ASSEMBLY – 35th SESSION

ECONOMIC COMMISSION

Agenda Item 29: Facilitation

THE AIR CURTAIN AS AN APPROACH TO AIRCRAFT DISINSECTION

(Presented by the United States of America)

INFORMATION PAPER

SUMMARY

Commercially available air curtains were evaluated by a United States Government laboratory as a barrier to flying insects entering a simulated aircraft doorway. Simulated passenger walkways and aircraft were assembled and three mosquito species were selected that have differing host-seeking characteristics. House flies were also selected as a representative large, strong flying insect. Results of the study demonstrated that vertically mounted air curtains with the airflow directed at a 45° angle into the passenger walkway were highly effective as barriers to mosquitoes and the house fly, 99 and 100% exclusion, respectively. The study validates the concept that air curtains can effectively prevent the passage of flying insects into an aircraft.

1. INTRODUCTION

1.1 International air traffic and the cosmopolitan nature of the world economy present serious challenges and responsibilities for those involved in the transportation of people and cargo bridging geographically isolated areas of the world. The unintentional introduction of invasive flying insect species via aircraft arriving from abroad is a concern for some countries. Mosquitoes species are of particular concern as their blood feeding requirements make them ideal vectors of many diseases of man and animals. Since these species readily track their human hosts unnoticed they could cryptically follow passengers on board an aircraft in one country with endemic mosquito vectors and disembark with the passengers at an airport in another country. This has been demonstrated directly through documented cases of mosquitoes in aircraft and indirectly through confirmed and probable cases of airport malaria (Gratz, et al. 2000).

1.2 The United States does not require disinsection of international flights arriving into its airports. Some countries require that international aircraft be disinsected with a pesticide prior to disembarkment of passengers and crew (DOT 2004). The efficacy of such treatments has been tested extensively, and results vary depending on the insecticide, target insect, method of insect exposure, and the location of the test insects in the aircraft (Brooke and Evans 1971, Sullivan et al. 1972, 1975, 1978, Cawley et al. 1974, Langsford et al. 1976, Liljedah et al. 1977, Russell and Paton 1989). The Report of the Informal

Consultation on Aircraft Disinsection, sponsored by the World Health Organization (November 6-10, 1995), noted that some individuals might experience transient discomfort following aircraft disinsection.

1.3 There is increasing concern over the effects of disinsection on the health of passengers and especially crewmembers, which are repeatedly subjected to pesticide exposure during overseas flights (Anon. 2001, Das et al. 2001, van Netten 2002, Sutton et al. 2003). The need to protect passengers and aircraft crew from potentially negative health effects of insecticide exposure and the need for assurance that an aircraft is free of flying insects represent a significant challenge.

1.4 The objective of this paper is to report research results on the efficacy of air curtains in preventing mosquitoes and house flies from entering airplanes through passenger doors via airport passenger boarding bridges. This methodology offers an alternative to the use of insecticides for disinsection and therefore obviates the health concerns centered on current disinsection methods.

2. METHODS AND MATERIALS

2.1 The United States Department of Agriculture's Mosquito and Fly Research Unit maintains many species of laboratory-reared mosquitoes and flies, including house flies. Large numbers of these species can be made available as needed for experiments.

2.2 **Mosquito Species.** The following three mosquito species were chosen for use in the experiments described below because each has unique host seeking behavior that impacts where they will be found in association with human hosts and how they may be affected by air currents: (A) *Aedes aegypti*, a yellow fever/dengue vector that attacks mainly around the feet and lower part of the body. *Ae. Aegypti* is a very skittish species; however, if the air stream is not strong enough near the floor, this mosquito species may be able to get through the air curtain barrier; (B) *Anopheles quadrimaculatus*, a malaria vector, attacks the upper torso. It tends not to bite in bright daylight, but once attached to the body it may be difficult to dislodge; and (C) *Ochlerotatus taeniorhynchus*, a persistent salt marsh species, which attacks mostly from mid-torso to the head area. It will cling tightly to the body and follow moving hosts very aggressively. Mosquitoes from colony cages were sexed by immobilizing them on a cold table at 1.7ºC and counting them into small cages for transfer to and release in the test facilities. Only blood-seeking females were used for the experiments. Mosquitoes were allowed to recover for at least 30 minutes after exposure to cold temperature and provided with a cotton ball saturated with a 10% sucrose solution until time for release.

