Meeting Report

Entomology and Vector Control for Malaria Elimination

Regional Meeting & Workshop

Kasetsart University, Bangkok, Thailand;
November 7-10, 2016
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Acknowledgements

The Entomology and Vector Control for Malaria Elimination Regional Meeting & Workshop was a collaborative effort, and the culmination of financial, technical and logistical support provided jointly by several regional partners.

First, sincere thanks to the Royal Government of Thailand and the Ministry of Public Health for their support to the meeting and workshop. Special thanks go to Kasetsart University, and the Faculty of Agriculture for their organizational, logistical and administrative support, and especially to the entomology students for their assistance in making the meeting a success.

For generous financial support and for managing coordination, logistics and communications among the various collaborative partners, thank you to the Asia Pacific Malaria Elimination Network (APMEN) Secretariat. We are also very grateful for the sponsorship of attendance of country representatives provided by the University of California San Francisco Global Health Group (UCSF Global Health Group), the World Health Organization, Emergency Response to Artemisinin Resistance (WHO-ERAR) Hub, and the Thai Research Fund (TRF).

For technical input to the structure and content of the meeting, as well as facilitation of some sessions, we wish to thank the WHO-ERAR Hub, the UCSF Global Health Group, the RBM-VCWG, and Malaria Consortium, Thailand, especially for leadership of the Mekong Outdoor Malaria Transmission Network workshop.

Finally, thank you to the participants and presenters from malaria control programs, and both the public- and private-sector partners for their valuable contributions to the meeting, and their dedication to malaria elimination across the Asia-Pacific region.
Executive Summary

A two-part, four-day regional workshop on entomology and vector control was convened at Kasetsart University, from 7-10 November, 2016. Participants included representatives from nine national malaria control programs, ranging from Pakistan to Papua New Guinea, as well as from academia, development partners, non-governmental, bilateral and international organizations and the private sector.

The first two days focused on the strategic shift from ‘control’ to ‘elimination’, and comprised three major focus areas commencing with sharing of best practices for vector control, such as bed net durability, preference and use studies and insecticide resistance monitoring. A second major theme was the reorientation of entomological surveillance, from trapping, identification and mapping, to community-based systems for vector surveillance. The third major focus area was capacity-building for public health entomology, which explored approaches to strengthen Human Resource (HR) capacity, and technical skills in epidemiology and Geographic Information Systems (GIS). Discussions focused on HR needs and career development; information and knowledge sharing; training needs at national and subnational levels; and institutional, infrastructure and operational research needs.

The second part of the meeting comprised the “Mekong Outdoor Malaria Transmission Network” workshop, with participants expanded to include partners from Industry and private sector vector control services, and additional academic and research institutions. Discussions began with entomological aspects of outdoor transmission in the region. Country updates were provided and the evidence and driving forces of residual and outdoor transmission were discussed. Sessions covered the anthropological aspects of outdoor transmission, including human spatial ecology and available tools, including use of GPS tools, spatial and topical repellents and treated clothing. A panel discussion with the private sector explored the development and market entry of new tools, including needs from the public sector in terms of product testing, market projections, and regulatory issues. The final sessions and group work further explored new tool development, the role of large private employers, the WHO framework for moving from proof of concept to implementation; and review of regional and national regulatory processes.

Overall, the 3 ½ days of presentation and discussions offered a wealth of information on technical and scientific developments as well as best practices and lessons learned for effective field implementation. The gathering of entomology program leaders from such diverse countries and partners enabled programs to learn from each other about the necessary shifts in entomological surveillance and vector control strategies to move from malaria ‘control’ to ‘elimination’ and strategies to address outdoor transmission. Inclusion of product development partners provided a unique opportunity to discuss the challenges of innovation to address outdoor and residual malaria transmission: from vectors, human behavior and measuring public health impact, to market size and stability, intellectual property rights, and national regulatory issues.

A common theme throughout both segments of the meeting was the value of networks and mechanisms to allow programs and partners to communicate, share best practices and learn from each other – and the necessity to work across sectors to meet vector control needs. The concluding discussion emphasized the roles of different partners and programs to ensure continued learning and advancement of entomology and vector control, as essential components for malaria elimination in the Asia Pacific region. Priority areas of need and action identified by participants are summarized in the following section.
Priority areas of need and recommended actions:

The following key areas of need, and suggested actions, were identified by participants through facilitated group work sessions across both parts of the workshop:

Part 1: Strengthening tools and entomological capacity for vector control programs shifting to elimination

Actions for National Malaria Control Programs, with support from regional partners:

A. Improve Human Resource development and career pathways for entomology and vector control cadre.
   1. Conduct assessment of vector control personnel needs to gauge how many entomology and vector control staff are needed, at what skill levels, where they should go, what support is needed and what training they need to carry out their work.
   2. Provide some level entomology orientation and training to other cadre involved with malaria control and elimination, including the community.
   3. Support career development of entomologists, with clearly defined roles and responsibilities, and a broad scope of work to ensure ongoing value and employment.
   4. Promote understanding that “Public Health entomologists are needed to eliminate malaria”. Programs should clearly advocate this message in one voice.

B. Provide epidemiology-centered entomology and vector control training
   1. Conduct needs assessment of training requirements at different country levels and sectors, including entomological and epidemiological surveillance, data management (including GIS) and program management training.
   2. Link training needs to development of new job descriptions and/or new skills needed by existing staff or community volunteers.

C. Strengthen infrastructural and institutional support for entomology and vector control
   1. Ensure coordination and alignment of efforts between national, sub-national and regional bodies supporting entomology and vector control including support to reference laboratories, GIS platforms and insectaries.
   2. Engage regional universities and research institutions to support program-driven training and operational research activities.
   3. Improve linkages with public (educational, government) and private (industry) sectors for skills-strengthening, data sharing and operational research.

Actions for regional/international elimination partners:

A. Advocate for increased vector control capacity
   1. In concert with the WHO Global Vector Control Response, advocate for the essential role of entomology and public heath entomologists within integrated strategies for malaria elimination, especially through bodies like APLMA, APMEN, RBM as well as the bi-lateral partners and WHO.
   2. Highlight that malaria elimination will require a shift in strategies, empowering staff at the peripheral levels to detect transmission foci, analyze the entomological and human behavior as well as the epidemiological aspects, and take appropriate action.
B. Improve vector control knowledge & information sharing
   1. Develop a standardized template to allow counties to share geo-referenced entomological information and data, using a platform that is understandable, easily harmonized and collatable.
   2. Establish a clearinghouse to collate vector control best-practices and SOPS, noting ACTMalaria’s previous efforts to do this.

C. Strengthen infrastructural and institutional support for vector control
   1. Ensure coordination and alignment of efforts between national and regional bodies supporting vector control.
   2. Support regional training opportunities to improve entomological surveillance, targeting and vector control/personal protection response.
   3. Stimulate Asia Pacific vector ecology research, and vector control tool development, especially to address the shift to elimination and the challenges of residual and outdoor transmission.
   4. Establish a resource person/clearing house within APMEN to assist in:
      • sharing and harmonizing of regional vector control best practices
      • collating and disseminating research
      • collating and disseminating regional entomology data
      • facilitating advocacy to governments, distilling WHO guidance
      • facilitate provision or exchange of regional technical advice to fill gaps, and ensure entomologists are engaged in elimination efforts.
   5. Engage regional universities and research institutions to support program-driven training and operational research activities.
   6. Improve linkages with public (educational, government) and private (industry) sectors for skills-strengthening, data sharing and operational research.
   7. Establish regional Reference Centers/Centers of Excellence for entomology and vector control.

Part II: Mekong Outdoor Malaria Transmission Network (MOMTN)

Priorities for the MOMTN to support:

A. Strengthen vector biology research, and vector control tool development
   1. Identify mechanism to share best practices for development of, and research on, personal protection and vector control methods.
   2. Compile list and define characteristics of potential tools to address outdoor transmission, including tools and strategies for monitoring and evaluation.
   3. Develop manual/Standard Operating Procedures to examine the role of outdoor/residual transmission, with precise indicators.
   4. Facilitate robust and comprehensive research on regional vector bionomics.

B. Enhance integration of anthropological approaches, community participation and engagement
   1. Enhance social sciences, participatory approaches and user-centered design to develop practices and processes adapted to the specific local context that will ensure greater “ownership” and sustainability.
2. Establish mechanism to give those at policy-making level a greater understanding of needs and issues of the at-risk population to better adapt procurement and implementation.

3. Empower peripheral staff to adapt national public health approaches to the local social, cultural and ecological context.

4. Leverage existing social networks and community structures, including the private and commercial sector for implementation of public health strategies.

C. **Enable access to necessary tools and capacity**

1. Share best practices, study designs and protocols for entomological evaluation of both existing tools and new tool development.

2. Ensure the appraisal pathway includes, in addition to entomological and epidemiological endpoints, user acceptance, manufacturability and other market and regulatory-related parameters.

3. Facilitate knowledge sharing, identify immediate actions, avoid duplication and maximise synergies.

4. Coordinate action to develop long-lasting, environmentally and user-friendly tools, with local specificity and acceptable within community and cultural practices; ideally, fitting in with current life styles, with no behaviour change needed by the end-user.

D. **Address market and regulatory challenges**

1. Advocate for reform and harmonization of national regulatory processes to facilitate the timely national registration of proven tools needed for malaria elimination.

2. Provide background technical documentation to National Regulatory Authority who may lack technical capacity and subject-matter experts to evaluate vector control tools.

3. Develop international standard data packages and easier collaboration/access to information about target markets.

4. Provide market-size projections to innovators, and explore mechanisms to support feasibility of supply, including linking to larger markets, reducing tariff barriers, and incentivizing product development.

5. Engage regulators in discussion to promote understanding of needs and priorities, to streamline processes without compromising safety.
Meeting agenda and objectives

The meeting agenda comprised the following sessions, described in detail in this report:

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<th>Part 2: The Mekong Outdoor Malaria Transmission Network (MOMTN) Regional Workshop</th>
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<td>Session VII: Monitoring - evaluating progress</td>
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The objectives for each part of the meeting were:

Objective 1: Strengthening tools and capacity

- Review common elements within national strategic plans enabling shifts to malaria elimination
- Review strategies and best practices for entomological surveillance: stratification, foci investigation, and longitudinal monitoring, insecticide resistance;
- Review VC targeting, use, sustainability and monitoring;
- Develop capacity strengthening, including better tools, coordination, information exchange, training and mentoring.

Output 1:

- Clear commitment by countries to share specific SOPs and guidelines to support development in those countries lacking these guidelines.
- To recommend priority actions to address regional gaps in tools and programmatic capacity for vector control.
- Establish on-going mechanisms, facilitated by partners, for communication and sharing of best practices among entomology and vector control units in the Asia Pacific region.

