Roll Back Malaria Vector Control Working Group (RBM VCWG)
15th Annual Meeting, 3-5th February 2020

Mövenpick Hotel, Rue de Pre Bois 20, 1215 Geneva

Co-chairs: Justin McBeath & Keziah Malm
Coordinator: Konstantina Boutsika
Rapporteur: Robert Jones

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RBM Partnership to End Malaria Vector Control Working Group

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Day 1: Monday 3rd February 2020

Session 1: Introductions and updates
Chairperson: Justin McBeath

Welcome, introductions and meeting objectives – Justin McBeath, Bayer

Justin McBeath welcomed participants and thanked all for their attendance. This is the first VCWG Annual Meeting with over 300 participants registered. Participants have come from 54 countries, and represent all six of the WHO regions. The main objectives of the VCWG were iterated:

1. to provide a forum for dialog, communication and discussion of best practices for vector control adaptation and implementation
2. to provide a supportive role in the generation of evidence to inform global policy and guidelines
3. to protect the efficacy of existing tools and stimulate the development of new tools
4. to coordinate support for malaria-affected countries
5. to develop networks and activities to overcome vector control challenges.

The Annual Meeting helps to support these objectives through best-practice sharing, aligning constituencies on challenges faced in malaria vector control, information dissemination, and networking.

Welcome - Keziah Malm, Ghana National Malaria Control Programme, Justin McBeath, Bayer, and Konstantina Boutsika, Swiss TPH

Keziah Malm added her welcome and encouraged all to ensure that the work does not end with this meeting. She thanked the Swiss Agency for Development and Cooperation for their funding, Konstantina and her team, the Work Stream leaders, and the companies providing sponsorship for affected country participants.

Update from the RBM Partnership to End Malaria - Matthew Boslego, RBM Partnership to End Malaria

The RBM Partnership is the global platform for coordinated action against malaria. It comprises more than 500 partners, with strategic objectives to keep malaria high on the political and development agenda, to promote and support regional approaches to fight malaria, increase the financing envelope for malaria, and build a high-performing Secretariat. National support has included High Burden to High Impact and technical assistance to 34 countries in 2019. Regional support platforms included Sahel Malaria Elimination Initiative, Elimination 8, and Great Lakes Malaria Initiative. High Burden to High Impact works with the 11 countries with over 70% of global malaria cases and death. It supports political will, strategic use of information, better guidance, and better coordination among partners. In the next year, there will be support for Global Fund applications. The Zero Malaria Starts With Me initiative has been established to unite communities, the private sector, the Commonwealth, Francophonie, and other groups. It works with these partners to address bottlenecks and ensure that malaria remains high on the agenda. Resource mobilization activities have included engagement with the private sector, supporting countries that are not eligible for Global Fund support, and mobilising resources for countries in emergency situations. It has also helped countries to fill key gaps, including

securing over US$230 million in portfolio optimization to fill gaps in long-lasting insecticidal nets (LLINs), indoor residual spraying (IRS), seasonal malaria chemoprevention (SMC) and case management.

The Lancet Commission on Eradication: countries perspective on practical approaches on implementation for impact

Moderator: Fred Binka, University of Health and Allied Sciences Ghana

The discussion was opened by Fred Binka. The panel members were asked which vector control activities were being conducted in their country, and whether there was any stratification into low and high burden areas. Further, what benefits do mapping systems bring, whether there is monitoring of insecticide resistance, and what access do sub-populations, such as farmers and migrants, have to vector control interventions.

Okefu Okoko, National Malaria Elimination Programme Nigeria

The strategic objective of Nigeria is to provide at least 80% of the targeted population with preventive measures. A mass distribution approach has been used for LLINs, with continuous distribution through health facilities for pregnant women and children being immunized. The country is not concentrating on IRS. They are developing a framework for implementing larval source management (LSM). A stratification exercise was recently conducted by the National Malaria Elimination Programme (NMEP) to determine the best-fit interventions for the country considering that the various states are at differently levels of progress in malaria elimination. They have a system for monitoring insecticides resistance, with 16 active sites across the country, but this is much lower than they would like. Resistance to pyrethroids has been detected across Nigeria. All parts of the country are transmission zones, so interventions need to reach as many people as possible, regardless of social status or location.

Lamin Jarju, National Malaria Control Programme Gambia

The Gambia has high transmission and low transmission regions. Vector control activities for malaria include LLINs and IRS in high transmission regions. They also have SMC. Low transmission areas also have LLINs, coupled with intermittent preventive treatment in pregnancy (IPTp) components and social and behaviour change communication (SBCC). Communities-case follow-ups will be implemented this year. Vector mapping takes place across the country. Insecticide resistance management (IRM) is conducted at sentinel sites every two years. The sub-population categories are not applicable in the Gambian context, with all having access to vector control interventions.

Zakia Yaji, Ministry of Health Sudan

Sudan has been divided into 6-7 strata, which has allowed for vector control to be concentrated where it is needed. IRS and larval control are used, as well as the distribution of bed nets. In particular, stratification allows LSM to be implemented in urban areas, while the hard to reach groups are given bed nets and are supported with case management. In this way, stratification considers the sub-populations such as farmers, miners and migrants. To monitor distribution of vectors, 106 sentinel sites are employed in vector surveillance activities, with monthly collections. Chikungunya and dengue outbreaks were reported last year, so there has been a concentration on surveillance of vector distribution across the country. They have 73 sites that monitor insecticide resistance, and data gathered at these sites allow updates to be made to their strategic plan.

Ahmad Raeisi, Ministry of Health and Medical Education IR Iran

In Iran, stratification and a focus on case classification are required for malaria elimination. They were the first country in the region to develop a plan for insecticide resistance management (IRM), and they have already started to implement this. The number of indigenous cases is coming down, but in 2019, they had many more introduced cases than in previous years, and this has increased the possibility of transmission. Flooding at the Iran/Pakistan border may have been the source of outbreaks. Cross-border data sharing has become important because of the flow of people, and rapid diagnostic tests (RDTs) are distributed among people at borders. Volunteers at the border are asked to report any cases of malaria positivity.

Muhammad Mukhtar, Directorate of Malaria Control Pakistan

In Pakistan, services for malaria control, diagnosis and treatment, is free, including for migrant populations, but malaria is not uniformly distributed. More than 60% of the population live in Punjab, which is a low transmission zone. High transmission is found along the western borders with Afghanistan and IR Iran, where more than 90% of cases occur. An important challenge is the distribution of LLINs. Due to security clearance issues it has not been possible to make distributions in some of the key areas. In addition, a huge outbreak of dengue occurred, so resources have been diverted for this and other vector-borne disease. Another challenge is insecticide resistance management, as bed nets are the main intervention for malaria and pyrethroids have now been used for many years.

Helene Hiwat van Laar, Ministry of Health Suriname

Suriname has malaria in the interior, where there are isolated communities with little infrastructure. There are also migrant populations that are active in gold mining. Of the 80,000 people at risk, 20,000 are mobile migrant populations that move across the border into French Guiana and back to Suriname. This movement results in a lot of malaria importation, but the country is in the elimination phase. There were just under 100 indigenous cases last year, in Amerindian populations. Vector control has largely relied on LLINs, delivered through mass and continuous distribution, with a particular focus on villages and migrant population. IRS was reintroduced in 2019 in affected village communities, but it is more challenging to protect the populations with a high turnover of people. The capacity for entomological surveying and control is limited, with few personnel, but they do try to have entomological surveys in outbreak situations. There is also good data sharing with neighbouring countries, and a partnership has been established with Brazil and French Guiana to address issues at mining sites.

Horace Cox, Ministry of Public Health Guyana

Guyana is not a high burden country, but there is transmission in the gold mining areas where there is deforestation and exposure to vectors. Vector control interventions have been difficult to implement. Guyana collaborated with partners to study behaviours and risk perception. This study revealed that recognition of risk was not a leading factor in the use of vector control, but improved knowledge has helped to encourage use of protection. IRS is not adequate because of the types of structures in areas where there is malaria, and human resources can be limited. Indeed, there has been little mapping of vectors, but the Ministry of Health (MOH) is attempting to map on a broader scale. The focus of vector control has been on LLINs, which are now provided through mass distribution campaigns. Use of LLINs was about 31% in the last survey, but they have put a lot of effort into behaviour change communication, so this is expected to have improved. There have been operational challenges in reaching out to mining communities, including a preference among miners

sleeping under hammocks, and the LLINs available have not always been of the correct size. In addition to mapping, the MOH wants to improve surveillance and use this to guide adjustments of their intervention policies.

Panel discussion - all

- It was asked to what extent has the consortium of universities with expertise in entomology has been used in Nigeria. The different sentinel sites are supervised by principal investigators from the different universities. These ultimately report to the National Malaria Control Programme (NMCP), so there is an active relationship. They also work in the different states where they are domiciled.
- It was asked the impact of larval source management has been. In Nigeria so far, a LSM framework has been developed but not yet launched. It is at the finance stage. It will not be used countrywide but will be used based on stratification. In Sudan, LSM has been used in urban areas after the rainy season.
- It was asked how parallels between Suriname and Guyana with Cambodia can cross-fertilise. There are many parallels including the use of hammock nets, and there is an opportunity to learn from Cambodia.
- It was asked what the experience in Sudan and other places has been for trying to eliminate the vector *Anopheles stephensi*. In Pakistan, following an outbreak of dengue, an operational plan was developed. The government has allocated huge financial resources for institute for vector control interventions and training. They have a good LSM plan after the dengue outbreak, but it has a limited role for malaria control. LSM was the only intervention used in Punjab. *Anopheles stephensi* has been considered an urban vector, with no role of transmission in rural areas. It is in their control plan to control this vector. In Iran, thermal fogging seems to have been more effective than IRS or LLIN for the elimination programme. This is the result of the analysis of the data they had. Vector control is based on reactive and proactive interventions, focused on active foci. LSM has a role in the high-risk areas at the border with Pakistan. In Pakistan, fogging is often considered a political weapon, but has been found to be very effective during outbreaks. IRS has also been found to be more effective than LLINs, particularly in the high transmission, high burden areas.
- It was commented that in the Gambia, the environment and housing is a key area to focus on. Where there is improved housing there is less malaria. They also need commitment from the government, as it includes huge capital and human resource investment. Cross border activities are also important. They are working with Senegal to plan, implement, and monitor LLIN distribution, so this is important as they move towards malaria elimination.
- The panel was asked how many entomologists are working for national programmes in each country. Pakistan has almost 100, with 36 in one district. The Gambia has 3 entomologists at the programme level, and 7 vector control officers. Sudan has 30-35 entomologists in master's degree training. Over 200 entomologists have now been trained for the malaria control department. In Nigeria, there are 6-7 entomologists at the state level, working in each of the 16 sentinel sites. In the national office, they also have 5 entomologists. In Iran, medical education is also responsible for public health services, including malaria. There are 62 medical universities, with at least one focal point for malaria and vector-borne disease in each university, and in the four high-risk regions, the universities also have a district level focal point. Suriname's vector control department has 80 people, but they are focused primarily on vector control. Guyana is re-structuring entomology and vector control. They have 200 staff,

but no entomologists attached to the programme. However, they work with other partners to get technical support. A pool of 6 biologist from the university has been built.

- The panel was asked what their expectations from the VCWG group in the next couple of days. There is a need to integrate more nimble data programmes. The same approach of vector control is not needed in across a whole country, so it is important to be able to stratify the country and have a programme that deals with the problems in these strata. There is also a need to use and share data in a timely manner, including across borders. This has been one of the biggest challenges in Asia. Further, it is necessary to leverage the private sector, including the sharing of data from private sources.
- Finally, countries were asked what they would have on a wish list for vector control tools, and what would make eradication feasible. Pakistan has provincial level laboratories and sentinel sites at district level, and has built a strong network. Gambia would like to have a comprehensive stratification to inform them of what to do in the next 5 years. In Nigeria, stratification is complete, so now they will start the implementation based on the stratification. They hope to expand mass distribution of LLIN and sentinel sites, and continuous distribution in order to maintain coverage in the intermittent years, and improve the culture of net use. Sudan are aiming for continuous technical support. IR Iran would like more engagement with communities and health practitioners. Suriname would like to improve capacity for entomology and vector control, and hope to provide some guidance on how to protect mobile populations. Finally, Guyana would like to decentralise entomology and vector control efforts. Getting as much data as they can will help with decision making.

Individual Work Stream Meetings

5th IRS IRM Priorities Work Stream meeting

10:30 – 13:30, Monday 3rd February 2020

Co-leaders: Mark Hoppé and Dereje Dengela

Introduction - Mark Hoppé, Syngenta Crop Protection AG

Mark Hoppé opened the session and noted that participation is key to the success of this Work Stream. He encouraged continued contribution and the sharing of knowledge, experience and ideas with the Work Stream and other vector control colleagues.

IRS - Impact and opportunities

NgenIRS Project – Catalytic market impact and evidence of cost-effectiveness and impact of 3GIRS in combination with LLINs - Molly Robertson, PATH

NgenIRS was created to address the decline in IRS coverage in Africa reported between 2010 – 2015, which was caused by increasing costs of IRS. The programme has led to significant price reductions through forecasting and price negotiation. The downturn was reversed, and there was both market expansion and diversification. The unstable market was stabilised and sub-national rotation has been enabled. There are now three suppliers of next generation IRS insecticide products, rather than one, and this has allowed for rotation strategies. The NgenIRS project partners have allowed for the evaluation of evidence. Overall, 3rd Generation IRS, in addition to LLINs, was found to be working. Data gathered from observational studies in Mali, Uganda, Ghana and a cluster randomised trial in Mozambique showed that 3GIRS resulted in a 22–47% reduction in confirmed cases recorded in the public health system compared to similar regions without IRS. 3GIRS was also found to be cost-effective or highly cost-effective in all these settings when used in addition to current standard of care (including LLINs, testing with RDT and treatment with ACT, and IPTp and SMC where appropriate). Factors contributing to the case reductions and cost-effectiveness include the lower insecticide costs, but there is heterogeneity in terms of both the cost and impact of IRS campaigns. Regardless of this, IRS campaigns with 3GIRS are expected to be cost-effective to very cost-effective in sub-Saharan Africa when used in addition to the current standard of care. Adding 3GIRS is likely to maximise the impact of drug-based interventions.