2.3 **The House Fly.** House flies are known to mechanically transmit a number of pathogenic organisms to humans, livestock, and poultry. There are a number of flies similar to the house fly in size and flight ability that could cause serious problems with livestock and humans if introduced accidentally. These include a variety of blow flies (Calliphorids), *Musca sorbens*, bush flies, and screwworm flies. The house fly is a cosmopolitan species and readily available in our laboratory colonies; therefore, it was selected as a representative large strong flier in contrast to weaker flying mosquitoes. Laboratory reared house flies of both sexes were immobilized with CO_2 and counted into small cages for transfer to and release in the test facilities. Flies were allowed to recover for at least 30 minutes after exposure to CO_2 and provided with a cotton ball saturated with a 10% sucrose solution until time for release.

2.4 **Test Facility.** The test facility was composed of two corrugated aluminum sheds, one serving as the simulated aircraft unit (3.05 x 6.1 m) and the second the simulated passenger boarding bridge unit (2.44 x 7.32 m). Units were placed contiguously in a T configuration, leaving a screened space of ~ 15 cm between the two units to simulate the space generally observed between a real aircraft and the loose-fitting passenger boarding bridge. Both units were fully insulated and fitted with paneled walls, acoustical tile or wooden ceilings, and wooden floors. All interior surfaces were white in color to

maximize visibility and assist with the observation and recapture of insects released in the test facility. During testing the air in both units was maintained at 22.8ºC, a temperature conducive to insect flight activity. There were no windows and all doors were solid to eliminate distraction of insects by outside light. Overhead banks of standard fluorescent tubes provided light. A small entry room without lights separates the passenger boarding bridge from its door leading outside. There is a solid wall between the entry room and a pocket door can close the doorway between them. A double curtain of fine mesh fabric covers the passenger boarding bridge side of the doorway to prevent exit of insects when the pocket door is opened for insect introduction and test transits. A larger exit room separates the aircraft unit from its door leading outside. The wall separating these two rooms is made of the same fine mesh fabric described above as are the double curtains covering both sides of the doorway between the two rooms. The mesh curtains keep insects inside the aircraft unit during testing when people are passing through the test facility. Figure 1 shows the configuration of the two simulated units.

2.5 **Air Curtains.** The air curtains used in these experiments were mounted inside the simulated passenger boarding bridge in the exit doorway adjacent to and leading into the simulated aircraft. One 1.83-m FSA unit (1.12 kW, Berner International, Pittsburgh, PA) was mounted vertically on each side of the doorway and one 1.1-m MK-2 unit (0.15 kW, Berner International, Pittsburgh, PA) was mounted horizontally above the doorway (Fig. 1). The air from each vertical unit was directed at a 45-degree angle across the doorway such that the two air streams met at a 90-degree angle ca. 1-m inside the doorway and the air flow was directed towards the interior of the passenger boarding bridge. Air from the horizontally mounted unit was directed downward towards the interior of the passenger boarding bridge at a 15-degree angle. This air stream filled the void between the convergent air streams of the two vertically mounted units and the exit doorway. The intake sides of the vertically mounted units were framed with window screen to prevent insect entry.

