ORIGINAL ARTICLE

Comparative Efficacy of Water-Based and Oil-Based Insecticides in Peri-Domestic Fogging for the Control of Aedes aegypti: A 10-Week Field Study

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ABSTRACT

Introduction: Fogging, also known as peri-domestic space spraying, is a widely used vector control method where chemical insecticides are dispersed into the air as fine droplets to target adult mosquitoes. This study aims to evaluate and compare the efficacy of two different insecticides in controlling Aedes mosquito populations in residential areas. **Materials and Methods:** A 10-week field trial was conducted in three distinct locations. Two areas received routine preventive fogging using different insecticides one water-based and the other oil-based while the third area served as a control with no intervention. Weekly ovitrap surveillance was performed to assess the impact of fogging on Aedes mosquito populations, measured by the ovitrap index. **Results:** Preliminary observations identified Aedes aegypti breeding primarily in flowerpots and tires across the neighborhoods. The ovitrap index in locality A, treated with the water-based insecticide, decreased from 41.96% to 15.98%, while in locality B, treated with the oil-based insecticide, the index dropped from 34.76% to 18%. Despite these reductions, no statistically significant difference was observed in the ovitrap index between the two insecticide treatments (p>0.05). **Conclusion:** While both insecticides demonstrated some reduction in Aedes populations, fogging had no statistically significant impact on ovitrap index outcomes in either locality. Future research is needed to further investigate the efficacy of these compounds, particularly in long-term control of Aedes mosquitoes.
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INTRODUCTION

Dengue fever (DF) and dengue haemorrhagic fever (DHF) are significant public health challenges in tropical and subtropical regions, caused by four serotypes of the Flavivirus genus (DEN-1, DEN-2, DEN-3, and DEN-4) (1). These vector-borne diseases, primarily transmitted by Aedes aegypti, have shown a steady rise in incidence since their emergence in the 1940s. Contributing factors include rapid urbanization, global trade, inadequate waste management, and climate change, which has intensified the conditions conducive to dengue transmission through rising temperatures and increased humidity (2-4).

Vector control remains the cornerstone of dengue prevention due to the absence of widely available vaccines and effective antiviral treatments. Among the commonly employed strategies are larviciding, outdoor residual spraying (ORS), indoor residual spraying (IRS), and mass abatement efforts. These interventions, coupled with public education campaigns, are frequently implemented to reduce vector populations and interrupt transmission. However, the efficacy of these measures, particularly space spraying (commonly referred to as fogging), remains a contentious issue due to inconsistent outcomes and limited field data, especially in residential and domestic settings where mosquitoes typically breed (5-7).

In Sandakan, Sabah, dengue remains a persistent issue, exacerbated by factors such as dense populations, informal settlements, and suboptimal waste management practices. Despite widespread implementation of fogging during outbreaks, its effectiveness as a control measure in reducing adult mosquito populations and mitigating disease transmission remains underexplored. Existing research predominantly focuses on large-scale urban environments or agricultural applications of insecticides, leaving a critical knowledge gap in localized residential settings. This lack of data hinders the development of effective, evidence-based vector control strategies tailored to the specific needs of communities at risk.

This study aims to address these gaps by assessing the efficacy of space spraying in controlling adult Aedes aegypti populations in Sandakan. By incorporating ovitrap surveillance and larval counts, the study seeks to provide a comprehensive evaluation of the impact of fogging on vector dynamics. The ultimate objective is to generate actionable insights that can guide health practitioners in optimizing vector management strategies, particularly in localized residential areas where the logistical application of fogging and ultra-low volume insecticides poses challenges. By addressing the unique local context and leveraging empirical evidence, this research aspires to enhance the effectiveness of dengue prevention efforts and reduce disease transmission within vulnerable communities.

MATERIALS AND METHOD

Study area

This study was conducted in the Sandakan District, located in the northeastern region of Borneo, encompassing an area of 2,266 km (Figure 1). Administratively divided into 15 zones and comprising 620 localities under the Sandakan Health District, the district has undergone rapid urbanization, which has significantly elevated the risk of dengue transmission. With a population of approximately 502,900, including 316,100 local residents and 186,800 non-locals, Sandakan presents a diverse demographic landscape with varying residential types. The study sites included a mix of high-rise buildings, terrace houses, traditional village homes, and informal squatter settlements. The latter, particularly within the urban core, are associated with higher dengue incidence rates due to overcrowding, inadequate waste management, and limited municipal services.

