Pan African Malaria Vector Control Conference
October 25–29, 2009
Zanzibar, Tanzania

Compendium
Acknowledgments

We wish to acknowledge support of the Pan African Malaria Vector Control Conference by the following co-sponsors: World Health Organization-Africa Regional Office, U.S. Agency for International Development, U.S. President’s Malaria Initiative, Roll Back Malaria Partnership, and the Governments of Tanzania and Zanzibar. We are grateful to all the conference speakers and participants for making the event a success.

We also wish to thank the following individuals for their assistance in developing the conference proceedings: substantive editors Jennifer Bitticks and Eve Van Devender; technical reviewers Jake O’Sullivan, Rodaly Muthoni, Betsy Brown, Erin Smith, and Jacob Williams; graphics, design, and layout by RTI Creative Services; and meeting rappatuer Clifford Mutero. Photos in Part 1 of the compendium were taken by Zamani Zanzibar Kempinski Hotel.

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Executive Summary

Malaria is one of the leading causes of morbidity and mortality across Africa. It accounts for 30%–50% of outpatient visits to health facilities, resulting in more than 1 million deaths annually. Although it affects the whole population, malaria disproportionately afflicts the most vulnerable groups—pregnant women, children under the age of five, and the chronically ill. Malaria constitutes a major economic burden on communities across sub-Saharan Africa, yet it is a disease that is preventable and can be controlled. With this goal in mind, from October 25–29, 2010, RTI International sponsored the first Pan African Malaria Vector Control Conference in Zanzibar, co-hosted by the U.S. President's Malaria Initiative (PMI), the World Health Organization-Africa Regional Office (WHO-AFRO), Roll Back Malaria (RBM) Partnership, and the Governments of Tanzania and Zanzibar.

The meeting brought together more than 90 leading international scientists, leaders of national malaria control programs from 16 African countries, and representatives from private businesses, foundations, and global health development agencies, for four days to share technological innovations and lessons learned. Presentations highlighted an array of approaches to malaria vector control, with a special emphasis on best practices and lessons learned from indoor residual spraying (IRS) as a key, life-saving vector control intervention. The conference concluded with a field visit to sites of the comprehensive vector control programs that have contributed to Zanzibar's near elimination of malaria.

The themes of this first Pan African Malaria Vector Control Conference included

- Recent innovations in malaria epidemiology and vector control;
- Resource mobilization priorities for malaria vector control programs;
- Resistance management and insecticide selection for vector control;
- Monitoring and measuring the impact of vector control programs;
- Commodity management and new products;
- IRS implementation, highlighting specific African country experiences;
- Capacity building, training, and communications strategies for IRS, including community mobilization;
- Safer use of insecticides, including environmental risk mitigation and emerging solutions to waste management and disposal in different country contexts; and
- Cutting-edge approaches and best practices for the next generation of vector control programs.

Conference outcomes and recommendations are as follows:

1. IRS plays an important role in malaria vector control in Africa, especially when implemented in combination with other vector control interventions, such as long-lasting insecticide-treated nets (LLINs) and case management strategies with artemisinin-based combination therapy (ACT).

2. Malaria elimination is feasible in sub-Saharan Africa. Operational and financial feasibility for achieving major reductions in malaria prevalence—and ultimately elimination—requires addressing a range of challenges. These include sustained national and donor financing for scale up of the most effective malaria vector control and treatment interventions and commodities; improved monitoring and evaluation tools to track trends in malaria transmission, including across borders; and better, more consistent entomologic monitoring of the effectiveness of vector control measures and insecticide resistance. Scientific application of mosaic and rotational use of insecticides is also a key priority.
3. Capacity building for malaria prevention across sub-Saharan Africa is a key element to sustained successful prevention of malaria. A cross-cutting theme echoed in many presentations is that strengthening institutional and human capacity at all levels of national malaria control programs for vector control and environmental compliance—including the safe and judicious management, application, and disposal of pesticides—is necessary to sustain and scale up vector control measures. Human capacity development must become the main priority area for future investments in malaria control.

4. Finally, to respond to consumer demand and keep pace with growing insecticide resistance, continued research and development of new technologies and products—such as a new generation of long-acting pesticides to control malaria vectors and insecticide-treated durable wall linings—are being tested across Africa. Another important research avenue that merits continued investment and operations research is the application of cost-effective practical techniques in housing construction—such as closed eaves, window screens, and new ceiling materials—that have proven to be effective vector control measures on a small scale.

Conference participants called for continued partnership among donors and increased opportunities to collaborate and share experiences across Africa institutions and globally. Participants advocated for universal coverage of malaria interventions to achieve a 50% reduction of malaria morbidity and mortality in African by 2010 and progress toward malaria elimination by 2015. Based on the data presented at the conference, currently only 2 of 16 countries have a malaria slide positive rate of less than 5% (the prerequisite for malaria elimination). The participating country representatives affirmed a strategic move toward universal coverage with a combination of the three key malaria interventions—IRS, LLINs, and ACT—over the next five years.

The goal of the Pan African Malaria Vector Control Conference 2009 Compendium is to impart the thoughtful ideas and recommendations from this landmark conference and to share the important country models and programs that are making a difference in battling the malaria vector in every setting in sub-Saharan Africa. The compendium includes session highlights, questions, and key papers, and is meant to broadly disseminate these findings and conclusions to participants and global health leadership throughout Africa and to donor and business communities engaged in malaria prevention and control.

RTI is honored to have sponsored this unique opportunity, bringing together so many experienced, internationally recognized malaria and global health experts and scientists, and stimulating a rich exchange of experiences. RTI firmly believes that malaria elimination is not only possible but central to improving the human condition, and pledges its continued support for the advancement of the science and application of effective malaria vector control programs.

The goals and objectives of this first-ever Pan African Malaria Vector Control Conference reflect RTI’s mission to improve the human condition by turning knowledge into practice.

Conference Recommendations

Summary of Key Outcomes and Recommendations

Main Outcomes

Following is a brief summary of the key messages from the many presentations during the 4-day conference.

- Based on the work recently supported by PMI and other international and national partners, IRS has been shown to have a critical role in malaria control in Africa, especially when implemented in combination with other vector control interventions and case management strategies.

- Malaria elimination is technically feasible in certain areas of Africa. However, the operational and financial feasibility for maintaining elimination in areas of potentially high transmission is less obvious due to a host of important scientific, policy, and funding challenges. These include occurrence of insecticide resistance in IRS programs; importation of new malaria cases into areas in which the disease has been eliminated; weak health systems, including inadequate national capacities for vector control; lack of intersectoral collaboration; poor
community participation; and inadequate financial resources to fund program implementation, research to measure impact of vector interventions, and develop new technologies and products.

Recommendations
The participants of the Pan African Malaria Vector Control Conference called for the following recommendations:

1. Commitment by all to develop capacity to
   - Use evidence and benchmarks to guide decisions and assessments of activities;
   - Ensure judicious use of pesticides;
   - Carry out and use monitoring and evaluation; and
   - Conduct resistance monitoring, prevention, and management.

2. Support national health systems strengthening as the rubric for sustainability of vector control.

3. Standardize and harmonize core indicators, to be used by all partners in vector control as the basis for developing
   - Process indicators;
   - Program indicators;
   - Health systems indicators; and
   - Outcome and impact indicators.

4. Identify new opportunities and promote south-to-south collaboration and sharing of experiences.

5. Work across sectors to promote buy-in among various stakeholders and strengthen local oversight to sustain programs, safeguard health, and ensure protection of the environment.

6. Renew efforts in partnership among PMI-supported programs and WHO-AFRO, RBM, the WHO Pesticide Evaluation Scheme, and the WHO Global Malaria Program/Vector Control Program.

A Call to Action on Malaria Vector Control
Participants called for universal coverage of malaria interventions to achieve a 50% reduction of malaria morbidity and mortality in its member states by 2010 and progress toward malaria elimination by 2015.

Countries in Africa are at varying stages in achieving the 2010 targets. From the evidence presented at the Pan African Malaria Vector Control Conference, participating countries propose a strategic move toward universal coverage, utilizing a combination of the three key malaria interventions: 1) IRS; 2) LLINs; and 3) ACT.