Practical implementation of insecticide resistance monitoring to guide an IRM programme

Windows of selection and windows of dominance in the evolution of insecticide resistance in human disease vectors - Andy South, Liverpool School of Tropical Medicine

How do we expect the evolution of insecticide resistance to change in the months and years following deployment of IRS? Laboratory experiments have investigated the effect that deltamethrin concentration has on resistant and susceptible genotypes. At high concentrations, all are killed, and at low concentration, none are killed, but at intermediate concentrations, there is divergence between the response of the two genotypes. Tiles of cement, mud and wood were treated with deltamethrin. Immediately after spraying there is a selection pressure, and this continues for the following 18 months. As time passes, it is expected that the difference in mortality, or window of selection, closes as the concentration of the insecticide is reduced. At an intermediate insecticide concentration, partially resistant individuals can survive, opening a window of dominance. These individuals might be

heterozygotes of a resistance gene if resistance is controlled at a single genetic locus. As the concentration declines, these individuals survive and selection for their genotype becomes even greater. Experimental studies with *Culex* mosquitoes confirmed this expectation. Windows of selection can last months to years and are of less concern in agriculture where insecticides are generally short-lasting. Evolution of insecticide resistance is likely to be greatest when mortality of partially-resistant mosquitoes is less than that of susceptible individuals. Measurement of changing mortalities of resistant, susceptible, and heterozygous genotypes over time is needed to address implementation questions.

Practical experience of sub-nation rotation of insecticides in PMI supported IRS countries - Bradford Lucas, Abt Associates

Actellic® 300CS (organophosphate) was the only IRS product available for five years following its introduction in 2013. There were no alternatives to use for rotation or where there was evidence of resistance. SumiShield® 50WG (clothianidin) was approved in late 2017, followed by Fludora Fusion® (clothianidin and deltamethrin) in 2018. These were both introduced into the field as soon as possible. Across 14 countries, approximately 40% of structures, treated with IRS, were sprayed with clothianidin products in 2019. In 2020, it is expected that most structures, in IRS programmes, will be sprayed with one of these products. Insecticide resistance management (IRM) strategies are intended to maintain the effectiveness of vector control, despite the threat of resistance. The IRS IRM strategy is to rotate two, or preferably more, insecticides with different modes of action from one year to the next. Rotation can be across a whole country, but it is preferred that rotation is achieved at the sub-national level. Both will mitigate IR, but since IRS is used at district level, it is not difficult to use different products in different districts. A lot of countries are now using this sub-national rotation. In 2019, 11 out of 14 countries used two or more insecticides. However, some are rotating every two years and not every year. Now that there are more products available, there is marketing at the country level, which may impact choice. There is no longer price parity, but the differences in price are marginal, and calculating average price/country will smooth insecticide cost variances.

Panel discussion - All

- It was asked if there have been any micro-level analyses of IRS coverage and effects. It is difficult to get coverage data on a district level, only at a programmatic level, so such data cannot be included in their analysis. However, the cluster randomized trial in Mozambique will allow for more interrogation of the coverage and insecticide resistance.
- It was asked what the rationale is for having three products if two of them have the same insecticide. Fludora Fusion® and SumiShield® 50WG have different formulations (different concentrations, and the addition of deltamethrin), so it is believed that resistance profiles over time will be different. The deltamethrin provides a very quick mosquito knockdown, which is popular at the consumer level.
- PMI's policy on insecticide rotations was discussed. If there is resistance to one insecticide, as long as the treatment continues to kill the individuals that are susceptible to the other chemical, then the insecticide provides a benefit.
- It was asked whether underdosing increases the likelihood of resistance developing. At high doses, when both resistant and susceptible individuals are killed, there is no window of selection. However, at lower concentrations there can start to be selection for resistance. If PBO increases the difference between the resistant and susceptible individuals, then it will increase selection. Having a short-lasting insecticide will keep the window of selection open for the shortest period possible and will reduce the selection pressure for resistance.

- It was asked if the outcome of selection depends on the resistance mechanisms, because there are often multiple resistance mechanisms. The modelling studies are trying to keep the system simple to enable them to understand what is happening. If there are multiple mechanisms there will be multiple windows, but the system is still the same.
- It was commented that there is no information that the impact of IRS on transmission is highest in high burden areas. If cost-effectiveness is based on burden, then the cost-effectiveness of IRS differs in different settings, but caution should be taken when basing decisions on cost. There is not enough data to show whether the high burden areas have seen the biggest impact.
- It was commented that if there is a reduction in transmission, it is necessary to go through the high burden phases to get to the overall reductions. More DALYs might be bought in the intermediate transmission areas, but it is ultimately necessary to reduce the burden in the higher areas as well.
- It was commented that there are new nets available, and people are looking at LSM with a wish is to pull them all together. A lot more data are needed. The entomological data are not at the granular level necessary. New nets and insecticides might be needed in some places, but data and analytics are needed to understand how they can work.
- It was commented that a plan is needed to escape from the arms race – e.g. products with two new active ingredients, to which the mosquitoes are fully susceptible. One option is genetically modified mosquitoes.

Innovative approaches to optimize planning, implementation quality and impact of IRS

New developments and best practices in IRS training - Allan Were, Abt Associates

If application of IRS to walls is not implemented correctly, the effects discussed will not be possible. Training for IRS is, therefore, very important and is cascaded from the national level to the spray operator level. PMI trainees about 4,000 seasonal workers annually, and ensuring quality is a challenge. The condition of target houses for spraying differs by countries, so the training needs to be customised for each context. There is little standardization across countries to do the same tasks. Limitations include a lack of needs assessments for training, and training in realistic scenarios that might be encountered during implementation. PMI developed a new curriculum for training based on assessment. They had consultations with technical teams and trainers in the field to develop new materials and a comprehensive capacity building programme. The PMI curriculum has materials for people at the national and district levels, as well as for the seasonal workers. Material is appropriate for each level of responsibility and literacy. They have workshops that include practical sessions, case-based training, and field situation training in real houses.

Harmonized IRS capacity building and the preliminary findings from a review of the entomological surveillance fellowship: Experience from E8 regional capacity development and training - Chadwick Sikaala, SADC - Malaria Elimination 8

Elimination of malaria in southern Africa requires the coordination of eight countries. It is important that there are harmonised activates across these countries, and important to make information available between them. An assessment in 2017 showed that the different countries in the partnership are at different levels in their progress towards elimination. It was also found that there were differences in training across the region. Different countries also used different indicators and definitions. Elimination 8 developed a document for best practices to improve IRS across the eight countries. Different countries are supported by different partners, but as an Elimination 8 regional body they need to be accountable to one another and have the same indicators. A scorecard has been

used for monitoring vector control activities, entomological surveillance, and quality assurance. It included such factors as IRS coverage net ownership, net utilisation, vector species identification and vector resting behaviour. Key lessons learned through the Elimination 8 collaboration have included harmonisation and synchronisation of activities, data sharing, and the adoption of best practices. Recommendations to others are to have independent review and consultations between all partners.

Result of community level evaluation of Imergard™ Wettable Powder (WP): a new potential molecule for IRS - Sarah Moore, Swiss TPH/Ifakara Health Institute

If IRS is to remain an important element in an integrated vector control approach for sub-Saharan Africa, alternative insecticides with different modes of action are urgently needed. A mineral particle, Imergard™ WP, has been developed that draws liquids from epicuticular lipid layer of insects. The Imergard™ product was tested in a cluster randomized trial in Tanzania, with seven villages per arm, each being at least 2 km apart. The WHO guidelines were followed in the study design. Community engagement was used to ensure there was community acceptance. Mosquito collections were made to determine sporozoite rates as the primary endpoint, and mosquito density was measured using light traps and human landing catches. The efficacy of Imergard™ was tested with cone bioassays. Further, insecticide susceptibility was tested using WHO tube bioassays. The study was powered to detect a difference in sporozoite rate with 51,200 mosquitoes collected per arm. This was reached in the Imergard™ arm, but not in the Actellic® 300CS arm because of the mosquitoes being rapidly killed. *Anopheles funestus* and *An. arabiensis* remained susceptible to pirimiphos methyl throughout the study. Imergard™ and Actellic® 300CS both provided 100% efficacy eight months after treatment. Sporozoite rates were not found to be different between the two arms of the study. *Anopheles funestus* densities were higher in the Imergard™ arm but not statistically different between the two arms. The mean entomological inoculation rate was also not statistically different between the two arms.

Use of mobile technology for real-time data collection and improved decision making in IRS: the Burkina Faso experience - Mariandrea Chamorro, Abt Associates

PMI sprayed over 200,000 structures in a 2019 spray campaign in Burkina Faso. The spray teams piloted a mobile data collection tool to evaluate its feasibility, and to provide close to real time spray data to enable data-driven programmatic decision-making. The tool was also used to enhance validation of spray coverage data, reduce processing time and improve reporting. An ODK collect form was used for data collection on a tablet device. Over 600 spray operators were trained, who then inputs data via the mobile device, as well as on paper forms. Team leaders then checked the data quality, and it was sent to VectorLink Collect. VectorLink Collect gathered data such as the number of structures being sprayed per operator per day, the number of people being protected, and number of structures found at each operational site. It could be used to make corrective actions when the teams were operating. For example, if there were high refusals they could intensify mobilisation activities. The data could also be used to strategize the next days' spraying activities. Challenges included providing unique numbers to each structure, GPS coordinate selection, and connectivity. PMI VectorLink is doing further pilots in Kenya, and will do mobile data collection in at least six further countries. The device has minimised paperwork and requirements for data entry, eliminated data transport time, and is expected to reduce overall implementation costs.

Leveraging routine data sources for vector control decision-making: country-specific examples - Sara Burnett, PATH

Countries want to be able to use entomological, disease surveillance, coverage, intervention cost and other data for national vector control decisions, such as where to deploy IRS and what is the impact

of an intervention. A lot of this information exists but is often not accessible or actionable. PMI tries to reduce these barriers and use national and global guidance to integrate them for national decision-making. In Zambia, each district receives IRS every year. A Technical Advisory Committee must make recommendations on which IRS product each district should use, but there are five main partners that collect relevant entomological data, and they may present it to the committee in different formats. PMI VectorLink put the data into integrated visualisations to help with IRS product choice. Data included mortality, number of mosquitoes collected, and resistance, filtered by province, chemical class and year. The data were also presented in maps. This systematic use of the data has allowed recommendations to be made in each district. Similarly, in Mali the NMCP needed to decide which provinces and districts would most benefit from Interceptor® G2 ITNs. Data were collected on the estimated number of nets required, malaria case incidence, and sites where entomological data were being collected. The data visualisation using tableau plat form was developed by PMI VectorLink based on different inputs, allowing the NMCP to select the top four districts for prioritisation of these nets. NMCPs are being supported in seven countries to help them to leverage the data they already have for vector control planning and decision-making. Indicators and analyses are documented in a best practices guide.

Rational deployment of vector control interventions and impact of IRS on malaria incidence and entomological indicators: Result from descriptive analysis of routine health facility and entomological data - Shadreck Mulenga, National Malaria Control Programme Malawi & Leonard Dandalo, Abt Associates

Malaria remains a major health problem in Malawi, with 191 cases per 1000 population. LLINs are the primary vector control intervention, and IRS and LSM are also used. Eleven million nets were distributed in 2018, of which 9 million were standard and the remainder were PBO nets. The PBO nets were distributed in areas with high malaria transmission and increased pyrethroid resistance. IRS use has been associated with a reduction in malaria cases in the past. Mosquitoes were collected using insecticide sprays, traps, and human landing catches, to monitor the effects of IRS. Epidemiological data were also collected in IRS and non-IRS districts. Indoor mosquito densities were very high prior to IRS intervention. PBO net and IRS use appear to be associated with reduction in indoor resting density as measured using Pyrethrum spray catches. *Anopheles funestus* s.l. and *An gambiae* s.l. human biting density were also much reduced in the PBO and IRS districts compared areas that received standard nets. Entomological inoculation rates were also determined. The highest rates were in a district that received standard nets, followed by the district with IRS and lastly the district with PBO nets. Epidemiological data from 2017 show that the malaria burden was high but was found to drop considerably after the IRS campaign, and low levels were maintained for several months. Overall, the malaria incidence in districts with standard nets was reduced by 11%, but where PBO nets were used the reduction was 57%. A similar 58% reduction was seen where IRS was used.

Panel discussion – All

- It was asked what the experience has been of teaching people to use tablets for data collection. Data were still collected on paper forms for quality assurance purposes. However, in the long term the paper will not be required. There were two people responsible for checking the data. Spray operators were trained for one day, but the use of visual cues helped to make it easy for them to use.
- It was commented that LLIN and IRS keep being used, but are faced with residual malaria. Regression to the traditional tools that target indoor biting results in a shift to biting outdoors and biting on cattle. An approach to deal with outdoor transmission is needed.

- It was commented that precision agriculture has lots of tools and data, and asked if anyone has approached the Ministry of Agriculture. It was commented that there has not been communication except for regulatory purposes and as a wider stakeholder.

IRM MOOC update

Contracts are being finalised so no announcement can be made at present.

Summary and close

IRM is not just related to IRS. IRM needs to be more integrated and data driven, so that the right suite of interventions can be applied to each situation. Genetically modified approaches should also be considered. Improving training and the delivery of these tools will further support vector control.

5th New Tools, New Challenges in Vector Control Work Stream meeting

14:30 – 18:00, Monday 3rd February 2020

Co-leaders: Allison Tatarsky & Sheila Ogoma

Welcome and work plan updates - Allison Tatarsky, University of California, San Francisco & Sheila Ogoma, Clinton Health Access Initiative

Allison Tatarsky opened the session. There were three projects in this Work Package: i) identification of *Anopheles* vectors, including the association of molecular and morphological techniques and an update of sub-Saharan African keys; ii) the development of draft guidelines for measuring residual malaria transmission and its drivers. A set of indicators has been developed and a manuscript is under review. Some work in this area has already been published from the Work Stream; iii) vector control tool and roadmap mapping. An inventory of publicly available information on tools that are in development and evaluation has been prepared. Ideas for vector control paradigm roadmap tracking were welcomed.