To ensure a robust study design, specific insecticide treatment sites and control areas were selected based on prior dengue case reports and ovitrap surveillance data. The treatment sites represented diverse residential settings, including densely populated urban centers and semi-urban zones, while control areas were chosen for their comparable environmental and demographic characteristics. Detailed maps were created to enhance geographic contextualization, highlighting the treatment and control sites alongside nearby landmarks, such as schools, hospitals, and marketplaces. Key natural and man-made features, including major roads, rivers, and mangroves, were incorporated into the maps to improve their interpretability and relevance for the local environment and community.

The climate in Sandakan during the study period was tropical, characterized by temperatures ranging from 25°C to 35°C, relative humidity levels fluctuating between 75% and 95%, and annual rainfall exceeding 2,200 mm. These environmental conditions were

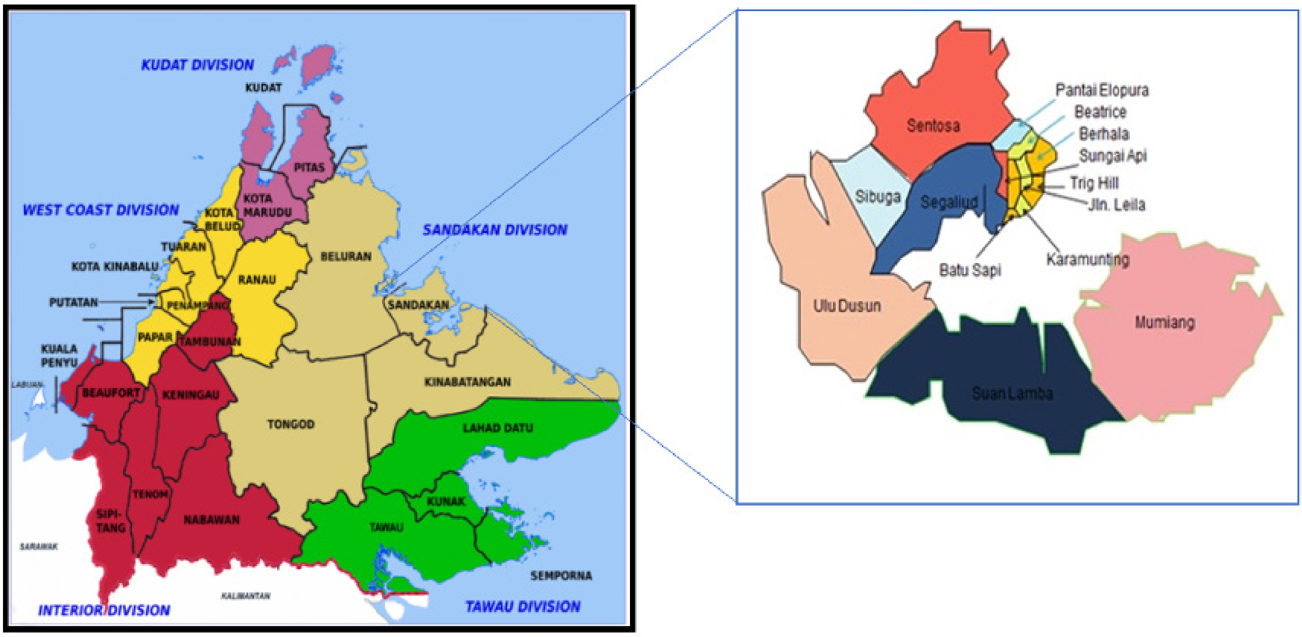


Fig. 1: Map of the study areas

monitored closely as they are known to influence mosquito breeding and dengue transmission dynamics. Additionally, site-specific features such as proximity to natural water bodies, shaded areas, and waste disposal sites were documented to assess their potential impact on vector populations. By incorporating geospatial details and environmental variables, this study design aimed to provide a comprehensive evaluation of the effectiveness of insecticide treatments in reducing dengue transmission, particularly in high-risk, localized residential settings. This integrative approach enhances the applicability of the findings for designing targeted vector control strategies in Sandakan and other urbanizing regions with similar ecological and socio-demographic challenges.

