

EFFICACY OF COMMERCIAL HOUSEHOLD INSECTICIDE AEROSOL SPRAYS AGAINST *Aedes aegypti* (LINN.) UNDER SIMULATED FIELD CONDITIONS

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Abstract. A simulated field study on the efficacy of commercial household aerosol insecticides was conducted. The bioefficacy of three pyrethroid aerosols, designated as PA1, PA2 and PA3, was tested in cabins furnished to simulate bedroom conditions. Each aerosol product was tested against lab-bred *Aedes aegypti* mosquitoes based on the insecticide manufacturers' recommended dosages. Ten cages with mosquitoes were placed in the following locations: one cage in the middle of the room; two each on and underneath the bed; three each placed inside, behind and on top of the wardrobe; and four placed on and in the desk. With the desk, each cage was placed inside each of three drawers (totally closed, partially closed and opened). Prior to the experiments, the discharge rate of each aerosol can was determined. Ten to 20 lab-bred 2-5 day-old sugar-fed *Ae. aegypti* adult mosquitoes were placed inside the test cages. The aerosol was then discharged into the cabin at the recommended dosage. After 30 minutes, the mosquitoes were transferred into clean paper cups and their mortality recorded after 24 hours. All the aerosols induced complete or very high mortality in the caged *Ae. aegypti* females, except in the cages hidden completely inside the drawers and wardrobes. Insecticide droplet analysis indicated variable uniformity of the droplets was produced. The aerosol insecticides were effective against mosquitoes provided they were used in accordance with the manufacturers' recommendations.

INTRODUCTION

Chemical control is still considered the most important element in the integrated control of insect-borne diseases and nuisance pests in general (WHO, 1999). At the same time, there has been an increasing recognition of the role of domestic chemical control products which can be used by the public around their homes, work sites etc. These

products are commonly classified as household insecticides. Insecticide aerosol spray is a major product the public has been using. In general, pyrethroids are the main active ingredients in these household aerosol products. For the years 2000-2002, on the average, 519 tons of pyrethroids were used annually for vector control at the global level (Zaim and Jambulingam, 2004). The quantity of pyrethroids used for vector control increased 16 times in 2002 compared to the year 2000.

A preliminary study of the effects of household aerosol insecticides against mosquitoes in test houses was highly effective against adults of *Aedes aegypti* and *Culex*

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quinquefasciatus (Lee and Khadri, 1997). However, since then, very few field evaluations of these aerosol products have been reported.

Hence, this study was undertaken to evaluate the field efficacy of commercial household aerosol insecticides applied at their recommended dosages against *Aedes aegypti* placed in cages in various exposed, semi-exposed and unexposed places in simulated room conditions.

MATERIALS AND METHODS

Test cabin

Two cabins measuring 10 feet wide, 20 feet long and 8 feet high (3.03 m x 6.07 m x 2.42 m) with a total volume of 44.51 m³ for each cabin were used to simulate bedrooms. The internal cabin surfaces were painted with epoxy paint for washing and cleaning purposes. All the internal surfaces of the cabins were thoroughly wiped with a damp cloth after each aerosol test. The washed cabin was used for the next aerosol test after an interval of 5 days.

Tested mosquitoes

Laboratory-bred 2-5 day-old sucrose-fed *Aedes aegypti* female mosquitoes were used in the test and kept in cages at concentrations of 20/cubical cage and 10/cylindrical cage.

Test cages

Two types of cages were used: a cubic cage 15 cm x 15 cm x 15 cm in size and a cylinder cage 15 cm in height x 2.5 cm in diameter. These two cages were used based on the space inside the test cabin. Polyester netting at a size of 25-36/mm² was used for both types of cages.

Insecticide aerosol testing

Three commercial aerosol formulations coded as PA1, PA2 and PA3 were used for the test. The active ingredients of the aero-

sols were: PA1: prallethrin 0.076% w/w, d-phenothrin 0.046% w/w, inert ingredients 99.878% w/w; PA2: water based, prallethrin 0.076% w/w, d-phenothrin 0.046%, inert ingredients 99.878%w/w; PA3: transfluthrin 0.040% w/w, cyfluthrin 0.025% w/w, inert ingredients 99.935% w/w. These aerosols were purchased from a local supermarket.

Droplet analysis

The droplet profiles of the aerosols were determined using magnesium oxide-coated glass slides. The slides were prepared as described by Lee (1995). The MgO-coated slides were collected 30 minutes post-spraying. The slides were examined at 400X magnification and the droplet sizes were measured with an ocular micrometer.