Universal coverage is a noble goal, but one not easily achieved. Several challenges continue to impede the effective combination of the vector control interventions. These include lack of sufficient antimalaria commodities, lack of human resource capacity (both the number of workers and skills of those workers), and lack of adequate financial resources. In addition, elimination efforts require effective coordination, harmonization, alignment, and commitment, which currently must be strengthened at various levels.

To address these challenges, countries will need support for a number of actions, including procurement of antimalaria commodities and expansion of IRS implementation based on country plans (including sound environmental management interventions and safe management and disposal of insecticides); transfer of technology; strengthening of human resource capacity at all levels; and sustaining and enhancing political commitment. All stakeholders are therefore called upon to support governments in their efforts to achieve universal coverage toward malaria elimination.
PART 1

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Presentations Narrative and Discussions

Session 1. Opening Ceremony

Master of Ceremonies: Mr. Napoleon Graham, RTI International

The master of ceremonies welcomed participants to the *Pan African Malaria Vector Control Conference*. He thanked the participants for creating an opportunity to share experiences, best practices, and success stories, which could serve as lessons learned and be adapted for country-specific interventions against malaria. The following high-ranking Zanzibar government officials and prominent individuals involved with malaria control in Africa and globally opened the conference with short speeches:

- Dr. Oladapo Walker, inter-country support coordinator for eastern and southern Africa, World Health Organization–Africa Regional Office (WHO-AFRO)
- Dr. James Banda, senior advisor, Roll Back Malaria (RBM) Partnership Secretariat—representing Dr. Awa Coll-Seck, executive director, RBM Partnership Secretariat
- Admiral Timothy Ziemer, U.S. Global Malaria coordinator, U.S. President’s Malaria Initiative (PMI)
- Dr. Victoria Haynes, president and chief executive officer, RTI
- Hon. Shamsu Vuai Nahodha, chief minister, Revolutionary Government of Zanzibar—representing President Amani Abeid Karume, Revolutionary Government of Zanzibar

The speakers highlighted the following issues:

- Partnerships and their role in the fight against malaria;
- Indoor residual spraying (IRS) as a key intervention in malaria vector control;
- Concerted and sustained efforts in achieving the goal of malaria elimination;
- Operational research to help guide vector control interventions with the necessary evidence base;
- Sharing successful efforts, knowledge, expertise, best practices, and lessons learned;
- Capacity building;
- Health systems and infrastructure strengthening;
- Environmental management as an important complementary intervention in malaria control in local areas where its effectiveness is indicated;
- Historical perspective, focusing on progress and impact;
- Greater community mobilization and involvement, including engaging local authorities; and
- Moving from talk to action and from action to results, which will generate continuous funding.

Chief Minister of Zanzibar Hon. Shamsu Vuai Nahodha officially opened the conference and
thanked RTI and its partners, RBM, WHO, and PMI, for bringing the conference to the beautiful island of Zanzibar. He emphasized his government’s determination in the fight against malaria and highlighted the successes achieved thus far in the country, including the significant reductions in Zanzibar and parts of Mainland Tanzania. Hon. Nahodha affirmed his government’s enduring strong partnership with PMI, and also stated that he hoped the conference would contribute to generating lessons learned to guide country-level implementation.

Session 2. Malaria Epidemiology and the Role of IRS

Chair: Dr. Mohamed Saleh Jiddawi, Principal Secretary, Zanzibar Ministry of Health and Social Welfare (MoHSW)

Presentations Narrative

The Epidemiological Context of Vector Control in Africa

Presenter: Dr. Jonathan Lines, WHO

Dr. Lines began his discussion on malaria epidemiology and containment by providing a historical account of global malaria prevalence and vector control methods. He discussed the challenges to malaria control in Africa posed by the varying topographies and complex epidemiology found throughout the continent, and discussed the two most prevalent technologies for vector control in terms of their ease of use, affordability, and applicability for a variety of environments.

He outlined the three-pronged agenda of WHO’s Global Malaria/Vector Control Program, which focuses on universal coverage, recognizing and addressing insecticide resistance, and vector control capacity. He distinguished the three forms of vector control used to achieve elimination: 1) attack—using IRS and insecticide-treated nets (ITNs); 2) pre-elimination—involving snuffing out remnant foci by using a fire brigade response for outbreaks (e.g., in China, Sri Lanka); and 3) consolidation—reducing receptivity through improved environmental management, housing, land use, etc. (e.g., Thailand). He compared IRS and ITNs, discussing the strengths; appropriateness; and challenges of each, and explored the feasibility of malaria elimination in Africa.

Dr. Lines noted that recent declines in malaria reported in Africa could be a result of improved housing and socioeconomic development, in addition to targeted interventions. He stated that development and poverty reduction ultimately are the factors that may make malaria elimination feasible in Africa. He concluded by quoting L. W. Hackett:

“Ignorance, poverty, and disease constitute the vicious triangle of social inadequacy. An attack on any of them helps to dissipate the other two. But the causes of malaria [are] independent of the ignorance and poverty, and can be separately handled... Persistence is more important than perfection... our duty is to fight the disease now, with weapons already proved useful, albeit imperfect, rather than to fold the hands while awaiting a problematical *therapia magna* of the future.”

Overview of Indoor Residual Spraying in Southern Africa

Presenter: Dr. Rajendra Maharaj, Medical Research Council (MRC)

Dr. Maharaj noted that IRS is the most common vector control intervention in southern Africa because it has proven to have the greatest impact in a relatively short time span. He shared results—illustrated by geographic information systems (GIS) maps, including pre- and post-spraying scenarios in South Africa—and the impact of IRS in Mozambique.

Dr. Jonathan Lines, WHO
Presentations Narrative and Discussions

Presentations Narrative

Over the past decade, Dr. Maharaj pointed out that IRS has long-term proven efficacy in areas of southern Africa and is relatively cost-effective. IRS interventions have scaled up successfully in six southern African countries. IRS is also being increasingly used now by mining, industrial, and development projects in Africa.

Indoor Residual Spraying in Different Epidemiological Settings
Presenter: Dr. Birkinesh Ameneshewa, WHO-AFRO

Dr. Ameneshewa provided a broad overview of IRS through a series of questions that explored its rationale and trends of use in Africa. She described IRS as an intervention for high-coverage community protection; the most standardized and well-defined malaria vector control intervention; and one of the two most effective and widely used malaria vector control methods (the other being long-lasting insecticide-treated nets [LLINs]). IRS is designed to reduce the average life span of vector mosquitoes, mosquito density, and human-vector contact through a knockdown effect. It is generally applicable in various epidemiological settings: low seasonal transmission areas; perennial transmission areas with significant seasonal peaks; and perennial transmission with little or no seasonal fluctuation. Despite its success in Africa, IRS faces several significant challenges, including development of vector resistance; operational issues such as quality, coverage, and timeliness; consolidation; and difficulty in sustaining success due to decreased focus on investments in systems development/strengthening and the historical lack of a clear strategy to sustain and build on gains.

Dr. Ameneshewa noted that a current challenge faced by countries is finding the right combination between the current two major interventions (IRS and LLINs), to provide maximum impact in the different local eco-epidemiological settings. There is uncertainty about the individual interventions’ contributory impacts in mixed deployment. She also stated that better evaluation protocols are needed.

Session 3. Resource Mobilization for Malaria Vector Control Programs
Chair: Dr. Awa Coll-Seck, RBM Partnership Secretariat

Presentations Narrative

Partnerships for Vector Control: Learning From the Past, Looking Forward
Presenter: Dr. James Banda, RBM Partnership Secretariat

Dr. Banda highlighted the evolution of partnerships for malaria vector control by reflecting on past, present, and future scenarios. He focused on three issues: 1) where we come from—learning from the past; 2) where we are—implications for vector control; 3) the way forward—Global Malaria Action Plan (GMAP) implementation.
Lessons learned include the need for continuous advocacy efforts to ensure strong political commitment and ongoing funding, as well as the importance of continuing regular spray cycles, using alternating insecticides to mitigate resistance. Other key success factors include strong coordination at the regional level; alignment of different sectors at the national level; building systems for monitoring resistance to pesticides; and continuous investment in research and integrated vector management (IVM).

