Aedes aegypti control: indoor residual spraying and the impact of insecticide resistance

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Vector control, if expeditiously implemented and sustained, can be successful at controlling *Ae. aegypti* and interrupting pathogen transmission.
Contemporaneous *Aedes aegypti* control tools: diverse but with limited epidemiological evidence

**Existing Methods**

**Immature control**
- Major categories: Container cleaning (bleach/wash/dump), Container manipulation (treated covers/polystyrene beads), Container treatment, Social campaigns (education, source reduction), Environmental Management
- Legislation
- Container treatment: Insecticides - Temephos, - Noviluron, - Spinosad, - Pyriproxyfen; Bleach - Methoprene; Biologicals - Copepods - Larvivorous fish

**Adult control**
- Major categories: Space spraying, Indoor residual spraying, Personal protection
- Space spraying: Truck ULV, Low-flying aircraft, hand-held portables, perifocal treatment
- Personal protection: - DEET - Picaridin - Bed nets - Consumer products
- Indoor residual spraying

**Emergence**
- Mating
- Sugar Feeding
- Blood Feeding
- Resting
- Egg Laying

**Methods under Development**
- New entomopathogenic fungi
- Molecular insecticides, medea/HEGs, new insecticides

**REVIEW**

**A Critical Assessment of Vector Control for Dengue Prevention**

Nicole L. Achée1,*, Fred Gould2, T. Alex Perkins1,3,4, Robert C. Reiner Jr.3,4, Amy C. Morrison1,6, Scott A. Ritchie2, Duane J. Gubler6,9, Remy Teyssou2, Thomas W. Scott2,6,9

**Policy Platform**

Quantifying the Epidemiological Impact of Vector Control on Dengue

Robert C. Reiner, Jr.1,2,*, Nicole Achée1, Roberto Barrera1, Thomas R. Burkot2, Dave D. Chadee1, Gregor J. Devine1, Timothy Enby1, Duane Gubler6, Joachim Hombach16, Immo Kleinschmidt15,7, Audrey Lerhardt13, Steven W. Lindsay16,19, Ira Longini19, Mathias Mandy10, Amy C. Morrison1,6, T. Alex Perkins3,4, Gonzalo Vasquez-Prokopec18, Paul Reiter16, Scott A. Ritchie26, David L. Smith12,17, Daniel Strickman2, Thomas W. Scott1,2

**Research Article**

Is Dengue Vector Control Deficient in Effectiveness or Evidence?: Systematic Review and Meta-analysis

Leigh R. Bowman1, Sarah Donegan2, Philip J. McCall1,*
WHO boss: Zika result of 'massive' mosquito control failures

By Euan McKirdy, CNN

Updated 0652 GMT (1452 HKT) May 24, 2016
Thermal fogging, New Dehli IPL match 2015 (courtesy Bruce Murphy, DFAT)
Feb. 1, 2016 | Municipal workers trim vegetation as part of efforts to prevent the spread of the Zika virus in Tegucigalpa, Honduras. (Jorge Cabrera/Reuters)
Mosquito (vector) control emergency response and preparedness for Zika virus

18 March 2016 | Geneva

Conclusions and recommendations of VCAG

1. Well-implemented vector control programmes using existing tools and strategies are effective in reducing the transmission of Aedes-borne diseases including Zika virus. Appropriate vector control interventions for the response to the Zika virus outbreak include:

- **Targeted residual spraying** of resting sites of Aedes spp. mosquitoes primarily inside and, to a lesser extent, around houses as the primary vector control intervention for immediate response.

- **Space spraying** is effective inside buildings where Aedes spp. mosquitoes rest and bite. It has no residual effect. Its application outdoors only suppresses vector populations temporarily and is not as effective as indoor space spraying.

- **Larval control including source reduction** and larviciding should be applied where appropriate through community mobilization.

