks away” procedure by crew members should be developed by WHO, taking into account the special conditions in high capacity aircraft, such as the Boeing 747.

The main purpose of the worldwide aircraft disinsection trials reported in this paper was to obtain answers to these problems by the use of new and greatly improved insecticides used as aerosols and that contained no DDT or kerosine. A further purpose was to minimize the discomfort caused to passengers by the treatment.

The study was a co-operative effort in which the following participated:

(a) the Governments of India, Italy, Japan, the Philippines, Switzerland, Thailand, the United Kingdom, and the USA;
(b) the Entomology Research Division, Agricultural Research Service, United States Department of Agriculture;
(c) the International Air Transport Association;
(d) the London School of Hygiene and Tropical Medicine, University of London;
(e) the Istituto Superiore di Sanità, Rome, Italy;

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(f) the Bureau of Quarantine, Department of Health, Manila, Republic of the Philippines;

(g) foreign Quarantine Department, Public Health Bureau, Ministry of Health and Welfare, Tokyo, Japan;

(h) The Vector Control Branch, Department of Health, State of Hawaii, USA;

(i) Trans World Airlines, Swissair, Air India, Scandinavian Air System, Philippine Air Lines, and Japan Air Lines; and

(j) The World Health Organization.

MATERIALS AND METHODS

The trials were performed on scheduled flights of commercial jet passenger aircraft with cabin volumes varying from 96 m³ to 1076 m³ (see Table 1). Disinsection was done at "blocks away" immediately after the required safety briefing because:

1. the circulation of air in the cabin at that time is at a minimum but is sufficient to disperse the aerosols properly;
2. the aisles are free of passengers;
3. no food is being served;
4. the stewardesses have a free period; and
5. the taxing time of approximately 10 min permits the insecticidal aerosol to remain suspended in the cabin for a reasonable length of time.

Experimental aerosols

Research by Schechter et al. (1949) and Elliott et al. (1967) has led to the development of synthetic pyrethroids that are highly effective against adult mosquitoes. Elliott (1967) states that (5-benzyl-3-furyl)methyl (±)-cis,trans-chrysanthemate "is the most toxic compound tested so far, of any class of insecticide, to 1–2-day-old unfed females of Anopheles stephensi and Aedes aegypti (results provided by Dr A. B. Hadaway) ". Fales et al. (1968) and Okuno (1969) confirmed these results.

The effectiveness against mosquitoes of three of these pyrethroids, resmethrin (Elliott, 1967), bioresmethrin, and (±)-trans-allethrin, was compared with that of the G 1707 formulation, which contained pyrethrum extract plus a synergist and an auxiliary solvent (odourless petroleum distillate). Relatively high concentrations of the pyrethroids were used, 1% and 2%, because of the difficulty of killing all the mosquitos in the many hard-to-reach hiding places in passenger aircraft and to provide a safety margin. No auxiliary solvents such as petroleum distillates were needed to formulate the pyrethroid aerosols as it is usually necessary when formulating conventional aerosols containing pyrethroid extract, DDT, and synergists. This was a distinct advantage as it reduced odour and thus improved their acceptance by passengers.

Materials tested

The composition of the materials tested was as follows (w/w):

1. resmethrin, 89% (tech.) without added solvents ................................. 2.25% propellant: Freon 11 + Freon 12 (1:1) 97.75%
2. resmethrin, 89% (tech.) without added solvents ................................. 1.12% propellant: Freon 11 + Freon 12 (1:1) 98.88%
3. bioresmethrin .......................................................... 2.00% propellant: Arcton 11 + Arcton 12 (1:1) ........................................ 98.00%
4. bioresmethrin .......................................................... 1.00% propellant: Arcton 11 + Arcton 12 (1:1) ........................................ 99.00%
5. (+)-trans-allethrin, 90% (tech.) ................................. 2.22% propellant: Freon 11 + Freon 12 (1:1) 97.78%
6. (±)-trans-allethrin, 90% (tech.) ................................. 1.11% propellant: Freon 11 + Freon 12 (1:1) 98.89%
7. G 1707 pyrethrum extract (20% pyrethrins) ................. 2.25% Tropial synergist 1 ........................................ 2.70% petroleum distillate ........................................ 10.05% propellant: Freon 11 ........................................ 25.50% propellant: Freon 12 ........................................ 59.50%

A mixture of Freon 11 and Freon 12, in equal proportions, was used as a control treatment.