Work plan update on associating morphological and molecular ID - Seth Irish, Centers for Disease Control and Prevention

Maureen Coetzee has an updated morphological tool for the morphological identification of African *Anopheles.* Species added since 1987 are present in the key, including *Anopheles stephensi*. The manuscript is published: https://doi.org/10.1186/s12936-020-3144-9. There is also an updated country list of *Anopheles* species, which has been accepted for publication, and Mosquitoes of the World is available in two volumes. The Walter Reed Biosystematics Unit has a new website, which is due for launch 14th February 2020. Finally, a new species in the *An. gambiae* complex has been described, *Anopheles fontenillei*, which was found in central Gabon. There are still many species that do not yet have sequence data available for molecular identification. There is a lot of work still to be done on these less-common species. This will likely be done on an ad hoc basis, but a more targeted effort would be welcomed to obtain sequence data to support species identification.

Control tools

Transgenic insect-killing fungi for versatile mosquito control - Etienne Bilgo, IRSS/Centre Muraz, Adboulaye Diabate, IRSS/Centre Muraz & Brian Lovett, University of Maryland

Fungi are able to directly penetrate the insect cuticle, thereby functioning as contact insecticides. These fungi are easy to mass-produce, and the cost of production is comparable with that of chemical insecticides. A study published in 2005 found that fungi outside people's houses reduced mosquito numbers and infectious bites, but the most virulent fungi take 10-14 days to kill the mosquito, so it can feed and reproduce in this time. Transgenic strategies can increase the virulence of the fungus *Metarhizium anisopliae*. Recent work in Burkina Faso demonstrated that with a specific strain of fungus can deliver specific arthropod toxins. Just one spore is enough to kill mosquito. Other transgenic fungi can increase the susceptibility of resistant mosquitoes to insecticides. Through impregnating cloths with the transgenic fungi, mosquito numbers in an experiment were found to collapse. It is a very promising strategy that can be adapted further through making the fungi resistant to UV and to directly attack mosquitoes. Interestingly, an infected male can pass on the infection to female mosquitoes, opening the possibility of establishing an approach similar to the sterile insect technique or a *Wolbachia*-based strategy. There is a development plan with this research moving from Phase 2 to Phase 3 open field trials.

Electronic Mosquito Barriers: a non-chemical insect repelling technology using electric fields - Krijn Paaijmans, Arizona State University

Insects can sense electric fields, most likely through their hairs, which start to bend and send signals through their neurons. This causes the mosquito to move away from the source of the field.

Experiments were conducted with electric fields in the range of 30,000-40,000 volts. When the field is sufficiently strong, *Aedes aegypti* mosquitoes were repelled away from a human attractant. This could therefore be used as a non-chemical insect repellent. The device is safe and can be touched without getting a shock. It has been shown to repel 80% of mosquitoes at 1,500 volts. The electricity can be pulsed to create irregular electric fields, which would reduce the battery requirement and avoid mosquito learning. The technology is patented. A plug and play device is being developed, but it may in the future be used for window blinds and shades, eaves and wall opening, grids on storm drains, and mosquito repellent fences. The devices could be used with a trap for a push-pull system since the mosquito still reacts to host stimuli.

MAïA repellent ointment: leveraging existing daily habits of families to protect them from malaria - Franck Langevin, Maïa Africa

Long-lasting repellent soap was created to protect people in Mali from mosquito bites after their evening shower. However, it was noted that after a shower, 80% of children under 5 were given a skin treatment. A repellent ointment has been developed to align with this existing daily habit. The product was co-designed with local mothers. When it was provided to mothers without them knowing that it had a repellent, it was well accepted, and some indicated that it has a repellent effect. Field and semi-field tests in Burkina Faso have shown 8 hours or more of complete protection time. There have been no proven effects on malaria, so the developers are interested in epidemiological studies.

In2Care® EaveTubes as a new tool to control insecticide resistant malaria vectors - Marit Farenhorst, In2Care®

Eave tubes are ventilation tubes with removable insecticide treated disks that attract, block and kill mosquitoes. The netting is developed by In2Care® and has a positive charge that attracts negative particles. Static netting holds the insecticide particles on the outside, so is more available for contact with the mosquito. Any type of biocide can be incorporated, even in combinations. These tubes are installed at roof level so there is no contact with humans, and much lower amounts of biocides are needed per house than bed nets or IRS. It is easy to rotate the biocide by replacing the netting disks in the tubes. A large randomized control trial of eaves tubes and screens has been completed in the Ivory Coast. Eaves tubes alone can be effective as a standalone tool, and will be validated in a further randomized control trial. Installation of eaves tubes into existing houses is very easy, and gaps can be filled with local materials. Eaves bricks and pre-fab bricks have also been produced as versatile alternatives. Installation costs average $40 per house, with only $5 per house per year for re-treatment, which contrasts with IRS where the costs of retreatment remain high. Further, because of the lower quantities of insecticides, they could make use of new chemistries that are more expensive. A coverage of 60% is expected to be sufficient to provide community protection.

Panel discussion – All

- It was asked if it would it be preferable for fungi to kill mosquitoes quickly. Killing the mosquito very quickly, as with chemical insecticides, would put a lot of pressure on resistance development. Transgenic fungi can be developed that express genes to kill the mosquito, or to target the parasite.
- It was commented that using genetically engineered fungi rarely gets to the market because people are uncomfortable with genetic modification. The real challenge is not to make it effective, but to make it accepted. The tool is going to reach people, so it is important to contact communities at this stage so that they understand the technology and ask questions. How the tool can be delivered needs to be considered early on. There are a lot of partners on the ground working on this.
- Social studies were discussed. It was asked if any social science studies have been done with the EaveTubes to determine acceptability due to the increased temperatures that might be experienced inside the house, and how frequently the nets need to be replaced. A lot of social

studies were done as part of the randomised controlled trial (RCT) in the Ivory Coast. These communities had few eave openings, so the tubes were welcome. In Tanzania, house temperatures were studied and the results have been published. The EaveTubes in these settings have helped to increase air flow and light. Under field conditions, pyrethroid formulations have lasted more than 12 months, but novel chemistries that are less stable may require more frequent replacement.

- It was commented that West African houses have closed eaves and people cook outdoors. In East Africa, houses typically have open eaves and people cook indoors. It is important that people's habits are changed if there is a risk of smoke building up insides. EaveTubes are only installed in rooms that people use at night, but trials will include reports of respiratory impacts
- It was asked if electric fields affect devices in the house, such as mobile phones. The prototypes presented were evaluated for impact on pacemakers, hospital equipment and mobile phones.
- It was commented that there is a high potential to use transgenic fungi on EaveTubes. Persistence could be a challenge but it should be possible to get them to last 3-4 months.
- It was asked how much of the Maia ointment was used to get protection for 8 hours, and whether the cost affects uptake. The product is 15% DEET, but when in an ointment with Vaseline it stays on the surface for longer, so it can perform better than a 20% DEET solution in ethanol. This makes it cheaper. The manufacturers are trying to make it as low price as possible. It is currently €1.50.

Surveillance tools

New tools addressing quality assurance in vector control - Michael Coleman, Liverpool School of Tropical Medicine

Programmes deserve the tools to allow them to deliver better quality vector control in order to reduce disease burden, mortality and reach their end targets. Could a unique signature of alpha-cypermethrin be detected, using a sensor, vector network analyser, and data acquisition system? Filter papers can be applied to walls, then the filter papers tested for alpha-cypermethrin concentration. A miniature system that is portable can be taken out into the field. It was found that an 80-90% correlation could be achieved between HPLC systems and the simple filter paper assays. A torch-size unit is now available, which gives a reading on the amount of active ingredient that was being applied to a surface. Machine learning is being used to improve the accuracy of the system, and a field validation will be performed in March. The system is also being developed for other insecticides, and for nets, including both bioavailability and the amount of active ingredient in the net.

Electronic tools for vector control tracking and decision-making

MESA Track: a malaria research-mapping platform - Maria Tusell, MESA Alliance

Completed research is visible, easy to access, and reference. However, ongoing research is more difficult to find and to reference. MESA Track is a platform to show what projects are being undertaken, and can be used for grant applications. One thousand projects, in more than 100 sites, are currently on the platform. They are searchable by filters, such as by key word, funding body and project site. The platform also collects information on investigators and an abstract. It is useful for researchers to help them highlight their work, and to find potential collaborators. Policy makers can use MESA for evidence review exercises, identify new questions being asked, and foresee emerging evidence. MESA Track can be useful for funding institutions to help them make smart investments and identify the next issues to tackle. Finally, it allows research groups and institutions to increase the visibility of their work. Users are encouraged to explore the site and give feedback.

Strategic information applied to vector control: Digital tools for entomological surveillance and vector control monitoring - Lucia Fernandez, World Health Organization

Many countries are using the DHIS2 tool for epidemiological data. It is becoming a core system and is receiving funding. WHO standard DHIS2 Modules for entomology and vector control are being used to facilitate the collection and interpretation of data from entomological surveillance and vector control interventions monitoring. The modules can integrate entomology and vector control data into national health information or disease surveillance systems. Activities covered by the modules include insecticide resistance monitoring, IRS and LLIN campaign results, breeding site mapping, and adult surveillance. The DHIS2 package has a data collection form, and provides indicators that are automatically generated, such as for campaign coverage and mosquito densities. Maps and plots are also generated. Four countries have been supported with the modules, and there is customisation for the specific needs of each country. This is then integrated into the national health information system, and prospective data collection can begin. Malaria Threats Map is a platform to monitor key threats for malaria control and elimination. It has both insecticide resistance data and a new feature, invasive vector species. When *Anopheles stephensi* was detected in East Africa, the data were added to the map, and it is continually updated. The map has a traffic light system for which regions are recommended to use of PBO nets. The map has also been improved to allow better access in low bandwidth settings and for mobile devices. Plans for 2020 include a data download feature to allow better sharing, a map export feature, and time slider to show how resistance has changed over time. User subscriptions will allow people to be updated with alerts. Feedback is encouraged from researchers, policy makers, companies and other users.

- It was asked what the link is between these resources and the malaria data repository. This is a resource for countries to share their malaria data. Any data collected through the modules will be fed into the repository.

Future Work Stream priorities

Discussion on work plan priorities, including new tools roadmaps - Allison Tatarsky, University of California, San Francisco & Sheila Ogoma, Clinton Health Access Initiative

Three ideas for future Work Streams were proposed. Idea number 1: House an inventory of vector control products that are on the market or are under evaluation. This is currently being prepared as an Excel file, but there may be better ways to make this available for researchers and product developers. It would need to be updated regularly to make it relevant. Funders and people interested in taking this on are sought. WHO already has an R&D observatory. This should be explored to see if it synchronizes with the vector control tools tracker as well as the MESA tracker. Idea number 2: Improve collaboration with ARMPC and SCPC around innovation messaging and roundtables. These groups open discussions but are lacking information on how products work, so a partnership could be very useful. Idea number 3: A tracking roadmap for new tools and paradigms in vector control. This should include use cases, products, ongoing and planned research, access, and status in regulatory and policy pathways. The ivermectin roadmap could serve as a guide and could be applied for bite prevention, for example. Further ideas for work plan projects, identified as priorities by the New Tools, New Challenges Work Stream, were welcomed.

- It was commented that human behaviour impacts vector control and usage, and should be brought into discussions about vector control. Vector control beyond nets, which will include

protection outside the home, will have even more important human behaviour factors. Further, issues around how new tools can be implemented should be researched.

- It was commented that the Work Stream should devise innovative ways to support programs to conduct operational research of new tools so as build evidence.
- Human-centred design was discussed. It was commented that there is room for this, such as for the development of LLINs that people would actually like to buy. There are lessons from the consumer sector that can be applied to other tools that are being developed. Starting from the end user is very important in product design, and should be discussed in future meetings. Focus group studies should be encouraged to make sure new products will be accepted.
- It was commented that people's usage of bed nets should be recorded. Campaigns still distribute new nets every 2-3 years, but they often do not last this long. Measurements of use need to be taken. Round nets are more expensive to produce and distribute, but may be more cost-effective if they are used more widely.
- Finally, it was commented that many countries have a national policy to only use WHO pre-qualified tools. A lot of tools are very convincing but they are not available, so those presenting next year should show where they are in the pre-qualification process.

5th LLIN Priorities Work Stream meeting

08:30 – 12:00, Tuesday 4 February 2020

Co-leaders: Hannah Koenker & Ikupa Akim

Introduction - Hannah Koenker, Tropical Health & Ikupa Akim, Swiss TPH

Hannah Koenker opened the session. The current Work Stream has three main components. The first focuses on ITN durability, and asks how durability monitoring feeds into post-marketing quality assurance processes. This work is currently ongoing. A manuscript is in review for a study of whether ITNs expire in their packaging. Second, activities are ongoing for ITN distribution, including stratification of distribution by endemicity, what households do with old nets, and what are effective LLIN distribution micro-strategies for low-transmission urban areas. Finally, new net types activities centre on key issues during and after the pre-qualification transition process.

This work plan will be dissolved and group feedback will be gathered, then organised post meeting. The new ideas will be sent to Work Stream members. The communication system will be revamped to promote more dialog.

LLIN Durability – What Next?