- **Personal protection measures** should be used to protect against day biting mosquitoes. These include the use of appropriate repellents and wearing of light-coloured loose fitting clothing. This is especially important during pregnancy.
Indoor Resting Behavior of Aedes aegypti (Diptera: Culicidae) in Acapulco, Mexico


Quantifying the Spatial Dimension of Dengue Virus Epidemic Spread within a Tropical Urban Environment

Gonzalo M. Vazquez-Prokopec, Uriel Kitron, Brian Montgomery, Peter Horne, Scott A. Ritchie

Combining contact tracing with targeted indoor residual spraying significantly reduces dengue transmission

Gonzalo M. Vazquez-Prokopec, Brian L. Montgomery, Peter Horne, Julie A. Clennon, Scott A. Ritchie

Effectiveness of indoor residual spraying for reducing dengue transmission

Thomas J. Hladish, Carl A. B. Pearson, Diana Patricia Rojas, Hector Gomez-Dantes, M. Elizabeth Halloran, Gonzalo M. Vazquez-Prokopec, and Ira M. Longini
Resting <1.5m 17x more likely than >1.5m & primary resting locations included bedrooms (44%), living rooms (25%), and bathrooms (20%), followed by kitchens (9%) (Dzul-Manzanilla et al. 2017, Vazquez-Prokopec et al. 2009).
SC 2.5% lambda-cyhalothrin on *Ae. aegypti* resting sites: exposed low walls (<1.5m), under furniture, inside closets and on any dark and moist surfaces.
Epidemiologic impact of TIRS during 2008-2009 DENV 3 Epidemic in Cairns, Queensland

900+ confirmed cases. Tracked to address level. TIRS performed at the premise level.

Vazquez-Prokopec et al. Science Advances
Will controlling exposure locations have a sustained impact on DENV transmission?

SC 2.5% lambda-cyhalothrin on Ae. aegypti resting sites: exposed low walls (<1.5m), under furniture, inside closets and on any dark and moist surfaces.

Vazquez-Prokopec et al. Science Advances
Effectiveness of TIRS

\[
\text{Effectiveness} = 1 - \frac{\text{Risk of infection in treatment group}}{\text{Risk of infection in control group}}
\]

Table 1. Effectiveness of TIRS applied at contact locations in preventing dengue symptomatic infections, Cairns, Australia.

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Treatment</th>
<th>Total locations</th>
<th>No. DENV positive locations</th>
<th>Proportion infection</th>
<th>Effectiveness</th>
</tr>
</thead>
<tbody>
<tr>
<td>All cases</td>
<td>IRS</td>
<td>1007</td>
<td>52</td>
<td>0.052</td>
<td>0.861</td>
</tr>
<tr>
<td></td>
<td>Control</td>
<td>369</td>
<td>137</td>
<td>0.371</td>
<td></td>
</tr>
<tr>
<td>Excluding first 10 days*</td>
<td>IRS</td>
<td>817</td>
<td>11</td>
<td>0.013</td>
<td>0.961</td>
</tr>
<tr>
<td></td>
<td>Control</td>
<td>325</td>
<td>113</td>
<td>0.348</td>
<td></td>
</tr>
</tbody>
</table>

*This scenario excludes the first 10 days post intervention to exclude transmission events likely originated prior to the intervention.
Insecticide resistance: a threat for TIRS

Primarily to pyrethroids and likely driven by fogging by MOH and also household insecticides.

Advantage for TIRS: other insecticide groups exist (Carbamates and Organophosphates).
Is pyrethroid resistance a problem?

- Randomized Controlled Trial: Merida (Yucatan State, Mexico)
- 14 clusters with 3 treatments: unsprayed controls, bendiocarb spraying (Carbamate, susceptible pop.), deltamethrin spraying (pyrethroid, resistant pop.)
Very high levels of deltamethrin resistance
Adult *Ae. aegypti* infestation indices significantly lower in houses treated with bendiocarb compared to untreated houses. No statistically significant difference between untreated and deltamethrin-treated houses. On average, bendiocarb spraying reduced *Ae. aegypti* abundance by 60%.
Modeling long-term effectiveness & optimal timing of TIRS campaign

Agent based DENV model
1.8 mil people in Yucatán, Mexico
500k houses, workplaces & schools

Optimal TIRS timing is several months before epidemic peak

Modelled effect of TIRS start date
Houses treated across 90 days

Overall effectiveness
- 75% coverage
- 50% coverage
- 25% coverage

Average DENV seasonality in Yucatan, 1995-2011

Hladish et al. unpublished
The challenge ahead: scaling-up interventions

Current paradigms for DENV surveillance and *Ae. aegypti* control need to be adapted to local contexts of virus transmission.

TIRS is an effective vector control approach to prevent DENV. Scalability of TIRS challenged by insecticide resistance and extent of urban environments.

Preventive TIRS would lead to higher effectiveness. How? Target DENV hot-spots.
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