The RBM Partnership was founded by four partners in 1998 and now encompasses all key actors in malaria control and elimination. During the last 10 years, RBM partners have built a solid political commitment at national and international levels. Due to efforts by RBM and other stakeholders, international funding to fight malaria increased nearly ten-fold in the past decade to US$1.1 billion in 2008. As proof of success, the RBM scale-up strategy has shown a sharp reduction in malaria morbidity and mortality in countries such as Eritrea, Ethiopia, Rwanda, Tanzania, and Zambia. The malaria community also developed a common action plan: the GMAP, launched in 2008, provides a road map for malaria control and elimination worldwide.

Dr. Banda provided an overview of the tools available for scale up of prevention and case management, while cautioning that even with RBM coordination, malaria control efforts face many challenges. These include procuring nets and insecticides; effectively using LLINs; increasing parasite resistance to antimalarial medications and increasing insecticide resistance; accepting IRS at the household level; securing global political commitment for supporting IRS; agreeing on IRS insecticide to use (e.g., ongoing debates on DDT); integrating monitoring for insecticide resistance into scaling up LLINs and IRS (i.e., building entomologic capacity at regional, subregional, and national levels); and monitoring impact in high-burden countries in Africa.


Presenter: Admiral Timothy Ziemer, USAID/PMI

Admiral Ziemer opened with an introduction of the strategic and tactical issues that are the focus of the U.S. Government’s (USG’s) global malaria strategy. The strategic components include PMI from 2006 to 2010; Hyde-Lantos Authorization from 2010 to 2014; and the Global Health Initiative. Tactical components include diagnostics, community case management; IVM; corporate and community partnerships; cell phones, systems, and surveillance.

The PMI’s future priorities are to continue support for IRS, including expansion within countries as resources allow; to study how best to employ IRS and LLINs in a complementary fashion; to partner to ensure sustained acceptance of IRS; and to support ministries of health and national malaria control programs (NMCPs) in development and revision of country IRS/vector control strategies.

Admiral Ziemer highlighted key challenges facing PMI and the global malaria community in expanding and improving malaria diagnosis, especially rapid diagnostic tests (RDTs); delivering artemisinin-based combination therapy (ACT) in both the public and private sectors; determining how best to employ IRS and ITNs in a complementary fashion; ensuring sustained acceptance of IRS; attaining high ITN usage in areas of high ownership; modifying approaches as malaria drops (e.g., in Madagascar, Rwanda, Zambia, Zanzibar, etc.); sustaining and expanding achievements; and transitioning of USG assistance. He concluded by touching on the new Global Health Initiative goals and principles.

Resource Mobilization for Malaria Vector Control Programs: Resources for Evolution and Innovation

Presenter: Dr. Kathryn Aultman, The Bill & Melinda Gates Foundation

Dr. Aultman addressed financial resources needed for malaria vector control program activities. She noted that as countries approach elimination, overall implementation costs should go down. However, additional costs will be incurred as new countries enter the global financial mechanisms for malaria control and prevention.

Support and commitment from all stakeholders and partners—including global donors, national governments, corporations, community groups, and individuals—must be ongoing and extend beyond mere provision of financial resources.
to improve program efficiency and impact. Dr. Aultman noted that opportunities now exist for improved efficiency and effectiveness in vector control through activities such as the Innovative Vector Control Consortium—a public private partnership that is shepherding the development of long-lasting insecticide formulations and alternative active ingredients to circumvent existing insecticide resistance among malaria vectors, as well as supply chain improvements. She noted ongoing efforts to develop new decision support systems, which will strengthen monitoring and evaluation (M&E). Innovation in vector control should be informed by carefully studying the shortcomings of existing tools and strategies; innovative paradigms should include both new tools and new strategies. Some examples include contracted implementation services, altered procurement terms, focus on personal and community hygiene versus government-supplied services, and new modes of action and delivery. Resources required for innovation include initial proof of principle studies, more carefully designed community-wide studies, and an engagement of the wider community.

Overview of Clinton HIV/AIDS Initiative (CHAI) Malaria Support
Presenter: Dr. Bruno Moonen, The William J. Clinton Foundation (The Clinton Foundation)

Dr. Moonen provided an overview of The William J. Clinton Foundation, with a particular focus on CHAI and the CHAI Malaria Control Team (MCT). The Clinton Foundation’s mission is to strengthen the capacity of people in the United States and throughout the world to meet the challenges of global interdependence. To advance this mission, The Clinton Foundation has developed programs and partnerships in the following areas: health security; economic empowerment; leadership development and citizen service; and racial, ethnic, and religious reconciliation. Unlike many other foundations, The Clinton Foundation generally does not make grants to outside organizations. Instead, it directs its financial resources to its own programs, both domestically and throughout the world. CHAI works with governments and manufacturers to increase access to HIV/AIDS care and treatment by bridging the market gap between supply and demand. The model has enabled CHAI to broker significant and repeated price reductions so countries can do more with limited resources.

MCT’s goal is to enable countries with endemic malaria to achieve dramatic and sustained reductions in malaria by increasing access to essential commodities, strengthening program design and management, and informing and shaping effective policies. CHAI’s malaria work is focused in private sector and home-based treatment, malaria elimination, and diagnosis strengthening. Much of CHAI’s malaria work rests at the fulcrum between evidence and action—proving solutions and translating them into practice.

Malaria Control as a Best Practice Corporate Social Responsibility (CSR) Program
Presenter: Mr. Steven Knowles, AngloGold Ashanti (AGA) Oubasi Limited

Mr. Knowles stated that AGA, a global gold producer operating in 22 countries, feels strongly about CSR and that local community involvement and development are key to sustainable company operations. He shared the experiences of AGA’s integrated malaria control program in Obuasi, Ghana, an AGA mining town, which began in 2005. He quoted a 2004 company report: “[M]alaria remains the most significant public health threat to AngloGold Ashanti operations in Ghana, Mali, Guinea and Tanzania.” In response to this threat, the AGA malaria control program in Obuasi implements various antimalarial interventions, encompassing the mine, town, and surrounding villages.

Mr. Steven Knowles, AGA
According to Mr. Knowles, by 2009, the AGA program significantly reduced the community’s malaria burden by 76%, increased school attendance, reduced absenteeism at the Obuasi mine by over about 95%, and reduced malaria-associated medical expenses from US$55,000 per month to US$10,000 per month, a savings of about US$0.5 million in one year. At the corporate level, the malaria control program has a return on investment and the backing of shareholders.

The AGA program is characterized as having an active partnership with the Ghana Health Service (GHS), NMCP, and Obuasi Municipal Assembly, as well as having the Ministry of Health’s (MOH’s) strong approval. AGA’s success in malaria control has led to significant international attention and support from donors to scale up IRS in other districts. Mr. Knowles underscored the multifaceted role that the private sector can play in combating malaria, using well-noted sector competencies in project management; expertise in sourcing, planning, and strategy support base; on-site infrastructure; training facilities and skills; financial controls and audits; operational, safety audits. Private companies can act as catalysts for NMCPs. Mr. Knowles noted of that it is within the private sector’s means to initiate malaria control programs, establish infrastructure, and conduct baseline assessments, even before looking to international funding for sustaining and scaling up interventions.

Session 4. The Role of Vector Control in Malaria Prevention
Chair: Dr. Shiva Murugasampillay, WHO

Presentations Narrative

Vector Control Interventions and Their Effectiveness in Malaria Prevention
Presenter: Dr. Michael Macdonald, USAID/PMI

Dr. Macdonald discussed the role of vector control and its implications for overall malaria control by describing the theoretical underpinnings of malaria transmission and epidemiology. He highlighted that mosquito survival rate is the variable with greatest impact on malaria transmission compared to the other entomological factors. He also emphasized that IVM has been recognized as the most practical approach to sustainable vector control, noting the limitations normally encountered with individual interventions, such as advocacy, social mobilization, and legislation; cross-sector collaboration; integrated approaches involving complementary interventions; evidence-based decision making; and capacity building. Major challenges currently facing vector control, such as the development of insecticide resistance, could be effectively addressed through IVM. Possible new tools to improve IVM include improvements in satellite imagery to enhance targeting of interventions, new repellents, insecticide-treated uniforms for soldiers, and treated clothing.