Objective 2: The Mekong Outdoor Malaria Transmission Network Regional Workshop

- Review and exchange information and experience of good practices and studies for outdoor malaria transmission;
- Identify gaps in vector control and personal protection for partners and the product development consortia, with special focus on new approaches to eliminate malaria;
- Provide estimates of malaria attributed to outdoor transmission in each country.

Output 2:

- Engage partners from a range of sectors to exchange information, review available tools, and collectively explore solutions to meet these challenges.
- Recommend priority actions to address outdoor malaria transmission;
- Identify next steps to establish a dedicated MOMTN secretariat to facilitate collaboration and information exchange on outdoor transmission among partners and countries; develop work plan, including funding, activities and deliverables.
Part I: Strengthening tools and capacity for vector control programs

Opening, Global Vector Control Response and Shifting from Control to Elimination

The meeting was opened by Dr. Sutkhet Nakasathien, Dean of Faculty of Agriculture and Dr. Siree Chaiser, Acting Vice President for Research, Kasetsart University. Opening remarks were then offered by Former Minister His Excellency Yongyuth Yuthavong, BIOTEC & RBM Board Member. Prof. Yongyuth noted that this workshop was an opportunity to learn from each other and from the past, including our program mistakes and successes. He highlighted the need to take advantage of this opportunity to succeed in our hopes for malaria elimination, and the importance of not only improving vector control but also our understanding of entomology and the biological, ecological and social interactions underlying malaria transmission.

It was emphasized that moving from ‘control’ to ‘elimination’ requires a profound shift in entomological surveillance; not continue to implement traditional “solutions” but to problem-solve the challenge of foci determination and elimination and the challenges of outdoor and residual malaria transmission.

Global Vector Control Response
Dr. Tessa Knox, World Health Organization Global Malaria Programme (WHO GMP), Geneva

Development of the GVCR strategy began in June 2016, is scheduled to go to the WHO Executive Board in January 2017 and then to be presented and endorsed by the World Health Assembly in May 2017. There is an opportunity from now till 30 November to comment on the 3rd version of the draft, and will be time for discussion and comments at the end of Day 2 of this meeting.

The GVCR emphasizes the global importance of vector control, and the need to both solve entomological problems and strengthen vector control in general. The launch of the GVCR next year will be a great opportunity for the vector control community to advocate for regional needs. However, we will need a strategic shift from ‘business as usual’ control approaches to a new strategy to achieve elimination.

Despite achieving major successes against malaria, there remain big issues to be addressed, as evidenced by recent up-surges in vector-borne diseases, especially Aedes-borne viruses. The WHO Director General, Dr. Margaret Chan stated that “…above all, the spread of Zika, the resurgence of dengue, and the emerging threat of Chikungunya are the price being paid for a massive policy failure that dropped the ball on mosquito control in the 1970s.” These outbreaks have, however, brought the importance of vectors and vector-borne diseases to the attention of the public and to policy-makers.

The GVCR recognizes:
- Successes of vector control, especially for malaria, although some emerging and re-emerging diseases emphasize the need for strengthened vector control; vector control can be effective but there is sometimes a lack of skilled personnel and dedicated finances; economic development is improving some things (malaria) but urbanization exacerbating others (Aedes-borne diseases).
- The need to communicate what is needed: simple, practical and actionable.
- The lack of public health entomologists; financial investments; limited M&E and research.
- Priority to strengthen inter- and intra-sectorial action and collaboration, including networks.
The need the Vector Control community to speak ‘with one voice’ to advocate for ‘solving the problems’ of Vector Control.

Opportunities to link with the Sustainable Development Goals, existing regional strategies, innovative research, technical advances and WHO’s improved emergency responses.

**GVCR foundation:**
- Enhanced capacity for vector surveillance and control within all locally relevant sectors (including human, infrastructural, and health systems);
- Expanded basic and applied research and harnessed innovation.

**Pillars of action:**
- Strengthen inter- and intra-sectoral action and collaboration;
- Enhance entomological surveillance, and vector control monitoring and evaluation;
- Scale up and integrate tools and approaches;
- Engage and mobilize communities

**Enabling factors:**
- Country leadership;
- Advocacy, resource mobilization and partner coordination;
- Regulatory, policy and normative support.

Country leadership of prevention and control efforts is critical; policies and activities should not be limited to the health sector and should always be evidence-based; action within countries and between countries should be harmonized and strengthened. Adoption of novel tools when validated for operational use is encouraged. The aim is to ensure all countries can achieve success, irrespective of their current capacities and resources with an emphasis on integrated, community-based approaches.

**Discussion and comments on the draft GVCR document**

The goal should be clear: effective vector control to reduce vector-borne diseases. How do we track progress for the individual vector-borne disease? It does not make sense to aggregate across diseases and we may need disease-specific indicators. An overall percent reduction in vector borne diseases may not be relevant for all countries as they are starting from different baselines.

Should there be morbidity targets? If the document uses the phrase “free of human suffering” should there be morbidity targets? We should add a pillar to engage national level decision makers. Quality Assurance for vector control tools is an important consideration. Likewise, there needs to be emphasis on maintaining sustainability of interventions, managing insecticide resistance, maintaining integrity of interventions. The “at risk population” and “protection” needs to be more clearly defined, especially since different populations are at risk for different vector borne diseases.

**Vector control in the Asia Pacific region: shifting from control to elimination**

Dr. Bill Hawley, Centers for Disease Control and Prevention (CDC), USA

Dr. Hawley presentation stressed the differences in entomological surveillance and vector control in the shift from control to elimination. The elimination strategy is to reduce transmission to the extent that individual human cases can be mapped and treated before onward transmission to mosquitoes. The aim is to prevent infection of mosquitoes through prompt diagnosis and treatment. But this is possible only if mosquito populations have been sufficiently suppressed.
Some actions are the same in both settings; insecticide resistance monitoring, species identification; programmatically relevant operational research. But in elimination the epidemiological data informs where to do the entomology, given that case and foci investigations with the aid of maps will determine the origin and (probable) date of malaria infection. Hence, there is less emphasis on longitudinal surveys and a recognition that interventions not suitable for a broad scale may be used in specific local contexts.

Foci investigations for *P. falciparum* (more difficult to estimate time and place of transmission for *P. vivax*) included data validation on where transmission might have occurred; intervention coverage and assessment of potential larval control. Examples were provided from Indonesia illustrating the diversity of context and the need for unique solutions to each, including cross-border collaboration. There is no standard model, but political financial support and capacity building at the subnational level are critical. Epidemiological thinking and data validity is critical to determine when and where transmission is occurring and making control decisions for foci elimination. There is a need to understand human as well as vector behavior. To eliminate malaria, we must interrupt transmission, not just parasitemia.

**Session I: Entomological Surveillance**

**Chair: Indra Vythilingam, University of Malaya, Malaysia**

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<th>Session 1 summary</th>
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<tr>
<td>• Collection, identification and mapping are three essential steps for entomological surveillance.</td>
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<td>• Indonesia provided an example of their surveillance system with threshold indicators and an on-line geo-referenced data base.</td>
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<td>• Examples of more efficient collection methods were presented, but the efficiencies for each varies with species and context with the recommendation to do lots of collections well and don’t overinterpret.</td>
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<td>• Programs will need to broaden and decentralize entomological surveillance in the shift towards elimination. An example from Zambia showed how community health workers could manage CDC light traps, sort mosquitoes by genus and package samples for identification and analysis by central-level staff.</td>
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<td>• Accurate identification remains the foundation of all entomological surveillance. Vietnam provided examples of a strong system for mosquito identification and specimen preservation for training and voucher verification.</td>
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<td>• Many vectors in the region are part of morphologically similar complexes and in certain locations where sympatric sibling species exist should be identified through molecular techniques. Thailand provided an example of identification and mapping of species complexes in the Dirus, Minimus, Maculatus and Sundaicus Complexes. Examples were also shown of identification errors between vector and non-vector species that led to programs targeting the wrong locations and wrong mosquitoes.</td>
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Indicators and collection methods
Rahmad Isa & Budi Pramono, MoH Indonesia

The entomological surveillance system in Indonesia has three different types: the spot survey, the intensive survey and the longitudinal survey. They use both the traditional hand collection methods described in the 1975 WHO Manual as well as CO₂ baited CDC light traps. They have also developed risk thresholds between low risk and high risk for different indicators, e.g. Man biting rate = 0.025; parity rate = 50; vector density = 0.03; EIR= 0.001 and the larval index habitat = 1. Indonesia also has a web-based entomological surveillance information system with the collection sites geo-reverence can linked to maps.

Efficient mosquito trapping methods to identify origin of malaria infection and vector species composition
John Gimnig, CDC USA

The goal of mosquito collections is to
- Estimate risk of infection: Predominant vector species; estimate biting rates; infection rates
- Characterize mosquito behavior: Host preferences; biting times and locations; resting locations
- Collection of live/fresh specimens for secondary analyses: parity; insecticide resistance

The gold standard for mosquito collections is the Human Landing Collection (HLC). This provides direct estimates of biting rates and EIRs; information on biting times and locations, and the ability to collect live specimens. However, the technique is tedious and requires skilled collectors.

Light traps are a common proxy for HLC. There are various ways to bait them, by placing next to a person or animal or using with artificial sources of CO₂. Indoor collections can be with Pyrethrum Spray Collections and Indoor aspiration. Animal baited traps collect a large number of mosquitoes across a wide range of species; however, importance in malaria transmission is unclear. Animal baited traps may potentially be useful as a proxy for estimating transmission.

Summary of collection methods
There are some promising new approaches, including tent trap as an alternative to HLC; mosquito electrocuting traps; and the human decoy trap, a modified version of odor-baited entry trap.

Sampling strategies and locations is the key. For selecting sits in elimination settings, collection sites should be guided by epidemiological data with priority given to areas of persistent foci; within the village sites should target areas where human-vector contact is most likely (this requires discussions with residents. The number of collections is limited by logistics and so we need to target efforts because of very limited resources. We need to target areas with persistent foci as determined through epidemiological data. In conclusion, no single trapping method is perfect – do lots of collections well, and don’t overinterpret.

Decentralizing mosquito control: approaches to engage the community in surveillance activities
Neil Lobo, University of Notre Dame, USA

Dr. Lobo described the importance of vector surveillance to detect potential transmission rebounds because of insecticide resistance, behavioral changes or implementation issues and to define the level of residual transmission. Vector control can cause species shifts, as for example the impact of LLINs in
Western Kenya was more pronounced on the more anthropophilic *An. gambiae* than *An. arabiensis*. LLIN coverage can also change resistance markers such as kdr in *An. gambiae* in Kenya. Control measures can also shift biting times as in The Solomons where IRS appeared to shift *An. farauti* to feed earlier in the evening and outdoors. Vector surveillance is therefore essential, but there are limits to centralized surveillance due to costs, and availability of trained staff limiting the geographic scope and frequency of the collections.