The aerosols were packed in 177-ml or 355-ml cans, and those samples prepared at Beltsville, Md., were equipped with precision valves. The flow rate of all the aerosols used was about 1.2 g per second. The mass median diameter of the droplets of the 2% resmethrin aerosol was 12.5 μm. The mass median diameters for the 2% and 1% (±)-trans-allethrin aerosol sprays were 10 μm and 7.8 μm, respectively.

1 Piperonal bis[2-(2-butoxyethoxy)ethyl] acetal.
2 Mass median diameter information was supplied by R. M. Waters and E. S. Fields, Entomology Research Division, Agricultural Research Center, Beltsville, Md., USA.
Table 1. Mosquito mortality and experimental data for the 13 test flights

<table>
<thead>
<tr>
<th>Test no.</th>
<th>Aircraft</th>
<th>Flight</th>
<th>Temperature (°C)</th>
<th>Aerosol tested</th>
<th>Dose (g/100 m²)</th>
<th>Test mosquitos</th>
<th>Insect mortality after 24 h [^a]</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Ae. aegypti</td>
<td>An. stephensi</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Location</td>
<td>No. of cages</td>
</tr>
<tr>
<td>1</td>
<td>B-747 (1 076 m³)</td>
<td>Washington, D.C., to London</td>
<td>23</td>
<td>2 % resmethrin</td>
<td>12.0</td>
<td>cabin</td>
<td>9</td>
</tr>
<tr>
<td>2</td>
<td>DC-9 (98 m³)</td>
<td>London to Geneva</td>
<td>23</td>
<td>2 % (+)-trans-allethrin</td>
<td>23.3</td>
<td>cabin</td>
<td>5</td>
</tr>
<tr>
<td>3</td>
<td>DC-9 (98 m³)</td>
<td>Geneva to Rome</td>
<td>23</td>
<td>2 % bioresmethrin</td>
<td>26.8</td>
<td>cabin</td>
<td>10</td>
</tr>
<tr>
<td>4</td>
<td>DC-8 (227 m³)</td>
<td>Rome to New Delhi (Beirut-Tehran)</td>
<td>23</td>
<td>2 % resmethrin</td>
<td>29.7</td>
<td>cabin</td>
<td>7</td>
</tr>
<tr>
<td>5</td>
<td>B-707 (227 m³)</td>
<td>New Delhi to Bangkok (G 1707)</td>
<td>23</td>
<td>2 % bioresmethrin</td>
<td>37.4</td>
<td>cabin</td>
<td>6</td>
</tr>
<tr>
<td>6</td>
<td>DC-8 (series 63) (283 m³)</td>
<td>Bangkok to Manila</td>
<td>23</td>
<td>1 % bioresmethrin</td>
<td>15.9</td>
<td>cabin</td>
<td>5</td>
</tr>
<tr>
<td>7</td>
<td>BAC 111 (96 m³)</td>
<td>Manila to Cebu</td>
<td>23</td>
<td>2 % bioresmethrin</td>
<td>20.1</td>
<td>cabinet</td>
<td>3</td>
</tr>
<tr>
<td>8</td>
<td>BAC 111 (96 m³)</td>
<td>Cebu to Manila</td>
<td>32</td>
<td>1 % resmethrin</td>
<td>7.4</td>
<td>cabinet</td>
<td>4</td>
</tr>
<tr>
<td>9</td>
<td>BAC 111 (96 m³)</td>
<td>Manila to Davao</td>
<td>23</td>
<td>2 % resmethrin</td>
<td>7.1</td>
<td>cabinet</td>
<td>5</td>
</tr>
<tr>
<td>10</td>
<td>BAC 111 (96 m³)</td>
<td>Davao to Manila</td>
<td>23</td>
<td>2 % resmethrin</td>
<td>7.1</td>
<td>cabinet</td>
<td>5</td>
</tr>
<tr>
<td>11</td>
<td>DC-8 (227 m³)</td>
<td>Manila to Tokyo</td>
<td>25</td>
<td>1 % (+)-trans-allethrin</td>
<td>19.4</td>
<td>cabinet</td>
<td>6</td>
</tr>
<tr>
<td>12</td>
<td>B-747 (1 076 m³)</td>
<td>Tokyo to Honolulu</td>
<td>26</td>
<td>2 % resmethrin</td>
<td>8.8</td>
<td>cabinet</td>
<td>5</td>
</tr>
<tr>
<td>13</td>
<td>B-707 (227 m³)</td>
<td>Honolulu to San Francisco</td>
<td>23</td>
<td>G 1707 (see text)</td>
<td>18.7</td>
<td>cabinet</td>
<td>6</td>
</tr>
</tbody>
</table>