IRS in Africa: A Brief Discussion
Presenter: Dr. John Chimumbwa, RTI

Dr. Chimumbwa provided an overview of IRS based on his experience implementing the intervention in 15 African countries with support from PMI. He focused on RTI’s efforts in demonstrating to host countries why, when, where, and how to deploy IRS. However, he stressed that IRS, despite its known effectiveness, was not intended to be a substitute for LLINs, case management, or other interventions. He emphasized that there is no single solution to malaria control. He described IRS as most applicable in settings where the vector population feeds and rests indoors; where vectors are susceptible to insecticide use; where people normally sleep indoors; and where
houses and other structures are suitable for spraying. Dr. Chimumbwa highlighted the need for specialized training for local workers engaged as spray operators and the environmentally safe disposal of IRS residual chemicals and obsolete stocks.

Among the important lessons learned from RTI’s experience with PMI-funded projects in Africa is that IRS needs adequate time for preparation, up to six months’ lead time in many cases. In addition, M&E and strict supervision are crucial to program success.

**Achievements in Malaria Vector Control: Zanzibar Experience**

**Presenter: Dr. Abdullah Suleiman Ali, Zanzibar Malaria Control Programme (ZMCP)**

Dr. Ali focused on the recent impressive achievements of malaria control in Zanzibar. The main interventions include ITNs, intermittent preventive treatment for pregnant women (IPTp), ACT, and IRS. IRS commenced in 2006, and RTI has helped the country to achieve nearly 100% coverage. Malaria parasite prevalence has reduced drastically, from about 41% pre-intervention to less than 1% currently. Advocacy and community involvement are central to the ZMCP’s IRS program.

**Discussion (Q&A)**

**Questions**

- What is the current status of other vector control interventions, such as larval control and the use of mosquito coils and repellents, in general?
- In the case of IRS in Zanzibar and other malaria interventions involving the community, how are volunteers maintained after training?
- Is it still necessary to implement IRS in areas where there is near-universal coverage with LLINs?
- How is the IRS waste disposal issue being addressed in Mozambique and other countries?
- What is the next step for Zanzibar as the country contemplates malaria elimination?
- What is the status of insecticide resistance among mosquito populations in Zanzibar?
- On what basis does Zanzibar spray only one round of insecticide per year?

**Responses**

- Mosquito larval control is relatively more difficult to implement than targeting adult mosquitoes with IRS and LLINs, primarily due to the large number and wide distribution of mosquito breeding sites. Locating breeding sites is often tedious, especially during the rainy season when standing water pools serve as ideal mosquito-breeding habitats, especially for the main malaria vector in Africa, *Anopheles gambiae*. However, larviciding is feasible if sites are few, fixed, and easily identifiable. It has been used successfully in limited parts of Africa including the highlands and some drier regions of eastern Africa (e.g., Tanzania, Kenya).
- Larval control is especially important in urban and peri-urban areas where it could be effective in reducing populations of the nuisance mosquito *Culex quinquefasciatus*. The presence of the *C. quinquefasciatus* mosquito, which is not a malaria vector, is often mistakenly viewed as a failure to control malaria vector populations. Therefore, there is a need to educate communities, politicians, and other non-specialists regarding the difference between general mosquito control and malaria vector control. On the other hand, mosquito coils and many repellents are not cost-effective as interventions against malaria at the community level. Furthermore, the commonly available coils have a limitation in not being protective throughout the night.
• Waste disposal related to IRS and LLINs is usually addressed during implementation of interventions, but is sometimes hampered by lack of capacity. Waste disposal is considered a priority in IRS. If not addressed, it could consequently lead to an escalation in costs incurred in clean up of the environment.

• An important next step for Zanzibar will be to strengthen disease surveillance to curb importation of malaria cases, especially from the Mainland. Community participation and education will also be strengthened to enhance the buy-in needed to sustain interventions. Volunteers who have been trained as IRS operators will continue to be maintained through modest payment incentives.

• The London School of Hygiene and Tropical Medicine (LSHTM) is currently conducting vector susceptibility tests to determine the status of resistance, if any, in Zanzibar. The ZMCP is contemplating using insecticides for IRS that are different from those used to treat the nets (non-pyrethroids), in order to mitigate potential development of resistance.

• Finally, bioassay data regarding the IRS pyrethroid insecticide currently being used in Zanzibar has shown that effectiveness lasts for nine months, hence the decision to have only one spray round in a year.

Other Comments and Observations
• Accurate communication of messages related to malaria interventions is of great importance, especially when politicians are involved. Communication minimizes potential misrepresentation of facts by different stakeholders.

• There is a need to develop country capacity to conduct problem solving in malaria control and not just program implementation. This will enable programs to correctly diagnose constraints and generate innovative and appropriate solutions. Well-designed studies and good data are crucial in tracking the success or failure of interventions and to respond in a timely manner.

Session 5. Insecticide Selection and Management of Resistance in IRS
Chair: Dr. Robert Wirtz, U.S. Centers for Disease Control and Prevention (CDC)

Presentations Narrative
Management of Pesticides in Vector Control
Presenter: Dr. Morteza Zaim, WHO

Dr. Zaim provided an overview of pesticide management. He underscored the need for adopting a life cycle approach by addressing challenges in all the key stages in the development and application of pesticides and not simply focusing on their judicious use. The key stages include manufacturing; storage, transportation, and distribution; application and use; container management; and disposal of obsolete stocks. Some challenges he highlighted include a depletion in the arsenal of safe and cost-effective insecticides; decentralization of health services; inadequate national capacity for regulation of public health pesticides, including post-registration and monitoring; and substandard, illegal, and counterfeit pesticide products. Noting the growing menace of counter-insecticides, Dr. Zaim stressed the importance of quality testing of insecticide. Important requirements for effective pest management include a life cycle approach; shared responsibility by various stakeholders; intersectoral approaches; sufficient resources supported by legislation; safe and judicious use; M&E of vector control interventions; IVM; and insecticide resistance monitoring and prevention.

According to Dr. Zaim, WHO has responded to the need for improved management of pesticides for vector control through the development of guidelines, norms, and standards; intensified collaboration with other stakeholders; mobilization of resources for strengthening national regulatory capacity; intensification of country support; promotion of harmonization, networking, and work-sharing; and promotion of judicious use of insecticides through the principles of IVM. WHO also has urged international organizations and donor agencies to include capacity strengthening for the sound management of public health pesticides within their activities, and as a mandatory component of project support to vector-borne disease control.
The latest introduction of new public health insecticide was in 1990.

**Principles of Pesticide Selection**

**Presenter:** Mrs. Rodaly Muthoni, RTI

Mrs. Muthoni focused her talk on the criteria to be used when selecting insecticides for vectoral control in predetermined areas. The WHO Pesticide Evaluation Scheme (WHOPES) has approved 12 insecticides to be used for IRS, including:

- **Organochlorines:** DDT;
- **Organophosphates:** malathion, fenitrothion, and pirimiphos-methyl;
- **Carbamates:** bendiocarb and propoxur; and
- **Pyrethroids:** bifenthrin, cyfluthrin, deltamethrin, etofenprox, lambda-cyhalothrin, and alpha-cypermethrin.

Mrs. Muthoni stressed the careful selection of insecticides as a prerequisite to any vector control program. The process includes primary criteria such as residual efficacy period, resistance in target areas, regular monitoring with susceptibility tests, monitoring changes in vector behavior, safety in area of use, and country-specific supplemental environmental assessments (SEAs). Other criteria focus on water-soluble sachets and packaging with correct dosages, timely delivery, precautions against spillage, possible representation of the insecticide supplier, and adequate preparations.