To solve this problem, Zambia instituted a decentralized mosquito collection scheme. Results were presented for the period between 2011 and 2013. Across two districts, 14 clusters of 1000 households each were determined. In each cluster a community health worker used CDC light traps and Ifikara Tent Traps to collect one night per month in fifteen households. They were trained to sort mosquitoes by genus, store in containers with silica gel and record *Anopheles/Culex*. These containers were collected monthly by the NMCP staff who later morphologically and molecularly identified the mosquitoes, and for the vector species, determined sporozoites infection by ELISA. A total of 20,683 mosquitoes were collected. The primary vector was *An. funestus* with 23/555 ELISA positive. The CDC light trap was far more efficient than the tent trap collections under these circumstances. There were challenges in trapping efficiencies especially in seasons with lower mosquito populations but it was concluded that the Community-based surveillance was cost-effective and practical; brought community buy-in and ownership; was epidemiologically relevant and could be used at a programmatic scale.

**Mosquito identification and processing**
Dr Vu Duc Chinh, NIMPR, Vietnam

Dr. Chin explained the critical importance of accurate identification and the methods they use, first with morphological identification keys, then sometimes with PCR and Enzyme electrophoresis. There are 63 species of *Anopheles* in Vietnam described in the NIMPE identification key for larvae and adults. Morphological identification training is provided in Hanoi and in the field. The program also maintains a collection of preserved specimens from their study sites as voucher specimens and for training purposes.

**Mapping anopheline mosquitoes – an example from Thailand**
Theeraphap Chareonviriyaphap, Kasetsart University

Dr. Chareonviriyaphap described the high biodiversity of species that can transmit malaria in the region. In Thailand, there are 438 mosquito species and of these 73 are *Anopheles*. Many of these are species complexes. Presented were maps of the distribution of the three species of the Minimus complex; the eight species of the Dirus complex; eight species of the Maculatus group; four species of the Sundaicus complex. Also explained was the importance of accurate species identification to differentiate between the sometimes confusing morphological distinctions of *An. minimus*, a vector and the non-vector *An. fluviatilis* (in Assam) and *An. varuna* (in Vietnam). Maps were then presented showing the geographic distribution in Thailand of the Dirus Complex, the Maculatus Complex and the Minimus Complex.

In summary, precise identification of malaria vector species is needed to target the right vectors. Using various non-morphological tools, geo-referenced maps were generated from both published and non-published data to generate an updated, countrywide distribution of malaria vectors in Thailand. There are 11 maps with the distribution of 18 species and 20 tables with GPS coordinates on malaria vector
distribution from Thailand available. Information from vector distribution map is very helpful in preparation of the precise malaria transmission zoning map of the country and help precisely target the areas at risk.

Session II: Vector Control

Chair: Muhammad Mukhtar, NMCP Pakistan

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<th>Session II Summary: Vector Control</th>
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<tr>
<td>• LLINs are essential. Programs are challenged with sustained funding monitoring durability, net preference and use vs untreated nets, and monitoring insecticide resistance.</td>
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<td>• Thailand shared actions for surveillance and targeting to bring interventions in line with available funding. Prioritization and advocacy to increase domestic funding are key.</td>
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<tr>
<td>• Durability and actual preference and use of the LLINs we freely distribute are critical data for best use of available funds. Myanmar offered a protocol for durability and Cambodia data on what types of nets actually meet community needs, important ‘value for money’ data for procurement.</td>
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<td>• For the large number of untreated nets still being used, Vietnam explained their successful strategy of community net re-treatment campaigns.</td>
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<td>• While insecticide resistance in the major vectors is not yet a severe problem the Thai/Lao MALVEC project provided an update on insecticide resistance monitoring and management in the region.</td>
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<td>• Sri Lanka shared their surveillance and control systems for preventing reintroduction of malaria transmission in their country.</td>
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Maintaining universal coverage of ITN/LLIN after the departure of Global Fund in Thailand

Prayuth Sudathip, MoPH, Thailand

Dr. Sudathip first described the Thai system for foci classification at the village level:

Reduction of Transmission
- A1 = With indigenous cases at least 6 months per year
- A2 = With indigenous cases less than 6 months per year (+residual non-active)

Prevention of Reintroduction
- B1 = No transmission and presence of vector/suitable environment
- B2 = No transmission and non-presence of vector/unsuitable environment;

The number of villages in the A1 or A2 category reduced from 5,815 in 2014 to just 2,777 villages in 2017. The program provides LLNs to A category villages and long-lasting insecticidal hammock nets (LLHIN)to forest-goers. This amounted to nearly 500,000 LLINs and 140,000 LLIHNs in 2016.

Financing will be a challenge in the future and the program will need to bring interventions and surveillance in line with available funding. Need to increase domestic funding and need to prioritize and focus investing. Will need to engage with local organizations for support and implementation. Decentraliza-
tion will be a challenge, including due to retirement of skilled staff. There will be a need for internal reorganization to streamline activities managed by the national program and to simplify forms and methods. There will need to be SOPs and training for the general public health staff.

More than 50% of transmission related to forest-based activities. No effective methods to protect people who go into the forest from mosquito bites. Would like to use mobile technologies – do operational research to investigate how to do that – to address outdoor malaria transmission. There are also problems with the mobile migrant populations, especially cross-border movement where it is very difficult to do an investigation, response and treatment. It is also difficult to quantify the effectiveness of hammock nets and other personal protection for mobile populations at different transmission risks. The aim is to increases community involvement and harmonize actions with neighboring countries.

**Net preference studies**

Elijah Filip, PSK Cambodia

A qualitative study on mosquito net preferences was conducted in Cambodia, led by PSI with funding from PMI. The study revealed that often mosquito nets distributed by the program don’t meet the particular needs of the people who received but there was not strong evidence base on preferences for types of nets provided. The study aimed to get stated preferences from users – and to identify determinants of use. Driving forces for preferences: perceived protection net offers – seasonal; and sense of control over environment; comfort is another driving factor. The study revealed that a major factor was the size of the net – both the length/width and the height. The nets distributed by the program were smaller, whereas commercial nets purchased from the market are bigger – allowing multiple people to sleep together under the net. The material was also seen to be important with large difference between the rough attributes of the polyethylene net vs the softer polyester nets. The polyethylene nets tended to shrink and lose shape when washed and had a larger hole size, leading to the suggestion that mosquitoes will be able to slip through when he chemical wears off. Nets distributed by the program may not meet all the needs of users, but people will still use them depending on the context. Specific relationship between preferences and use remains to be determined and follow-up studies are required. Current oversupply might be avoided by taking into account some of these preferences. Oversupply of nets leads to use for other purposes, e.g. fishing and protecting livestock or crops. People accept these nets because they are free, but end up using them for other things, then procure untreated conventional nets from the market.

**Durability monitoring of LLINs in Myanmar**

Si Thu Thien, PSI Myanmar

Dr. Si Thu Thein described the LLIN durability monitoring study now underway in Myanmar, managed by PSI and supported by PMI and the VectorWorks project. The study includes reasons for attrition – either given away or stolen and discarded or used for some other purpose. The net integrity is calculated by the “composite hole index and classified into “Good, damaged or Torn (no longer useful). “Serviceable” nets are those classified as good plus damaged. “Durability” is calculated as a combination of attrition and integrity, the number of nets still present and fit for use, divided by the number of nets originally received and not given away. Given the high loading dose in new LLINs the insecticidal effect is expected to last three years. The Myanmar start will assess the physical durability and people’s attitude to two brands of LLINs the 100 denier polyester, deltamethrin-treated DawaPlus 2.0 and the PermaNet 2.0. that were distributed in 2015. The prospective study is planned to last 3 years and includes a multi-
stage cluster sampling of households, with a total of 300 households. There will be bioassays of insecticide retention annually and a chemical residue assessment at the end of the three-year study. The baseline assessment at 6 months showed a usage of 52%, all were still serviceable, but there was an overall attrition of 20% mostly due to nets being given away. There was not yet any significant difference in damage caused by being torn on the edge of a nail, burned, damaged by rodents or torn on corner. Further information can be found at www.durabilitymonitoring.org

Insecticide resistance monitoring
Hans Overgaard, Khon Kaen University, Thailand

Dr. Overgaard presented a general overview of what insecticide resistance is and the negative role it may have for malaria control. Insecticide resistance in mosquitoes may develop from exposure to pesticides used in vector control and agriculture, but also from natural xenobiotics, pollutants from urbanization and industry, and host interactions of the insect microbiome. Resistance mechanisms can include behavioral modification and avoidance; reduced penetration across the cuticle; increased excretion; increased detoxification and target site modification. The available WHOPES-recommended chemicals were reviewed and an update on insecticide resistance statues in Africa and Asia provided. The WHO Global Plan for Insecticide Resistance Management was reviewed and current research and development of new active ingredients and formulations. The recently completed MALVEC project (expertise supported by France) in Lao PDR and Thailand 2013-2015 revealed some resistance to deltamethrin and permethrin in An. hyrcanus s.l. in Thailand and resistance among An. vagus in Lao PDR. Except for suspected resistance in An. barbirostris s.l. in Thailand, there was susceptibility to pyrethroids across the 12 Anopheles tested, including the major malaria vectors An. dirus s.l., An. maculatus s.l. and An. minimus s.l. The conclusion was that while there need to be more studies across the region, insecticide resistance in the main malaria vectors is not common.

Net retreatment
Le Trung Kien, NIMPE Vietnam

Dr. Kien described the Vietnam program for community insecticide treatment of convention nets. More than 600,000 LLINs are provided to at risk populations every year, but to ensure sufficient provision of treated nets, the program also treated conventional nets with either alpha cypermethrin 10SC or lambda-cyhalothrin 2.5CS.

Mass treatment can be done by trained health trained personnel and provincial and district health staff. The commune health station or community meeting house is used as the dipping center which is a fixed central place where people bring their nets for retreatment. The community campaigns that offer re-treatment are usually done once or twice a year, preferably before the malaria season. Malaria IEC/BCC is provided along with the re-treatment campaigns to raise awareness for malaria.
risk. The list of the commune population and quantity of existing bed nets is already determined before the campaign begins. The equipment consists of nets, insecticide, basin or plastic bag, measuring equipment, gloves, plastic sheeting and soap. Make sure the nets are clean. It is best to treat the nets outdoors in the shade.

