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In-flight Disinsection as an Efficacious Procedure for Preventing International Transport of Insects of Public Health Importance

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Aircraft disinsection with aerosol insecticides during flight has generally been held to be inadvisable because it was assumed that the insecticides would be rapidly removed by the cabin air-conditioning system. We have developed protocols to deliver 2% d-phenothrin at a dose of 35 g per 100 m^3 in various aircraft, and trials undertaken on Boeing 747 and 767 aircraft showed that their air-conditioning systems do not preclude effective disinsection. Mortality levels of 100% for Culex quinquefasciatus and Musca domestica test insects were recorded under normal operating conditions during routine scheduled passenger flights with disinsection procedures undertaken at "blocks-away" or at "top-of-descent". As a result, "top-of-descent" disinsection has been introduced as the recommended procedure for aircraft landing in Australia.

Introduction

In many countries the risks of international air transport of the insect vectors of malaria and other disease are recognized[1-3]. However, quarantine procedures to counter this threat by carrying out aircraft disinsection pose problems for airline companies, airport operators, and government health officials.

Although in many areas of the world the requirements for aircraft disinsection are being relaxed or eliminated, a number of Asian and Pacific countries are interested in maintaining this procedure as a quarantine measure to prevent introduction of exotic mosquito pests or vectors. Also, the United Kingdom has recently introduced a selective requirement for disinsection of aircraft arriving from countries that present a potential risk of introducing malaria.

By preventing the introduction and establishment of exotic mosquitoes, airport sanitation is an important component of any quarantine programme; however, in many countries aircraft disinsection is viewed as the initial protective barrier. In some countries, aircraft load at night under lights at airports that are often situated near major mosquito breeding areas in swamps or marshes. Also, airport terminals may be situated in areas where container-breeding vectors are prevalent. Under such circumstances, aircraft could carry exotic vectors (and possibly diseases) to other countries.

The greater part of the Pacific region is free of malaria and malaria vectors, and the spread of arboviruses such as a dengue virus and Ross River virus to parts of the region hitherto considered not to be affected by them as highlighted the importance of developing better vector surveillance systems that could minimize the chances of potential outbreaks.

In Europe a number of reports have appeared of "airport malaria" involving people working at or living in the vicinity of airports that handle aircraft arriving from malarious countries[1,4]. Furthermore, there has been a report of malaria infections apparently acquired on board an international aircraft that was flying outside endemic areas[4].

At airports where aircraft disinsection is carried out, the procedures followed are generally those approved by WHO. Insecticides and systems for their delivery are tested before being used for aircraft disinsection, although in general there has been little evaluation under operational conditions.

Almost 40 years ago the WHO Expert Committee on Insecticides recommended that aircraft disinsection be carried out before take-off after all luggage and/or freight has been loaded, but with no passengers on board[5]. It was recommended that the aircraft be kept closed during spraying and for 5 minutes afterwards. Spraying during flight was held to be ineffective and unacceptable. Also, Laird proposed that disinsection during flight would suffer from problems with insecticide dispersal[6]. It was acknowledged, furthermore, that spraying on arrival involved unsatisfactory delays.

In 1961 the Expert Committee reaffirmed its previous recommendations against in-the-air disinsection of aircraft with aerosols[7] and noted that insects aboard aircraft could escape after planes have landed but before on-arrival disinsection, a procedure which would, in any case, introduce undesirable on-the-ground delays. Since pre-departure disinsection allows opportunities for re-infestation, it was recommended that cabin disinsection should be performed at "blocks-away" with single-use aerosols. Nevertheless, it was pointed out that, at best, aircraft disinsection should be regarded only as a compromise that balanced the relative risk of introducing disease, entomological efficiency, passenger comfort, facilitation, and aircraft safety.

Subsequently, in 1966, WHO recommended the options for disinsection that are outlined below[8].

- "Blocks-away disinsection" – aerosol spraying of the passenger cabin after the doors have been locked at embarkation but before take-off.
- "Disinsection on the ground" – aerosol spraying before take-off, with all luggage and freight loaded, but with no passengers on board.
- "Vapour disinsection" – use of a dichlorvos dispensing system for in-flight treatment (this procedure was, however, never, accepted because of adverse side-efforts on aircraft fittings).

The concept of "blocks-away" disinsection supported by the results of other studies[9-11], and WHO continued to endorse this procedure[12,13], pointing out that aerosol disinsection during flight was not effective because the insecticide would be rapidly removed by the aircraft's ventilation system and that disinsection on the ground after arrival would cause delays in servicing aircraft as well as discomfort to passengers.