**Tracking Insecticide Resistance in Africa**

**Presenter:** Dr. Maureen Coetzee, University of the Witwatersrand and South African National Institutes for Communicable Diseases

Dr. Coetzee provided a historical perspective on the use of IRS in Africa. After successful malaria control interventions using pyrethrum, widespread use of DDT for IRS increased across Africa. However, monitoring reports began showing insecticide resistance. WHO-AFRO established the African Network for Vector Resistance to help track and manage insecticide resistance. The network has published resistance maps and created a Web-based resistance database. Within West Africa, resistance has been reported for DDT and pyrethroids in different countries, including Benin, Ghana, Guinea, and Nigeria. Dr. Coetzee concluded with the observation that insecticide resistance was an important factor in current malaria vector control efforts in Africa, stating, “The best way of managing insecticide resistance is not to have it evolve in the first place.”

**Integrated Resistance Management in the Control of Disease-Transmitting Mosquitoes**

**Presenter:** Mr. Mark Hoppé, Insecticide Resistance Action Committee (IRAC)

Mr. Hoppé began by sharing information about IRAC, a specialized agrochemical technical group formed by CropLife International in 1984. IRAC provides a coordinated industry response to the development of resistance in insect and mite pests. Overall, IRAC is involved in promotion of resistance management for sustainable agriculture and improved public health.

Insecticide resistance was itself defined as the decrease in the susceptibility of an insect population due to a genetically controlled mechanism. The aim of insecticide resistance management (IRM) is to take actions that reduce an insect population to an acceptable level in such a way that maintains the long-term effectiveness of the control interventions employed. The period for resistance to develop against newly introduced insecticides usually ranges from about 2 to 20 years. Prior to observing the field “failure” of a particular insecticide, selection pressure increases the proportion of individuals carrying the gene(s), conferring resistance in the insect population. Thus, the best time to stop the selection pressure is when resistance genes are present at a low prevalence, before field failure is observed.

The detection of resistance at low levels is possible by use of certain monitoring tools such as bioassays, the WHO diagnostic assay, bottle-based assays, and molecular methods. The ideal steps of an IRM program involve conducting a baseline study, understanding resistance mechanisms where present, choosing effective insecticides, and applying them correctly. Under ideal conditions, consecutive generations of insects and different life stages should not be exposed to insecticides with the same mode of action. In the case of disease vectors, IRAC recommends IVM, including habitat modification, education, minimizing of non-vector control sources.
of exposure, proper maintenance and calibration of spray equipment, and use of products following IRM recommendations.

Mr. Hoppé recommends that IRM be made an integral part of all vector control programs, a stewardship responsibility of the commercial companies that market vector control insecticides, and a stewardship duty of those who design and implement vector control programs.

Discussion (Q&A)

Questions
- Would it be of any benefit for the health sector to rotate IRS insecticides when similar chemicals are still being used by the agricultural sector?
- Can large-scale larviciding be a feasible approach to the management of vector resistance?
- A clarification is needed regarding the disparity between WHOPES guidelines that indicate that lambda-cyhalothrin persistence on walls is four months while manufacturers’ reports indicate nine months.

Responses
- The best way to mitigate vector resistance that could potentially originate from agricultural use of pesticides would be to forge close cooperation and research collaboration between the health and agricultural sectors. However, in the future, it may be worth exploring the development of insecticides that might only be used for vector control. Linkages between agricultural pesticides and vector resistance are nevertheless not very well understood and need further investigation.
- Larviciding has not been ruled out as a means of managing resistance. The intervention may be applicable in certain local situations. (Also see responses in Session 4.)
- Duration of insecticide persistence: The WHOPES report indicates that lambda-cyhalothrin will remain effective for at least four months but may vary according to local conditions. Continuous local monitoring would therefore be necessary to assess efficacy.

Other Comments and Observations
- On rotation of insecticides for vector control, resistance to certain insecticides has been observed in countries such as Ethiopia and Nigeria, even before vector control had been implemented. Resistance was thought to have originated from the agricultural sector.
- According to the Tanzania NMCP manager, the war on malaria could be lost in the medium to long term due to insecticide resistance; promoting larviciding and environmental management are possible means for managing resistance.
- One participant suggested creating a “pesticides for malaria venture,” modeled on the successful “medicines for malaria venture.” Such an initiative could help the malaria control community stay ahead of insecticide resistance. While there was support for such an effort, it was also observed that the best option for winning the war against malaria for now would be in making the best use of the available resources. The judicious use of insecticides was considered to be of paramount importance in any case.
- Finally, another participant speculated that high levels of resistance to DDT and pyrethroids recorded in Ghana may have been due to the
continued use of DDT in agriculture in spite of an official ban. A vector oversight committee exists in the country to, among other things, address the resistance issues.

Session 6. Safe Use of Insecticides
Chair: Dr. Michael Macdonald, USAID

Presentations Narratives

Emerging Solutions to Waste Management and Disposal in the PMI IRS Program
Presenter: Mr. Tito Kodiaga, RTI

Mr. Kodiaga opened with a definition of compliance as the “state of being in accordance with established guidelines, specifications, or legislation.” He followed by providing background and historical information on tools and procedures for compliance, mainly focusing on IRS programs currently being implemented by RTI in Africa, with support from USAID/PMI.

IRS operations must follow pesticide procedural requirements in order to safeguard the environment and human health from potentially harmful effects of pesticides. RTI complies with both the USG’s code of federal regulations and the host country government’s regulations in IRS operations. RTI uses SEAs to consider the environmental impacts of IRS interventions by taking into account environmental sustainability in designing and carrying out USAID’s development programs. Mitigating measures identified during the process must be implemented and monitored over the life of the activity. The Pesticide Evaluation Report and Safer Use Action Plan (PERSUAP) is a response to the pesticide procedural requirements and identifies actions and actors for mitigation and monitoring, including compliance with host country and private sector procedures. IRS compliance themes include insecticide transport and storage; training for spray teams in ensuring compliance; personal protective equipment; health and safety of spray operators, such as pregnancy tests for females; health and safety of communities; insecticide stock control; capacity building for host government ministries; and management of IRS wastes.

Mr. Kodiaga explained that potential pathways for environmental contamination by waste generated in IRS involve various media, including ground and surface water, soil, and food and drink storage containers. The standard procedure for disposing effluent waste from pyrethroids is to use soak pits. Charcoal and sawdust are often added to soak pits so that the chemicals do not reach the water table when it rains. Soak pits are effective in this instance because pyrethroids are biodegradable. Evaporation tanks are normally used for DDT effluents. In the case of solid waste disposal, such as packaging materials and contaminated clothing, he noted that pyrethroids are destroyed by incineration to minimize the emission of harmful chemicals. Disposal of DDT solid waste is more complex, involving shipments to appropriate incineration facilities in South Africa or Europe.

Challenges affecting efficient disposal of pesticide waste generated from IRS are lack of capacity among governments and environmental agencies for monitoring and enforcing compliance and the unavailability of incinerating facilities that meet the compliance standards.

Senegal Country Experiences in Waste Disposal Due to Pyrethroid Use in IRS
Presenter: Dr. Abdoulaye Diop, Senegal Programme National de Lutte contre le Paludisme (PNLP)/NMCP

Dr. Diop provided a detailed account of the steps followed in Senegal in disposing of liquid and solid waste associated with lambda-cyhalothrin, including supply, storage, contaminated liquid waste
management, and incineration of contaminated solid waste. The objective of the IRS waste disposal is to minimize the potential of negative environmental and social impacts to acceptable levels. More specifically, waste management aims to reduce pollution of ground and surface waters and to reduce the risk of exposure to communities and nontarget organisms. Various risks relate to the type of insecticide used, disposal methods of unused residue, cleaning equipment in the field, and solid waste disposal systems.

Dr. Diop noted that a good partnership has been developed between RTI, government partners (e.g., ministries of health, environment, agriculture, and university), beneficiary populations, and key nongovernmental organizations (NGOs) in Senegal. The multisectoral collaboration will be further strengthened to ensure that IRS contributes to a reduction of malaria morbidity and mortality without causing any disastrous effect to the environment, human population, and nontarget fauna.