Study design

This study employed a detailed field research design to evaluate the effectiveness of preventive fogging on entomological parameters relevant to dengue control, focusing specifically on the ovitrap index (OI) Table I**.** The study tested two insecticides: oil-based malathion UL 96 and water-based Acpidor. Fogging operations were conducted in two selected localities within the Sandakan District, with one locality designated as the intervention area and the other as the control. This setup facilitated a comparative analysis of the insecticides' impact on mosquito populations. Ovitraps, used to attract and capture mosquito eggs, were strategically placed both indoors and outdoors in each locality to ensure comprehensive monitoring. The study spanned 10 weeks, from October 2021 to January 2022, during which continuous surveillance was maintained. Data collection involved measuring various entomological parameters, including the ovitrap index to gauge mosquito breeding activity, and performing species identification and larval counts in the laboratory. The collected data were analyzed to compare the effects of the fogging treatments on mosquito populations between the intervention and control areas. Statistical analyses were conducted to determine the significance of differences observed in the ovitrap index and larval counts. The study aimed to provide valuable insights into the impact of preventive fogging on mosquito control, helping to optimize strategies for reducing dengue transmission risk in endemic regions.

Data analysis

The data analysis for this study focused on assessing the impact of preventive fogging on mosquito populations using the ovitrap index (OI). Initially, a five-week baseline surveillance period was conducted to measure mosquito activity levels before the fogging interventions. During this phase, ovitraps were placed both indoors and outdoors in each locality to collect data on the presence of mosquito eggs. After this baseline period, preventive fogging was carried out, and post-fogging surveillance was conducted for an equivalent duration to assess changes in mosquito activity. The analysis involved calculating the mean and standard deviation (SD) of positive ovitraps those containing mosquito eggs both before and after the fogging interventions. The OI, representing the proportion of positive ovitraps relative to the total number of ovitraps, was used as the primary metric for evaluating mosquito breeding activity. To determine the statistical significance of the observed changes, a paired t-test was employed to compare the mean OI values from the baseline and post-fogging periods. This test was chosen for its suitability in comparing paired measurements from the same locations, and a significance level of $p < 0.05$ was set to ensure the reliability of the results. All statistical analyses were performed using SPSS version 20, which facilitated accurate calculations and comprehensive interpretation of the data. The results provided insights into the effectiveness of the fogging interventions in reducing mosquito populations, thereby informing strategies for controlling dengue transmission. This detailed approach ensured a robust evaluation of the fogging measures' impact, offering valuable information for optimizing mosquito control efforts.

RESULTS

In this study, we evaluated the effectiveness of preventive fogging measures against Aedes aegypti in Sandakan, Sabah, focusing on both indoor and outdoor settings. Our findings revealed a predominant presence of Ae. aegypti in both environments, with larvae primarily located in flowerpots and tires. The fogging intervention, conducted during the fifth week of the study period, was designed to address this infestation. The results, summarized in Table II, indicate that the fogging had a significant impact on Ae. aegypti populations. In indoor settings, all types of insecticides used led to a substantial reduction in mosquito density. Specifically, the oil-based malathion and water-based Acpidor treatments resulted in notable decreases in the positive ovitrap index (POI), with reductions of 54.5% and 59.2%, respectively. Conversely, the control area, which did

Table I: Timeline of the ovitrap surveillance for three area.

Locality	Types of Insecticides	Observational week for pretreatment (grey color) and post treatment (blue color)									
		W1	W2	W3	W4	W5	W6	W7	W8	W9	W10
Taman Sejati Ujana A	Oil-based Malathion Ul 96					★					
Taman sejati Ujana B	Water based (Acpidor)					★					
Taman Airport	Control										

Note: Baseline study (pre-treatment) based on ovitrap surveillance (grey shading) was conducted for each locality. Each locality is applied with the preventive fogging using different insecticides (★) in week 5. Taman Airport was a control locality where no treatment been applied during the study periods. Post treatment were co ducted a week after completed the treatment application (Blue shading).