Final results from monitoring under VectorWorks - Albert Kilian, Tropical Health

PMI-funded VectorWorks aims to monitor the durability of LLINs distributed through mass campaigns in 2-3 sites per country. The same brands were compared in different places, and two different brands were compared within the same place. Five countries were covered in the study, which was designed as a representative, prospective cohort study of campaign LLINs, with a baseline assessment, and sampling of nets at 12-month intervals. The physical durability outcome combined attrition (nets lost) with integrity (physical condition of the net), and insecticidal durability was assessed using WHO cone assays, as well as tunnel tests in Tanzania if the nets failed the cone tests. The study has found huge differences in durability between sites, and only some differences between brands. Factors of net use environment and durability were explored to establish a risk index. Good net care attitude was found to prolong the useful life of the net, if a net is only used by adults it lasts longer, and if the net is not folded during the day it does not survive as long. Can such household factors be used to predict the survival of a net? Reducing the risk index of a net may be able to extend the survival of a net by 0.5 years. Use of nets was closely linked to hanging, and hanging was dependent on the availability of other nets in the household, the overall net supply situation in households, and the physical condition of the net. Insecticidal effectiveness was also investigated. The results suggested that in some places, such as in Democratic Republic of Congo (DRC), it is probably best to replace nets more frequently, but in other areas there is sufficient evidence that the insecticidal effectiveness is maintained. More durable nets are needed, but it is not clear what needs to be changed and whether they will still be cost-effective. There is also room to improve net care. There needs to be a focus on preventive net care, and forget about repairs.

Planned monitoring under VectorLink - Stephen Poyer, President's Malaria Initiative VectorLink

Durability monitoring of LLINs is being supported by PMI VectorLink in nine countries, with fieldwork already underway in six of these. Five of the countries only have standard LLINs, but four have PBO synergist or dual active ingredient ITNs. VectorLink is interested in seeing how the durability of the new nets will compare to the standard LLINs. Most of the 36-month data will be available in 2021 and 2022, with the new countries not expected to have endline data until 2023. Durability monitoring

process updates for VectorLink include extension of follow up training in some countries to improve quality standards in field work, strengthening ODK files, and the introduction of much more user-friendly user interfaces to allow easier submission of field data.

New SOPs for monitoring bioefficacy of new active ingredients - Mark Rowland, London School of Hygiene & Tropical Medicine

Four nets are currently being evaluated in Tanzanian CRTs: Interceptor® LN, Olyset® Plus, Royal Guard®, and Interceptor® GN. Once the efficacy of these has been established through the CRT, we need to focus on the duration of the bioefficacy of the partner active ingredient (AI). The pyrethroid is expected to last for three years, and the durability of the partner AI needs to be assessed with a pyrethroid-tolerant strain. The efficacy of chlorfenapyr can be tested in a tunnel test. For pyriproxyfen, the survivors from an experimental hut test or cone bioassay can be kept and used for an oviposition bioassay. Determining sterility through ovary dissection may be preferred. For the PBO nets, it is necessary to separate the role of the PBO using a highly resistant strain. The loss of inhibition of synergy over time can be assessed using strains that have metabolic resistance to pyrethroids. Higher mortality is expected when a net is new but there will be less mortality over time of the PBO wears off. In addition to nets with simulated use and washing, nets can be taken from the CRTs at 12-month intervals then tested for durability in experimental huts.

Non-inferiority testing of long-lasting insecticidal nets through ambient chamber tests (I-ACT) - Sarah Moore, Swiss TPH/Ifakara Health Institute

Factors to consider when calculating the functional life of a net include attrition and use, damage, bio-efficacy and chemical content. Net damage leads to people discarding nets, and there is an interaction between the state of the net and the mosquito. Holes in the net become more important as the insecticides wears out, and when a net becomes damaged, the probability of a mosquito feeding is substantially higher. A bioassay has been developed for convenience that has a chamber inside a long tunnel, allowing large numbers of samples to be tested. The bioassay was used to demonstrate superiority of PBO nets, and the results were comparable with those of standard WHO methods. The bioassay provides a more realistic idea of durability than other assays. Differences in fecundity can also be assessed for nets containing pyriproxyfen. Finally, a proportional hole index was developed that is a very useful metric to predict durability.

WHO PQ perspectives - Marion Law, World Health Organization PQT-VC

PQ gives a process for authority and makes use of research to improve the durability of nets. Prequalification before access includes a review of the data, and a decision document is prepared for prequalification listing. Post-market activities include inspections of nets, change submissions, complaints, and surveillance and monitoring of products when they are in use. All stages of the product have an action that affects durability, including design and data generation, pre-market evaluation, production, storage and distribution, and end user. PQ takes all of these stages into account when considering durability. PQ asks whether the policy of 20 washes and 3 years are still relevant for modern products, and whether the current data requirements for prequalification are useful in informing durability. Product complaints have allowed identification of problems with AI content, storage and stability, and most frequently with storage conditions. It recognises that the design, pre-market evaluation, and production stages do not have inputs from the real world, while the final stages of storage, distribution and usage have inputs from the real world, which include durability stressors, such as exposure to light, heat, and water. There may be a need to manage these stressors through characterisation and mitigation to inform and improve durability.

Panel and Plenary Discussion - Hannah Koenker, Tropical Health

Hannah Koenker asked the Work Stream to consider, given what we know about net durability, have net replacement cycles been changed and is it appropriate to do so? Changes to the replacement cycle in being considered in Nigeria and DRC. If the cycle is extended, people may feel undervalued. In DRC, they would have liked to change the cycle but the system is not well adjusted to it, so there are additional factors to consider outside of durability. Ideally, there should be replacement available. More demand-driven replacement is desirable and would be more cost-effective, and it is important to avoid people throwing out nets if they do not need them.

- It was asked who is responsible for post-market surveillance, and how does the complaint process currently work. PQ has the authority to do post-market monitoring and surveillance, but who is responsible depends on the activity. PQ is not in the field, so it requires a partnership. Complaints reach PQ. They typically come from procurement agencies, such as for an out-of-specification result, but anyone can submit a complaint.
- It was asked how capacity for durability monitoring is being strengthened, and what is the current capacity for running tests across Africa. Monitoring has been done through collaborations with local institution partners. The most important capacity building element was to establish the standardised way of taking measurements. PMI VectorLink is continuing along the lines of VectorWorks and has scope to build capacity so that more testing can be done within country. There has been success in using social media to get input from the NMCP and to track progress. There are now excellent resources for measuring holes in the field, but there remain limitations in data analysis and for running tests on new AIs is limited. There are suites of experimental huts available, but more may be needed to evaluate nets in different places. Evaluation of the dual AI nets is more technical.
- It was asked that, given we currently follow a single net until it is lost, should we focus on other nets in the household to consider what impact they have on survival. A more complete assessment of household nets over time is desirable. They know when other nets come in, but doing survival analysis of the extra nets is difficult because they don't know how old they are, and it does add to the complexity and cost of the study. A cohort analysis of household nets may be preferred.
- It was asked what impact washing has on durability? Washing is very relevant to durability. Generally, people wash their nets separate from other items, and they tend to wash in cold water in basins, and not in rivers. When asked how often people wash their nets, they get very stable data. No significant correlation was found with physical durability. However, those nets that are not used are not washed anymore.
- It was asked what the expectations are for dual AI nets. The role of PBO is difficult to understand, but it is clear from CRTs that they work. How PBO works, and when it is available, are questions for the formulation chemists.

Work plan development for 2020 - Ikupa Akim, Swiss TPH

Attendees were invited to submit their vote on what type of communication they would prefer to have for this work stream. Period updates and virtual conferences were the most common choices, preferred over a virtual discussion group or no additional communication. Attendees were then asked what are the most pressing issues for ITNs. Suggestions included user rate, quality and durability, clear policy for PBO, better understanding of distribution, decreasing attrition, quality and innovation, guidance on complementary systems, disposal of old net, texture preferences, strategies for mobile

populations, time and cost requirements for PQ listing, and community needs to improve usage. These recommendations will be grouped into topics, and a work plan will be established.

10th Larval Source Management Work Stream meeting

08:30 – 12:00, Tuesday 4 February 2020

Co-leaders: Silas Majambere & Ulrike Fillinger

Silas Majambere, Pan-African Mosquito Control Association

Silas Majambere opened the session. He announced that an election will be held for a new LSM co-chair, and members of the Work Stream were encouraged to apply. In 2019, the Works Stream has tried to support those countries implementing LSM. This has included Uganda, Namibia, Botswana, Eswatini and Ghana. There are three projects in the 2020 work plan, i) advocating for environmental management including habitat modification and manipulation and inter-sectoral collaboration as priority interventions in LSM; ii) innovative approaches to improve LSM, such as drones and GIS; and iii) reviewing operational LSM in national malaria control programmes.

Updates on a larviciding program in Ghana - Otubea Owusu Akrofi, National Malaria Control Programme Ghana

The Ghana Ministry of Health signed a Memorandum of Understanding with Zoomlion, a private waste management company, to implement LSM nationwide. Zoomlion is involved in the implementation and provision of human resources, while the government provides funding, NMCP provides guidelines, technical support and oversight, and the local government also provides human resources and supervision. Activities in 2019 included stakeholder engagement and training in habitat identification, larval sampling techniques, and data capture. A mapping exercise was also completed, mapping water bodies in all districts nationwide. A total of 16,666 potential breeding sites were mapped, approximately 90% of which contained mosquito larval species. Drains and ditches constituted the greatest percentage (35%) of the breeding site types mapped, and the highest number of sites was found in the northern region of the country. In 2020, a mobile app will be developed, and baseline entomology studies in sentinel sites will be conducted. Urban areas for larviciding will be plotted based on the mapping data, and application of Bti to positive breeding sites is expected to start in March/April.

Updates on a larviciding program in Uganda - Charles Ntege, Ministry of Health Uganda

Uganda is implementing LSM, guided by epidemiological data and WHO criteria. Sites for larviciding must be few, findable, and fixed. Environmental manipulation is being used at other breeding sites. The NMCP aims to teach communities to identify breeding sites and destroy them, involve the district leadership in the management of LSM activities in the communities, and map breeding sites for future management. LSM will be used to reduce the geographical extent of endemic areas, and attain pre-epidemic malaria levels. Vector Control Officers in the districts support the trained Village Health Teams to map breeding sites. Identified breeding sites that meet the WHO criteria are treated by SAFE (sunlight active formulated extract) larvicides. Post application monitoring is then done for 21 days. Selection criteria at the sub-county level include the disease burden, proportion of the population at risk, capacity for vector control in the area, and availability of other programmes to support IVM. LSM has support from the president of the republic, and many ministries are involved in larviciding, including the Ministry of Defence, Ministry of Health, and the National Task Force on Malaria Elimination. Currently, district sensitization meetings have been conducted in three of the six target districts in Kigezi region, and training of trainees has been completed in Kisoro, Kabale and Rubanda. Mapping of breeding sites is ongoing. Application is planned for February 2020.

Updates on a larviciding program in Tanzania – Samwel Mziray, Tanzania Biotech Products

Tanzania produces two types of larvicides, Griselesf® (*Bacillus sphaericus*) and Bactivec® (*Bacillus thuringiensis*). The Ministry of Health is collaborating with the President's Office, regional and local administration to run the process of larviciding. Larval Source Management by applying biolarvicides has been widely practised in different ecological settings in Tanzania since June 2017. There is a community-based programme, with the identification and application to breeding sites done by Community Owned Resource Persons. In each council, there is a malaria focal person and a district surveillance officer. Before larviciding began, these experts underwent training, and they in turn trained staff in their councils how to apply the larvicides. Larviciding has been accepted by the community as their own programme. Results collected from the programme indicate that the population of both aquatic and adult stages of Culicine and Anopheline mosquitoes was significantly reduced.

Contribution of larviciding intervention within the High Burden to High Impact (HBHI) strategy in Africa – Mavy Hernandez, LABIOFAM

Larviciding is effective against indoor and outdoor biting mosquitoes and can help to reduce the spread of chemical resistance. The aims of larviciding in high burden areas are to reduce the number of adult and larval mosquitoes. It may also contribute to a reduction in the malaria burden. An operational structure is required that includes the Ministry of Health providing policy and funds, and the NMCP and institutions involved in training, monitoring and evaluation. At the regional or district level, the vector control team is involved in entomological data collection, and at the village level there is larviciding execution. Experiences from selected African countries show that when larviciding is well implemented according to stratification criteria, a reduction in malaria cases is reported, ranging from 17% in Burkina Faso to 63% in Nigeria. Costs average US$0.69 per inhabitant. Challenges reported include a lack of local vector control structure and funds, poor entomological and epidemiological data, and absence of clear guidance and methodology at the country level.

Panel discussion with presenters – All

Silas Majambere opened the panel discussion, and stated that the Work Stream is trying to serve the national programmes in doing larviciding correctly.

- It was commented that it is difficult to assess larval populations before and after an intervention. It was asked what the basis was for entomological baselines in Ghana. At a particular site, the number of larvae will be recorded and monitored for several months after application. Other entomological indices will also be used at sentinel sites.
- It was asked why it is necessary to repeat mapping yearly in Ghana, and why there is a focus on urban settings. GPS coordinates are used to locate sites, and the diameter of the bodies of water are recorded. However, due to seasonality it is necessary to re-measure to know how much larvicide is needed. Ghana aims to have at least one intervention in each setting. In urban areas there is a challenge to get people to use nets, so larviciding is a good way to ensure there is vector control.
- It was asked whether satellite pictures have ever been used to identify sites Ghana. Funds restricted the use of satellite imagery.
- Types of equipment used for delivering larvicides were discussed. The equipment depends on the type of larvicide. SAFE is a powder so a duster is used, but SAFE Plus is in liquid form and is applied with sprayers. Both are broad spectrum larvicides.

- It was asked what process was used for community engagement in Uganda. This included a study of community behaviours, and it was found that including the community chairperson increases the level of acceptance and improves monitoring. Printed material and pictures are shown to the community.
- It was commented that larviciding uses Ministry of Tourism funds in Europe, and this might be a source of financing in African countries.
- It was commented that WHO sees LSM as a supplementary measure for malaria control, in both rural and urban areas. It is not recommended where there is extensive open water, such as flood plains, if being applied by teams on the ground. WHO does not say that LSM can only be used in urban areas.
- Mobilisation of technical support was discussed, as it has been limited in the past. It is recommended that the right data are agreed upon and collected, so that it can be presented to the WHO. It is not good practice for a company to evaluate the performance of a new product themselves. This should be done independently.
- It was asked if WHO prequalification was obtained for the products used in Tanzania. *Bacillus sphaericus* and *Bacillus thuringiensis* prequalification is in process.