The current recommendations for aircraft disinsection, as set out by WHO, include specifications for aerosols and approved insecticidal formulations, as well as a description of the following disinsection procedures:

- — disinsection before take-off ("blocks-away" disinsection);
- — disinsection on the ground ("on-arrival" disinsection); and a new option.
- — disinsection with a residual insecticide[14].

From an operational standpoint, the selection and limiting criteria for disinsection procedures have therefore become the acceptability of the chemical or formulation by the passengers and the potential for detrimental effects on the aircraft's avionics and fittings, rather than the technical efficiency of the insecticide. Airline operators are concerned with passengers safety and comfort, and also with the logistics and economics associated with delays due to disinsection procedures. However, government authorities remain concerned about maintaining an effective disinsection procedure.

In general, disinsection of aircraft after the doors are closed and before take-off ("blocks-away") has not been widely used as a routine measure. This has arisen partly because health authorities in some countries hold that disinsection is not satisfactorily carried out by the airline crew and that it is more effectively performed by quarantine officials at the airport ("on-arrival" disinsection). Also there is concern that passengers who suffer allergic reactions to the aerosol may not receive immediate appropriate medical attention.

Laird has argued that "blocks-away" disinsection is still the most efficient and desirable technique[15]. Also, although Smith & Carter maintain that in-flight disinsection is unacceptable, they concentrated in their study on the preoccupation of the cabin staff who conducted the spraying with avoiding upsetting the passengers, rather than considering the ineffectiveness of an aerosol spray that is prematurely dispersed by the air-conditioning system[3].

Since 1975 we have carried out a programme to investigate the efficacy of aircraft disinsection procedures in Australia. There have been two primary objectives: first, that any techniques or protocols available for adoption should be shown to be effective; and second, that techniques or protocols which reduce the amount of inconvenience to passengers and airlines should be assessed for their suitability as standard disinsection procedures. Here, we report our findings.

Materials and methods

The technical effectiveness of disinsection procedures was assessed throughout the programme using bio-assy methods, details of which have described elsewhere[2]. In general, 10 mosquitos (*Culex quinquefasciatus*) and five houseflies (*Musca domestica*), kept in duplicate sets of cages, and placed at one of a number of sites in Boeing 747 or 767 aircraft, were exposed to the aerosol formulations. Typically, the test cages were cardboard containers covered at both ends with cloth gauze, but occasionally wire gauze cylindrical cages were used. Cages isolated within polyethylene bags and attached adjacent to the test cages were always used as controls.

Typically, 10-12 test sites were used throughout the aircraft. For example, on the Boeing 747 these were: over the top of the bulkhead front section; under the bulkhead lip in front of seat 1K; above the overhead locker of seat 6J; on the toilet alcove wall opposite seat 8B; on the rear side-wall of the upstairs lounge; above the overhead locker of seat 31D; on the wall behind seat 33C; under seat 52G; above the overhead locker of seat 60H; on the door behind seat 73B; Behind seat 16K; and on the wall in the curtained rear coat locker. For the Boeing 767 the sites were; under the shute moulding of the exit door; under the bulkhead lip in front of seat 1F; on the overhead locker above seats 6A/6B; under seat 11F; on the wall under seat 15K; on the wall above seat 16K; beneath seat 20E; on the overhead locker of seat 25D; under seat 30B; on the wall behind seat 34E; near the floor on the wall of the rear galley; and on the wall in the curtained front coat locker.

All trials were conducted on Qantas aircraft during scheduled passenger flights. Insecticide was dispensed in accord with WHO specifications at a minimum dose of 35 g per 100 m^3 (10 g per 1000 cu. ft). Insect mortality was monitored for up to 24 hours after spraying.

Results and discussion

Trials were conducted initially in 1975-76 on Qantas Airways Boeing 707 and 747 aircraft under operational conditions, using live mosquitos (*C. quinquefasciatus*) as test insects, to develop an inflight disinsection protocol with an aerosol containing 0.4% pyrethrins and 1.6% piperonyl butoxide delivered at a dose of 35 g per 100 m^3. As a result, a precision disinsection format was developed in consultation with the airline[16]. Briefly, this consisted of aerosol disinsection carried out during taxiing after touchdown at Sydney following a flight from Singapore; the test insects exhibited 100% knockdown with no recovery after 24 hours. The insecticide delivery procedure was effective and acceptable, and the inconvenience of delay associated with normal "on-arrival" procedures was avoided. However, for non-technical reasons, the new procedure was not acceptable and was not introduced, with a result that normal "on-arrival" disinsection continued at Australian airports.