**IRS in Benin: Experience in Four Epidemic-Prone Districts**

Presenter: Dr. Yacoubou Imorou Karimou, Benin Programme National Intégré de Lutte contre le Paludisme (PNILP)/National Integrated Malaria Control Program

Dr. Imorou Karimou provided background on the malaria situation in Benin. The national malaria control strategy includes the key elements of case management of simple and severe malaria, distribution of LLINs, and IRS. Larviciding is also used to a lesser extent for vector control. In the case of IRS, several past studies have demonstrated a decrease in efficacy of lambda-cyhalothrin-treated nets on *Anopheles* mosquitoes in zones of strong insecticide resistance in southern Benin. Therefore, the Centre for Entomological Research in Cotonou was contracted to conduct a study to identify the most suitable non-pyrethroid insecticide to be used for IRS in Benin. During a 4-month evaluation, three insecticides proved to be good candidates against pyrethroid-resistant *Anopheles* species. The PNILP eventually chose to use a bendiocarb or IRS despite its shorter efficacy period (4 to 6 months) compared to the two other selected insecticides. Of the two other selected pesticides, one formulation does not yet have WHOPES authorization for commercialization in public health, while the other has some side effects and a foul smell.

Dr. Imorou Karimou noted that the Benin PNILP acknowledges that IRS, if not well-managed, would pose risks to health and the environment. Safety measures include providing spray operators, drivers, washers, and storekeepers with standard protective gear, including gloves, masks, and coveralls; prohibiting eating, drinking, and smoking during work hours and inside the warehouse; constructing and using soak pits for disposal of contaminated water; incinerating all contaminated solid waste; requiring all spray operators to take baths at the end of each spray day before going home; providing specific guidelines to communities in order to prevent the beneficiary population and the surrounding environment from possible contamination of the insecticide; and training all IRS personnel on actions to take in the event of accidental pesticide contact with the skin, eyes, or environment.

An inspection report on environmental monitoring noted that IRS operations are complying with environmental management plans as well as international recommendations for the transportation, storage, and application of insecticide.

**Waste Disposal in IRS: Individual and Environmental Protection**

Presenter: Dr. Shiva Murugasampillay, WHO

Dr. Murugasampillay spoke on waste disposal best practices and regulatory mechanisms from WHO's collective perspective. He made special reference to the disposal of DDT in view of its relatively greater controversy compared to other IRS insecticides. He addressed individual and environmental protection and intersectoral collaboration during vector control since insecticides are used for pest control both in agriculture and in public health. In either case, issues of safety and efficacy are of paramount importance, though WHO-approved insecticides are safe to human health and environment, if used as specified.

IRS waste includes empty cardboard boxes and insecticide sachets, residues in pumps, wash water, and expired insecticides. Measures that help minimize waste in DDT application include ensuring that the total sachet contents are emptied into the spray pump and thorough mixing and frequent
agitation of the spray mixture in order to minimize sedimentation of DDT at the bottom of the spray tank. Progressive rinsing of the pumps and the recycling of the contaminated water are simple methods that dramatically reduce, if not completely eliminate, environmental contamination. The most effective method of disposal of solid waste from DDT and other insecticides is incineration. However, governments and the international donor community must be prepared for the financial and technological challenges of using DDT in IRS. As a way of minimizing the burden of waste disposal, certain chemical suppliers offer comprehensive waste disposal services for a nominal additional charge that can be added to the tender specification.

Dr. Murugasampillay noted that DDT should be regarded as an environmentally hazardous substance despite its relatively low toxicity, because of its long half-life (and environmental persistence). Steps to mitigate accidental contamination and spills should therefore be implemented prior to commencing spray operations. Countries using DDT should also acquaint themselves with the provisions of the Stockholm Convention on persistent organic pollutants (POPs) and the Basel Convention on prior informed consent on transboundary movement of hazardous wastes. Nevertheless, all chemicals used in malaria vector control operations should be handled with due care and in compliance with the manufacturers' label and/or container instructions. Dr. Murugasampillay highlighted important considerations for working with insecticides such as tendering, packaging, disposal of empty card boxes and sachets, progressive rinse method, and disposals of expired stocks of insecticides.

**Discussion (Q&A)**

**Questions**

- Is further innovation needed to minimize risk of environmental contamination that may arise from use of cement evaporation tanks? Could plastic sheet lining or concrete be used to reinforce the tanks?
- How can potential conflicts be avoided between different regulating bodies for pesticides, i.e., those dealing with health and agriculture?
- How should contamination issues be dealt with outside the formal sector, e.g., due to pilfering or during transportation?

**Responses**

- Cement evaporation tanks are innovative in themselves, as they have been found to work in many situations. They are, however, a work in progress. Reinforcement with a second protective layer may be needed, while flooding of the tanks during the rainy season, which has happened in Mozambique, must be addressed.
- Regarding safety guidelines for pesticides, WHO regulations are quite stringent for all IRS insecticides including DDT. A joint review of pesticide usage in different sectors would nevertheless be useful in order to identify and act on gaps, if there are any. Although there has been much speculation about diversion of DDT intended for vector control to agricultural use, there has been little documentation of evidence in connection with such activities.
- Regarding minimizing risks during transportation, drivers, in Senegal, for instance, are trained by environmental officers and equipped with the necessary kits for cleaning up any accidental spillage. Crop Life has a useful manual on transportation.
- Regarding pilferage, a training manual is being developed on the subject by PMI in order to minimize risk.

**Other Comments and Observations**

- Capacity for IRS waste disposal must be strengthened in many African countries, such as in Ethiopia, where there is extensive usage.
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of DDT. Informal suppliers in Ghana also pose a big challenge to addressing contamination. It is however worth noting that WHO-AFRO is currently supporting six countries to develop their capacity. A situation analysis has already been carried out for the different countries.

- The management of IRS programs needs to be improved all the time. Periodic evaluation of the programs is therefore essential.
- The WHOPES and PMI Web sites have comprehensive sections on disposal of IRS waste. Reference to the Web sites is recommended—http://www.who.int/whopes and http://www.fightingmalaria.gov/.

Session 7. IRS Implementation
Chair: Mrs. Julie Wallace, USAID/PMI

Presentations Narrative

Critical Steps in Implementing IRS Programs
Presenter: Dr. Robert Ssengonzi, RTI

Dr. Ssengonzi provided a concise summary of the critical steps that need to be followed in implementation of IRS. He also provided a chart showing timelines of the different activities included that are broadly categorized into three phases: 1) pre-spray; 2) spray; and 3) post-spray. The key components and activities of implementing a spray round are procurement and logistics; IRS implementation and infrastructure strengthening; safe and judicious use of insecticide during spraying; capacity building; and research, M&E, and compliance. Dr. Ssengonzi stressed the importance of involving the main stakeholders in all the key phases of the IRS operation as a way of promoting and enhancing buy-in. He also emphasized the need for effective training of spray personnel regarding handling, use, and maintenance of spray pumps. He noted that correct spraying techniques and a basic knowledge of pump maintenance increases efficiency and efficacy of spraying.

Collaboration in IRS Scale-Up: Recent Experience in Ghana
Presenter: Mrs. Aba Baffoe-Wilmot, Ghana NMCP

Mrs. Baffoe-Wilmot opened with a brief background account of the malaria situation in Ghana, noting that the disease was the top cause of mortality and morbidity in the country. By 2008, mortality in Ghana decreased by 30%, largely due to various interventions, including IRS. However, due to widespread resistance, DDT is now considered ineffective for control of malaria vectors. Ghana’s malaria control goal is to reduce the burden of the disease by 75% by 2015.

The strategy framework is contained in two documents: 1) National Malaria Control Strategic Plan 2008–2015 (revised March 2009); and 2) Integrated Vector Management Policy (revised February 2009). The framework includes key components of scaling up IRS to one-third of all districts; scaling up of ITNs, ACT, home-based care, and IPTp; selectively involving larviciding and environmental management as additional forms of vector control; and prioritizing vulnerable populations, equity, and public-private partnerships (PPPs). Mrs. Baffoe-Wilmot provided a chronology of IRS scale up in Ghana, including AGA’s work near the Obuasi mines, Global Fund for AIDS, Tuberculosis, and Malaria (GFATM) support, and PMI/RTI spray operations. She noted that a strong collaborative approach exists between the AGA and PMI programs and the NMCP, as well as with the MOH/GHS, regional health authorities, regional technical staff (e.g., malaria focal person and regional biologist), district health management teams, Noguchi Institute of Medical Research, district
assemblies, traditional and opinion leaders, and community members.