Aquatic habitats of dominant malaria mosquitoes in Tanzania – Ismail Nambunga, Ifakara Health Institute

The larval habitats of *Anopheles funestus* were characterised to understand the basic cues influencing their oviposition. Larvae were sampled, and the physicochemical characteristics of the habitats was recorded, including conductivity, pH and temperature. It was found that at altitudes of <300 m, larvae were mostly in spring-fed bodies of water and swamps. At higher altitudes, the preferred habitats were rivers. Most larval habitats were characterised by clear water, emergent vegetation, and a depth of at least 50 cm. The water was mildly acidic, and had a temperature ranging from 25.2-28.8°C. Recognising that rivers are important habitats for *An. funestus* allows for appropriate control strategies to be designed. If larviciding is feasible in these habitats, the most appropriate method for application should be considered, as well as timing and optimal duration.

New theory on mosquito larvae respiration contradicting the scheme of direct atmospheric gas exchange - Herb Nyberg, New Mountain International

The classical theory of respiration is that the siphon and dorsal tracheal trunks of mosquito larvae play obligate roles in respiration by exchanging metabolic gas with the atmosphere. However, the use of acoustic larvicides revealed that the tracheal system is isolated from the environment. Transmitting sound energy into the water at certain frequencies causes the dorsal tracheal trunk to be severed, causing no other damage. Gas in the tracheal system is pressurised by a tracheal occlusion. Gas cannot pass through, and the larvae do not need oxygen in the trachea. Mosquitoes at the surface are resting, not respiring atmospheric oxygen. The oxygen concentration in the water is the highest at the surface, so this resting behaviour places the large ventral fan or brush in a stratum of high oxygen. As more is learned about the tracheal system, novel interventions can be developed. Acoustic lethal ovitraps are available that can reduce population densities of daylight and twilight flying mosquitoes. A cistern system has been developed that can kill mosquito larvae in the cistern. It is low costs and solar-powered.

Use of GIS tools in vector control planning and monitoring – Mikhail Tiounine, Grupo Anti Vector

Tools available for precision agriculture include satellite imagery and drone for remote sensing, GPS sensors for geolocation, and cellular networks and smartphones for communication. There is an opportunity to transfer these technologies to precision public health. In Angola, a pilot project has

been set up in the province of Huíla to report malaria case numbers daily from the Health Facility Registers to the municipal level, and share it weekly with the provincial level. It also allows for weekly activity programming according to case numbers, resource and equipment available, rather than monthly. The provincial level compiles daily vector control reports and builds visual maps that are shared with all levels. Cell phones with WhatsApp allow location data to be reported and vehicles are equipped with a GPS tracker. Drones are used for fast community evaluation and identification of potential breeding sites. QGIS has been used to create a community base map with drone-collected images. The pilot project has shown that real-time field data are easily processed and shared, and there is improved operational organization of vector control activities and accountability. The system was easy to set up and is low cost.

RASS for mosquito larviciding - Jane Bonds, Bonds Consulting Group

The Deployed Warfighter Protection programme funded work to produce remotely-piloted aerial spray systems (RASS) for both adulticiding and larviciding. There were three tasks for the project: (i) to develop standardized protocols to characterize the spray distribution, (ii) to optimize two systems - one large wide-area RASS and one smaller urban RASS, finding the optimal speed, altitude, boom placement and droplet size distribution, and (iii) work on a proof of concept spray distribution model. A new rotating disk atomizer has been used that can provide both a larvicide and adulticide droplet size spectrum. This is fitted to the RASS that has been developed specifically for mosquito control. It has autonomous systems with mapping capabilities and multispectral imagery. Breeding sites are found using a ratio between the infrared and the near infrared on a multispectral image. These are geo-referenced, and the RASS is set up for a flight path. Mechanistic modelling is being done to predict where the spray goes under different environmental conditions.

Discussion - All

- It was asked whether open windows and doors at night are a concern with adulticides. In Florida, spraying is done at night but people are still outside. Spray is 35 ml per hectare, in droplets the size of approximately 30 µm, and there are no problems. The insecticide is very dilute and a small quantity is used, so within the house there should be no issue.
- The cost implications for RASS were discussed. The systems are relatively expensive (about US$40,000 for the largest). Manned aircraft costs less than US$1 per hectare for adulticides in the United States. It costs about US$7 per acre for larvicide. RASS will be more affordable than manned aircraft in African countries but there are regulatory issues. Efforts are being made to open up the regulations on drone use.
- It was asked what the frequency of adulticiding is, how the impact is monitored, and if there is any communication to communities. A public announcement is made when there will be spraying. Different surveillance techniques are used for different species, and different thresholds are employed. Spraying is once every 5-7 days at the beginning of the season, then there are repeat sprays.
- It was asked if RASS would be useful for larviciding flowing rivers. The systems can do applications of Bti granules. The application can be more precise than manned aircraft.
- It was asked if larviciding can really be done in flowing rivers. Larviciding in fast flowing systems has been successful in South Africa using temephos for black fly larvae, and in the United States with Bti.
- It was commented that spectral signatures of water bodies can be used to predict where Anopheline vectors will breed. There is extremely useful technology that enables vector control to go far beyond the requirement for sites to be ‘few, fixed and findable’.

- It was commented that Ghana, Uganda, Tanzania and other countries are doing larviciding. The Work Stream should harness technology and help them to do it better.
- It was asked how community ownership can be maintained for new technologies such as drones, which require very little community involvement. There will always be community participation, and the technology will not replace the human factors. There are tools that can be given to communities, such as Mosquito Alert, an app for *Aedes* reporting in Spain.

Open discussion: How do we make the LSM Work Stream useful for National Programmes? – All

- Larvicide longevity was discussed. It was asked if larviciding products can be available that last for 4-6 months, as this will help with sustainability. A 6-month larvicide would cost a lot more than one that lasts 1-2 weeks, and if there are transient breeding sites it would not be necessary to use long-lasting products.
- It was asked what the vector control community wants to see from LSM in the next 5-10 years. It is not clear how LSM integrates into the bigger picture, and it is important to determine whether it is used as a core rather than supplementary intervention in some settings, and how it can be combined with bed nets.
- It was commented that epidemiology data should be used for targeted LSM.
- It was also suggested that there should be robust demonstration of impact, which would allow for stratification of interventions.
- It was commented that a databank of resources that can be shared across countries, and guidelines for evaluation of new products, are needed. Guidelines are being prepared for new larviciding products. An integrated vector management manual is being developed that includes LSM as a key intervention.

Day 2: Tuesday 3rd February 2020

5th IVM, Evidence and Capacity Work Stream meeting

14:00- 17:30, Tuesday 4th February 2020

Co-leaders: Josiane Etang & Birkinesh Ameneshewa

Work Stream introduction - Josiane Etang, Organisation de Coordination pour la lutte contre les Endémies en Afrique Centrale

Josiane Etang opened the session and introduced the new Work Stream co-leader, Birkinesh Ameneshewa, then she recalled the Work Stream's mandate. The Work Stream is mandated to generate and share evidence on integration of all vector control tools, including lessons from other regions and disease eradication programs. The second mandate is to work with WHO and RBM in order to build entomology and vector control capacity at all levels in endemic countries. To fulfil these mandates, four projects have been identified: i) to create a directory of training institutions, programs and resources, and support roll-out of Global Vector Control Response; ii) build capacity to manage insecticide resistance in the WHO African Region; iii) share best practices for entomological monitoring and outdoor/residual transmission across regions; and iv) enhance community engagement in Integrated Vector Management (IVM) toward improving service delivery with existing and new tools for vector control.

Session 1: IVM challenges and sustainability

IVM challenges and impact in IDP- and refugees-tented camps in South Sudan, 2013-2019 - Richard Allan, The MENTOR Initiative

South Sudan is heavily conflicted and has seen the displacement of over 2 million people. Constant exposure to insects has created a situation with high burden of malaria and massively reduced immunology. People are also malnourished. A package of IVM has been introduced to target a range of vector-borne diseases. This has included IRS, LSM, fly control, bed net distribution, and behaviour change communication. One hundred percent bed net distribution to the Maban Refugee Camp had no impact on malaria when there were heavy rains. Larviciding and IRS were then introduced, but pyrethroid resistance has spread very quickly. The use of IRS with an effective insecticide, timed correctly and combined with a larvicide, has allowed for very effective control of malaria. This has since been repeated with rotation of insecticides. Bentiu camp has had the same situation. A package with IRS has controlled malaria. At Malakal camp, insecticide spraying on plastic sheets has enabled very good control to be achieved. When the combination of active ingredients and right delivery systems are used with the right timing, interventions can be very effective. Larviciding has a very good additional impact.

Social and behaviour considerations for effective vector control interventions - April Monroe, Johns Hopkins Center for Communication

To get the most out of ITNs, it is important to ensure continued access, and to promote regular use. Qualitative research has been used to investigate factors that drive non-use of nets in Ghana. The research found that people frequently stated the build-up of heat, by restricting airflow, as a barrier to use. Some also reported skin rashes or said that there were times when it was not feasible to use a net, such as when they slept outdoors. A personal experience with malaria was a big factor in making people use nets. People also identified nets as helping to get a good night's sleep, and they found

solutions to barriers. A lot of exposure occurs when people are outside in the evening, or outside in the early morning. There are also people who work outside during the night. Recognition of these behaviours can allow for strategies to be developed to improve interventions. When new tools are created to fill these gaps, it is important to consider how they fit into people's everyday lives, and how people will use them. Effective vector control depends on understanding the perceptions and experiences of the target population.

Panel discussion 1 - IVM challenges and sustainability - Birkinesh Ameneshewa, Consultant & Diahara Traore, National Malaria Control Programme Mali

IVM challenges include adequate capacity, sustained commitment, and implementation of polyvalent innovations. Some countries may have a vector control programme separated from the malaria control programme, and it can be a challenge to get them to collaborate. Maintenance of the quality of vector control interventions requires knowledge of evidence based interventions. In addition, there must be cooperation with other sectors and engagement of communities. Sustainability requires investment in infrastructure and human resources for vector control and surveillance. A broader approach is needed and an increased role of research institutes should be encouraged. Furthermore, the generation of tangible evidences on the economic benefits of IVM to promote the use of new and proven approaches for community engagement are required.

- It was asked why nets are still used everywhere and not IVM packages. LLINs have been promoted as a one-shot answer, and they are easy to gather around politically and financially. They have a very important role to play in some settings, but they are not suitable for all settings. It has become a simple tool for donors to count, but policy and practice changes are required at donor levels, taking into consideration alternative and new tools.
- It was commented that with some extra resources, control of malaria can be expanded to control other vector-borne diseases. The emergence of arboviruses is a good opportunity to implement IVM. In 2017, the NMCP in Mali and stakeholders prospected gaining support for IVM, but IVM has not been implemented due to lack of financial resources. Indeed, there is a need for political commitment of high-level decision makers who can provide financial resources.
- It was asked why SBCC tools are not used more widely. IRS, LSM, LLIN and New Tools, New Challenges Work Streams have mentioned these tools, so there is increasing use of these approaches. In the other Work Streams, approaches have included adult learning techniques and field simulations for IRS spray operators, video games for insecticide resistance management, and use of radio programmes for message communication. In addition, it is important to increase capacity for social sciences in vector control, which will improve the impact of vector control interventions.

Session 2: Capacity building

Strengthening vector control capacity in the Asia-Pacific region - Leo Braack, Malaria Consortium & Htin Kyaw Thu, Asia Pacific Malaria Elimination Network

Asia Pacific Malaria Elimination Network (APMEN) is a multi-stakeholder network in Asia Pacific. They have various working groups, including the VCWG. Some countries in Asia Pacific are moving towards malaria elimination, while others are still struggling at the control stage. Several challenges are to be addressed, e.g. high species diversity of vectors, outdoor biting, forest transmission and mobile populations. The Online Resource Exchange Network for Entomology (ORENE) has been launched with a forum for asking questions to experts, a directory of institutions and entomologists, a resource centre for guidelines, and a space for information sharing. ORENE tries to link with other platforms to

maximise the scope and has a news section for up-to-date developments. Another programme is the Malaria Vector Surveillance for Elimination (MVSE). It provides courses for building surveillance skills and capacities. These include morphological identification, applying GIS for vector mapping, field sample collection, and insecticide susceptibility assays. Front-line entomologists from all 21 APMEN countries have taken part in these courses.

Innovation, education, communication and health promotion towards malaria elimination - Tiaan de Jager, University of Pretoria

Many of the Sustainable Development Goals (SDGs) are interlinked and associated with malaria. The University of Pretoria Institute for Sustainable Malaria Control has a strategic framework for building capacity that considers these SDGs, and is taking a transdisciplinary approach to tackle them. The framework has a strong focus on education. By educating children, there are opportunities for lessons to be shared with adults at home, so a programme in schools is one of the elements of their approach. Drama and music are used to communicate messages, such as cleaning up the environment and addressing other issues in communities. Infographics are widely used, as they are an easy way to communicate messages about the threats of malaria to travellers. Satellite laboratories have been set up, and employ people in the local areas. Housing is also an important consideration, as modern house designs consider vector control. A polyethylene wall lining is being tested in field trials as an alternative to IRS. There are also new repellents and clothing products, and a malaria 'Buddy' app, which can give directions to health care clinics. There are therefore many multi-sectorial actions and partnerships to reduce and eliminate malaria, and these have positive collateral effects. Global issues such as health, environment, food security, energy, social stability and sustainability should be solved together through a concentrated research offering/solution.

A game changer in malaria vector control training - Kirsten Duda, Liverpool School of Tropical Medicine

Two Insecticide Resistance Management (IRM) games were developed as a teaching tool, specifically for malaria vector control staff. Resistance 101 was an arcade style game designed to teach the fundamentals of insecticide resistance through game levels, videos and flashcards. The player has to choose the correct insecticides to use in the game, and they can make use of flashcards throughout the game for reference. Resistance SIM is a resource management simulation with discreet levels to facilitate incorporation into module-based learning. The games were evaluated in the context of a course. Questionnaires and interviews were both used to assess perceptions about the games. Self-efficacy and knowledge were found to increase after taking the course, with particular improvements in those that ranked poorly before they took part. In interviews, participants spoke about how their confidence had improved, and they said that they had better knowledge about subjects that they had not been exposed to previously. They also stated that the acquired knowledge will help them to make better informed decisions, and they were better able to explain things to their teams and people in their community, indicating that there is knowledge transfer.