**Surveillance & vector control tools needed to support the shift to elimination**

*Senarath Bandara, APMEN VcWG Co-Chair, MoH Sri Lanka*

Dr. Bandara described the surveillance system used for the Sri Lanka elimination program. The type of entomological surveillance used depend on the phase as well as the situation of the risk, e.g. sentinel surveys; spot checks on selected receptive localities; special surveys during outbreaks or epidemics; and case-based investigations.

![Schematic diagram depicting entomological surveillance and vector control](image)

Techniques used:

<table>
<thead>
<tr>
<th>Vector Prevalence</th>
<th>Cattle Baited Hut Collections</th>
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<tr>
<td></td>
<td>Cattle Baited Net Trap Collections</td>
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<tr>
<td></td>
<td>Larval Surveys</td>
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<tr>
<td>Resting Behavior</td>
<td>Pyrethrum Spray Sheet Collections</td>
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<td>Indoor Resting Hand Catches</td>
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<td></td>
<td>Window Trap Collections</td>
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<tr>
<td>Biting Behavior</td>
<td>Outdoor Resting Hand Catches</td>
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<td></td>
<td>Human Landing Collections (partial night)</td>
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<td></td>
<td>Human Landing Collections (Full night)</td>
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<tr>
<td>Breeding behavior</td>
<td>Larval Survey</td>
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<tr>
<td>Resistance Monitoring</td>
<td>Insecticide susceptibility Test</td>
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<tr>
<td></td>
<td>Efficacy of Insecticide Bioassay Test (IRS / LLIN)</td>
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</tbody>
</table>

The use of GIS for stratification for receptivity and vulnerability was described along with a schematic of steps for entomological investigations when a malaria case is reported. Studies continue on biting behavior and insecticide resistance.
### Session III Summary: Capacity Building

- Shifting from malaria control to malaria elimination requires a realignment of medical entomology to public health entomology with greater capacity and linkage for epidemiology, GIS and program management and the empowerment of periphery staff to collect and analyze data and eliminate local transmission foci.
- Equally important to training are jobs and career structures for entomologists and assistant entomologists at sub-national levels.
- Universities are key partners for both pre-service and in-service training. Students can be mentored through internship and class projects attached to the NMCPs.
- Materials are available through ACTMalaria including both technical and managerial aspects of entomology and vector control.
- AFRIMS provides an excellent reference to build national capacities for insectaries and reference laboratory support.
- Advances in GIS technology and spatial analysis will greatly help in both surveillance and program management of vector control operations.
- Regional networks can support elimination efforts through enabling partnerships, allowing exchange of information and experience; and building technical evidence/capacity.
- Examples of comprehensive, community-based vector control were provided by initiatives in Papua New Guinea.

### WHO Guidance on Capacity-building

**Michael Macdonald, WHO, Emergency Response to Artemisinin Resistance (ERAR), Greater Mekong Sub-region (GMS)**

Dr. Macdonald presented the WHO 2013 Guidance on capacity-building for public health entomology, shifting from the traditional ‘medical’ entomology that narrowly focused on mosquito biology to ‘public health’ including skills in epidemiology, GIS and program management. This is “not business as usual” but requires urgent action. Recommendations to governments include: development of a long-range plan including posts and career opportunities, university links and revised curricula; pre-service and in-service training supported by ongoing mentoring; ensuring public health entomology capacity in funding proposals including infrastructure (insectaries, laboratories and GIS platforms). Recommendations to partners includes ensuring country ownership and sustainability after project completion; and recommendations to WHO includes technical guidance and facilitation of networks (including the present one). One of the biggest challenges is civil service reforms that need to be in place so that young scientists can have a life-long career in public health entomology and vector control.

### Human Resource capacity for vector control and career pathways

**Christina Rundi, Sabah Department of Health, Malaysia**

Dr. Rundi outlined the scopes of work for field entomologists and career pathways. The scope of work included not just entomological surveillance, ensuring compliance to standards for equipment and insec-
ticide use, monitoring interventions; managing the laboratory and insectary, including monitoring of in-
ssecticide resistance, develop policy and support related regulatory and legislative issues; conduct re-
search. Dr. Rundi then described the Malaysia color-code system of risk area stratification based on the
thresholds of annual incidence of 1/1000 population. In Sabah, the “red zone” API>1 this is now below
10% of the localities; nationally it is just over 2%. The way we get better is through working collectively.

**Roles of government and academic partners**
Moh Seng Chang, UNIMAS Malaysia

Dr. Chang Moh Seng described the vector control challenges in the region, in addition to the work for
malaria elimination, there are new challenges related to dengue and Zika virus increases. New tools are
under development but there is a need for more epidemiological and entomological evidence before
they can be deployed because of a lack of quality and well-designed field intervention research. Insecti-
cide resistance monitoring is hampered by limited sample sizes, standardization of reporting and data
ownership; the low Anopheles vector densities often make it difficult to quantify transmission risk. The
is an extreme lack of capacity of entomologists needed to carry out vector surveillance and control in
elimination settings. There is an extreme lack of entomological capacity to carry out implementation
research on vector control, surveillance and evaluation in elimination settings. We need a multi-discipli-
nary approach to engage with academia, particularly in the research landscape. Malaysia has strong
links between the universities and the control programs, including *P. knowlesi* studies in Borneo, refer-
cence laboratory support and training of master’s and doctoral level of public health entomologists.
Other government sectors have a key role for legislative and regulatory issues, especially regarding pes-
ticides, registration and use, resource mobilization, intersectoral coordination (e.g. recently for Zika) and
community empowerment. There is also a need to foster collaborations with other sector for mosquito
larval control, better housing and use of personal protection tools. These sectors such as the land devel-
opment and local government agencies; rural development and housing; Forestry and Agriculture and
Ministry of the Environment. Academia/government partnerships are needed to accelerate operational
research, epidemiological risk assessment and stratification, including GIS and remote sensing; behav-
ioral and ecological studies; and social sciences.

**Training needs and materials**
Cecilia Hugo, ACTMalaria, Philippines

For 20 years ACTMalaria has been a strong partner in the region. Ms. Hugo presented the regional train-
ing needs related to entomology and vector control indicated in the Regional Training Strategy 2016-
2020 across the twelve countries in the network who participated in the needs assessment conducted in
2015. Many of these focused on malaria elimination, as well as basic entomological skills for collection,
identification and insecticide resistance management. ACTMalaria over the years has also included
many trainings on program management, transfer of training skills, social advocacy, community mobil-
ization and sustaining capacity of staff at the district and provincial levels. Ms. Hugo then described en-
tomological surveillance in the context of Sri Lanka regarding sentinel surveillance, spot checks and case-
based entomological surveys for foci investigations and “reactive surveys”. She also proposed that ento-
omologists be trained on core management skills, such as critical and analytical thinking, problem-solving
skills, decision-making skills (to make clear recommendations) and communication, advocacy and com-
unity mobilization skills.
**Insectaries and Reference Laboratory support**  
Silas Davidson, AFRIMS, Thailand

MAJ Davidson presented on the AFRIMS insectary and research capabilities. They have 41 employees, including 8 PhD Scientists. AFRIMS maintains 8 different mosquito species for Plasmodium and arboviral transmission studies, one colony of Toxorhynchities and colonies of Leptotrombidium. They also have a semi-field enclosure and five active field sites. In the vector biology and control section they are conducting research on ecology, epidemiology, disease transmission, surveillance and vector control including spatial repellents. AFRIMS also has a long history for mosquito identification and taxonomy and has published numerous morphological keys and monographs on mosquitoes in the region. The insectary colonies include *An. dirus* both free and forced mating strains), *An. cracens*, *An. minimus* and *An. sawad-wongporni* that they can provide to other insectaries in the region.

**GIS approaches to targeting high risk transmission zones**  
Felix Holl, UCSF Global Health Group, USA

Mr. Holl explained the UCSF work on GIS and mobile technologies for malaria control operations in Southern Africa. In Nambia, mapping houses sprayed in the IRS Program as well as a “Disease Surveillance and Risk Monitoring” system in Swaziland.

**Regional networks for knowledge sharing**  
Amanda Murphy, Asia Pacific Malaria Elimination Network (APMEN), Australia

Ms. Murphy reviewed the global and regional networks in the region, including the RBM Vector Control Working Group, the APMEN Vector Control Working Group and the Asian Collaborative Training Network for Malaria. Networks can bring together unique spectrum of stakeholders in elimination – to establish partnerships, exchange experience; advocate for (country-led) elimination efforts; support building technical evidence/capacity; and to share and assimilate information and tools. APMEN specifically works to advocate for increasing the level of vector control capacity at country and regional level required to attain and maintain malaria elimination; stimulates operational research on questions directly related to intensified malaria control and elimination; supports training and skills development; and develops and shares of information and resources between countries. APMEN’s Vector Control Working Group (VcWG) has supported vector control training fellowships, and produced a “Anopheles Pocket Guide” containing 26 main malaria vectors in the Asia-Pacific, jointly developed with the Walter Reed Biosystematics Unit and AFRIMS. Moving forward, the network can help address gaps related to vector surveillance and control, and continue to facilitate the translation of evidence to policy and practice. The APMEN and APLMA secretariats will soon co-locate for synergy and efficiency, although funding for the working groups is uncertain. The VcWG intends to provide an open forum for collaboration and communication as programs move to elimination, and to communicate country needs in a “simple, practical and actionable” way.

**Refocusing existing control strategies**  
Paul Zoborowski & Melinda Susapu, NHD Papua New Guinea

A presentation was given on the “New Guinea Islands Region (NGIR) Innovative Malaria Projects” in North East PNG. Across NGIR malaria projects are four pillars: Healthy Village/Healthy Wards Assessment; Vector Control Program; Malaria Impact Zones / Malaria Management Zones; and National Health Standards Survey including Drug & Diagnostic Supply Chain Review and Case Management & Diagnosis
Assessment. Also described was the Bougainville Healthy Communities Programme, emphasizing “Capacity Building” and “Ownership”. Key to much of this is well-functioning health centers, better and faster data, a coordinating body, malaria response teams and an organized educated public. The healthy communities project includes destruction of mosquito larval habitats through cleaned, “beautified” and well-drained village environments; Village Health Volunteers are involved in LLIN education and distributions; community initiatives in setting up model healthy villages and Islands, with support of BHCP; active swamp drainage near villages; and education about mosquito biology, identification and destruction.

**Capacity building priorities to support the shift to elimination: what can be done to strengthen regional entomological capacity:** Group work & discussion

Participants were divided into 3 groups to discuss needs and priorities in 3 areas, each described below: 1) human resources & career development, 2) information sharing, and 3) training needs. The outcomes are incorporated within the Priority areas of need and recommended actions section.