Determination of discharge rate

The discharge rate of each aerosol was determined for each experiment by first pre-weighing the new cans (to 0.1 grams). The can was then sprayed manually into the air in the room for 10 seconds and then re-weighed to compute the amount sprayed in 10 seconds. The procedure was repeated a 2nd and 3rd time. The amount sprayed per second was averaged to obtain the mean discharge rates.

Evaluation of spraying

The tests were conducted in the cabins as described above. The locations of the ten cages and six magnesium coated slides are shown in Fig 1. Cage 1 was placed on the bed, cage 2 under the bed, cage 3 placed was place in the middle of the cabin on the floor, cage 4 was placed on the desk, cages 5, 6, and 7 were placed in the drawers of the desk, one opened fully, one partially open (2 cm) and one completely closed. Cages 8, 9 and 10 were placed on the top middle of the wardrobe, top back of the wardrobe and inside the wardrobe between hung dresses.

The aerosol was sprayed from the cabin door corner (with the door closed) with the

nozzle held 45° upward and moved in a left to right motion. The air-conditioner in the room was switched off 3 minutes before spraying. The spray times were determined by the manufacturers' recommendations as stated in the label of each aerosol product (PA) can: PA1, 8 seconds; PA2, 4 seconds; and PA3, 6 seconds. The person who performed the spraying stayed in the cabin, with complete personal protection, to record the mosquito mortality/knockdown rates at 10 and 30 minutes. The closed places were opened for 10 seconds to observe the knockdown or mortality numbers in those areas. The number of mosquitoes knocked down was also recorded at 1 hour and 2 hours post-spraying. After 2 hours observation, all mosquitoes were transferred into clean paper cups with 10% sugar pads. Mortality was observed after 24 hours.

Control

The control was conducted in a control cabin of similar size and setup but with no spraying activity. The mosquitoes were also transferred into clean paper cups from the cages and fed with sugar solution. Knockdown or mortality number in the control mosquitoes of each cage were observed at 10 minutes, 30 minutes, 1 hour and 2 hours.

Data analysis

The droplet analysis was carried out following Sofield and Kent (1984).

RESULTS

Discharge rate of aerosol products

All three products were tested for their discharge rates (Tables 1 to 3). The mean discharge rates (for three discharges) for each of