Panel discussion 2 - Capacity building - Birkinesh Ameneshewa, Consultant

- It was commented that entomologists have become irrelevant to most programme decisions making. ORENE has sections for data analysis, how to write technical reports, how to write cover letters for new jobs, and how to prepare PowerPoint presentations, and it is important that entomologists are present in decision making. There is a lack of entomologists globally, but where they are present, they are often not used properly or suitably trained. The information they gather is not correctly integrated into programmes. Training should be available to make sure they can compete for top jobs and not remain as technicians.

- It was asked if there are any plans to compare the IRM games with traditional training methods, and if they will be developed any further. There is no course purely on IRM, so it has not been possible to make a direct comparison. Focus group discussions explored whether that they could be used in communities, and the developers are keen to develop further games.
- It was asked if there is a francophone version of ORENE. It is developed for Asia Pacific, and there is no French language version. The Global Vector Hub is expected to have French and other languages.

Vector Control in Humanitarian Emergencies Initiative - Michael Macdonald, Consultant

This Vector Control in Humanitarian Emergencies Initiative was set up to reduce suffering and death from vector-borne disease in humanitarian emergencies by improving delivery, uptake, integration and evaluation of existing vector surveillance and control tools, and facilitating the development of an evidence base and uptake of supplementary and emerging tools. There are three phases to consider: temporary houses, transition areas, and emergency situations. Options in emergency situations might include treated blankets. In addition to malaria vectors, filth flies, sand flies, *Aedes* mosquitoes, fleas and body lice, and rodents are all considerations of the working group. As tools are developed for emergencies, which include natural disasters, the possibility of using them in other settings should be considered. Gold miners in Suriname for example might benefit from tools developed for displaced people.

A novel capacity building program in the SADC elimination eight countries - Chadwick Sikaala, SADC - Malaria Elimination 8

There is a need to develop entomology capacity in the National Malaria Control Programmes (NMCP) in southern Africa. A model was developed to address what countries in Elimination 8 thought were the gaps in capacity, and entomological surveillance training courses were held for selected individuals at Wits University, Ifakara Health Institute, and Liverpool School of Tropical Medicine. During residential weeks, participants on the course learnt skills such as basic insectary management, morphological identification of vectors, and WHO susceptibility testing. The fellows then did research project field work, such as on the feasibility of decentralized entomological surveillance system in Okavango, Botswana, and an evaluation of IRS in Zambezi Region, Namibia. Evaluation of the course found that it was relevant to the Elimination 8 region, high value was achieved with limited resources, and the NMCPs were satisfied with the programme. Mentorship and networking are long-term outcomes of the programme, but to ensure sustainability, the support of partners is needed.

Panel discussion 3 - Novel evidences and best practices - Josiane Etang, Organisation de Coordination pour la lutte contre les Endémies en Afrique Centrale & Shadreck Mulenga, National Malaria Control Programme Malawi

- It was asked how decentralisation may be achieved in vector control. The role of central level organisations is to gather the information that has been collected in communities. This is very cost-effective in Zambia. Community health workers are trained in basic skills, such as morphological identification, and entering data into forms. Quality assurance is needed to make sure they are doing what you trained them. The samples can then be collected.
- It was asked if, in the Southern African Development Community (SADC) region, the sub regional economic community is involved in resource mobilisation to support the capacity building programme. The programme was supported by the Bill & Melinda Gates Foundation. They are interested in expanding the programme to Central Africa if the resources are available.

- It was commented that in Malawi a lack of entomologists has limited vector surveillance activities. Data is largely coming from partners that have their own entomologists. A vector control group meeting allows for the sharing of data, but it is a challenge not to have their own entomologists. It was added that some people may perceive a lack of possibility to advance in an entomology career, and this is recognised as a problem in recruiting staff.

Contributing to the 2020 work plan

IVM challenges and sustainability - Richard Allan, The MENTOR Initiative & April Monroe, Johns Hopkins Center for Communication

- The regulatory environment was discussed. It was commented that manufacturers need a regulatory environment that speeds the approval of new tools. A 3-5-year process is needed to get products to implementation. There is a need to push for all the different players in the system to work together and reduce the timelines as far as possible. This will result in a better toolbox. Manufacturers are willing to invest in new products if they know there is a marketplace.
- It was commented that if a country in SADC approves a product, other countries should be able to facilitate registrations in other countries. This would ease some of the problems. There will always be the core interventions of LLIN and IRS. It is difficult to see the bulk of investment going into other interventions. There is no shortage of other active ingredients or products, but it would be valuable to think separately about core and secondary intervention and how they can each be used.
- It was asked if there could be a mechanism where experiences from successful mosquito control programmes in other regions (e.g. Europe) are shared with stakeholder of IVM in malaria affected countries.
- It was commented that some products are already approved by the EPA for mosquito control and could be used in public health interventions.

Capacity building - Leo Braack, Malaria Consortium, Htin Kyaw Thu, Asia Pacific Malaria Elimination Network, Tiaan de Jager, University of Pretoria & Kirsten Duda, Liverpool School of Tropical Medicine

- It was discussed that there is always a conversation about funding, time and resources. In training sessions, it is important to encourage excitement and enthusiasm about the tools that are available. To move the field forward, we need to have mentorship and support for individuals, and not only the funding.
- It was commented that in Asia, there is a lot of need for capacity building in basic subjects. The species diversity can only be understood with molecular tools, but there are limited resources for this. Elimination of malaria is a realistic target but there is a disproportionate threat because of drug resistance. Different work streams dedicated to specific themes, are needed, but there is concern that people think in silos. A different mindset is needed, focusing not just on vector control but identifying transmission hotspots and then considering parasite control, case management, and engaging with communities.

Novel evidences and best practices - Chadwick Sikaala, SADC - Malaria Elimination 8 & Michael Macdonald, Consultant

There are three points in the work plan to act on: i) outdoor transmission, with an exchange of best practices; ii) opportunities for exchanging surveillance best practices for *Aedes* mosquitoes; and iii)

helping programmes transmission from surveillance to elimination, making use of risk area stratification and appropriate entomological data collection. Rather than collecting lots of information, it is important to focus on a handful of parameters that are most meaningful. Further, it is necessary to learn how to hold on to individuals that are trained, and for programmes to learn from each other, including from the regional networks.

Additional comments for the work plan

- It was added that recognising the best practices is very important, as is packaging them for others to use. Capacity building should use a general lens, and if there are barriers to engagement, it is important that people are mindful of this.
- It was commented that different strategies are needed for getting messages across to different groups, such as young children, teenagers, and adults. People need to use innovative ideas to get messages across, such as storylines in radio programmes that will reach the target audience. Future Africa is a platform building capacity for local problems.
- Finally, it was commented that involving local people can help create new solutions. They can help with the design of products that are suitable for the local environment. There are also opportunities to improve existing products to have better impacts.

7th Vector-Borne Disease and the Built Environment meeting

14:00 – 17:30, Tuesday 4th February 2020

Co-leaders: Steve Lindsay & Lucy Tusting

Welcome & Review of 2019-2020 – Lucy Tusting, London School of Hygiene & Tropical Medicine

Lucy Tusting opened the session and announced that the co-leader Steve Lindsay will be stepping down after six years. A new co-leader is being sought. There are many aspects of the built environment that are important for vector borne disease transmission. Now is a very important time to act because housing in many parts of the world is changing very rapidly, paired with economic development and population growth. Improved housing is associated with many health outcomes, not only malaria but diarrhoea, nutrition outcomes and anaemia. This Work Stream is helping through bringing together specialists in VBD and housing, supporting research to develop vector-free, healthy and comfortable houses, and supporting the scale-up of housing interventions against VBD. BOVA (Building Out Vector-Borne Diseases in sub-Saharan Africa), a research network funded by the UK Global Challenges Research Fund, has enabled the core activities of the Work Stream. Links have been forged with the Multi-Sectoral Working Group of RBM, and a list of consultants has been produced that can be called upon to support large-scale housing and infrastructure projects in incorporating vector control. A new *Lancet* commission on *Aedes*-transmitted diseases in cities is being edited by Steve Lindsay.

BOVA Network update – Fiona Shenton, Durham University/BOVA Network

Malaria is the major threat in rural and peri-urban environments and dengue in urban and peri-urban environments. BOVA is a network of 450+ members. It has eight pump-priming projects that cover i) basic science, such as filming mosquitoes in Malawi; ii) multi-sectoral and scale-up, including a housing development programme in Ethiopia and Trash to Treasure in Kenya; and iii) new tools, including mosquito repellent chairs. Seven grant-writing workshops have been held and cover the same three main areas. BOVA contributes to RBM work streams, has representation on the Strategic Technical Advisory Group for NTDs, and will contribute to International Guidelines on Urban and Territorial Planning. A video has been prepared to show how modifications to houses and the built environment can help with preventing mosquito entry and reducing mosquito populations, and where interventions such as LLINs and source reduction can contribute. A BOVA Open Network Meeting is planned in Morocco, September 2020.

Preventing vector-borne disease outbreaks in emergent peri-urban settings: a transdisciplinary study on the Integrated Housing Development Programme in Jimma, Ethiopia – Adamu Addissie, Addis Ababa University

Urbanization rates in Ethiopia are among the highest in the world. The Integrated Housing Development Programme is funded by the government to ensure that people have housing, but the government houses have important pitfalls, including poor quality construction materials and deficient sanitation. A study has been conducted to identify receptive spaces for vectors of malaria and schistosomiasis and to map household distribution and use of the space. This will allow a vector-preventive design to be proposed to the Ministry of Health and the Ministry of Work and Urban Development, which can be tested and evaluated for future social housing projects. A multi-disciplinary approach is being used, including social science, epidemiology, entomology, and architecture. There is the potential to affect hundreds of thousands of houses. A recommendations booklet will be produced and the research team would like to talk with the residents and policy makers when they have completed the study to inform them of the findings.

Trash to Treasure: Collecting trash for profit to reduce vector breeding sites in Kwale County, Kenya – Francis Mutuku, University of Mombasa

Plastic waste is a menace that contributes to the breeding of *Aedes aegypti* in Kenya. A literature review on the impact of waste on breeding showed that innovation research, governance and policy issues, and downstream education all have contributions to make. A multi-disciplinary team is working on a project to assess the potential for community-based recycling that engages aspiring entrepreneurs to repurpose trash for profit in Kwale County, Kenya. It aims to improve health by reducing arboviral disease transmission and help to alleviate poverty by generating income from waste collection. A target community was identified and the sources of waste in the community were identified. Opportunities for removing the waste that could be breeding sites were identified. Assessments will be made of whether people engaged in the programme are able to make money form it and whether there is an impact on disease. Key-informant interviews have been used to map the landscape of trash and identify market opportunities. The sources of trash were identified, and it was found that there was very low awareness of trash management, which was related to the stigma of being associated with trash. Next steps are to develop a curriculum and recruit social entrepreneurs, then execute business plans to remove trash from the environment.

Turning the house into a "lethal lure": results of a cluster randomised controlled trial from central Cote d'Ivoire – Matt Thomas, Penn State University

Eighty percent of malaria transmission occurs indoors at night in Africa, and eaves are the main entry point for anophelines. Screens on windows and tubes at eave height prevent mosquito entry. Screening in the tubes acts as a novel point source to deliver insecticides, while odours coming from the house make it a 'lethal house lure'. A two-armed RCT in Code d'Ivoire recruited 20 villages to receive new LLINs together with house screening and EaveTubes (SET), while 20 other villages received new LLINs only (control arm). Beta-cyfluthrin was used on the tubes. Despite there being pyrethroid resistance locally, there is such an efficient transfer of insecticides it was lethal to the mosquitoes. Entomological data were collected through human landing catches. Indoor and outdoor collections revealed a 61% reduction due to the SET intervention indoors, and 39% reduction outdoor. Entomological Inoculation Rate was reduced by 73% indoors and 63% outdoors. Children in the SET intervention villages had a 38% lower risk of having a malaria case than in control villages. Community benefits were observed in villages where there was >60% SET coverage. User acceptance was high, with 98% saying they like EaveTubes. A cost-effectiveness analysis suggested that the intervention is similar to IRS, despite only being implemented on a small scale. A second RCT is needed for VCAG with three arms to disaggregate the effect of screening from tubes.

Introduction to IG-UTP from Graham Alabaster, UN-Habitat

In 2015, UN-Habitat's International Guidelines on Urban and Territorial Planning was produced. It has a set of principles and recommendations, and is a multi-level, multi-stakeholder, multi-sector approach to incorporate a health dimension in urban and territorial planning. To be effective it needs national government, local authorities, the involvement of society, and the health and planning professionals. The IGTUP guidelines are leading to a range of rollout activities. In 2018, a Compendium of Inspiring Practices was published that provided an evidence base and best practices. Seventy case studies were submitted, from which 20 were selected to illustrate the conditions for and benefits of applying the key principles included in the guidelines. A guidebook for planning for health has also been produced. The rollout of these tools is being tested and refined in capacity building workshops held in Cameroon, Kenya, China, and Cape Town. Through these tools and publications, UN-Habitat's work in vector-borne diseases is becoming embedded into urban planning.

How do we build on what the BOVA Network has started?

Steve Lindsay opened the discussion, and asked how to make the activities of BOVA sustainable for the future.