1. **Human Resource needs and career development**

There is both a lack of incoming entomologists and difficulty in retaining existing entomologists. There is no support for a core team of entomologists, no career progression and no salary schemes. Entomologists are often seen as not as important. There is a general lack of training opportunities. To address this issue, we must consider the country human resource needs. Countries can do this by undertaking a vector control needs assessment to gauge how many entomologists are needed, where they should go, what support is needed and what training they need to carry out their work. This highlighted the importance of proper job descriptions which have clearly defined roles and responsibilities. We need to be unified and advocate understanding that “Public health entomologists are needed to eliminate malaria”.

2. **Information sharing**

There was consensus amongst all groups that counties should be sharing information and data using a platform that was understandable, standardised, easily harmonised and collatable. There were suggestions for a standardised template and to ensure it was in a common language (English) as well as the national language so it could be easily shared. The groups agreed on a wide range of information to be shared amongst countries. This included GIS and the establishment of a mapping group, including focus on transmission zones along border areas; vector surveillance; and insecticide resistance monitoring. Region-specific guidelines were needed and standardised so they would be easy to collate. There were questions over who would be most appropriate and best positioned to undertake this work. If it is WHO then do not duplicate with other information sharing networks. All of these functions expected to be carried out by Country Programs and that new systems should not be set up. The focus should be on building the capacity of programs to do this work. WHO has reporting processes but lacks resources, and the data management and analysis is only currently managed at global level, not at country/regional level. This is problematic as it means they cannot provide rapid feedback. The groups queried whether anyone else in the region was looking at vector control issues and suggested that this could be a role for APMEN. It was suggested to compile a list of institutes working in different technologies related to entomology and vector control. There were also suggestions to develop an e-library, repository to share data. There could also be an Asia-Pacific vector ecology meeting every 1-2 years as done in other regions. While it was suggested to set up a clearinghouse to collate best practices SOPS etc., it was noted that ACTMalaria recently decided to close their resource centre of 10 years, as countries stopped sending in
their documents. Following the initial call and enthusiasm for the resource centre, as time passed this diminished and contacts within countries moved on and there was little uptake in interest from their replacements. It was also noted the level of efforts for administration involved in the this work, the cost of both establishing and maintaining the database was both resource and labour intensive as it requires an information resource officer/librarian and can be expensive with high server costs to host online.

3. Training needs

This starts with a country level training needs assessment. There is a need for training people at national level and not just entomologists, but also those who are undertaking roles that may incorporate entomology. Everyone involved with vector borne disease control, even if just on the medical side or in management, should have a basic understanding of entomology and transmission ecology. For those who are trained as entomologists, then offer those staff epidemiology and public health training. Training in data management is also important to assist entomologists with methods of data collection to enable the information to go the national level and be analysed and translated for decision making.

At a national level, there was a need to contextualise the training needs to countries. When thinking of training people who aren’t entomologists, groups highlighted the need to consider Human Resource implications when training staff and developing new job descriptions. There were suggestions for a greater range of training courses with more flexible options. These included: developing a modified diploma course (similar to that provided by IMR in Malaysia), a short course with one specific module for those who are interested to enhance their capacity as entomologists, general training on vector control covering all stages of a project cycle and e-learning/distance modules.

At the subnational level, the group noted that these districts and communities should have control over solving their own problems and coming up with own solutions. There was also concern over whether new staff would be hired, or it would just involve other staff taking on additional tasks.

4. Institutional/infrastructural & research needs

There needs to be strong institutional links between the NMCP and the national universities and training institutes. Operational research, and in some countries in Africa, entomological surveillance and insecticide resistance monitoring is contracted out to national universities to implement. There are also examples of students completing their degree project requirements with NMCP activities and for the NMCP to help with curriculum development for both pre-service and in-service training. Universities involved with public health entomology should be networked as for example the Africa Network for Vector Resistance and the data-base currently being developed by WHO.

A number of countries in the region are developing insectaries and reference laboratories, including GIS platforms. Some of the more advanced facilities can share protocols and procedures both for maintaining the infrastructure, for mosquito colony maintenance and for laboratory procedures.

Research needs include sharing of field research designs for improved entomological and epidemiological evaluations, particularly for activities related to outdoor transmission. There was a specific request for an update of the morphological identification keys used in mosquito identification across the region. And finally, a request for mapping the results of the insecticide resistance monitoring.
Part II: The Mekong Outdoor Malaria Transmission Network Workshop

Introduction. The workshop expanded the second two days to the Mekong Outdoor Malaria Transmission Network (MOMTN) workshop to include the private sector, product development consortia and additional partners from academia and projects involved with outdoor malaria transmission (OMT). This is a complex problem that will require collaboration and information sharing across many diverse disciplines to find an answer. The aim of the following two days was to engage a range of sectors, recommend priority actions, and to establish a dedicated network to carry forward this work in the future.

Session I. Entomological Aspects of Outdoor Malaria Transmission

Chair: Tessa Knox, WHO GMP, Switzerland

Session 1 Summary: Entomological aspects

- The speakers reviewed the entomological aspects of outdoor transmission for both human and monkey malaria, and emphasized the importance of understanding species identification, and related transmission ecologies.
- Precise identification of malaria vector species is needed in order to define efficient vector control programs targeting the right vectors.
- Diverse mosquito behaviors and human activities are the key factors influencing the residual transmission. Better understanding of behavioral plasticity is needed.
- Existing interventions cannot break the outdoor transmission cycle, especially early biting behavior, as observed in studies of *P. knowlesi* in Malaysia. Unclear how to address this; more investment and collaboration required to map and find solutions to outdoor and early biting vectors.
- An example from the Thai-Myanmar border suggested that differences in mosquito biting behavior might be related to human activity; a better understanding of vector bionomics may assist vector control.
- A panel discussion with country program representatives explored the different ecological settings for outdoor transmission, and how this impacts control strategies.

Review of outdoor transmission challenges in the Mekong: detection, monitoring & response

Theeraphap Chareonviriyaphap, Kasetsart University, Thailand

Professor Theeraphap first reviewed human behavior that kept them outside and exposed including miners, forest workers and military. Then details were provided on the primary malaria vectors in the region, the eight species of the *An. dirus* complex, eight species in the *An. maculatus* complex and three in the *An. minimus* complex and the need for correct identification when examining the trophic behavior such as biting times of the three species complexes. A review of publications of vector biting times was provided. There was then a review of behavioral avoidance of *An. dirus*, *An. Maculatus*, *An. sawadwongporni* and *An. minimus*, to synthetic compounds (field doses) of deltamethrin, permethrin and DDT using the excito-repellency test system. Tests were also conducted with bifenthrin on *An. minimus s.l.* that showed very low irritancy for *An. minimus s.s.* but more irritancy for *An. harrisoni*. While *An. epiroticus* populations from eastern Thailand showed irritancy to pyrethroids, populations from southern Thailand did not. Prof Theeraphap concluded:
• Precise identification of malaria vector species is needed in order to define efficient vector control programs targeting the right vectors.
• Mosquito behaviors and human activities are the key factors influencing the residual transmission. Most malaria vector’s behavior in GMS is opportunistic; therefore, better understanding of such a diverse behavior is needed.
• Chemical actions (irritant, repellent, insecticidal) must be clearly defined before launching any chemicals into the program.
• IRS and ITNs will mainly affect indoor biting mosquitoes, leaving opportunity for early-biting, zoophilic and outdoor vectors to avoid contact with insecticide treated surfaces and to maintain a certain level of transmission.
• Close follow-up on the distribution of LLITM to populations at risk is recommended.

Entomological features & vector control measures of Asian vectors which make them amenable to indoor & outdoor control
Pradya Somboon, Chiang Mai University, Thailand

Prof. Somboon reviewed the Dirus Complex, the Minimus Complex, the Sundaicus Complex and the Maculatus Group geographic distribution across the region. He noted the Dirus and Minimus Complex contact avoidance to residual insecticides and the behavioral plasticity of the Sundaicus Complex and some members of the Minimus Complex. Members of the Maculatus Group may be zoophilic and exophagic in human settlements, but more endophagic and anthropophilic in farm huts or shelters in the forest.

Plasmodium knowlesi: Outdoor transmission of malaria
Indra Vythilingam, University of Malaysia

Prof. Vythilingam outlined studies in different parts of Malaysia looking at Plasmodium knowlesi transmission by members of the Leucophyurus Group. All countries in Southeast Asia, with the exception of Lao PDR and Timor Leste, have reported cases of knowlesi malaria. It is a life-threatening disease and comprise about 40% of the malaria cases reported in Malaysia. There is early biting in Sabah, 40% before 9 pm, including exophagy and early biting by other An. leucophyurus vectors in Sarawak and Pahang. An. balabacensis is found in large numbers in the village areas in Kudat as well as in the forest and farms. One mosquito can be the vector for up to four different species of malaria parasite. Dr. Vythilingam outlined an entomology investigation of a case-control study in Kudat where there was a higher infectivity rate of mosquitoes caught around case houses than the control houses. Biting occurs both around homes and in working/recreation areas. Due to deforestation, many mosquitoes were found in close proximity to humans. Indoor biting occurs early, before people are protected by bednets. Unclear how to address – need to explore solutions. Existing Vector Control measures cannot break the transmission cycle with outdoor biting vectors. There needs to be more investment to explore the ecology and find solutions to outdoor and early biting vectors. Collaboration very important to map the vectors throughout the country.

Three-year study on Bionomics of Anopheles minimus s.l. malaria vector along the Thai-Myanmar border in Mae Hong Son Province, Thailand
Wannapa Suwonkerd, Office of Disease Prevention & Control (ODPC), Ministry of Public Health, Thailand
Dr. Suwonkerd presented work conducted between 2011 and 2014. Among the three groups of malaria vectors in Thailand, *Anopheles minimus* s.l. is predominant in the three districts studied. The host preference showed focal differences with vectors being more anthropophagic in two districts and zoophilic in the third. Biting times also differed. In the two districts with more anthropophily, *An. minimus* s.l. prefers to feed after midnight until early morning with a peak during 02.00-05.00 hr. In the district with more zoophilic tendencies feeding was throughout the night with a peak at 22.00 hr. and after midnight until morning.

In the last 15 years, the malaria burden in Thailand has been gradually reduced; however, serious challenges remain. The differences in mosquito behavior might be related to human activities in each location as well as environmental conditions. Understanding the vector bionomics could lead to a better planning and control. In the three study districts *An. minimus* complex is the most abundant malaria vector. The biting pattern and host preference indicated site specific and molecular identification is required to confirm the species.

**Panel discussion: Evidence and driving forces of residual and outdoor transmission**

Panel members: representatives from Bangladesh, Cambodia, Malaysia, Pakistan, PNG, Sri Lanka, Thailand, and Vietnam

1. **What are the different ecological settings for outdoor transmission/how does this impact control strategies?**

Cambodia: people at risk are not protected by current vector control, including ITNs and IRS.

