Eave tubes for malaria control in Africa: From concept to market

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In2Care & PSU
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Malaria prevalence in 2-10 yr old has halved in 10 yrs (33-16%)
“Resistance to pyrethroids in the major malaria vectors poses the greatest current threat to malaria control.”

“...will almost certainly affect the effectiveness of vector control.”

- IVCC
- Toé et al. (2014). EID, 20, 1691-1696.
Killing pyrethroid-resistant mosquitoes (Tiassale strain; *An. gambiae*)

Mortality 24 hrs post-exposure (%)

- **C1 untreated bednet**
- **C2 electrost. coating**
- **Permanet (55 mg AI/m²)**
- **Deltamethrin powder (3.7 mg AI/m²)**
- **Deltamethrin powder (37 mg AI/m²)**

- **5 sec**
- **3 min**

- 33% less
- 93% less
Killing pyrethroid-resistant strains from across Africa

- An. gambiae (SUA)
- An. funestus (FANG)
- An. arabiensis (KGB)
- An. gambiae (KISUMU)
- An. gambiae (TONGS)
- An. gambiae (TIASSALE)
- An. arabiensis (SENN-DDT)
- An. funestus (FUMOZ - R)
- An. funestus (FUMOZ - Base)
- An. arabiensis (MBN-DDT)

- Susceptible strain
- Resistant strain
- Permanet 2.0
- Electrostatic coating
In2Care® Mosquito Trap
Eaves are the main entry point for anophelines

>15 papers, proven impact on disease (Lengeler, Cochrane review, 2004)
Testing of eave tubes in a semi-field system

Ifakara, Tanzania
Experimental hut used for overnight release-recapture experiments
Overnight release-recapture

3 nights per treatment, 200 mosquitoes released per night.
Overnight release-recapture

Deltamethrin (PermaNet 2.0)

- Control
- PermaNet

Total recapture: 58% reduction

Wettable bendiocarb (Ficam D)

- Control
- Bendiocarb (wettable)

Total recapture: 52% reduction

Dry bendiocarb (Ficam W)

- Control
- Bendiocarb (wettable)

Total recapture: 67% reduction

3 nights per treatment, 200 mosquitoes released per night.
3 nights per treatment, 200 mosquitoes released per night.
Semi-field evaluation in Kenya

• Local Kenyan houses constructed in semi-field screenhouses

• 200 mosquitoes (An. gambiae or An. arabiensis) released every experimental night

• Open tubes (no inserts): average 92% of released mosquitoes enter huts overnight

• Inserts with pyrethroid (deltamethrin): average overnight kill = 60%

• Inserts with carbamate (bendiocarb): average overnight kill = 28%
Testing eave tubes in the Malaria Village
Diagram of the Malaria Village

Larval habitat, resting sites, and houses
Mosquito numbers in the Malaria Village

Total nightly catches from indoor Human Landing Catches

Indoor host seeking adult females

No intervention

Kija Ng’habi
Mosquito numbers in the Malaria Village

Total nightly catches from indoor Human Landing Catches

Indoor host seeking adult females

Mar May Jul Sep Nov Jan

No intervention
LLINs only

Kija Ng’habi
Mosquito numbers in the Malaria Village

Total nightly catches from indoor Human Landing Catches

Indoor host seeking adult females

- No intervention
- LLINs only
- Eave tubes

Mar May Jul Sep Nov Jan

0 50 100 150

Kija Ng’habi
Mosquito numbers in the Malaria Village

Total nightly catches from indoor Human Landing Catches

Indoor host seeking adult females

Mar May Jul Sep Nov Jan

0 1 0 0 1 5 0

(b) Total nightly catches using Human Landing Catches (HLC)

Indoor host seeking adult females

No intervention
LLINs only
Eave tubes

Kija Ng’habi
Mosquito numbers in the Malaria Village

Average number of larvae collected from larval habitats in the 6 sampling zones

- No intervention
- LLINs only
- Eave tubes
A highly simplified version of the modeling approach to eave tubes:

Host seeking female *Anopheles*:

Properties can have eave tubes, LLINs, IRS, or some combination of these three:

Mosquito can end up in one of three states during her interaction with a property:

- Deflected by intervention (has to find another property)
- Fed
- Dead
Effect of eave tubes on the transmission potential of a vector population (relative to no intervention)

Eave tubes reduce infectious bites, even for people in unprotected properties.

Deflection does not result in more transmission in unprotected houses.
Effect of eave tubes on the transmission potential of a vector population (relative to no intervention)

This is true even with a smaller effect of eave tubes on mosquito mortality (based on values from Kenya screen house experiments).
Eave Tubes: From Concept to Implementation

Funded by:

INSTITUT PIERRE RICHET

PennState

In2Care

London School of Hygiene & Tropical Medicine

Bill & Melinda Gates Foundation
Study region in central Côte d’Ivoire:

Map courtesy of Institute Pierre Richet
Two armed randomized controlled trial (2016 – 2018):

• 20 villages will receive new LLINs + eave tubes.

• 20 villages will only receive new LLINs.

• Primary outcome: epidemiology (clinical malaria).