- It was asked if there was an opportunity to get more funding for BOVA from the existing funders. BOVA was intended as a three-year grant from UK Global Challenges Research Fund. It would be necessary to convince the funders, with the help of the pump-prime projects as a flagship for what can be achieved. There is reliance on the seven grant-writing workshops, which are seeking large funds.
- It was added that there is a WHO manual on housing that does not mention mosquitoes, and WHO is open to the idea of including vector-borne disease issues.
- It was commented that the DHS programme is keen to have questions on eave screening and window screening. There is the possibility to add these and related questions that would be essential to monitor through large household surveys.
- It was commented that UN Habitat and UNHCR have been working together because the longevity of many settlements has meant that there is a need to look at more long-term solutions. There is increasing opportunity to accommodate refuges in urban settings, and this may open a funding window that allows infrastructure to be improved.

Discussion – All. Led by Steve Lindsay, Durham University/BOVA Network, Lucy Tusting, London School of Hygiene & Tropical Medicine, Fredros Okumu, Ifakara Health Institute & Marceline Finda, Ifakara Health Institute

Communities give feedback that bed nets and IRS are limited with poor housing, but decision-makers cannot promote house improvements because it is very expensive and it is not the role of the government to give people better houses. There needs to be buy-in from communities and political will. It is important to look at the magnitude of the need, and determine whether new houses need to be designed, if there is an opportunity to tap into already-existing developments, and how to invest in more modest improvements.

- It was commented that in Tanzania, there has been a rapid increase in the building of brick houses with screened windows. This is a movement that has happened without external forces. However, there remain a lot of traditional houses, so different settings have different needs. Screens are not suitable in some houses.
- Behaviour change communication was discussed. It was commented that housing interventions should be approached in the same way as water and sanitation, with behaviour change communication encouraging improvements that can affect health. In Tanzania, the government provided assistance and 60-80% of houses now have semi-modern or modern toilets. Subsidies or loans could encourage people to improve their housing as a public health goal, which may save the government money.
- It was commented that education is important to increase community uptake. Advocating change to the younger generation may be helpful as they will be the ones who later return to villages and build houses.
- It was commented that the adoption of screens seems to be associated with access, with those closer to Dar-es-Salaam fitting more screens. Modest improvements, such as the use of screens, over time have helped to reduce malaria. A system that is durable and is applicable across multiple settings is necessary. However, it was added that it is important that interventions be promoted even if they cannot be used everywhere. For aspiring households, eaves tubes and screening are available, but for the poorest of the poor, there are other solutions such as eaves strips with spatial repellent. There is a need to scale up these

interventions because of the number of houses that will be built in the coming decades. It is important that the durability of screens is improved.

- Cost-effectiveness was discussed. A cost-effectiveness analysis for improved housing is needed, but there is a lack of data. It may cost US$6,000 to build a good house in Tanzania, but disease control is expensive. Rather than spending money each year on vector control, maybe expensive houses should be built. There should not be an assumption that interventions need to be cheap.
- It was commented that prefabricated housing is pursuing innovative financing. Improved housing often takes many years, so a mortgage product, loan or tax credit would allow people to live in their house and have mosquito control interventions. Cooperative systems are used in Haiti where people work together to build or pay for a house. These local systems should be leveraged. Sweat equity programmes allow people to put hours into working on a house and get a mortgage they can afford. Microfinancing initiatives are also valuable, but quite often people use financing for other purposes, so they need to be designed carefully and could be tied to some income generation.
- It as commented that if governments are not in a position to provide support, money may be available from philanthropy or social entrepreneurship. A finance mechanism could be developed in which the middle class pays slightly more, and excess money is used to help to provide modest housing for the very poor.
- It was commented that discourse with architects and the housing sector is very important. Engineers and designers are closer to officials than health professionals are and know about housing standards.
- Social studies were discussed as it is important to identify cultural factors associated with housing. It can be difficult to sell new models of housing in some settings: there can be resistance to different types of construction that goes against standard local practices, and there are also difficulties in getting materials in some locations.
- It was commented that this group should establish what a standard for a healthful house should be. This could then be presented to a government for new proposals, and to show to children. A deliver mnemonic manuscript is being prepared making use of the evidence base for the house improvement recommendations. Once this is published, the consensus status should be updated on the basis of these recommendations. Currently, there are no international standards on what is a healthy house. UN-Habitat is open to this.
- An idea from the government of India was discussed. The government has a policy to subsidise gas to make it affordable to poor households. Those that do not need the subsidy can return it to make if available to others. A bank account is needed for the subsidy, so people opened accounts and then had access to credit. A similar system could be used for eaves tubes.
- It was asked if there is a lack of ambition for house improvement. Some governments spend a lot on roads and railways, but they could do the same for the provision of houses. Everyone needs to get something out of it. The threat of climate change may concentrate political will. Cities should be made resilient against environmental threats, and *Aedes*-borne disease are a part of this.
- It was asked how different components should be considered, and whether there is space for innovation or if the challenge is how to get them into people's houses. A target product profile is needed, with targets for durability and costs. Companies can then work towards these.

Vector Control in Humanitarian Emergencies

Moderator: Michael Macdonald

Valentina Buj, UNICEF, Samira Al-Eryani, WHO, Justin McBeath, Bayer & Richard Allan, MENTOR Initiative

The mission statement of Vector Control in Humanitarian Emergencies was iterated: To reduce human suffering and death from vector-borne diseases in humanitarian emergencies by i) improving delivery, uptake, integration and evaluation of existing vector surveillance and control tools; and ii) facilitating the development of an evidence-base and uptake of supplementary and emerging tools. The conditions of humanitarian crises ramp up vector-borne and other disease transmission, and complicate disease prevention, diagnosis and treatment. Malaria is a top five killer in these settings, but is always accompanies by other vector-borne disease such as dengue and leishmaniasis. There are different challenges for settled camps, temporary shelters, and for the acute phase of emergencies. There is an urgent need for tool development. Currently, discussions are being held with manufacturers and implementing partners about reviving work on treated tarpaulins, a spray for tarpaulins, improved shelters, wall linings and treated eave ventilation screens. *Aedes* mosquitoes add to the overwhelming threats in humanitarian crises, but suitable vector-control tool types currently approved by WHO are currently extremely limited. 168 million people need innovative tools, fast-tracked through regulatory exemption.

Day 3: Wednesday 5th February 2020

Session 2: Updates and feedback

Wednesday 5th February 2020

Update from WHO Global Malaria Programme - Jan Kolaczinski, World Health Organization

Global Malaria Programme (GMP) implemented in 2019 improvements in how policy and guidance are developed. There was a focus on three areas: i) better anticipate, ii) better policy; and iii) optimize uptake. Better anticipate involves horizon scanning and Preferred Product Characteristics. The WHO PPC is intended to facilitate the development of products addressing the greatest and most urgent public health need. Two PCCs are under development - ITNS designed to provide improved performance against pyrethroid-resistant mosquitoes, and vector control tools for complex emergencies. For policy development, the guidance for malaria vector control has been published, which supersedes other WHO guidance, and has a list of priority areas. More recently, a Q&A has been put online at the request of many WHO staff and national programmes. Other work from 2019 was expansion of the malaria threats map to indicate which areas have the data requirements that WHO deems as useful to guide the deployment of PBO nets. The threats map can be expanded to include other vectors, but currently shows how well-established *An. stephensi* is in the Horn of Africa. For optimizing uptake, webinars have been delivered for dissemination, there have been improvements to the website and newsletters, and the 2019 World Malaria Report was produced. Planned for 2020, horizon scanning is ongoing, and PPCs will be published for public consultation. Guidelines for malaria vector control will be published later this year, and the WHO Position Statement on DDT will be reviewed and revised. A WHO position statement on gene drive is being prepared, and the active policy advisory group will look at the way PBO nets are classified. Updates are being made to the Handbook on Practical Entomology in Malaria, as well as the insecticide resistance monitoring and management guidance, and IRS manual. For implementation support, the roll out of DHS2 needs support in some countries. Further, GVCR case studies will be prepared.

Update on the Global Vector Control Response - Rajpal Yadav, World Health Organization

The GVCR resolution was passed in 2017 with a vision to reduce the burden and threat of vector borne diseases. It places greater emphasis on country leadership, advocacy, resource mobilisation and partner coordination, and regulatory, policy and normative support. The WHO Joint Action Group has facilitated the development of regional GVCR policy, holds regional workshops on vector surveillance on IRM, and documents the implementation of GVCR. Normative guidance and support has included guidance for policy and programme implementation, a Vector Control Needs Assessment, and guideline and SOPs for product testing. New guidelines are under development, including vector surveillance and control of leishmaniasis, a manual on IRS, and guidelines on pesticide management. Capacity strengthening activities have focused on regional training of trainers, training of GLP sites, and implementation of generic DHS2 platforms. Research support has included multi-centre validation of discriminating concentrations for insecticide resistance monitoring and a memorandum of understanding on the Sterile Insect Technique. Fourteen sites are being developed for GLP-based vector control product testing. Six sites are led by IVCC and eight by WHO. Key activities identified in Regional resolutions were presented. Different regions have made good progress, and a framework is in place to monitor progress that can be presented to the World Health Assembly. Challenges identified are resource generation and a need for improved coordination mechanisms. Suggested future directions are the establishment of dedicated staff at the HQ for GVCR implementation,

enhanced country implementation support, and the documentation of case studies of progress made in GVCR that can highlight success stories and present the lessons learned in the implementation process.

Feedback from Networks

Birkinesh Ameneshewa, African Network on Vector Resistance to insecticides

The goals and objectives of the ANVR were revised in 2019. The goal is to enhance integrated vector surveillance and control for vector-borne disease and promote operational and advanced research in the WHO African region. The objective is mapping and addressing regional and national needs for vector control. A vector control needs assessment (VCNA) tool was developed by the WHO HQ, and will be adopted by ANVR. Capacity building for vector surveillance has included theoretical, field and lab training in Gabon, Mozambique and Zimbabwe, provision of basic entomological supplies, and training on the revised insecticide resistance monitoring protocol. ANVR has also developed strategic documents in line with the GVCR. Activities planned for 2019-20 are to adapt a global VCNA tool and disseminate, continue to provide country support for the development and implementation of IVM strategic plans in line with the GVCR, continue capacity building for surveillance, and strengthen mapping.

Leo Braack, APMEN

APMEN has 22 countries in Asia Pacific dedicated to malaria elimination. It achieves its interventions through four working groups. Although Asia Pacific has a relatively low burden, the trend of the development of drug resistance has created specific challenges. There is delayed clearance of *P. falciparum* to three ACTs, which creates an urgency to eliminate falciparum malaria before there is spread of resistance to other areas. The ORENE websites has been launched, and the annual conference in March will be used for information sharing. APMEN also tried to support regional operational research, such as testing of alternative methods to human landing catches. The annual International Malaria Vector Surveillance for Elimination course is their flagship initiative that is an intensive two-week course that covers field techniques for mosquito collection, morphological identification, PCR, and others. The full costs are covered for 30 selected participants, and high-quality trainers are invited from across the world.

Prosper Chaki, PAMCA

The Pan African Mosquito Control Association has a mission to provide a platform for African scientists, public health practitioners and other stakeholders to drive efforts towards the control and elimination of vector-borne diseases. A survey in 2017 revealed that Africa does not have a shortage of entomological capacity, but there is a challenge to harness this capacity. On-going projects include an exploration of new models for community engagement, and gene drive courses designed to provide the basic technical understanding of the technology. PAMCA is strengthening vector surveillance systems and addressing *Anopheles* mosquito genomic data gaps in Africa, and strengthening local entomology capacity for malaria surveillance and elimination. Technical support is provided for NMCPs where capacity building is needed, such as for LSM. A new flagship programme is Women in Vector Control. To enhance the presentation of women in entomology, it is recognised that mentorship would be valuable, as well as support for grant writing, and networking opportunities to improve visibility. The outlook of PAMCA is to strengthen entomological capacity, build and formalise relationships with NMCPs, strengthen vector surveillance, fortify strategic collaborations with various stakeholders, to focus on arboviruses and other vector-borne diseases.

Samira Al-Eryani, EMRO Network on Vector Surveillance and Control

Major vector-borne diseases are present in EMRO, including malaria, leishmaniasis and arboviruses. There is inadequate infrastructure for vector surveillance and control, including at ports of entry. The Eastern Mediterranean Region has sub-regional networks on anti-malarial drug resistance HANMAT, the Horn of Africa Network for Monitoring Antimalarial Treatment and PIAM-Net, the Pakistan-Iran-Afghanistan Malaria Network. In the last year these networks were expanded to include building human resource capacity for entomology and vector control. A pilot initiative of vector surveillance at ports of entry was launched. At points of entry, staff can visit the website to look at keys to identify any mosquitoes that they find. Regional activities have included strengthening capacity for dengue vector surveillance and regional training of trainers on IRS for malaria and IRS. Future plans are to use the current networks to support capacity for surveillance and control. They would like to work with African countries in the sub-regional networks for support in their entomological investigations, and to strengthening networking. Finally, they will explore the potential of academic institutions in the region.

Chadwick Sikaala, Elimination 8

Elimination 8 initiative brings the southern African countries together with the aim of eliminating malaria in the shortest period of time. The neighbouring countries above the Elimination 8 have high burdens, and there is movement of populations at borders, so it important that infections are reduced here. In addition to technical support and resource mobilisation, highlights from 2019 have been support for the Angola IRS programme. Namibia cannot eliminate malaria if there is transmission in Angola, so they have helped Namibia to do an assessment of their equipment for IRS. They worked together to build a costing infrastructure for IRS, and support the procurement of insecticides. Best practices coming from Elimination 8 are available to WHO so that they can be adopted elsewhere. For 2020, Elimination 8 intends to have collaboration and coordination, and to develop research partnerships. They know which institutions and centres of excellence will be able to provide support. They are also looking at innovations that can be used to sustain their programme.

- It was asked how APMEN aims to achieve the goal of elimination, given that there is outdoor transmission, and we do not have very good interventions. Many of the countries are approaching elimination. China has a year to go and Sri Lanka has already achieved elimination, so there are lessons to learn from them. There has not been a mind shift from control to elimination. A different strategic approach is needed, that has a more focal approach that addresses places and situations that have persistent transmission. There is a lot of work on outdoor transmission, such as spatial repellent and treated uniforms.
- It was asked if WHO inter-regional collaborations could help in EMRO. Further, capacity building is challenging because trained entomologists go to Saudi Arabia and other countries. There is capacity even at state level, and these could be strengthened to act during outbreaks. The HANMAT will be strengthened to have further entomological investigations.
- It was asked which form of *An. stephensi* is present in the Horn of Africa – the vector or non-vector. Work is ongoing in Ethiopia, but there is limited information. *Anopheles stephensi* in Ethiopia can transmit plasmodia, and in Djibouti, it has been incriminated in recent outbreaks of malaria.