Mrs. Baffoe-Wilmot noted that effective education was behind the high IRS acceptance in Ghana. As far as possible, existing community structures and GHS health volunteer networks were used for information, education, and communication (IEC) campaigns, including the deployment of IEC implementers during the spray season; visiting targeted homes by community volunteers; radio spots and talk shows in English and local languages (e.g., Dagbani, Mampruli); and posters, signposts, information vans, and community resources (e.g., during festivals, market days). Generally, the IEC activities, as well as the social cohesion of rural communities and influence of chiefs, have succeeded in overcoming political suspicions and cultural sensitivities surrounding IRS interventions.

The Ghana NMCP and the Vector Control Oversight Committee intend to foster improved coordination among the existing programs, while also providing oversight and guidance to newly emerging partners (e.g., sanitation and larviciding companies) as the Government of Ghana will assume more responsibility with each new IRS round. The NMCP is aware that scaling up IRS nationally will place enormous demands on logistics, coordination, training, epidemiologic and entomologic monitoring, etc. However, there is optimism based on the current successful IRS implementation and proven willingness of the key partners (public and private) to collaborate selflessly and effectively in the common cause of malaria control.

IRS in Madagascar: Experiences in Central Highlands and Fringes
Presenter: Dr. Rodolphe Donatien Rakotobe, Madagascar NMCP

In Madagascar, malaria is a major public health issue. Dr. Rakotobe explained that officials hope for malaria elimination in some low-transmission areas, since the country previously reached pre-elimination stage in the Central Highlands during the 1960s. Both control and elimination of malaria are feasible in a contained island environment. The NMCP strategy has been to stratify the country into clearly-defined eco-epidemiological zones, which are then targeted with predetermined sets of interventions. The two IRS programs (GFATM and PMI) use alphacypermethrin WP 5% insecticide.

To date, Madagascar has achieved more than 90% coverage of structures and protection rate in all targeted spray districts. In 2008, 15,246 people completed training in IRS implementation, representing regional coordinators, zone and sector leaders, team leaders, spray operators, community mobilizers, health workers, storekeepers, and drivers.

Dr. Rakotobe noted that key lessons learned during IRS implementation in Madagascar include the need for epidemiological stratification for the choice of suitable strategies; involvement of all stakeholders in the planning process in order to get their full commitment; engagement of the community for the success of the IRS program in the country; and regular supervision for good performance.

Preliminary Report on IRS in the Seven World Bank Malaria Control Booster Projects in Nigeria
Presenter: Dr. Chioma Amajoh, Nigeria NMCP

Since malaria is a leading public health problem in Nigeria, Dr. Amajoh explained that IRS is used to reduce transmission of the disease by lowering the density and longevity of vector populations. IRS aims to protect 20% of the total households in the country by 2013. The NMCP’s overall goal is to reduce malaria-related morbidity and mortality by 50% by 2010, and to minimize the socioeconomic impact of the disease between 2009 and 2013. During the scale-up period, the country expects to roll out a national package of interventions, which include...
appropriate measures to promote positive behavioral change communication (BCC), capacity building, and prevention and treatment of malaria. The efforts will be sustained and consolidated in the context of a strengthened health system, which would create the basis for the future elimination of malaria in the country.

IRS in Nigeria only has occurred on a pilot scale, though there is renewed interest in using IRS more in national malaria control. Nigeria has been proactively implementing spray activities and expects the number of households covered to continue rising until an ambitious target of 6 million is achieved. The NMCP supports production and dissemination of IEC materials, including drama performances among various communities, airing of jingles on TV and radio, billboards, and an annual celebration of World Malaria Day. Capacity-building activities include training of trainers in malaria control interventions; training of health workers at tertiary, secondary, and primary health care levels; and incorporation of malaria control in curricula for nursing and medical schools.

According to Dr. Amajoh, the Nigerian vector control goals are ambitious and will have to deal with various challenges such as poverty, uneven distribution of human resources, possible emergence of insecticide resistance, inadequate financial support by policy makers at state and local government authority levels, inadequate empowerment of communities, and low uptake of new interventions. Nevertheless, Nigeria is committed to scaling up IRS implementation.

Discussion (Q&A)

Questions
- Are there any observations of a change in mosquito behavior in Ghana due to use of insecticides?
- How are RTI and PMI ensuring ownership and capacity building at various levels so that the programs they are supporting can continue even in absence of donor funding?
- What are the likely implications of poverty in the sustainability of relatively costly interventions such as IRS?
- Sustainability of IRS programs will to a large extent depend on strong political will in countries; what measures need to be taken to enhance buy-in among politicians and policy makers?

Responses
- Post-spraying entomological surveys conducted by Noguchi in Ghana have shown that there is an increased tendency of mosquitoes to rest more outdoors in areas undergoing IRS.
- Capacity building is a central theme in all RTI and PMI programs. Besides the extensive training of spray and other personnel in IRS programs, RTI is (through another USAID-funded project) conducting a survey of institutions in Africa that will be supported to build capacity in diverse IVM-related skills, including medical entomology, as well as pesticide and program management.
- Poverty is a critical factor that could negatively affect vector control initiatives due to, among other factors, lack of local resources to support activities, as well as poor compliance. However, experience in the context of IRS implementation has shown that this particular intervention contributes to the lifting of people out of poverty through local creation of employment. At a more strategic level, malaria control associated with IRS is expected to enhance economic well-being among communities in areas where the intervention is being implemented.
- Regarding buy-in of IRS and other interventions among politicians: Once there is a good evidence base, politicians are disarmed easily. As previously stated, the best marketing strategy for IRS is a successfully implemented IRS program.
Other Comments and Observations
- Tanzania is exploring the feasibility of PPPs in vector control as a way of promoting sustainability of interventions.
- If there is compelling data regarding feasibility and impact of other interventions such as larviciding, PMI and other funders will rally behind requests for more donor support of such interventions in Africa.
- Based on situational reports, Madagascar is potentially ready to enter an elimination phase for malaria. Ghana is also heading for elimination, but Nigeria is still in the early stages, although doing well.

Session 8. IRS Commodity Supply and Management
Chair: Dr. Jacob Williams, RTI

Presentations Narrative

Nuts and Bolts of IRS Supply Chain Management
Presenter: Dian Bobola, RTI (formerly)

Ms. Bobola provided a concise account of the steps to be followed in the procurement of goods or services. Such procedures are central to IRS and should be adhered to during the procurement of insecticides and personal protective equipment, among many other items and services. Supply chain management is the way a product or service is found and delivered to the end user.

The supply chain process involves four key steps: 1) field offices/end users collect information and request goods with particular specifications; 2) procurement teams source bids and purchase commodities; 3) logistics teams handle shipping and receiving of the goods; and 4) finance teams oversee budgeting and payments. Ms. Bobola noted that the earlier procurement specialists receive a request for product or service, the better; the more precise the specifications, the smoother the sourcing for the product will go. A planned or forecasted need will allow procurement specialists time to make better source selections, negotiate lower costs, and reach agreements with suppliers for timely delivery of the required goods.

Developing a Seamless Partnership in Planning, Procuring, and Providing IRS Projects
Presenter: Jean Benedict, Crown Agents

Ms. Benedict discussed Crown Agent’s role in procurement and logistics related to IRS supply chain management. Crown Agents is developing an integrated model procurement plan for IRS, including building capacity in all aspects of IRS supply chain management. Crown Agents provides integrated supply chain solutions, including procurement, quality assurance/quality control, logistics and distribution, warehouse assessment and renovation, and payroll management. They also provides security of supply, commodities, and funds and helps build sustainable supply chain systems and capacity in partner countries.