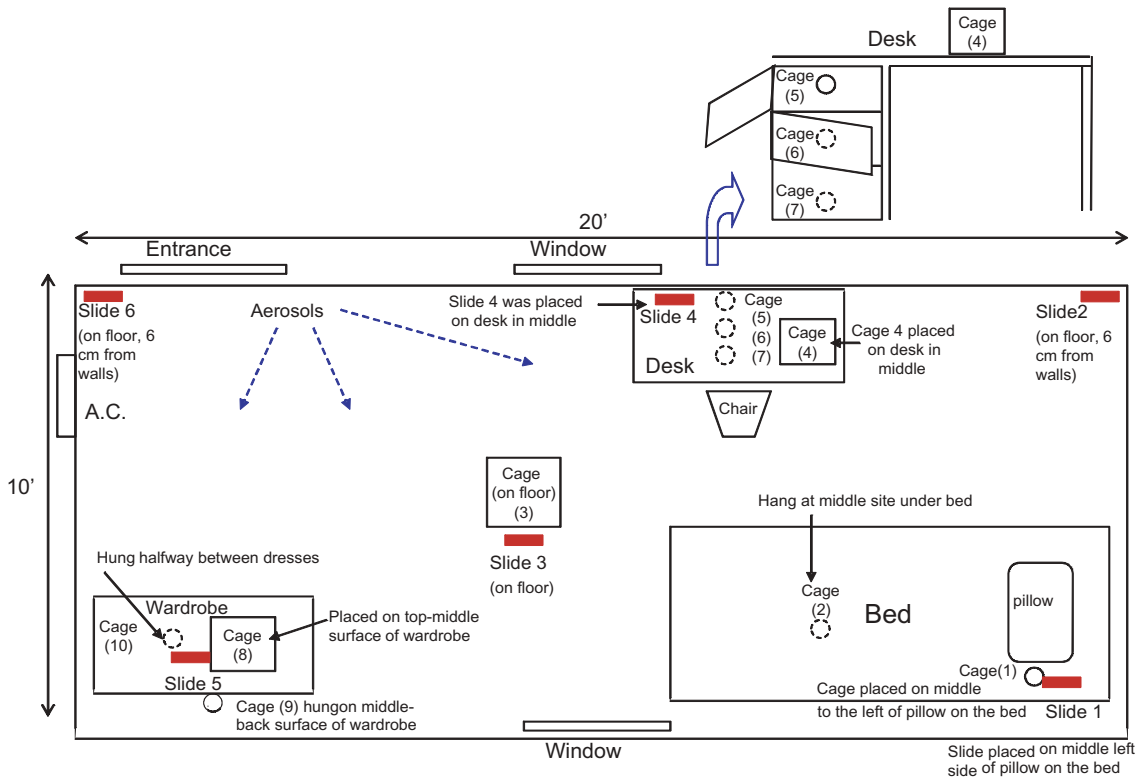


Fig 1–Setup of cylindrical and cubical cages (cages 1-10), Mg-oxide coated slides (slides 1-6) and bedroom furniture in the treatment-cabin and control cabin.

Table 1

Discharge rates of aerosol product PA1 (Prallethrin 0.076% w/w, d-phenothrin 0.046% w/w).

| Discharge no. | Weight of can (g) | | Amount sprayed (g) | Spray time (s) | Discharge rate (g/s) |
|---------------|-------------------|--------|--------------------|----------------|----------------------|
| | Pre | Post | | | |
| 1 | 519.91 | 502.18 | 17.73 | 10 | 1.773 |
| 2 | 502.18 | 484.38 | 17.80 | 10 | 1.780 |
| 3 | 484.38 | 466.69 | 17.69 | 10 | 1.769 |

Mean discharge rate = 1.774 g/s; test rate = 8 sec/44.51m³; total amount discharged = 14.19 g

Table 2

Discharge rates of aerosol product PA2 (Prallethrin 0.076% w/w, d-phenothrin 0.046% w/w).

| Discharge no. | Weight of can (g) | | Amount sprayed (g) | Spray time (s) | Discharge rate (g/s) |
|---------------|-------------------|--------|--------------------|----------------|----------------------|
| | Pre | Post | | | |
| 1 | 593.88 | 574.70 | 19.18 | 10 | 1.918 |
| 2 | 574.70 | 555.66 | 19.04 | 10 | 1.904 |
| 3 | 555.66 | 537.06 | 18.60 | 10 | 1.860 |

Mean discharge rate = 1.894 g/s; test rate = 4 sec/44.51m³; total amount discharged = 7.58 g

Table 3

Discharge rates of aerosol product PA3 (transfluthrin 0.040% w/w, cyfluthrin 0.025% w/w).

| Discharge no. | Weight of can (g) | | Amount sprayed (g) | Spray time (s) | Discharge rate (g/s) |
|---------------|-------------------|--------|--------------------|----------------|----------------------|
| | Pre | Post | | | |
| 1 | 544.55 | 526.36 | 18.19 | 10 | 1.819 |
| 2 | 526.36 | 509.36 | 17.00 | 10 | 1.700 |
| 3 | 509.36 | 493.38 | 15.98 | 10 | 1.598 |

Mean discharge rate = 1.7057 g/s; test rate = 6 sec/44.51m³; total amount discharged = 10.23 g

the products were 1.774 g/s (PA1), 1.894 g/s (PA2) and 1.706 g/s (PA3), respectively. PA2 had the highest mean discharge rate and PA3 had the lowest. Standard deviation for the discharge rates were 1.106 for PA3, .302 for PA2 and 0.056 for PA1. The higher standard deviation for PA3 was due to a steep decline in the 2nd and 3rd discharges, compared to other products. This may have been due to insufficient pressure in the can of the product.

Based on the cabin volume and the manufacturers' recommended rate, the test rate for each of the products was calculated. The test rates for PA1, PA2 and PA3 were 14.19 g, 7.50 g and 10.23 g per 44.51 m³, respectively.

Knockdown/mortality rates

Since the control mortality was 5% or lower for all the tests, no corrections in test mortality was required (WHO, 1981).