Industry perspectives on the vector control pipeline and private sector engagement (a panel discussion)

Moderator: Michael Macdonald

The discussion was opened by Michael Macdonald. The panel members introduced themselves, and gave a short summary of their company's role in vector control.

Achim Reddig, BASF

BASF is a chemical company with oil and gas, textile, agriculture and health products. In 2006 they produced their first mosquito net, and innovation has continued. The portfolio includes IRS products and a larvicide. These play roles in malaria control but also chikungunya and other vector-borne diseases. The chemistries are developed for agriculture and then adapted for public health. They also try to add value though other initiatives such as biodegradability.

Frederic Baur, Bayer

Bayer is involved in health, food, and agriculture. They continue to invest in innovation. Three areas of focus are tackling resistance, through development of IRS, with three products in a decade. They are working on a new active ingredient for both IRS and bed nets. The second mission is residual transmission. They recognise that this is critical for the elimination of malaria. Thirdly, they are focusing on sustainability. Two billion bed nets have been distributed, which is a great achievement, but creates a problem for plastic waste. They are asking if there is a different type of material that could be used. Bayer is looking at business models that work for countries, making the most of the private sector in each country. Bayer is also generating innovation for small holder farmers, trying to give them a better life through controlling malaria.

Kunizo Mori, Mitsui

Mitsui Chemicals Agro works in public health. They invented Etofenprox, which was approved by WHOPES in 1998. A new compound is tenebenal, a new active insecticide that acts as an antagonist and binds at a unique site. IRS containing this active ingredient, as well as dual LLINs, are expected to be launched. In an experimental hut study against resistant mosquitoes in Burkina Faso it showed excellent activity for more than eight months on concrete surfaces. Further studies are being conducted with wood and other materials.

Robertus Vink, Syngenta

Syngenta has made a valuable contribution to reducing malaria. The company has a track record of innovation, bringing Bti products to the market, the first long-lasting insecticides, and the first resistance-breaker. Syngenta works on several new active ingredients that can be used in both nets and IRS, and is working with IVCC.

Melinda Hadi, Vestergaard

Vestergaard has invested in developing products for vector control. Manufacturing LLINs is their core business under the PermaNet® brand. Vestergaard is aware of what it takes to bring these to market, they understand the continued role that vector control will make in malaria elimination, and work with VCAG and others to guide their efforts. They are committed to bringing tools that will maintain their efficacy against resistant mosquitoes. PermaNet 3® and PBO nets have been adopted by countries.

Discussion - All

- It was discussed that these companies have had outreach activities through agriculture, food security, and small hold farmers, and asked what can be transferred for vector control. Leveraging know-how is important. Agricultural companies have implementation technicians in country, and these can help with IRS spray, and this would be complementary to malaria control programmes. Staff and technology could therefore be used. Finally, the costs of new product development are very high and might be too high for companies if they do not also work in agriculture.
- Regarding vector control tools, it was asked if industry has any tools for humanitarian crisis scenarios. Some companies do intervene in these situations, providing products. Vestergaard has a history and mission to remain engaged in these discussions, and they made available an insecticide treated tarpaulin and wall linings. However, a company cannot make products that no one buys. Leveraging technologies that are currently available requires defining the target product profile, such as for mobile populations. These usually stall on price. There needs to be a space to both develop and bring these products to market.
- It was commented that in DRC, the practical challenge they have is stagnant water. Help from external partners is needed to find practical solutions. These areas are difficult to reach, and bed nets are not the solution. From a toolbox of interventions, there is a need to think about what would be most suitable for each situation, and partnerships to develop tailored campaigns is needed.
- It was commented that a wave of new compounds has been introduced, and asked if companies feel confident that there will be adequate guidance to utilise these. IRM guidance is available but it is important to go beyond this and make use of expertise, such as from agriculture and mathematical modelling, to revisit resistance management. Assumptions made from IRM in agriculture are being transferred to malaria management, but they do not always hold.
- It was commented that future development requires investment of companies now, and they need to consider the outlook in 10-20 years. One way to address this is to form partnerships, so that different competencies can be built. Horizon scanning and preferred product characteristic from WHO helps to encourage innovation but should not be prescriptive.
- It was commented that new active ingredients are already being used in the agriculture sector, so mosquitoes may have already had exposure to them and resistance develops quickly. It is important that companies be mindful of this. Also, the costs of insecticides can be up to 50% of the cost of programming, so if possible they are encouraged to reduce the costs. Lower costs of insecticides would allow countries to spray more, but the income is needed to help them invest in innovation. High volumes help, but there is the complexity of forecasting. If programs can plan ahead, it would help the companies know if they need to produce it.
- Finally, the panel was asked what companies need from the vector control community. It was responded that the most important thing is to listen to the vector control community. Customer insight is needed. The 2020s will be a decade of changes and disruption, but everyone needs to take part in this to facilitate it. Working as one team is very important. Sharing of success stories is helpful. Evolving further partnerships is vital; companies are willing to listen to countries and are committed to malaria elimination.

The Global Fund perspective: how to ensure country applications have vector control interventions high on the agenda

Sussann Nasr

Countries approaching the Global Fund are already prioritising vector control in their funding applications. Most try to cover the costs of RDT and ACT for case management, then move to vector control. They prioritise nets above IRS, then after this are other interventions. In 2019, the majority of nets were pyrethroid only, but a significant proportion of funding has gone to PBO nets, and a small proportion to dual active ingredient nets. With replenishment, countries can look at their implementations and consider new approaches such as High Burden High Impact. They consider what the access is to intervention, coverage and use. Sub-national tailoring helps with prioritisation, but all requests for funding should be grounded in national malaria control strategies and based on up-to-date entomological and epidemiologic data. They aim to ensure universal coverage of at-risk populations with at least one vector control intervention (IRS or ITNs). The Global Fund has had limited requests for help with entomological surveillance but they would like countries to approach them about this, both in terms of implementation and building capacity. The Global Fund is also interested in how countries are performing. Where there are in coverage or usage shortfalls, they want to know what is being done to make improvements. The Global Fund supports IRS, and encourage a sound IRM strategy. Routine monitoring and quality control of coverage is also important, as well as a waste management strategy. The Global Fund does not receive many requests for larval source reduction. This intervention is not supported unless other interventions have been covered and there is evidence that it is feasible.

- It was commented that a strategic plan for LSM was presented to the Global Fund, and GF asked for LSM to be removed so that the request could be funded. It was asked if GF could be included in the Work Stream.
- It was commented that the Global Fund appears to be most interested in LLINs and should consider IRS as a more important approach, and reconsider funding LSM. The Global Fund aims to maximise what countries can achieve with highly effective tools. Countries ask for case management, and vector control for specific populations. In reality, IRS is a very expensive intervention, and the coverage that can be achieved is much less than with LLINs. There is usually not much money left to look at LSM, which is a complementary intervention and not a core intervention. Evidence needs to be available for interventions, but for LSM it is modest. People need to think about how they can generate this evidence. WHO is not in a position to change its policy recommendations.

Updates from the other Working Groups

Update from Malaria in Pregnancy Working Group

MiPWG 2019 global malaria report shows that over 11 million pregnant women exposed to malaria. 61% off these women have access to mosquito nets. Only 18% of women attending ANC do not have access to IPTp. This is a major intervention supported through this Working Group. Focus areas are to support in-country policy, support advocacy and the implementation of tools, research, and partnerships at global, regional and country level. The call for action of IPTp will be launched this year. Their annual meeting will be in April.

Update from Social and Behaviour Change Communication Working Group

SBCCWG had their last annual meeting in September and had broad representation. Work Streams are focused on specific products, including a toolkit for community workers. Guidance for SBCC strategies across different malaria transmission settings, and a standardised module for DHS. Any countries interested in using this module in their upcoming survey can request this. The next meeting will be at the SBCC summit in Marrakech in March.

Update from Multi-Sectoral Working Group

MSWG will have its annual meeting back-to-back with the VCWG.

Update from Monitoring and Evaluation Reference Group

MERG has produced publications to get coordination between bodies. Their Working Group looks at indicators for net coverage and IRS. Their last meeting looked at high burden areas, and in the next meeting they will focus on elimination areas.

Update from Case Management Working Group

CMWG has task forces that look at tools. They are interested in knowledge sharing and aim to use best practices and tools. Their next meeting will be in September.

Work Stream highlights, next steps, way forward in 2020, and any other business
Keziah Malm, Justin McBeath, Konstantina Boutsika

Highlights from LLIN Priorities Work Stream

Most variation seen in LLIN durability is between places, but some is between products. The work plan has been dissolved and rebuilt. Foci are durability, new nets, targeting, and use.

Highlights from LSM Work Stream

The Work Stream heard from programmes in Ghana and Uganda. There was presentation of larval ecology and the introduction of new technologies in LSM. Much work is needed to convince WHO that it can be effective.

Highlights from New Tools, New Challenges in Vector Control Work Stream

The Work Stream wants to create links between MOH, academics and funding partners, where new innovators can pitch their ideas. This will help to fine-tune ideas. The Work Stream also wants to keep track of new tools, such as ivermectin, ATSB and spatial repellents, and to incorporate behaviour centred design and social science.

Highlights from IRS IRM Priorities Work Stream

IRM is not just an activity associated with IRS but needs to be considered more broadly for other interventions, even recognising the impact of non-chemical interventions. It should be considered as long-term sustainability. There is a need to build the capacity of countries to improve the quality of delivery of IRS for maximum impact.

Highlights from IVM, Evidence and Capacity Work Stream

The Work Stream discussed IVM sustainability and capacity building, new evidence, best practices, and ways to make information available. Also discussed were how to utilise the capacity available in research institutions and how to plan for continuous training activities. Scale up of best practices,

education, and innovation are important. Finally, the Work Stream will promote a better understanding of the community in order to design effective channels of education, such as using football teams, music and radio programmes to deliver messages.

Highlights from VBDs and Built Environment Work Stream

The Work Stream focuses on malaria in rural Africa and *Aedes* in urban environments. The BOVA network has been able to fund pump prime projects on developing new interventions. They have funded five workshops for multisectoral action, and have been very active in policy, as they want to link experts in vector control with those in the built environment, so it is important to be involved in urban planning. A Lancet commission is focussing on *Aedes* in cities in the tropics. They recognise that products need to be developed for the extremely poor through to the middle classes, so there is huge potential in Africa. The WHO position statement on housing in malaria needs to be revisited. The next meeting is in September. There will be a change in co-leader as Steve Lindsay is stepping down.

Any Other Business

All co-chairs were thanked for their hard work during 2019. Justin McBeath thanked all members for their attendance and contributions.

Sponsorship of affected country participants was provided by the Swiss Agency for Development and Cooperation (SDC), Swiss TPH, Bayer, Goizper Group, In2Care® BV, Mesto® Spritzenfabrik, Micron Sprayers Ltd, New Mountain, RealRelief, SC Johnson, Syngenta®, and Vestergaard®.

List of abbreviations

3GIRS	3rd Generation IRS
AI	Active ingredient
ANC	antenatal care
ANVR	African Network on Vector Resistance to insecticides
APMEN	Asia Pacific Malaria Elimination Network
ARMPC	Advocacy & Resource Mobilisation Partner Committee
BOVA	Building Out Vector-borne disease in Africa
Bti	*Bacillus thuringiensis* subsp. *israelensis*
CDC	Centers for Disease Control
CMWG	Case Management Working Group
CRT	Cluster randomised trial
DALY	Disability-Adjusted Life Year
DRC	Democratic Republic of Congo
GMP	Global Malaria Programme
GVCR	Global Vector Control Response
HBHI	High Burden to High Impact
I-ACT	insecticidal nets through ambient chamber tests
IG-UTP	International Guidelines on Urban and Territorial Planning
IPTp	Intermittent preventive treatment in pregnancy
IRM	Insecticide resistance management
IRS	Indoor residual spraying
ITN	Insecticide-treated net
IVM	Integrated vector management
LLIN	Long-lasting insecticidal net
LSM	Larval source management
MERG	Monitoring and Evaluation Reference Group
MiPWG	Malaria in Pregnancy Woking Group
MOH	Ministry of Health
MOOC	Massive On-line Open Course
MSWG	Multi-Sectoral Working Group
MVSE	Malaria Vector Surveillance for Elimination
NMCP	National Malaria Control Programme
NMEP	National Malaria Elimination Programme
NTD	Neglected tropical disease
ODK	Open Data Kit
ORENE	Online Resource Exchange Network for Entomology
PAMCA	Pan African Mosquito Control Association
PBO	Piperonyl butoxide
PMI	President's Malaria Initiative
PPC	preferred product characteristics
PQ	prequalification
RASS	remotely-piloted aerial spray systems
RBM	Roll Back Malaria
RCT	Randomised Controlled Trial
RDT	Rapid diagnostic test
SADC	Southern African Development Community
SAFE	sunlight active formulated extract

SBCC	Social and behaviour change communication
SBCCWG	Social and Behaviour Change Communication Working Group
SCPC	Strategic Communications Partner Committee
SDC	Swiss Agency for Development and Cooperation
SDG	Sustainable Development Goal
SMC	Seasonal malaria chemoprevention
SOP	Standard Operating Protocol
SSA	Sub-Saharan Africa
UN	United Nations
UNHCR	United Nations High Commissioner for Refugees
USAID	United States Agency for International Development
VBD	Vector borne disease
VCAG	Vector Control Advisory Group
VCHE	Vector Control in Humanitarian Emergencies
VCWG	Vector Control Working Group
WHO	World Health Organization
WHOPES	World Health Organization Pesticide Evaluation Scheme
WP	wettable powder