2.6 **Treatments.** The following combinations of air curtain units were used to evaluate the ability of the test insects to pass through the doorway from the simulated passenger boarding bridge into the simulated aircraft: (1). All units off (control); (2). Two vertical units on, horizontal unit off; (3). All units on. For each air curtain combination, two levels of insects were evaluated:(A) Five (5) of each mosquito species and five (5) house flies or 20 total insects, (B) Fifty (50) of each mosquito species and fifty (50) house flies or 200 total insects. To begin a test, both parts of the test facility were checked and determined to be insect free; air conditioning units were turned on, and air curtains were placed at the proper setting (either on or off) depending upon the selected combination. The selected number of insects was carefully released in the passenger boarding bridge unit under the fine mesh curtain inside the pocket door. Insects were allowed to disperse naturally within the room for five minutes, after which any insects that had passed into the aircraft unit were counted and recorded. Then, available personnel entered the passenger boarding bridge from the entry room and walked through the door with the air curtains into the aircraft and out through the aircraft exit door. Simulated passenger movement was continued until 25 passenger equivalents were obtained.

2.7 **Data Collection.** After the last person passed into the aircraft unit, the door separating it from the passenger boarding bridge unit was closed and any insects within the simulated aircraft were captured with a battery powered vacuum aspirator, frozen, and later counted and mosquitoes identified to species.

2.8 **Data Analysis.** Differences in numbers of insects collected in the simulated aircraft were evaluated by pairwise analysis of treatments using the G-test. This non-parametric test, also known as the log-likelihood-ratio, computes a test statistic "G" whose distribution is essentially equal to the chi square distribution (Sokal and Rohlf 1981).

3. CONCLUSION

3.1 The use of air currents for fly control has been known from ancient to modern times in the form of hand held fans. The commercial application of air currents also is not new (see Waldron 1958); however, the systematic study of air currents as barriers to flies appears to have been first reported by Hocking (1960). He suggested that air barriers moving at 457m/min would effectively prevent flies from entering a doorway. Later an often cited USDA directive specified that air barriers were somewhat effective if the air velocities were 488m/min 1m above the floor (Anonymous1963). Mathis et al. (1970) determined in laboratory experiments that 92% exclusion of house flies could be obtained with an air curtain velocity of 547m/min and angle of release of 15°. In less controlled, but passive (no human activity involved) field conditions, 80% exclusion was obtained. Passage of people through the air curtain would lead to even less efficacy. Generally, air curtains are assumed to be ca. 80% effective at excluding house flies in commercial operations (PCT, June 2002). These air curtains are mounted horizontally above the doorway to be protected. In our experimental design when only the horizontal air curtain was on a mean of 28% (SE = ± 3.1; N=3) of 50 house flies were found in the simulated aircraft after 25 passenger equivalents had passed through the passenger walkway. This level of efficacy is not acceptable as an alternative to insecticide disinsection.

3.2 Results for the protocol using 50 each of three mosquito species and the house fly are shown in Figure 2 (number entering simulated aircraft) and in Figure 3 (Percent excluded from the simulated aircraft). The statistical comparison of the results are shown in Table 1. Significant reduction of house flies and mosquitoes were obtained with only the two vertically mounted air curtains and with the two vertical plus the horizontal air curtains, when compared with the air curtains off. There was no difference between the use of two vertical versus two vertical and one horizontal air curtains for house flies; however, the three air curtain system was significantly better in excluding mosquitoes. Of the total possible house flies and mosquitoes placed in the passaenger walkway the vertical only and the vertical plus horizontal air curtains excluded 93.5 and 96.2% mosquitoes, respectively and 94.4 and 97% of the house flies, respectively.

3.3 Table 1. Results for the number of mosquitoes and houseflies that entered the simulated aircraft from the simulated passenger walkway after 25 passenger equivalents passed through the walkway into the aircraft. Fifty (50) of each species were released.

Treatment	Ae. aegypti	Och. taeni.	An. quad.	Tot. mosq.	House flies
All off	12.8 (2.0)a	7.2 (2.2)a	11.8 (5.0)a	31.8 (8.1)a	15.2 (1.9)a
Vert only	4.2 (0.6)b	3.2 (1.1)b	2.5 (0.9)b	9.8 (1.8)b	2.8 (0.5)b
Vert and Horiz	2.5 (0.6)b	2.0 (1.1)b	1.2 (0.4)c	5.7 (1.2)c	1.5 (0.5)b

Means within columns followed by the same letter are not significantly different at P=0.05 (G-test of independence).