Table 4
Droplet profiles of aerosol products on magnesium oxide-coated slides placed at various sites in the room.

| Product | Slide no. ^a | VMD (µm) | NMD (µm) | VMD/NMD ratio |
|---------|------------------------|----------|----------|---------------|
| PA1 | 1 | 25.96 | 19.26 | 1.35 |
| | 2 | 25.28 | 20.78 | 1.22 |
| | 3 | 26.80 | 19.85 | 1.35 |
| | 4 | ND | ND | ND |
| | 5 | 30.09 | 25.78 | 1.17 |
| | 6 | 34.70 | 27.26 | 1.27 |
| PA2 | 1 | 11.82 | 9.99 | 1.18 |
| | 2 | 13.14 | 11.03 | 1.19 |
| | 3 | 11.55 | 10.87 | 1.06 |
| | 4 | 16.30 | 13.02 | 1.25 |
| | 5 | 15.56 | 13.38 | 1.16 |
| | 6 | 32.17 | 27.08 | 1.19 |
| PA3 | 1 | ND | ND | - |
| | 2 | ND | ND | - |
| | 3 | ND | ND | - |
| | 4 | ND | ND | - |
| | 5 | ND | ND | - |
| | 6 | ND | ND | - |

ND = no droplets detected

^a30 droplets/slide were measured

All the aerosol products tested contained various pyrethroid formulations. Both products PA1 and PA2 contained a combination of prallethrin and d-phenothrin, while PA3 contained a combination of transfluthrin and cyfluthrin. The Knockdown/mortality rates for *Aedes aegypti* mosquitoes at 10 minutes post-spray for PA1, PA2 and PA3 are shown in Fig 2. These aerosols were very effective in inducing knockdown in most of the mosquitoes placed in exposed positions in the cabin. However, in position 6 (drawer opened 2 cm), position 7 (drawer closed) and position 10 (in the wardrobe) no knockdowns were noted. At position 5 (drawer opened) different knockdown rates were seen with the different aerosols. PA3 had a 100% knockdown rate and PA1 had a 70% knockdown

rate. PA2 had only a 10% knockdown rate 10 minutes post-spray.

By 30 minutes (Fig 3), knockdown of mosquitoes started to occur in all the hidden places. However, the knockdown percentages were still very low (<20%). Surprisingly, the knockdown rates 1 hour post-spray increased in the unexposed positions 7 and 10 (Fig 4) with PA2 having the lowest knockdown rate (<10%).

At 2 hours post-spray (Fig 5); PA2 was the least effective in inducing knockdown. PA3 induced total knockdown of mosquitoes in all positions, including unexposed positions.

At 24 hours post-spray (Fig 6) PA2 induced less than 20% mortality of mosquitoes

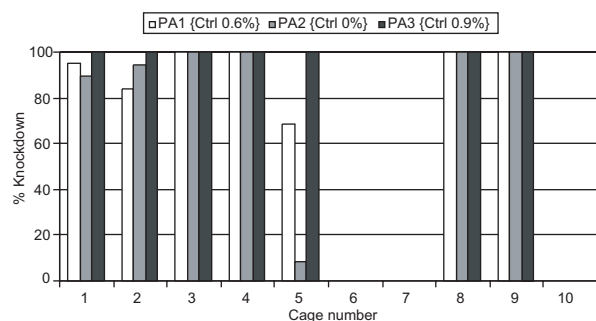


Fig 2-Knockdown rates of mosquitoes in ten cages at different positions 10 minutes post-spraying. The corresponding control mortality for each aerosol is indicated.

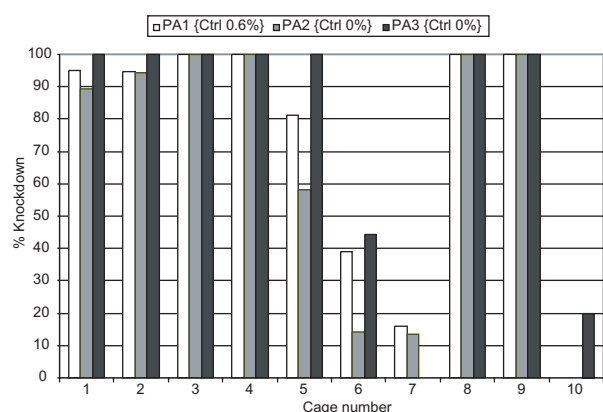


Fig 3-Knockdown rates of mosquitoes in ten cages at different positions 30 minutes post-spraying. The corresponding control mortality for each aerosol is indicated.