Sri Lanka: has found residual transmission, especially during festival times; residual transmission is a driving force against elimination in many countries.

Bangladesh: more than 90% malaria is in 3 hill districts, bordering India and Myanmar; hill districts. They use ITNs and IRS but many people (~200,000 people) are in shifting (“Jhum”) cultivation so spend two months outdoors – this is an important population missed in control program.

Thailand: high incidence along border; two high risk groups: near forest and far from forest – outdoor transmission is higher in near-forest areas. Still need control measures to reduce man-vector contact. They need tools that don’t have insecticide because there is high contact avoidance among vectors.

Vietnam: to determine residual transmission, need to know: 1) species, 2) distribution in time, space, activity and season. There are three ecological settings: village fringe near forest, farm hut, forest; construction sites are also a problem, including dams. Only *An. dirus* is collected in the forest, becoming rare; similar phenomenon with *An. minimus*, also becoming rare.

Pakistan: don’t have any evidence of outdoor transmission; it’s mostly indoor transmission in the country; 93% of case load is along Afghanistan border, which is only 7% of the population. Ecological factors: malaria is a rural problem, there no malaria in urban settings. *An. culicifacies* has limited larval habitats. As it is all Indoor transmission Pakistan relies on IRS and ITNs which have been deployed on a large scale. There may be some indications that LLINs are causing some feeding behavior change for more exophilic behavior.

PNG: only one group of mosquitoes that transmit malaria, mostly bite outdoors. Global Fund supported a large rollout of LLINs, the country was questioning whether that will actually help; emphasis was on individual protection so people stopped keeping surroundings clean. Still need to evaluate whether LLINs have contributed to malaria reduction. The high-risk populations are those people moving for gardening/agriculture. They focus on environmental management; need individual protection before people go to sleep.
Malaysia: *P. knowlesi* malaria is 73%, all outdoor transmission; of the 27% for other species, it is about 50/50 indoor and outdoor transmission. The ecological setting is mostly related to farming and agriculture. They don’t have many LLIN distributed, only for remote areas that are hard to reach populations.

Indonesia: interventions are based on stratification. Ecological settings: village, using IRS, LLIN and environmental management; in forest areas, distribute LLINs. In some places, they provide repellents for migrants, plantations, etc. but not national policy yet; waiting to see how effective the repellents will be. 74% of the populations lives in malaria-free areas.

2. **How accurate are estimates of the number of people at risk, especially mobile and migrant populations?**

Vietnam: every 5 years there is a stratification exercise that includes data for each commune; identified areas that have risk of resurgence, low malaria, moderate malaria, and high malaria and have calculated the number of people who live in each area. They now have lot of imported cases from Africa, especially Angola.

Thailand: stratifies into transmission area vs. no transmission area (A1, A2; B1, B2; a free malaria zones – different zones/foci); malaria is occurring along border. One indicator is % of cases investigated so using this data to look at importation.

Pakistan: has population-at-risk estimates, including refugees along border.

Sri Lanka: has non-malarious areas and those areas that had malaria recently; for mobile populations, it is difficult to calculate especially since these populations are often illegal but try to get estimates from companies and other ministries.

Bangladesh: 13 districts are endemic and have classified into different API; 3 districts have 90% of cases. Mobile populations include armed forces, tourists, and Jhum cultivators ~200,000, mine workers going to India. They just started to work with these populations. They do microstratification for LLIN distribution.

3. **How are different *Anopheles* vectors implicated/targeted? What are best practices?**

Thailand: Have laboratories to implicate vectors in the “A strata” areas.

Cambodia: *An. dirus* and *An. minimus* are most prominent; *An. dirus* is still primary vector, although it is decreasing in abundance. Best practice is the LLIN, but now with residual transmission it is the LLIN plus something else, perhaps topical repellent, insecticide treated hammock or clothing; could be additional tools on top of LLINS.

Pakistan: has 24 anopheline species; of 24, have 1 major which is *An. culicifacies*, but also have *An. stephensi* and *An. subpictus*. *An. culicifacies* is endophilic so that’s why the program targets LLINs, which Global Fund supports; use IRS paid for by the government. Also since *An. culicifacies* has restricted larval habitats they also look at Larval Source Management.

Sri Lanka: *An. culicifacies* and *An. subpictus* at the coast; control measures include night fogging during high abundance. For soldiers that go into forest, they use insecticide treated hats and LLINs.

Vietnam: *An. dirus* and *An. minimus* in mountain areas, *An. epiroticus* in coastal areas. The environment is changing as well as the climate, which is affecting vectors and the control program. Harvesting season affects contact with vectors. They are only doing LLINs and ITNs; for IRS, only doing in focal sites. The program would like to do studies on repellents and for barrier nets to surround huts or where people are spending time in the evening.
Bangladesh – for *An. vagus*, trying to do research on *An. vagus* and LLINs to look at efficacy. There are problems with registration as deltamethrin is the only insecticide registered. Fine for LLINs but for IRS they would like a broader choice of insecticides.

Malaysia: they do ITNs, IRS and LSM; also treated clothing and treated curtains but not yet policy; individuals also use coils. Outdoor transmission is still a problem, focus only on repellents.

Indonesia: rotate insecticides for IRS in the 5 provinces with highest transmission.

PNG: they have resistance and only doing LLINs; some people are using coils. Most population with malaria are poor and rely on LLINs which have boosted people’s belief that malaria can be controlled. They do IRS but only when there are outbreaks; this is sponsored by WHO.

4. What is known about LLIN usage and its impact on anthropophagy? How is this measured?

Bangladesh: surveyed 100 household to look at usage; most people are illiterate and poor and not using LLINs, also because it is too hot and humid. Another issue is improper care of nets. Need to look at other options; have also seen human behavior changes and vector behavior changes; conducting a vector bionomics study right now to inform the program.

Vietnam: have good coverage of LLINs; did a study and found that LLIN can be used for 3 years, including residual killing effect on anthropophilic *Anopheles*. They use human bait and cattle bait to compare biting animal vs. biting human; also use indoor light traps. Have analyzed fed vs. unfed and net vs. no net; also analyzed blood meals to ascertain anthropophily.

Sri Lanka: LLINs were very helpful in getting to elimination; the vector is zoophilic. Did a mass survey (3000-4000 population) to look at LLINs, measured usage by looking at school children; usage is good especially between 9 and 14 age groups. Now very restricted to distributing LLINs since the country achieved elimination.

Pakistan: distributed 9.8M LLINs between 2006 and 2016; problem is with usage despite ownership being high; had to have a large communication program. In 2013, universal coverage strategy but usage could not surpass 50%. They are getting reports from field that vectors are changing behavior so have operational research to investigate. There were surveys and an MIS in 2014 which indicated low utilization.

PNG: every household is given 2-3 LLINs, supported by Global Fund, achieving almost 100% coverage. The MOH is not giving out nets, partners are giving out nets, including Rotary International; feels confident in distribution. Usage is a problem, although there has been reduction of malaria but still have high numbers of malaria cases. People at high risk living in coastal areas have very low usage given heat and humidity.

Malaysia: use of LLINs is very limited, only to remote areas that are hard to reach; durability is good but some people misuse them (e.g. catch fish). Other areas want to maintain ITNs so have more education and communication with public

Indonesia: conducted an LLIN survey; use LLINs, not ITNs for past five years. Distribution is integrated in other programs; pregnant women in high endemic areas are given LLINs through ANC

Cambodia: high coverage of LLINs but usage is low; PSK already mentioned why there is low usage so hopefully the net will change and can increase utilization. The impact of LLIN has been included in publications and shows the impact on anthropophilic vectors and has also demonstrated the shift in biting. *An. dirus* shifted from indoor to outdoor.

Thailand: have net distribution program to high risk areas; the national program support but it’s up to the province to distribute and sometimes the province delays so coverage is 80-90%. Usage is low ~40%. People get malaria outside the village.
5. **What products do we have to face these challenges? Have we asked people what they want?**

Cambodia: have done net preference studies. Have also done extensive anthropological studies about repellents and people said they like repellents.

Pakistan: did survey to ask people what they need; most common response was LLINs and had preferences for specific LLINs, although usage is still very low; they tried repellents but people didn’t like them; tried giving for free but didn’t use, community said they like LLINs more.

Thailand: a problem is forest goers often leave nets with family when they go out; they don’t take anything with them. There is also a problem that net campaigns are delayed. Maybe increasing the number of nets will help.

Bangladesh: net calculation is now 1 net per 1.8 people; universal coverage is goal but not achieving it.

Malaysia: used treated clothing outdoors, used same insecticide as bednet but issue with identifying the right insecticide.

PNG: did survey on net usage and showed that 30% of people not using the net feel there is something wrong with them, some feel it’s too hot, and some putting away for special occasion; Education is needed. Families also have to prioritize who in the family gets the nets.

**Session II: Anthropological and Ecological aspects of Outdoor Malaria Transmission**

**Chair: Muhammad Shafique, Malaria Consortium, Thailand**

<table>
<thead>
<tr>
<th>Session 2 Summary: Human and Ecological aspects of OMT</th>
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<tbody>
<tr>
<td>• Varied ecological environments and human/vector behaviors create different transmission foci to be targeted.</td>
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<tr>
<td>• Understanding individual movement from the village to the farm to the forest is a critical factor in for addressing outdoor malaria transmission. Better understanding of these factors influencing at-risk populations could inform improved approaches to elimination.</td>
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<tr>
<td>• Likewise, programs need to understand how perceptions on social risks affect malaria infection using new social science methodologies for better client interaction.</td>
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**Defining transmission foci; use of GPS taggers and mixed-methods design in Tak, Thailand & Son Thai, Vietnam**

Hannah Edwards, Malaria Consortium, Thailand

Ms. Edwards presented the methodology and preliminary results of an ongoing study to look at residual malaria transmission occurring in the village, in the farm huts and in the forest in two study sites in Thailand and Vietnam. The study is collecting the following data within four broad themes: i) epidemiological factors: prevalence, incidence, species of infection, risk factors for infection; ii) entomological factors: vector abundance, vector species, biting time, biting site; iii) social-behavioral factors: human movement, behavior, practices; ecological/meteorological factors: ecological niches, climate. Part of the study was to use GPS data loggers to investigate human movement around the village, the farm hut and the forest. So far, results have found that LLIN coverage is not optimal at the community level and so does not completely fit the “Residual Malaria Transmission” definition and there is thus a need for village-level LLIN coverage data. Transmission foci differ between areas with Thailand having high abundance of vector in village, biting indoor and outdoor; and An. dirus, An. minimus and An. maculatus all
found in forest. While in Vietnam, there was no evidence of exposure in village; only An. dirus in farm and forest. In Thailand, evidence of early evening biting (including indoor), before people retire under nets, and in Vietnam evidence of biting in later morning, after people have woken up. Regarding human movement & behavior, Thailand sites had high amount of border crossing, though limited distance of travel, and Vietnam had varying and longer distance of travel. In both sites villagers have “dual residence” both the village and the farm hut.