Soon after the above-mentioned trials, a new formulation aerosol containing 2% d-phenothrin was introduced, and as a consequence of other studies[2], the "on-arrival" disinsection procedures for aircraft landing in Australia were amended to comprise a single spraying with 2% d-phenothrin at a dose of 35 g per 100 m^3, in line with WHO recommendations. However, because of the continuing delay problems associated with "on-arrival" disinsection, investigations of "blocks-away" disinsection with 2% d-phenothrin were undertaken in 1980 Three trials were conducted on the Auckland-Sydney route from May to July 1980 under operational conditions of Boeing 747 and 747 COMBI aircraft using *C. quinquefasciatus* mosquitos as test insects and following the evaluation protocol established previously[2]. Disinsection was carried out after all passengers had boarded the aircraft and the doors had been closed before taxiing. Although the procedure was effective, again, for non-technical reasons, the "blocks-away" procedure was not introduced as a quarantine procedure for flights into Australia. As a result of the trials, however, the procedure (carried out by cabin staff) was accepted by authorities in Papua New Guinea, New Caledonia, Tahiti, and the Philippines for Qantas aircraft landing in these countries.

With the introduction of Boeing 767 aircraft to the Qantas fleet, "blocks-away" trials were conducted in July 1985 on the route between Sydney and Auckland on a Boeing 767-238 series aircraft. In the 767, unlike the 747, the air-conditioning was kept on during disinsection. The results indicated that the air-conditioning did not reduce the efficacy of the disinsection procedure, since 100% of the test mosquitos experienced knockdown, with no recovery within 24 hours. Also, in separate trials, use of air-conditioning was kept on during "on-arrival" disinsection in Boeing 767 aircraft did not lead to a reduction in the level of insect mortality.

An in-flight trial between Sydney and Singapore in February 1986 on a recently introduced Boeing 747-300 series aircraft was undertaken primarily to test disinsection at "top-of-descent" with the air-conditioning on, as well as to evaluate the standard protocol within the new configuration of the extended upper deck (747 EUD). *C. quinquefasciatus* and *M. domestica* were used both as test insects and controls; 100% mortality levels were obtained for both species.

An "on-arrival" trial involving a Boeing 747-200 series aircraft that landed in Australia from Singapore was also carried out to test the effect of operating the air-conditioning for the duration of disinsection. *C. quinquefasciatus* mosquitos and *M. domestica* flies were again both used as test insects and controls. The disinsection was carried out by quarantine officers. Mortality was 100% for the mosquitos and 60-100% for the flies.

To further assess the "top-of-descent" disinsection procedure in Boeing 767 aircraft, we carried out trials on a routine flight between Australia and Singapore in May 1987; satisfactory results were again produced with the air-conditioning operating. Two further in-flight trials were undertaken between Sydney and Brisbane in July 1987 on a 767 aircraft, and when the insecticide was dispensed accurately at the suggested dose in all the cabin areas, 100% mortality levels of the mosquitos and flies were recorded.

By placing test cages at appropriate sites, the efficacy of the disinsection procedure was assessed for virtually all types of location where insects could rest within the cabin; satisfactory insect mortality was observed for all the test positions monitored. Even in particularly "difficult" sites, such as under bulkhead lips and areas that were shielded by passenger's cabin baggage, insect mortality levels of 100% were achieved, provided the aerosol was dispersed in the recommended manner in that area of the aircraft. The overhead lockers on the 747 aircraft had netting tops that permitted the aerosol to penetrate inside, and if, as required, the curtains of the clothes lockers were drawn open during disinsection, 100% insect mortality resulted. The test insects were generally enclosed with cardboard cylinder test cages were thus somewhat protected from the spray. Free-lying insects would be expected to be more exposed to the insecticide and the mortality levels found in the trials should therefore be under-estimates.

Overall, the results of the trials demonstrated a satisfactory "lateral" dispersal and circulation of insecticide within the Boeing 747 and 767 aircraft, although it appears that "longitudinal" dispersal may be limited. Therefore, while it is important that the recommended dose of insecticide be delivered within the aircraft, it is important also that it is evenly distributed.