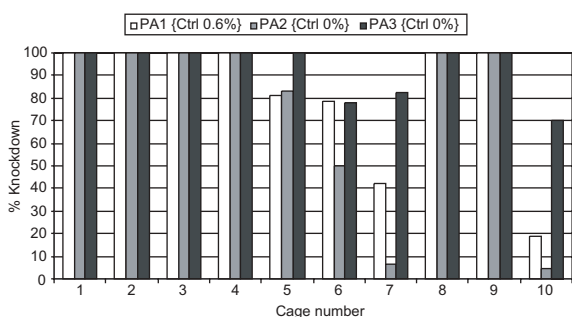


Fig 4-Knockdown rates of mosquitoes in ten cages at different positions 1 hour post-spraying. The corresponding control mortality for each aerosol is indicated.

placed in the closed drawer (position 7) and <40% mortality in the mosquitoes placed in the wardrobe (position 10). PA3 induced total mortality of all mosquitoes in all positions except in the wardrobe, which exhibited approximately 90% mortality. PA2 caused 100% mortality in mosquitoes in all exposed locations but failed to kill all the mosquitoes in cage number 8 located on the wardrobe.

Fig 7 shows the knockdown/mortality rates for all aerosol products tested at 10 minutes, 30 minutes, 1 hour, 2 hours and 24 hours post-spray. Generally, the knockdown/mortality rates were < 80% at 10 minutes post-spray, and increased at 30 minutes, 1 hour and 2 hours. At 24 hours post-spray PA3 had 100% knockdown/mortality, and 99% at 2 hours. The mortality rates at 24 hours induced by PA1 and PA2 increased from those at 2 hours post-spray to 92% and 83% mortality, respectively.

Droplet profiles

No droplets were detected from PA3 product on six MgO-coated slides, whereas PA1 and PA2 showed satisfactory VMD: NMD ratios (Table 4). Another method more sensitive in detecting smaller droplets from PA3 aerosol may need to be used. On slide No. 4 (on the desk) PA1 droplets were not detected. Although droplets were not detected on slide No. 4, mosquitoes were completely knocked down and caused total mortality at 24 hours. This may be due to a fine aerosol droplet size of 10 μm or less that affected the mosquitoes but did not show on the MgO-coated slides. A Teflon® coated slide might be more useful than a MgO coated slide for detecting finer droplet sizes. Nondetection of PA3 droplets shows it had produced very fine aerosol droplets (<11 μm) but it gave high mortality to all the mosquitoes on all exposed and unexposed places.

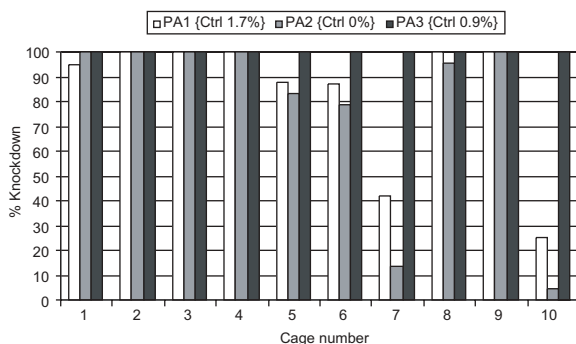


Fig 5–Knockdown rates of mosquitoes in ten cages at different positions 2 hours post-spraying. The corresponding control mortality for each aerosol is indicated.

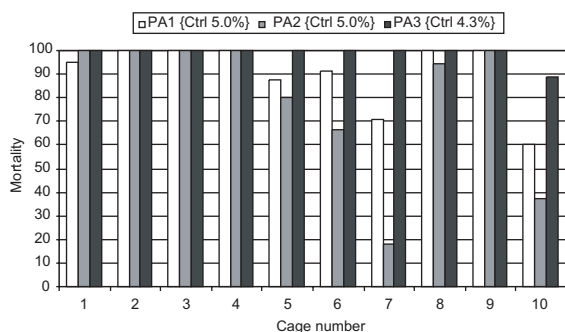


Fig 6–Mortality of mosquitoes in ten cages at different positions at 24 hours post-spraying. The corresponding control mortality for each aerosol is indicated.

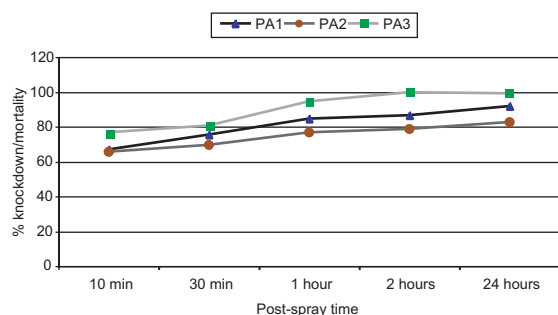


Fig 7–Mean knockdown/mortality for mosquitoes with aerosol products PA1, PA2 and PA3 at post-spray intervals.