3.4 The protocol using 150 mosquitoes and 50 houseflies uses a much greater number of insects than would be expected to be found in a passenger walkway under normal conditions; therefore, a smaller set of test insects using 5 each of three mosquito species and the house fly were evaluated in the same way as described above. The results are shown in Figure 4 (number entering simulated aircraft) and in Figure 5 (Percent excluded from the simulated aircraft). The statistical comparison of the results are shown in Table 2. Significant reduction of mosquitoes were obtained with both the two vertically mounted air curtains and with the two vertical plus the horizontal air curtains, when compared with the air curtains off. There was no statistical difference between the use of two vertical versus two vertical and one horizontal air curtains. Of the total possible mosquitoes placed in the passenger walkway the vertical only and the vertical plus horizontal air curtains excluded 99 and 97% of the mosquitoes, respectively. No house flies

were able to penetrate the air curtain barrier using the two vertically mounted air curtains and only one house fly managed to get through in four replicates using the three air curtain system. This represents 100 and 98% exclusion of house flies using the two and three air curtain systems, respectively.

3.5 Table 2. Results for the number of mosquitoes and house flies that entered the simulated aircraft from the simulated passenger walkway after 25 passenger equivalents passed through the walkway into the aircraft. Five (5) of each species were released.

Treatment	Ae. aegypti	Och. taeni.	An. quad.	Tot. mosq.	House flies
All off	3.0 (1.1)a	2.3 (0.9)a	1.3 (0.9)a	6.7 (2.7)a	1.3 (0.9)a
Vert only	0.0 (0.0)b	0.2 (0.2)b	0.0 (0.0)b	0.2 (0.2)b	0.0 (0.0)b
Vert and Horiz	0.2 (0.2)b	0.0 (0.0)b	0.2 (0.0)ab	0.5 (0.5)b	0.2 (0.2)ab

Means within columns followed by the same letter are not significantly different at P=0.05 (G-test of independence).

3.6 These results demonstrate that air curtains can be used to effectively exclude mosquitoes and flies, 99 and 100% respectively, from passing through a doorway that has human traffic similar to passengers boarding an aircraft. Commercial air curtains are in use throughout the United States and the world primarily to provide a doorless barrier to non-conditioned outside air. The momentary air flow experienced by customers is not considered detrimental and it is anticipated that airline passengers will also be accepting of air curtains.

3.7 We demonstrated the potential effectiveness of air curtains in excluding flying insects from entering an aircraft, and it should be noted that if the air flows were reversed, toward the aircraft door as the passengers disembarked, any flying insects on board would be kept on board. Comparison of air curtain results with insecticide disinsection is difficult, because we used free flying insects, whereas, insecticide evaluations have all used caged insects positioned in several locations throughout an aircraft.

3.8 We recently did a mosquito and house fly release and recapture trail on an aircraft and noted that after two hours only ca. 50% of the insects had been found and recaptured. We concluded that the aircraft offered innumerable refuges for the free flying insects released. Thus, the real life situation may be considerably different from the caged insects used in insecticide/aircraft evaluations. Interestingly as well, a recent schedule of aircraft disinsection procedures issued by New Zealand and Australia quarantine services states that for evaluation of aircraft residual treatments ceiling cages of house flies receive a pass if 30% or more of the flies are affected and all other cages receive a pass if 70% or more of the flies are affected. In other words, 100% effectiveness is not required. Our result indicates that air curtains can provide an alternative to insecticide disinsection of aircraft.

4. REFERENCES

Anon. 1963. Facilities and equipment fact sheet, Meat Inspection Division Agr. Res. Serv. USDA MID-FE-1.

Anon. 2001. The airliner cabin environment and the health of passengers and crew. National Academy Press, Washington DC.