**Human spatial ecology and residual transmission of malaria**

Dan Parker, Shoklo Malaria Research Unit, Thailand

Despite ongoing successes in reducing malaria case numbers in the GMS the disease tends to persist in some areas, clustering in specific communities and in subsets of the population. One of the reasons for this persistence is that public health tools are mostly geared toward traditionally understood human settlements and relatively specific times. For example, mosquito nets are most commonly used in the household and at night. Community based health posts work well at the community level and offer easy access to diagnosis and treatment for people who are in the community when they become ill. Most demographic and geographic surveillance systems are focused at these same human settlements – with high resolution systems having geographic coordinates for houses in target communities. However throughout Southeast Asia people are exposed to mosquito vectors outside of these places and times. Rural populations in the area tend to be heavily dependent on agriculture, with many people spending time working and even living in agricultural fields during different times of the year. Many people also spend time in forested areas gathering wild produce, hunting and fishing. These are the spaces that remain unmapped in surveillance systems and are frequently missed through public health interventions. Described are ongoing efforts at mapping these largely ignored spaces as well as for understanding the links between malaria infections and the ways that humans interact with their environments.

**Perceptions on the social risks to Malaria infection: Field Experience in Malaria Endemic Communities in Palawan, Philippines**

Gloria Luz M. Nelson, University of the Philippines, Laguna, Philippines

Dr. Nelson presented work from Palawan where they looked at risk factors for exposure and the community perception and treatment seeking patterns. They used a technique called ‘photovoice” using photos the participants themselves have taken.

**Session III: Current Personal Protection tools**

**Chair: Bill Hawley, CDC, USA**

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<thead>
<tr>
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<tr>
<td>• Current tools including spatial repellents and insecticide treated clothing were presented, as well as studies investigating the effectiveness of these.</td>
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<tr>
<td>• Protocols were presented on treated clothing, acceptability, durability and entomological efficacy based upon “moving landing collections” that simulates the movement of rubber tappers when working.</td>
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<tr>
<td>• The entomological impact of a large randomized control trial of topical repellents was described examining both density and parity rates.</td>
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Role of passive and active spatial repellents and topical repellents in outdoor malaria transmission
Neil Lobo, University of Notre Dame, USA

Dr. Lobo reviewed studies on the ‘spatial repellency’, which refers to a range of insect behaviors induced by airborne chemicals, movement away, attraction inhibition and feeding inhibition. Work with transfluthrin coils used indoors from China (77% protective efficacy) and Indonesia (52% PE) were reviewed. In Cambodia, the use of four metofluthrin emanators reduced landing rates by 67%. Semi-field studies in Tanzania with transfluthrin showed a 69% protection against bites/landing. A current project on impact on malaria in Indonesia and dengue in Peru scheduled to run from 2014 to 2018 was described.

SOPs for the evaluation of insecticide treated clothing in rubber plantations
Jeffrey Hii, Malaria Consortium, Thailand

Dr. Hii presented work with rubber tappers and insecticide treated clothing in Myanmar. This included determination of wearing practices, bioefficacy and durability. The protocol was a cluster randomized non-inferiority crossover trial to determine population preference and acceptability of permethrin-treated clothing. A series of guidelines and Standard Operating Procedures were developed including surveys and focus group discussions, recording both the positive and negative perceptions about the distributed clothing and how much they would be willing to spend. They then assessed the durability of the clothing with the same WHO guidelines (2011) used for mosquito net durability and the Proportionate Hole Index. They also looked at the insecticide retention through bioassays of the “Probing protective efficacy” by *An. dirus* and by moving-landing collections in rubber forest plots. As expected the large drop in bite protection is consistent with US Army/USDA research showing 97.7% overall protection provided by treated clothing only. The studies conclude that the treated clothing did offer short-term protection in outdoor settings.

Entomological assessment of repellents in Cambodia
Mao Sokny, MoH Cambodia

Described a large study in North East Cambodia on with the topical repellent picaridin. A two-year randomized control trial of 98 clusters of 113 villages. Part of the study looked at vector density and parity rates. There were 24 species of *Anopheles* that made up about 10% of the total mosquito collection of over 41,000 mosquitoes. Early biting was confirmed, especially *An. maculatus*. There was an effect of repellent on reduction of densities of *Anopheles, Mansonia* and *Aedes*, but not on *Culex*. There appeared to be a reduction of *An. barbirostris* and *An. maculatus* populations but not the densities and parity rate on primary malaria vectors. There was not sufficient evidence to show a reduction on malaria incidence. It is challenging to show the impact of mosquito repellents on malaria transmission due to a complex situation and the heterogeneity of humans, vectors and transmission. There may have been an impact of the repellent on the density and parity rate of the secondary malaria vectors but not the primary vectors. The repellent might be useful for mobile worker such as rubber plantation workers, forest goers, police and soldiers working outside at night.
## Session IV: Tools under development

**Chair: Aekthada Chivakanit, WellTech Healthcare, Thailand**

<table>
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<td>• Product developers need more communication and transparency with health programs and other sectors; they need to know what is lacking and what is needed to implement the program, to understand the goals of programs.</td>
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<tr>
<td>• Some companies already have nets that address pyrethroid resistance and some are working on non-pyrethroid treatments. But support of programs and partners (WHO) is required to bring them to market at a faster rate. There is also no evaluation criteria for treated clothing. Many companies are willing to invest, but need to improve communication to guide the development of new products.</td>
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<tr>
<td>• A number of products are delayed by registration, especially when required to have efficacy-testing performed in the country; they need support to fast-track this process. This group could support industry by advocating for harmonization of registration processes across the region.</td>
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<tr>
<td>• There must be a balance between ensuring testing and fast-tracking availability to ensure we reach elimination.</td>
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<tr>
<td>• A number of products are no longer produced because the market is unstable or fragmented. It is essential to find a way to stabilize the market and give industry more reliable forecasting data to enable them to maintain production.</td>
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### Panel discussion by product developers: Approaches for development of outdoor transmission tools

Panel members: representatives from BASF-DFI, Bayer, InsectShield, Sumitomo Chemical Co., Syngenta, Tana Netting, Vestergaard

#### Questions posed to the panel:
1. What does industry need from programs and other public sectors to proceed? For example, the market size. Are there any forecasting aspects that will guide industry?
2. What are the challenges of developing new products (including regulatory)?
3. Discuss other issues and processes that affect distribution and utilization of vector control products; including solutions.

#### Discussion:
Product developers need more communication and transparency with programs and other sectors; they need to know what is lacking and what is needed to implement the program, to understand the goals of programs. The private sector is happy to bring the technology and reduce the price through social enterprise. But they need to better understand what is needed from a public health perspective. This includes an overview of the forecasted demand and the funding projected. Becomes a cost rather than quality issue. How do you balance coverage versus quality? How long do we see the future funding pipeline to be?
It is important to understand community preferences. It would be good to get ideas from the ground so we can think outside the box and develop products that fit people’s needs. We need to use the learnings from the LLIN preference and use studies and try to be more flexible with solutions, to also learning about preferences and willingness to pay so we can develop the costing models to support this. What we need is a data-driven approach – collecting evidence on procurement and impact – indicators such as LLIN usage rate over time, durability over time, and user satisfaction with the product. Ideally, also health indicators if that were possible. There are novel ways of using products – we have products – out of the box ideas are lacking – people don’t come to us to see how the existing range of products could be used. Not many companies are investing right now. The investment required for new active ingredients is enormous. Would like a new system for WHO evaluation. We need to address insecticide resistance and IVM. Some companies already have nets that address pyrethroid resistance and some are working on non-pyrethroid treatments. But we need support of programs and partners (WHO) to bring them to market at a faster rate. There is also no evaluation criteria for treated clothing. Many companies are willing to invest, but need to improve communication to guide the development of new products.

A number of companies have products but are delayed by registration, especially when required to have efficacy-testing performed in the country, they need support to fast-track this process. This group could support industry by advocating for harmonization of registration processes across the region. It currently takes about five years to have a product registered in the country, then another two years by the MoH. One product mentioned was registered in over 50 countries, but there are still problems in the Philippines to get registered. WHO could have a role, even though they are not strictly a regulatory body, as many of the National Regulatory Authorities are guided by WHOPES. There need to be as many tools available for programs as possible. Clearly the tools currently available are not enough. WHO is working to optimize the pathway for new tools, while ensuring that it’s thorough – with safety protocols and clear evidence of effectiveness. There is a balance between ensuring testing and fast-tracking availability as industry is an essential partner to ensure we reach elimination.

It is relatively easy to get the market predictions for LLINs from national and partner plans. But there are a number of other products that are no longer produced because market is unstable or fragmented. It is essential to figure out how to stabilize the market and to give industry more reliable forecasting data to enable them to maintain production. There was some discussion on the emergency relief market such as permethrin treated blankets and other treated nettings or wall linings or tents. Some products like treated uniforms are used by the military but are not taken up in the public health market. The ideal is a product that don’t rely on human behavior change.

Session V: Market and regulatory aspects

Chair: Manesh Sharma, Vestergaard

<table>
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<tr>
<td>• In addition to the entomological and epidemiological endpoints, developers also need to consider issues like manufacturability, user compliance, cost and regulatory issues.</td>
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The private sector role in supporting malaria elimination – opportunities, partnerships and collective actions against malaria
Michael Bangs, Kasetsart University, Thailand

Dr. Bangs described public private partnerships, primarily within the resource extraction (mining and energy) industry, to maximize productivity, ensure a healthier workforce and for corporate social responsibility outside the direct workforce into the local industry-affected communities. These projects often go through distinct development phases, at the start up with an emphasis on the workforce when the infrastructure is being developed and then into a broader, integrated workforce and community program during the longer-term production phase. The programs described included a comprehensive entomology and vector control program that supports both workforce and the surrounding communities in western Sumbawa and in southern Papua, both locations in Indonesia with endemic malaria. The mining industry is uniquely well-positioned with strong risk management culture, systems and tools in place; excellent logistics and networking capabilities; secure locations; advanced systems in health care & public health; stable resources assets and availability; development of strong long-term local, national & international relationships; capacity building – ‘nationalization’ of people and institutions; easily absorbed program costs relative to primary business objectives and secure funding base. It was effectively argued that to ignore industry contributions, especially in remote locations in developing countries, is to disregard unique opportunities for mutual long-term and productive collaborations. In particular, malaria control programs can serve as ‘foundation’ to build in other health initiatives and can serve as ‘Centers of Excellence’. These established program structures can leverage and complement local and regional resources to expand the base of operations far beyond the primary work location, participate in emerging disease early warning sentinel networks, and promote and support operational studies and research.