Table II: Percentage reduction of positive ovitrap index (POI) between pre and post treatment according to indoors and outdoors setting

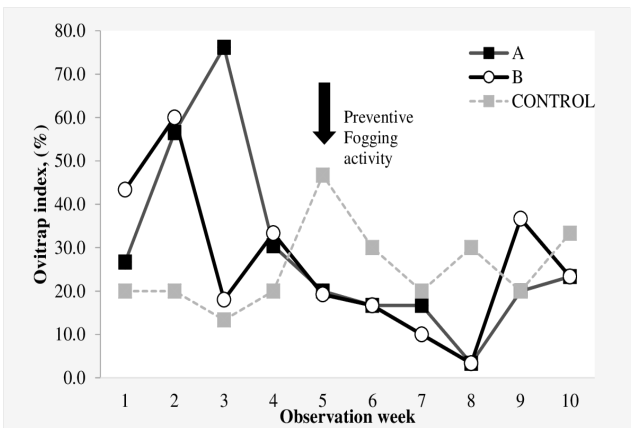
Localities	Positive Ovitrap index (%)								
	Indoor			Outdoor			Both		
	Pre-treatment	Post-treatment	%	Pre	Post	%	Pre	Post	%
A	32.5	20.0	- 32.3	57.5	32	- 63.9	36.67	16.67	- 54.5
B	57.5	32	- 44.4	75	22	-70.7	44.17	18.00	- 59.2
C	27.5	35	+ 27.3	13.75	27.5	+ 100	18.33	30.00	+ 63.7

Note: Symbol of (-) shows there is reduction of ovitrap positive while (+) shows there is increasing number of ovitrap positive.

not receive fogging, exhibited an increase in Aedes density, highlighting the effectiveness of the intervention in treated areas.

In outdoor settings, the fogging also effectively reduced Aedes species density, regardless of the insecticide type. This was evident from the dramatic decrease in POI two weeks after the fogging, particularly in outdoor environments. The data, depicted in **Figure 2**, underscores that preventive fogging is particularly suited for outdoor settings. However, an analysis of ovitrap readings from week 5 (pre-treatment) through weeks 6 to 10 (post-treatment) revealed a significant initial reduction in mosquito populations in localities B and C. Despite this, a resurgence in ovitrap positivity was observed from weeks 8 to 10, suggesting potential re-emergence of mosquito populations, possibly due to incomplete eradication or migration from untreated areas.

(A)



(B)

Localities	Type of insecticide	Mean	95% Confidence Interval	t	Sig. (2-tailed)
A	Water based (Acipidor)	29.80	13.12- 65.08	1.845	0.139
B	Oil based (Malathion)	16.76	11.33 – 44.85	1.656	0.173

Fig. 2: (A) Distribution of positive ovitrap index based on types of insecticides used in two different residential areas; Locality A (Taman Sejati Ujana A) & B (Taman Sejati Ujana B) were fogging using water based and oil based respectively. (B) Paired t-test for comparison between pre and post fogging

Table III presents the statistical analysis of POI reduction, showing mean differences ranging from 3.96 to 8.80 for water-based insecticides and 1.20 to 9.20 for oil-based insecticides. These results indicate that while fogging generally reduced Ae. aegypti populations, the effectiveness varied depending on the insecticide used and the specific locality. The overall decrease in POI immediately following treatment highlights the short-term efficacy of fogging, but the increase in POI after several weeks suggests that sustained monitoring and additional control measures are necessary to manage re-infestations and achieve long-term effectiveness. This study emphasizes the importance of incorporating preventive fogging into integrated mosquito management strategies and underscores the need for a comprehensive approach that includes regular monitoring and supplementary control measures to effectively reduce mosquito populations and mitigate dengue transmission risk.

DISCUSSION

The findings of this study highlight the ongoing challenges in vector control strategies, particularly fogging, which is widely used in Southeast Asia for controlling adult mosquito populations. While fogging has been a cornerstone approach, its efficacy remains debatable. Chua et al. (2005) reported the ineffectiveness of fogging in significantly reducing female Aedes mosquito populations (9). This aligns with the findings of this study, where the ovitrap index (OI) remained persistently high, ranging from 13.33% to 76.2%, indicating a limited impact of fogging in curbing mosquito breeding and survival. Comparable studies in Malaysia, including university campuses, have documented similarly elevated OI values, often exceeding 90%, with no marked differences observed before and after fogging activities in terms of mosquito densities or dengue incidence (9-13).

