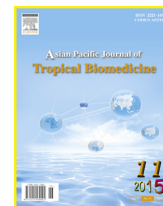




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High resurgence of dengue vector populations after space spraying in an endemic urban area of Thailand: A cluster randomized controlled trial

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ABSTRACT

Objective: To examine the resurgence rate, house density index (HDI) and parous rate of the *Aedes aegypti* vector after space spraying carried out by the routine spraying team, and compare with the rates after standard indoor ultra low volume (SID-ULV) spraying carried out by the trained research spraying team.

Methods: Between March and September 2014, a cluster randomized controlled trial including 12 clusters (6 regular ULV, 6 SID-ULV) with totally 4341 households was conducted, and around 20–31 houses in each cluster were selected for assessment. The parous rate and HDI of collected mosquitoes 2 days before and 1, 2 and 6 days after spraying were obtained and compared.

Results: The HDI dropped significantly from the baseline 1 and 2 days after spraying to a non-zero value in the SID-ULV treated locations but not in the regular ULV group locations. However, by 6 days after spraying, the HDI of both groups had returned to the base value measured 2 days before spraying. There were no statistically significant differences in the parous rate between groups.

Conclusions: SID-ULV is more effective in reducing *Aedes aegypti* populations. However, rapid resurgence of dengue vector after spraying in urban areas was observed in both groups.

1. Introduction

Dengue infection is a well-known rapidly spreading mosquito-borne disease, which causes significant public health problems in Thailand. The most effective way to prevent dengue virus transmission during an outbreak is exterminating the disease-carrier *Aedes aegypti* (*Ae. aegypti*) [1,2]. In emergency conditions, space spraying is the only effective means of suppressing an acute dengue virus outbreak [3,4]. However, it has been demonstrated that routine space spraying does not completely prevent secondary dengue cases [5,6]. Therefore,

more field research is needed on the effect of various kinds of space spraying [7,8].

In Thailand, local administrative organizations (LAO) are the main organizations responsible for conducting space spraying. Two forms of space spraying have been implemented since 2002, ultra low volume (ULV) and thermal fog [6]. The effect of ULV spraying is more sustained for vector suppression when applied as an indoor space spraying [9], but the effectiveness is dependent on the droplet size and the application method because there is a low probability of contact between adult mosquitoes and the insecticide droplets [8]. During dengue outbreaks, LAO space spraying has been shown to be ineffective in preventing dengue transmission and evidence of the effectiveness of standard indoor ultra low volume (SID-ULV) spraying is still lacking [6,8,10,11].

The infected vector density in outbreak clusters is linked to the parity rate (PR), the proportion of female mosquitoes that

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have laid eggs at least once [12]. To effectively interrupt transmission, the PR should be kept below 10% which results in a reduction in the adult dengue vector population of more than 97% [2,13]. While it is difficult to assess the effectiveness of measures taken to prevent secondary dengue cases, the number of female *Ae. aegypti* per house, (a good proxy for PR [2]) and the house density index (HDI), the number of adult female *Ae. aegypti* mosquitoes collected in each house for 15 min, can be employed as an indication of potential success.

The objective of this study was to verify the resurgence rate of the *Ae. aegypti* vector, by comparing the rates after regular ULV treatment carried out by the municipality and SID-ULV spraying, which was carried out by the research team.

2. Materials and methods

2.1. Study site

The study site was Songkhla City which is located at 7° 12' N, 100° 36' E on a peninsular of the east coast of Southern Thailand. The municipality covers 9.3 km², and is divided into 32 communities with 26000 households containing a population of 71000 people, a population density of 7400 persons/km² in 2013. The study was conducted in both the dry (February–July) and wet (August–January) seasons during which periods there was an average annual rainfall of 1434 mm, an average temperature of 28.4 °C and an average relative humidity of 73% (South Eastern Meteorological Center, Songkhla, 2014). The study site was selected because it is urban area prone to endemic transmission, with an average annual incidence rate of 500 per 100000 population [6,14].

2.2. Study design

A clustered randomized control trial was used with, for practical reasons, only one type of spray being used in each community. The design also covered externality effects, *i.e.*, the spray affecting nearby unsprayed houses. The trial was designed comparing 6 randomly selected SID-ULV clusters with 6 regular ULV clusters. A cluster in this study consisted of households located in a circle of 120 m in radius. In each cluster, around 20–31 houses were randomly selected for entomological assessment.

The inclusion criteria for eligible clusters were that they were all communities in dengue endemic areas with high population density; at least 100 houses; and a minimum area per cluster of at least 120 m × 120 m. The minimum distance between each SID-ULV cluster and regular ULV cluster with which it was compared was at least 1000 m. Maps of all the clusters were generated and the clusters were geo-located using high resolution satellite images (Quick Bird, USA) and Geographic Information System software (ArcGIS 9.3) from Southern Regional Geo-Informatics and Space Technology Center, Faculty of Environmental Management, Prince of Songkla University.

2.3. Spraying operations

SID-ULV spraying was conducted by well-trained officers from the Office of Disease Prevention and Control 12 (DPC-12).

The application strictly followed the World Health Organization (WHO) guidelines. Regular ULV treatment was based on routine space spraying conducted by LAO. This application did not follow the WHO guidelines [15]. Both the SID-ULV and regular ULV treatments were carried out with portable ULV equipment (Fontan Portastar S, Germany). Both the SID-ULV and regular ULV treatments were conducted based on the same spraying conditions representing controlled variables within the study. These included time, wind, rain and temperature. The meteorological conditions were monitored using the same daily time slot data from the Songkhla Weather Observation Station located in the center of Songkhla City. The dates of spraying and the locations sprayed were informed to the local health department and there was regular surveillance and response to dengue cases in cooperation with the local health officers.

2.4. Calibration of chemicals and spray generators

The equipment and the insecticides used were calibrated before the field spraying operations were conducted. The measurement of the volume median diameter of the droplets produced by the ULV generators was conducted according to the slide wave technique [15]. Then 2% deltamethrin (w/v) (Type II pyrethroids insecticides) was applied for field spraying operations. A droplet bio-assay test was used to evaluate the efficacy of deltamethrin by semi-field evaluation in experimental rooms [16]. Both tests were performed at DPC-12.

2.5. Entomological surveys

The pre- and post-space spraying parameters of the *Ae. aegypti* populations were monitored. The parameters included PR and HDI assessed 2 days before, and 1, 2 and 6 days after spraying in the same houses. Adult *Ae. aegypti* mosquitoes were collected using hand-held nets by the trained collecting team following WHO guidelines [2,15]. The adult mosquitoes were collected from the living areas of around 20–31 houses in each cluster over a period of 15 min. The identification of the collected mosquitoes and the dissection of the ovaries from the female *Ae. aegypti* to establish their parity status were conducted at Faculty of Medical Technology, Prince of Songkla University.

2.6. Statistical analysis

The data were analyzed using the R statistical program (R Development Core Team) and RStudio software (RStudio, Inc., USA). The PR and HDI of the SID-ULV and regular ULV clusters were compared using line graphs and paired sample *t*-tests at a 95% confidence interval ($P < 0.05$).

3. Results

3.1. Droplet size and bio-assays

The volume median diameter of the five ULV generators (four belonging to DPC-12 and one from LAO) used in the study was measured. The equipment delivered droplets of 23, 25, 25, 26 and 26 μm respectively, which were within the acceptable ranges (5–27 μm) recommended by WHO [2].

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