\[^a\] R = resistant insects. In test no. 2 the Culex mosquitos were resistant to DDT; in test no. 12 they were resistant to organophosphorus compounds; and in test no. 13 they were resistant to DDT.
Experimental procedures

Thirteen tests with the experimental insecticidal aerosols and one test of the propellants alone were carried out on regular flights in temperate and tropical climates between 1 March and 31 March 1971. The numbers of susceptible and resistant *Aedes*, *Anopheles*, and *Culex* mosquitoes used in these trials are given in Table 1.

A few hours before the departure times of the selected flights the participating laboratory released 10–30 mosquitos into the exposure cages. The cages, which had been made by knocking out both ends of 237-ml ice cream cartons and inserting wire screens in their place (mesh equivalent to 6.4/cm), were then labelled, placed in trays, and covered with moist towels to provide a humid atmosphere. Exceptions to this procedure were made on flight no. 3, when larger numbers of mosquitos were placed in cages made of wire frames covered with fine nylon mesh and on flight no. 13, when cylindrical cages, 7 × 15 cm, with wire screens were used.

Approximately half an hour before the departure of each flight, clearance was obtained to board the aircraft in order to complete preparations for the test before the passengers embarked. The captain and crew were briefed on the purpose of the WHO disinsection trials. The chief steward(ess) was then given: (1) the test aerosol, (2) a stopwatch to record the time taken to treat the aircraft, and (3) an announcement to be broadcast over the loudspeaker system at “blocks away” so that the passengers would understand the purpose of the test. The chief steward(ess) was instructed on the method to be used to disinsect the aircraft immediately after the safety demonstrations at “blocks away”. In all aircraft except the Boeing 747 the procedure was for the chief steward(ess) to walk the full length of the main aisle at a normal pace spraying the aerosol from side to side from just above eye level at a slightly upward angle.

The method used in the two Boeing 747 trials was to position two stewardesses back to back at the midpoint of each of the two 56-m-long aisles and for them to disinsect the aircraft while walking at a normal pace to the ends of their respective aisles. In all instances the cabins of the aircraft were disinsected in 15–57 s, except for the Douglas DC-8 Series 63, in which the operation took 120 s. The cockpit and toilets were not disinsected.

In preliminary tests this disinsection procedure gave a dosage close to the target of 17.5 g of aerosol per 100 m³. However, each aerosol can was carefully weighed before and after use to obtain the actual dosages that are listed in Table 1.

After the crew had been briefed, the cages with insects were placed in the cabin in from 4 to 11 different places at high, medium, and low levels. A special effort was made to choose places where live mosquitos are often found in aircraft, i.e., under seats, in overhead racks, in galleys, and in magazine racks. In some instances, mosquito cages were placed in the cockpit and in the toilets. At least one cage of each species of mosquito enclosed in a plastic bag was used as a control. Where possible, the aircraft cabin temperature was recorded at “blocks away”. The insects were collected from the test stations towards the end of the flight, and were fed 5% sugar water on cotton-wool as soon as possible after the end of the flight. Preliminary observations were made at that time and final mortality counts were made 24 h later.

Approximately half an hour after the start of each flight, the stewardess distributed passenger reaction questionnaires and asked the passengers to complete them.