The spraying protocols derived from the trials were aircraft-specific. Aerosol cans of 100 g of 2% d-phenothrin with a nozzle that delivers a dose at 1 g per second were used in all circumstances to disperse the insecticide at a walking pace of 1 seat-row per second. On Boeing 767 aircraft, two cabin staff each used on aerosol can per aisle; starting from the aft door each operator sprayed for the entire length of the aircraft. In contrast, on Boeing 747 aircraft, four cabin staff each used one aerosol can; one pair of operators sprayed the rear half (door 5 to door 3) of the aircraft along each aisle, while the other pair sprayed the aisle forwarded from mid-aircraft (door 3 to door 1), with one operator continuing to the upper deck, while the other sprayed the forward cabin area along both aisles. Only minor modifications to this procedure were necessary for 747 EUD, 747 SP, and 747 COMBI aircraft. Areas not accessible for in-flight aerosol disinsection, such as the flight deck, toilets, enclosed lockers, lower galley and elevator, were treated with permethrin, a residual insecticide.

There is often difficulty in gaining acceptance for "blocks-away", rather than "on-arrival" disinsection, because of concerns about acute allergic reactions that may be produced in some passengers by the aerosol. Such concerns can, however, be obviated to a great extent by using the "top-of-descent" inflight procedure because of the proximity to touchdown and of medical attention; furthermore, our results indicate that "top-of-descent" disinsection is technically effective. The reaction of Qantas Airways to the "top-of-descent" approach is favourable, since it overcomes the delays caused by "on-arrival" disinsection and has, in general, also gained the acceptances of passengers. The procedure is currently recommended for use by all aircraft that land in Australia, and failure to comply results in delays due to "on-arrival" disinsection, which is undertaken by the aircraft cabin crew. In addition to Australia, all other countries (with the exception of New Zealand) that require disinsection of aircraft cabins now accept the Qantas "top-of-descent" procedure.

Conclusions.

In-flight disinsection of Boeing 747 and 767 aircraft is efficacious. The procedure is most suitably carried out at "top-of-descent", and, provided the aerosol is distributed uniformly throughout the aircraft at the prescribed dose, there is no evidence that the air-conditioning system has a detrimental effect on the mortality induced by the insecticide. The protocols developed in this series of trials therefore offer an effective disinsection procedure against insects of public health concern.

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REFERENCES

1. Curtis CF, White GB : Plasmodium falciparum transmission in England: entomological and epidemiological medicine and hygiene. 1984; 87 : 101-114

2. Russel RC et al : Mosquito and other insect introductions to Australia aboard International aircraft, and the monitoring of disinsection procedures. In: Commerce and the spread of pests and disease vectors. Editor Laird M. New York, Praeger Scientific 1984.

3. Smith A, Carter ID : International transportation of mosquitos of public health importance. In: Commerce and the spread of pests and disease vectors. Editor Laird M. New York, Praeger Scientific, 1984.

4. White GB : Airport malaria and jumbo vector control. Parasitology today. 1985 ; 1: 177-179

5. WHO Technical Report Series, No 34, 1951 (Insecticides : report on the second session of the Expert Committee).

6. Laird M : The accidental cariage of insects on board aircraft. J Roy Aeronaut Soc 1951 ; 55 : 735-743

7. WHO Technical Report Series, No 206, 1961 (Aircraft disinsection : eleventh report of the Expert Committee on Insecticides).

8. International sanitary regulations. Annotated edition. Geneva, World Health Organization. 1966.

9. Sullivan WN et al : Studies on aircraft disinsection at "blocks away" in tropical areas. Bull WHO 1962; 27 : 263-273

10. Sullivan WN et al : Studies on aircraft disinsection at "blocks away"s in tropical areas. Bull WHO 1964; 30 : 113-118

11. Sullivan WN et al : Worldwide studies on aircraft disinsection at "blocks away". Bull WHO 1972 ; 46: 485-491

12. Vector quarantine in air transport. WHO Chronicle. 1971; 25: 236-239

13. Bailey J : Guide to hygiene and sanitation in aviation 2nd eidition, revised and expanded. Geneva, WHO, 1977.

14. Recommendations on the disinsecting of aircraft. Weekly epidemiological record. 1985; 60: 45-47

15. Laird M : Overview and perspectives. In : Laird M, ed. Commerce and the spread of pests and disease vectors. New York, Praeger Scientific, 1984.

16. Langsford, WA et al. A trial to assess the efficacy of in-flight disinsection of a Boeing 747 aircraft on the Singapore/Sydney secotr. Pyrethrum posts. 1976; 13: 137-142

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