Brooke, J.P. and M. Evans. 1971. Disinsection of aircraft with pressure packs containing the pyrethroids, resmethrin and bioresmethrin. Pestic sci. July/Aug 1971. 2 (4): 133-137.

Cawley, B. M., W.N. Sullivan, M.S. Schechter, and J.U. McGuire. 1974. Desirability of three synthetic pyrethroid aerosols for aircraft disinsection. Bulletin of the World Health Organization 51 (5):537-540

Das, R. J. Cone and P. Sutton. 2001. Aircraft disinsection. Bulletin-of-the-World-Health-Organization. 79 (9): 900-901.

DOT . 2004. Aircraft disinsection requirements.
http://ostpxweb.dot.gov/policy/Safety%20Energy%20Env/disinsection.htm

Gratz, N.G., R. Steffen, and W. Cocksedge. 2000. Why aircraft disinsection?. Bulletin-of-the-World-Health-Organization. 78 (8): 995-1004.

Hocking, R. 1960. An insect proof doorway, Bull. Entomol. Res. 51: 135-44.

Langsford, W. A., N Rajapaksa, and R.C. Russell. 1976. A trial to assess the efficacy of in-flight disinsection of a Boeing-747 aircraft on the Singapore/Sydney sector. Pyrethrum Post, 1976, Vol. 13, No. 4, pp. 137-142.

Liljedah, L. A., H. J. Retzer, W. M. Sullivan, M.S. Schechter, B. M. Cawley, N.O. Morgan, C.M. Amyx, B.A. Schiefer, and E.J. Gerberg. 1977. Aircraft disinsection; the physical and insecticida; characteristics of dextro phenothrin applied ny aerosol at blocks away. Bulletin of the World Health Organization, 54(4): 391-396.

MQS/AQIS. 2004. Schedule of Aircraft Disinsection Procedures. 14 January 2004.
http://www.affa.gov.au/corporate_docs/publications/pdf/quarantine/airports/mqs_aqis_disinsection_procedures.pdf

Mathis, W., E.A. Smith, and H.F Schoof. 1970. Use of air barriers to prevent entrance of house fkies, J. econ. Entomol.63: 29-31.

Russell, R. C. and Paton, R. 1989. In-flight disinsection as an efficacious procedure for preventing international transport of insects of public health importance. Bulletin of the World Health Organization, 67(5):543-547.

Sokal, R. R. and F. J. Rohlf. 1981. *Biometry*. W. H. Freeman, New York, 859p

Sullivan, W. N., R. Pal, J.W. Wright, J.C. Azurin, R. Okamoto, J.U. McGuire, and R.M. Waters. 1972. Worldwide studies on aircraft disinsection at "blocks away". Bulletin of the World Health Organization 46 (4): 485-491.

Sullivan, W. N. , A. N. Hewing, M.S. Schechter, J.U. McGuire, R.M. Waters, and E.S. Fields. 1975. Further studies of aircraft disinsection and odor characteristics of aerosols containing resmethrin and d-trans-resmethrin. Botyu-Kagaku 40 (1): 5-13.

Sullivan, W.N., B.M. Cawley, M.S. Schechter, D.K. Hayes, K. Staker, and R. Pal. 1978. A comparison of Freon based and water based insecticidal aerosols for aircraft disinsection. Bulletin-of-the-World-Health-Organization. 1978; 56 (1):129-132.

Sutton, P., X. Vergara, J. Beckman, and R. Das. 2003. Occupational illness among flight attendants due to aircraft disinsection. Report published by the Occupational Health Branch, California Department of Health Services.

Van Netten-C. 2002. Analysis and implications of aircraft disinsectants. Science of the Total Environment. 293:257-262.

Waldron, W.G. 1958. A study of the effectiveness of mechanical fans used as fly control measures in public eating-places. MS Thesis in Public Health and Preventive Medicine. Univ. Calif. Los Angeles, CA