RESULTS AND DISCUSSION

The basic data and data on insect mortality for each flight are given in Table 1, and the results of the analyses are given in Table 2. The insect mortality data were compared by calculating the 95% confidence interval for each value. Since the magnitude of a binomial confidence interval depends on the sample size, and since this varied considerably in our tests, we arbitrarily selected a mortality of 97% as an acceptable level for the cabin and judged a material to be acceptable in this respect if the 97% point was included in the confidence interval or if its lower limit was greater than 97%. Only three of the average mortality levels were lower than 97%, and in each case the confidence interval contained the 97% point. Thus, all the materials were judged to be satisfactory for quarantine purposes in view of the sample size and the effect of the containing cage in reducing the effectiveness of the aerosol.

The results in the lavatories were less satisfactory, but we feel that a lower mortality level in these places is acceptable as the doors would usually be closed during those periods when the insects could

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Table 2. Passenger response and insect mortality by treatment

<table>
<thead>
<tr>
<th>Material</th>
<th>No. of trials</th>
<th>Total no. questioned</th>
<th>No. who liked or did not care</th>
<th>No. who disliked</th>
<th>Liked or did not care</th>
<th>Disliked</th>
<th>Disliked (adj. a)</th>
<th>No. tested</th>
<th>% killed b</th>
<th>No. tested</th>
<th>% killed b</th>
<th>No. tested</th>
<th>% killed b</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 % resmethrin</td>
<td>4</td>
<td>214</td>
<td>197</td>
<td>17</td>
<td>92.06</td>
<td>7.94</td>
<td>0</td>
<td>1669</td>
<td>99.8 (99.5–100)</td>
<td>32</td>
<td>43.8 (26.4–62.3)</td>
<td>60</td>
<td>33.3 (21.7–48.7)</td>
</tr>
<tr>
<td>1 % resmethrin</td>
<td>1</td>
<td>38</td>
<td>38</td>
<td>0</td>
<td>100.0</td>
<td>0</td>
<td>0</td>
<td>120</td>
<td>94.2 (78.3–97.6)</td>
<td>30</td>
<td>100 (98.4–100)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 % (+)-trans-allethrin</td>
<td>1</td>
<td>51</td>
<td>33</td>
<td>18</td>
<td>64.71</td>
<td>35.29</td>
<td>29.03</td>
<td>94</td>
<td>100 (96.2–100)</td>
<td>24</td>
<td>100 (86.8–100)</td>
<td>39</td>
<td>0 (0–9.0)</td>
</tr>
<tr>
<td>1 % (+)-trans-allethrin</td>
<td>1</td>
<td>50</td>
<td>49</td>
<td>1</td>
<td>98.00</td>
<td>2.00</td>
<td>0</td>
<td>194</td>
<td>96.4 (91.4–97.8)</td>
<td>27</td>
<td>86.2 (66.3–95.8)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 % bioresmethrin</td>
<td>3</td>
<td>110</td>
<td>79</td>
<td>31</td>
<td>71.82</td>
<td>28.18</td>
<td>21.23</td>
<td>1374</td>
<td>99.2 (98.7–99.7)</td>
<td>45</td>
<td>100 (92.1–100)</td>
<td>75</td>
<td>0 (0–4.8)</td>
</tr>
<tr>
<td>1 % bioresmethrin</td>
<td>1</td>
<td>49</td>
<td>44</td>
<td>5</td>
<td>89.80</td>
<td>10.20</td>
<td>1.51</td>
<td>111</td>
<td>99.1 (95.0–100)</td>
<td>10</td>
<td>30 (6.7–65.3)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>G1707</td>
<td>2</td>
<td>79</td>
<td>67</td>
<td>12</td>
<td>84.81</td>
<td>15.19</td>
<td>6.99</td>
<td>392</td>
<td>94.9 (92.4–97.0)</td>
<td>12</td>
<td>75 (42.8–94.5)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>control</td>
<td>1</td>
<td>68</td>
<td>62</td>
<td>6</td>
<td>91.18</td>
<td>8.82</td>
<td>—</td>
<td>287</td>
<td>0.70 (Aedes)</td>
<td>68</td>
<td>2.9 (Anopheles)</td>
<td>367</td>
<td>0.56 (Culex)</td>
</tr>
</tbody>
</table>

a Adjusted using Abbott’s correction.

b The 95% confidence limits are shown in parentheses.
invade the plane. The insecticide could be sprayed directly into the lavatories if required. The cockpit should be sprayed before the crew boards the aircraft.