The lack of significant reduction in mosquito populations or dengue cases post-fogging raises several potential explanations. First, the phenomenon of re-emergence of adult mosquitoes shortly after fogging could be attributed to the presence of untreated breeding sites or areas inaccessible during fogging. In this study, re-emergence was observed as early as two weeks post-fogging. Additionally, household resistance to indoor fogging remains a critical barrier, as many residents deny access to private properties, leaving indoor adult mosquito populations largely unaffected. The inability to achieve lethal insecticide concentrations indoors is a major limitation of fogging efforts, as Aedes aegypti, a primary vector of dengue, predominantly rests

Table III: Paired t-test for comparison between pre and post fogging at week 5 and subsequent week (weekly) after preventive fogging; A (water based) and B (Oil based)

(A) Water based

Week	Mean (SD)	95% Confidence Interval	t	Sig. (2-tailed)
5th and 6th	6.85(5.02)	-38.257-51.957	1.930	0.304
5th and 7th	4.85(2.616)	-18.656-28.356	2.622	0.232
5th and 8th	8.80(7.087)	-8.806 – 26.406	2.151	0.164
5th and 9th	5.77(8.372)	-7.547 – 19.097	1.380	0.262
5th and 10th	3.96(8.309)	-6.357 – 14.277	1.066	0.347

(B) Oil based

Week	Mean (SD)	95% Confidence Interval	t	Sig. (2-tailed)
5th and 6th	7.05(9.9702)	-96.6287-82.5287	-1	0.500
5th and 7th	5.85(4.7376)	-36.7158 -48.4158	1.746	0.331
5th and 8th	9.20(6.700)	-7.4437- 25.8437	2.378	0.140
5th and 9th	2.52 (14.4274)	-20.4322 – 25.4822	0.350	0.749
5th and 10th	1.20 (12.8410	-14.7441 – 17.1441	0.209	0.845

indoors. Environmental factors further complicate the interpretation of fogging effectiveness. For three consecutive weeks before the fogging activity, the weather was characterized by cloudy skies and light rainfall, with an average temperature and humidity of 31°C and 85%, respectively. Previous studies have shown inconsistent relationships between climatic changes and dengue incidence in Malaysia (5). Temperature, however, remains a critical factor influencing mosquito biology and virus replication. Elevated temperatures have been associated with shorter extrinsic incubation periods and accelerated viral replication, thereby enhancing the transmission potential of Aedes mosquitoes (16). Nevertheless, this study could not establish a direct association between ovitrap results and weather conditions, as the evidence from existing literature varies significantly.

It is worth noting that a recent study by Amal et al. (2021) reported a significant reduction in larval counts following fogging, although the effect lasted for only about five weeks (14). This contrasts with the current findings, where no significant changes were observed before and after fogging. The discrepancies between studies may be attributed to variations in fogging protocols, insecticide formulations, and environmental conditions. Lastly, community engagement and awareness play a pivotal role in the success of vector control measures. Without active participation and compliance from residents, efforts such as fogging are unlikely to achieve sustainable results. The findings underscore the need for integrated vector management (IVM) approaches that combine chemical control with environmental management, community involvement, and continuous monitoring to address the limitations of fogging as a standalone intervention. In conclusion, while fogging remains a widely adopted method for vector control in Southeast Asia, its limited efficacy as observed in this study highlights the need for complementary strategies that address underlying environmental and behavioral factors. Future studies should consider exploring the impact of localized environmental conditions, vector behavior, and the role of community engagement in improving vector control outcomes.

CONCLUSION

The findings of this study reveal significant insights into the efficacy of insecticide-based vector control in residential settings. While the ecological background between the case and control areas was similar, the ovitrap results highlighted notable differences. The conducive environments for mosquito habitats, including scattered vegetation, artificial breeding sites such as uncovered water tanks, flowerpots, discarded waste, and clogged drains, underscore the complexity of controlling mosquito populations in urban settings. Importantly, Aedes aegypti was found to be more abundant than Ae. albopictus in the studied locality, despite Aedes albopictus being commonly associated with dense urban areas. This unexpected abundance of Ae. aegypti in Sandakan raises critical questions about its role in the potential transmission of arboviruses, necessitating further investigation.

These preliminary results contribute to a growing understanding of insecticide efficacy and the factors influencing vector control in residential settings. The study emphasizes the importance of considering environmental conditions, community behaviors, and urban ecological factors in designing effective control strategies. However, the findings also highlight limitations that warrant further exploration. Future studies should investigate additional factors not addressed in this research, such as the role of insecticide resistance, the influence of microclimatic conditions, and the behavioral adaptations of Aedes mosquitoes in urban settings. Moreover, comprehensive community engagement strategies should be integrated to enhance the accessibility and effectiveness of vector control measures. By addressing these gaps, future research can build upon these findings to develop more sustainable and effective approaches to managing mosquito populations and reducing the risk of arboviral disease transmission.

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