• Secondary outcomes: other health measures including upper respiratory infections, sociology, entomology, and indoor climate.
## Eave tube implementation scenarios

<table>
<thead>
<tr>
<th>Implementation model</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Donor-driven model</td>
<td>Full subsidizing; no costs for end users</td>
</tr>
<tr>
<td></td>
<td>Implementation via GOs/NGOs/foundations</td>
</tr>
<tr>
<td>2. Cost-sharing model:</td>
<td>Partially donor-driven/subsidized</td>
</tr>
<tr>
<td></td>
<td>Installation funded by GOs/NGOs/foundations.</td>
</tr>
<tr>
<td></td>
<td>Upkeep by end users</td>
</tr>
<tr>
<td>3. Business-to-Business (B2B) model</td>
<td>Fully commercial</td>
</tr>
<tr>
<td></td>
<td>Implementation via the professional segment</td>
</tr>
<tr>
<td>4. Business-to-Consumer (B2C) model</td>
<td>Fully commercial</td>
</tr>
<tr>
<td></td>
<td>Implementation by consumers</td>
</tr>
</tbody>
</table>

Modified house in Tanzania
84% suitable for eave intervention
## Initial installation costs in USD

<table>
<thead>
<tr>
<th></th>
<th>Rural housing</th>
<th></th>
<th></th>
<th></th>
<th>Assumptions:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Existing houses</td>
<td>Newly built</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Open eaves</td>
<td>Closed eaves</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Manufacturing costs</td>
<td></td>
<td>1,26</td>
<td>1,26</td>
<td>1,26</td>
<td>- # Eave tubes needed for 100m²: 8</td>
</tr>
<tr>
<td>tube+insert</td>
<td></td>
<td>0,35</td>
<td>0,35</td>
<td>0,35</td>
<td>- Margin In2Care insert: 40%</td>
</tr>
<tr>
<td>Eave tube standard PVC</td>
<td></td>
<td>0,91</td>
<td>0,91</td>
<td>0,91</td>
<td>- Price/kg insecticide: $ 220</td>
</tr>
<tr>
<td>Insert</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>- Labour Daily wage: $ 8.64</td>
</tr>
<tr>
<td>#tubes/house</td>
<td></td>
<td>8</td>
<td>8</td>
<td>8</td>
<td>- #houses/day/team(5p): 2.75</td>
</tr>
<tr>
<td>Costs tubes/house</td>
<td></td>
<td>10,11</td>
<td>10,11</td>
<td>10,11</td>
<td>Costs of screening:</td>
</tr>
<tr>
<td>Other installation</td>
<td></td>
<td>35,37</td>
<td>15,86</td>
<td>10,12</td>
<td>- Open eave: 10% of initial install</td>
</tr>
<tr>
<td>Initial installation</td>
<td></td>
<td>45,48</td>
<td>25,97</td>
<td>20,23</td>
<td>- Closed eave: 20%</td>
</tr>
<tr>
<td>costs/house</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>- Newly built: 20%</td>
</tr>
</tbody>
</table>

## Total costs per year (in USD)

<table>
<thead>
<tr>
<th></th>
<th>Open Eaves</th>
<th>Closed Eaves</th>
<th>Newly built</th>
<th>IRS unburdened</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost/area sprayed or</td>
<td>19,19</td>
<td>17,22</td>
<td>16,38</td>
<td>23,02</td>
</tr>
<tr>
<td>tubes/yr</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cost per person per</td>
<td>4,68</td>
<td>4,20</td>
<td>4,00</td>
<td>5,44</td>
</tr>
<tr>
<td>year</td>
<td></td>
<td></td>
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## Cost per person per year (USD)

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<th>IRS unburdened</th>
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<tr>
<td>4 treatment/year</td>
<td>4,68</td>
<td>4,20</td>
<td>4,00</td>
<td>5,44</td>
</tr>
<tr>
<td>3 treatments/year</td>
<td>3,96</td>
<td>3,48</td>
<td>3,27</td>
<td>5,44</td>
</tr>
<tr>
<td>2 treatments/year</td>
<td>3,23</td>
<td>2,75</td>
<td>2,54</td>
<td>5,44</td>
</tr>
</tbody>
</table>
80% of mosquitoes around a house fly into tubes.

Cost: $2.5-4.7 ppy

1800+ houses completed in Tanzania – excellent community acceptance

Exploits natural host-seeking behavior

Electrostatic coating with actives kills 100% for 3-6 months

Screening reduces indoor density of mosquitoes by 80-90%

Indoor climate not compromised

Extremely safe: No contact by house occupants; passive technology

>95% reduction in insecticide use compared to IRS

Easy servicing and resistance management options

>95% reduction in insecticide use compared to IRS

Exploits natural host-seeking behavior

Cost: $2.5-4.7 ppy
Thank you!

Please come to our booth!
Indoor temperature and air sampling
Tanzanian village data (12 houses)
Use of air sampler to detect powders within the house (5 village houses, 3 rooms per house). Powder is fluorescent bendiocarb with fresh-treated netting placed on eave tubes. Samples taken day 1 and day 7.

Positive control – freshly treated net shaken to remove excess powder next to air sampler

Illustrative slide from within house – shows particulates in the air but no fluorescent powder detected on any indoor sample.