The analyses of the data concerning passenger preference are based on a tabulation of the passengers' responses to the different materials sprayed (Table 2). The data were converted to percentages and these were then transformed to arcsines.

Since the pertinent response was that of dislike we selected it for analysis. A hierarchical model was used and the data were grouped in three different ways so as to answer specific questions: (1) the full set of data with eight treatments, to compare the treatment effects; (2) according to the material used, to compare the effects of the different dosages; and (3) according to dose level, two treatments being discarded.

Of the three analyses the only one to indicate statistically significant differences was the last, which concerned the dose levels. The difference in passenger dislike between the 1% and 2% doses, 6.21 ± 7.17 and 23.26 ± 4.39, is judged to be a real increase in reaction owing to the increased concentration of the active material.

The proportions of people who disliked the different treatments (Table 2) have been corrected, by means of Abbott's correction, for the proportion who judged the control treatment to be unpleasant. It can be seen that a few of the treatments were disliked by a larger proportion than would normally dislike any spray.

Considering both the passenger reactions and the mortality data it can be stated that resmethrin was the best of the materials tested. The objection of the passengers to the 2% resmethrin aerosol was no greater than that to the control treatment.

The 99–100% mosquito mortality under the rigid conditions of these tests demonstrated that "blocks away" disinsection with resmethrin provides a simple and effective procedure for disinsecting the cabins of jet aircraft. Insect mortality in the untreated cockpit was poor because most cockpits have a separate ventilation system. The mortality in the toilets was erratic but this is probably of minor importance as the toilet doors are usually closed while the aircraft is on the ground.

In these trials excellent results were obtained by a disinsection procedure whereby the steward(ess) continuously discharged the aerosol while walking the full length of the cabin aisle at a normal pace. However, the actual dosages, obtained by weighing the aerosol cans before and after use, were considerably lower than the estimated dosages obtained by multiplying the spray times in seconds by the delivery rate of the aerosol valve (1.2 g/s). This suggests that the operator did not always press the discharge button right down. For this reason, and because the empty numbered container is needed for quarantine evidence that the aircraft was adequately treated, it is recommended that single-use (one-shot) aerosol dispensers be used for disinsecting aircraft as follows:

**DC-9, BAC 111 (approx. 110 m³)**

One 59-ml single-use dispenser containing 20 g of 2% resmethrin in Freon 11 + Freon 12 (1 : 1)

**Boeing 707, DC-8 (approx. 220 m³)**

One 118-ml dispenser containing 40 g of 2% resmethrin in Freon 11 + Freon 12 (1 : 1)

**Boeing 747 (approx. 1076 m³)**

Five 118-ml dispensers each containing 40 g of 2% resmethrin in Freon 11 + Freon 12 (1 : 1) (the fifth container to be used to disinsect the cockpit and the upper lounge before the crew board the aircraft).

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Résumé

Études, à l'échelle mondiale, sur la désinsectisation «cales enlevées» des aéronefs

Dans le courant de l'année 1971, on a procédé à bord d'aviions à réaction de divers types à une série d'essais de désinsectisation suivant le procédé dit «cales enlevées» (traitement insecticide effectué après l'enlèvement des cales immédiatement avant le départ). Cette étude collective a été rendue possible grâce à la collaboration de plusieurs gouvernements, d'institutions scientifiques, de compagnies de transports aériens et de l'Organisation mondiale de la Santé.

Les essais ont confirmé l'efficacité de la méthode. Parmi les aérosols testés, une formulation comportant 2% de bioresmethrine (un pyréthrôlde), sans solvant, dans un mélange à parties égales de Fréon 11 et de Fréon 12 s'est montrée très active contre les Aedes, les Anophèles et les Culex sensibles et résistants. Elle n'a causé qu'un minimum d'inconfort pour les passagers. Les aérosols de bioresmethrine ont fait preuve d'une efficacité du même ordre, mais leur odeur a été jugée déplaisante. Il sera sans doute possible de pallier cet inconvénient en purifiant davantage le produit. L'emploi de kérosène et d'autres solvants, dont l'odeur risque d'incommoder les passagers, n'est pas indispensable dans les formulations de pyréthroides.

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