Framework for moving from proof of concept to implementation
Michael Macdonald, WHO

Dr. Macdonald presented a framework for moving an idea, a ‘new paradigm’ from initial concept through to policy adoption and implementation. Four stages were described, each with a number of parameters that must be addressed. In addition to the entomological and epidemiological endpoints, developers also need to consider issues like manufacturability, user compliance, cost and regulatory issues as illustrated here in the second stage of ‘proof of concept’. The WHO Vector Control Advisory Group, WHOPES and the Prequalification Programme are currently being reviewed and optimized to facilitate more efficient product development, evaluation and deployment.
National Regulatory Processes
Aekthada Chivakanit, WellTech Healthcare, Thailand

Mr. Chivakanit described the ASEAN Single Market Initiative that came into effect 1 January 2016. There has been talk of regulatory harmonization but no significant progress has been made. Each country has unique issues related to the access to technical information needed for evaluations, poor infrastructure and loose protection for registration holders. Some have unrealistic requirements for LLIN registration. It is quite often a long review process, in one country with every feedback from the Pesticide Board taking 3-4 months. Some require local efficacy studies, even of WHOPES-recommended products, but there are limited capacities to carry out these studies which are costly, not guaranteed to yield a successful application and a very high financial risk for the company, especially if the projected market size is small, unstable and fragmented. Reforms are needed. The regulatory structure needs to be streamlined to make business sense. The opportunity costs are not just for the company but also for the end users of these potentially life-saving tools needed by programs.

Session VI: Study protocols for efficacy and effectiveness

Moderator: Amanda Murphy, APMEN

Group work: Requirements to address outdoor and residual malaria transmission, including guidelines, methodology, indicators and common protocol

This session entailed group work aimed at identifying the requirements to address outdoor and residual malaria transmission, including relevant guidelines, necessary methodology, indicators, and common protocols. Four break out groups focused on discussing needs and priorities within four key areas, as described below. The priorities agreed for each area are summarized within the Priority areas of need and recommended actions section.

Entomology
There was an identified need for more comprehensive data on vector control methods available. There is a need for research on vector bionomics in the Asia Pacific region that is strong and robust and at a larger scale than has previously been done. Operational research needs to be program focussed. We need to advocate for, and develop a step by step protocol for foci investigation. The region should create a baseline manual and prioritise indicators to determine what tools are needed. We need a list of possible tools to combat outdoor transmission and a list of tools for monitoring and evaluation. There must be greater advocacy to convince policy makers the need for local tailored solutions. Holistic approach is required – both entomological and non-entomology approaches needed to combat outdoor transmission.

Anthropology
Programs must engage community through better understanding who they are through participatory approaches and identify and put aside biases. Look at what the community behaviours are, what are the personalities and understand their lifestyles as we need to learn from them. Empower communities and give them an active role. Do this by engaging them in decision-making processes to allow communities to take ownership. This will result in better uptake of new practices, processes. It is important to give those at policy-making level a greater understanding of needs and issues at community level – provide them with information on the community. There is a need for direct feedback from end users. We
should consider appropriate communication and easy marketing tools; we need straight forward messages. Programs need to recognize the importance of involvement of local volunteers for public health tools and to understand community needs and to empower them. Examples of projects such as beautification in PNG and positive deviance in Myanmar were discussed. We must respect local wisdom and develop approaches appropriate for the contexts.

**Tool development**

Characteristics/features of new tools:
- Need to define the necessary and desirable characteristics of new tools
- New tools need to be long-lasting, and circumvent the need for reinvention.
- They need to have local specificity with acceptable within current community/cultural practices and lifestyles with no behaviour change involved.
- Ideally combine with exciting tools, be environmentally friendly with no impact on non-target organisms.
- Need to consider personal protection and community impact and to avoid creating access issues (i.e. avoid diverting mosquitos from the user to the non-user).
- While it is unlikely that all of these features will be in a single tool, it is important to try and leverage exciting tools and tap into consumer products that can be used more broadly in programs

Some key issues limiting deployment of new tools:
- Lack of appropriate testing protocols can restrict developers (i.e. not sure what their aiming for and what’s appropriate) and restricting researchers testing and applicable in local context
- Funding for new tools – who is going to fund these evidence generation projects. Funding from innovators is often not trusted and considered biased. But then who will fund?
- Who will do the research? We need new young people and increase capacity – to test what is on the horizon.

Actions and way forward:
- Critical need for appraisal pathway. If there’s a new tool who evaluates at global level, what does it look like, what are the data requirements?
- Needs to be driven by national program – what would be appropriate in different settings.
- Need for market size projections, this is key for innovators
- Knowledge management critical when developing new tools
- Important not to replicate or leave gaps
- Need to explore leveraging modelling
- Establishment of a think-tank - what is needed what actions can we take immediately
- Reiteration of importance for early engagement – innovators need to approach programs and stakeholders early on, to receive guidance from an early stage

**Market and regulatory**

There is a lack of coordination that needs to be addressed, with more communication and international standard data packages. There is often a lack of subject matter experts in the National Regulatory Authority. We need a paradigm shift, rethinking of how we approach the registration process and also the market that is going to product these products. We need to reduce tariff barriers. There is a need for WHO and those who have influence in the area of public health and insecticide (public health bodies within each country) to advocate their needs and priorities with regulators. This effort needs to be streamlined without compromising safety. There should be consideration of incentivising companies
who need to know that they can deliver a product without losing money. More talk and collaboration needs to be achieved at a higher policy level over needs and issues. We also need to bring the conversation down to a grass-roots, community level to receive input and ideas. It is important to engage the regulators themselves and bring them into the picture to explain our needs and frustrations.

Session VII: Proposed role and structure of the MOMTN based at Kasetsart University

Dr. Theeraphap presented the proposed roles and structure and function of the network.

Role of the Network:

- Inventory current practices and ongoing research related to outdoor malaria transmission;
- Stimulate and guide common research that will respond to the challenges of outdoor malaria transmission in the GMS;
- Support the development of standardized operations research protocols for entomology, social science and epidemiology related to vector control and personal protection for outdoor malaria transmission;
- Facilitate technical support and sharing of information and research results;
- Facilitate the translation and distillation of those results for use by policy-makers that can be the foundation for action for personal protection and vector control for outdoor transmission;
- Strengthen and sustain existing entomology research, monitoring and evaluation capacities in the GMS.
- Advocate and mobilize resources

Focal Points

The MOMTN Secretariat at Kasetsart University (KU) will request nominations for country-level focal points to be engaged with the network on issues related to outdoor malaria transmission. The main functions of the focal point are to coordinate information and activities within the country and communicate with the Network Secretariat. This information includes:

- Assist the Secretariat to develop an updated inventory of institutions and researchers working in the area of outdoor malaria transmission, with full contact details. The secretariat will develop a template and provide to the countries, with a request to submit to the secretariat on 22 April, 2017, after Songkran.
- Develop a comprehensive review of research by country, based on available literature and reports in order to support advocacy for decision-makers, partners and donors.

The KU Secretariat will take forward the recommendations and outcomes of this MOMTN workshop, and incorporate them within planning of future meetings. The Department of Entomology, Faculty of Agriculture has received technical and financial support from the Thailand Research Fund since 2015 through the International Research Network (IRN) program. The purpose of the IRN is to facilitate a coordinated approach among scientists and international development agencies to share the knowledge and identify opportunities for collaborations. The KU Secretariat will initiate or further develop partnerships with other regional networks including, ACTMalaria, the APMEN VcWG, the RBM VCWG and WHO.
**Appendix 1. List of Participants**

The meeting comprised 70 participants working in health and vector borne disease control, with national and provincial health program representatives, as well as development partners from international non-governmental organizations, and academic and industry sectors (in alphabetical order):

<table>
<thead>
<tr>
<th>Name</th>
<th>Position &amp; Institution</th>
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<tbody>
<tr>
<td>Dr M M Aktaruzzaman</td>
<td>Program Manager, National Malaria Control Programme, Director General of Health Services, Bangladesh</td>
</tr>
<tr>
<td>Dr Siddhi Aryal</td>
<td>Director, Asia Regional Office, Malaria Consortium, Thailand</td>
</tr>
<tr>
<td>Ms Martina Aureli</td>
<td>Business Development and Sales Executive, Asia and Oceania, Business Development and Sales, Tanna Netting, United Arab Emirates</td>
</tr>
<tr>
<td>Dr Michael Bangs</td>
<td>Professor (adjunct), Department of Entomology, Kasetsart University, Thailand</td>
</tr>
<tr>
<td>Mr Maxime Besnier</td>
<td>Consultant, Insect Shield, Thailand</td>
</tr>
<tr>
<td>Dr Siree Chaiser</td>
<td>Acting Vice President for Research, Kasetsart University, Thailand</td>
</tr>
<tr>
<td>Dr Jintana Chaiwan</td>
<td>Malaria Consortium, Thailand</td>
</tr>
<tr>
<td>Dr Moh Seng Chang</td>
<td>Adjunct Professor &amp; Research Fellow, Faculty of Medicine &amp; Health Sciences, University Malaysia Sarawak, Malaysia</td>
</tr>
<tr>
<td>Dr Theeraphap Chareonviriyaphap</td>
<td>Professor of Entomology, Kasetsart University, Thailand</td>
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<td>Dr Nipon Chinanonwait</td>
<td>Director, Bureau of Vector Borne Diseases, Department of Disease Control, Ministry of Public Health, Thailand</td>
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<tr>
<td>Dr Wichai Chivakanit</td>
<td>Managing Director, Management WellTech Healthcare, Thailand</td>
</tr>
<tr>
<td>Mr Aekthada Chivakanit</td>
<td>Executive Director, Management WellTech Healthcare, Thailand</td>
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<tr>
<td>Mr Dave Dela Cuesta</td>
<td>Senior Manager, Public Health BASF - DFI, Philippines</td>
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<tr>
<td>Dr Silas Davidson</td>
<td>Chief, Entomology Department, Entomology AFRIMS, Thailand</td>
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</table>
Ms Hannah Edwards  
Regional M&E Specialist, Technical, Regional Asia, Malaria Consortium  
Thailand

Mr Elijah Filip  
Malaria and Child Survival Fellow, Population Services International (PSI)  
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USA

Dr Deyer Gopinath  
Medical Officer, Malaria and Border Health, SEARO  
World Health Organization  
Thailand

Dr Bill Hawley  
Chief, Entomology Branch, Division of Parasitic Diseases and Malaria  
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