DISCUSSION

At 24 hours post-spraying the highest mortality rate recorded was 99% and the lowest was 73%. Total mortality of mosquitoes can be obtained if the mortality of mosquitoes in the hidden places is excluded. Lee and Khadri (1997) also found total mortality of mosquitoes placed in exposed areas of a sitting room, bedroom and kitchen at 24 hours post-spraying. However, they did not make observations at 10, 30, 60 and 120 minutes post-spraying. Our study found greater than 80% knockdown/mortality rates for mosquitoes at 10, 30 and 60 minutes post-spraying in open places. At 60 minutes and 24 hours post-spraying, the open places had more than 90% mortality. However, most of the products gave total mortality at 24 hours post-spraying in open places.

The knockdown/mortality rates in the closed areas may be because at 10 seconds post-discharge when the observer opened the closed space to observe for knockdown/mortality, the spray may have entered the closed area since the droplets may still have been suspended in the air. A narrow gap of 2-3 mm when the drawer was closed could have allowed droplets to enter the closed space.

The manufacturers of all the aerosol products recommend a minimum of 10 minutes should be allowed before the user re-enters the sprayed room. This would also imply the user allows the drawers and closets to be open for 10 minutes. Interestingly, at 10 minutes post-spraying, all the products induced total knockdown of the mosquitoes in all exposed places, however, in the hidden places not a single knockdown or mortality was observed. Knockdowns and mortalities were only observed at 30 minutes post-spraying. This might be due to insecticide droplets entering into the hidden places during the 10 second observation time. This

also indicates at the 10 minute observation period, droplets of insecticide were still suspended in the air. This 10 second observation period appeared to affect the mosquitoes in the closed places, inducing some degree of knockdown/mortality. However, in the partially closed drawer, the knockdown/mortality rates were 39%, 14% and 44% for PA1, PA2 and PA3, respectively. In the closet, only PA3 induced knockdowns/mortalities (20%) at 30 minutes post-spraying.

At the one hour post-spraying observation the knockdown/mortality rates in the hidden places continued to increase. This increase may have been due to droplets entering those places during the 10 second observation time at 10 minutes and 30 minutes post-spraying, resulting in knocking down and killing of mosquitoes in the hidden places.

The knockdown/mortality rates of mosquitoes in hidden places increased at 2 hours post-spraying, in which PA3 showed total knockdown of the mosquitoes. However, PA1 and PA2 gave only 25% and 5% knockdown/mortality rates, respectively, in the closet. The 5% knockdown/mortality rate induced by PA2 in the closet remained unchanged at 1 hour post-spraying.

At 24 hours post-spraying in the closet, PA3 caused an 89% mortality rate, a decrease of 11% from the 2 hour post-spraying rate. Efficacy of this product in the closed drawer, however, remained at 100% mortality. This may be due to an insufficient number of droplets required to kill the mosquitoes hidden in the closet.

Overall, PA3 gave a better performance than the other products, however, no droplets were detected on the slides. This may be due to PA3 producing very fine (aerosol) droplets that could not be detected on the MgO coated slides. Although no droplets were detected, PA3 successfully induced

higher mortality in the mosquitoes. Besides the finer droplets, the active ingredient(s) and strain of mosquito may have played an important role in determining the high mortality. PA3, containing transfluthrin and cyfluthrin, gave a satisfactory performance, giving the highest mortality rate of *Aedes aegypti* mosquitoes in both exposed and unexposed places. Whereas, PA1 and PA2, both containing prallethrin and phenothrin gave a satisfactory performance in open places only. The effect of aerosol products on field mosquitoes should also be evaluated since it has been shown that field collected mosquitoes are more tolerant to insecticides (Nazni *et al*, 2000). Therefore, aerosol insecticides should conduct testing against field strains mosquitoes and after testing against laboratory mosquitoes.

This evaluation method of aerosols should be further improved and adopted at respective insecticide testing laboratories in order to gather more information, especially regarding unexposed and semi-exposed places. There are many more hiding places for mosquitoes that were not included in this study, such as kitchen cabinets and dining tables.

The field efficacy of commercial household aerosols applied at their recommended dosages against *Aedes aegypti* mosquitoes placed in exposed areas induced total mortality. However, in semi-exposed and unexposed areas, the tested aerosol products induced only some degree of mortality on lab strains of *Aedes aegypti* mosquitoes.

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