Ms. Benedict demonstrated the importance of supply chain to health programs using a “5 Rights” model, involving the right product (e.g., selection that meets specific country settings); right condition (e.g., quality assurance, secure delivery); right cost (e.g., efficiency savings through integrated procurement and logistics); right place (e.g., delivery coordination with spraying team); and right time (e.g., rainy season deadline). Crown Agents has forged strategic partnerships with manufacturers and malaria control programs, among other partners. The company is moving toward greater innovation in relation to quality and cost controls through improved planning tools.

How Do You Arrive at the Quantity of Pesticide Required for an IRS Operation?
Presenter: Dr. John Chimumbwa, RTI

Dr. Chimumbwa addressed an often-asked question regarding the quantity of insecticide required for operations. Quantity has important implications for cost, insecticide life span, and accumulation of obsolete stocks, among other things. He outlined several key points.

- Use the national response system for malaria to provide characteristics (e.g., households, ecology) of the area to be selected for IRS.
- Undertake ground-truthing of the characteristics at the district and IRS facility levels.
- Prepare comprehensive maps to show, among other features, road networks, rivers, etc., to identify suitable locations for operational centers.
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- Conduct geographic reconnaissance of the target area to determine the number of households and subsequently estimate the total surface to be sprayed.
- Quantify the amount of insecticide needed on the basis of the surface to be sprayed and other characteristics, e.g., seasonality of malaria transmission.
- Go through the standard cycles of IRS planning and microplanning.

Discussion (Q&A)

Questions
- How should quality control be ensured in procurement of IRS insecticides and equipment?
- How will the quality of DDT be regulated after China ceases production in 2013?
- Could RTI chiefs of party or others involved in IRS implementation comment on management of pesticides, particularly with regard to storage and transport?
- What is PMI’s policy with regard to existing structures for pesticide storage?

Responses
- Standard operating procedures (SOPs) for IRS insecticides have been provided by WHO. As for quality control, a dual approach is recommended whereby an independent assessment is undertaken by the relevant government authority (e.g., government chemist), and procurement is made from an internationally recognized supplier. Consideration should, to the extent possible, be given to companies that have proven stewardship and support.
- On the specific issue of DDT supply after production ceases in China, any country meeting WHO specifications can supply. However, it must be noted that while inspection of a manufacturing plant may declare it as complying with the specifications, this is no guarantee that the product is also of the right quality. Thus, a further assessment of the product may still be necessary, especially with regard to levels of toxic impurities.
- Regarding pesticide management in countries, Ethiopia produces its own DDT. At the district level, there are structures for storage, but the facilities are nonexistent at a more local level in some of the regions. In such places, temporary storage structures have to be constructed.
- PMI does not dismantle existing storage structures but rather works with the country governments to improve them and bring more efficiency, for instance in terms of protecting the operators and the environment. Ethiopia is an example of a country whose structures have been improved upon, based on prior identification of weaknesses in existing facilities. RTI helped the country improve packaging and tracking sachets.

Other Comments and Observations
- CDC has liquid and gas chromatography facilities for scientific determination of the quality of IRS insecticides.

Session 9. IRS Monitoring and Evaluation—Measuring Impact

Chair: Dr. Peter McElroy, CDC Tanzania

Presentations Narrative

IRS Monitoring and Evaluation
Presenter: Dr. John Chimumbwa, RTI

Dr. Chimumbwa defined the terms “monitoring” and “evaluation” in the context of malaria vector control, emphasizing entomological indicators. He described monitoring as a continuous process whose purpose is to correct actions through planning and re-planning. More specifically, monitoring is needed for improving actions through enhancing efficiency, performance, and quality; minimizing human and environmental exposure to IRS insecticides; determining effectiveness and controlling costs; measuring accomplishments and needs versus time; disseminating knowledge and techniques; modifying IRS implementation; justifying IRS technically, socially, economically, environmentally, and politically; and establishing priorities for resource allocation and IRS activities.

Evaluation, on the other hand, focuses on assessing the impact of IRS on malaria morbidity and mortality and the health of the people and the environment. Evaluation also assesses the overall performance of the IRS exercise against
the implementation plan. Areas to monitor in IRS include community awareness and advocacy; quality implementation; capacity development; impact on malaria vectors; cost-effectiveness; pesticide consumption, efficacy, and safety; environmental compliance; and supervision.

The indicators used by PMI to assess the status of spray operations and capacity building include IRS coverage as the percent of sprayable structures found in the target area that were sprayed; total number of people who occupy sprayed structures—not total population of an area; pregnant women and children under five residing in sprayed structures; and all cadres trained during the current IRS cycle.

Entomological monitoring is also carried out during IRS to track changes in the following parameters: vector species composition and density; insecticide susceptibility; vector behavior, especially in relation to tendency to feed and rest outdoors; seasonality of the vector; and insecticide decay rate. Vector specimens are further analyzed to determine infectivity and resistance mechanisms. PMI uses an SOP for entomological monitoring that defines minimum requirements for baseline and ongoing entomological surveillance. The SOP, among other things, specifies the types of data required and alternative arrangements for assigning responsibility to perform entomologic surveillance. However, it does not include detailed technical protocols for sample collection and analysis or interpretation of results.

**Combining Indoor Residual Spraying and Insecticide-treated Net Interventions**

*Presenter: Dr. Immo Kleinschmidt, LSHTM*

Dr. Kleinschmidt provided a comprehensive account of the effect of introducing IRS alongside ITNs in Bioko, Equitorial Guinea, and Zambezia, Mozambique. IRS and ITNs have each been shown to be highly effective methods of malaria vector control in their own right. ITNs are the most promoted vector control intervention in many countries, but net ownership and use remain generally low. IRS, on the other hand, requires complex and costly operational delivery systems. The specific objectives for an approach combining ITNs and IRS would be to reduce transmission—and hence the disease burden—more rapidly than may be feasible with one method alone; to increase overall coverage of vector control protection (e.g., when full IRS coverage is difficult to sustain); and to manage insecticide resistance by using different insecticides for IRS and for ITNs.

Dr. Kleinschmidt provided many case study examples of single versus multiple intervention results in malaria vector control. Generally, there is remarkably consistent evidence of added protection to individuals who sleep under a mosquito net or ITN in an IRS-treated house. The option of combining vector control interventions should therefore be considered in the context of sustainable scale up of malaria control. However, combining IRS with LLINs also means an increase in cost. Also, there is currently no direct evidence of postponing resistance when using different insecticides in combined interventions.

**Added Value of Combining IRS and LLINs: Results from Experimental Hut Studies**

*Presenter: Dr. Sarah Panvec-Moore, Liverpool School of Tropical Medicine*

Dr. Panvec-Moore presented findings from experimental hut studies in Tanzania to demonstrate how insecticides used for IRS and ITNs affect mosquitoes. The findings will help design appropriate tools to measure insecticidal modes of actions and infer the best combinations of insecticide-based control tools to protect households and communities. She focused on assessing mosquito feeding and resting behavior in relation to insecticides on the walls of houses, ITNs, and presence of repellents or alternative nonhuman blood-meal hosts. Adult mosquito behavior determines how vectors...
come into contact with insecticides or repellents. Knowledge of such behavior is therefore important in the development of effective strategies for control of different species of mosquitoes, including malaria vectors. Mosquito behavior, however, needs to be monitored on an ongoing basis, as it could change due to application of insecticides or changes in the microenvironment.

The study methods involved setting up experimental huts with entrance and exit traps to collect mosquitoes every four hours. As for the interventions, five huts were sprayed with IRS compounds with different modes of action and four huts remained unsprayed. Three types of LLINs were rotated between the huts so that the IRS compounds were tested alone and in combination with the different kinds. Huts without treated nets had regular nets as a minimum acceptable placebo for a holoendemic area. Dr. Panvec-Moore shared conclusions from the study and stated that the study is continuing to see how the mode of action changes through time, e.g., how reduction in irritancy may increase mosquito mortality.

Rwanda Country Experience in Using IRS and ITNs

Presenter: Dr. Emmanuel Hakizimana, Rwanda TRACPlus Malaria Unit

Dr. Hakizimana provided a brief historical overview of IRS in Rwanda. He stressed the aspects of IRS programs that need to be continually monitored, such as spray data, IEC in field operations, daily data recording, side effects and malaria cases, entomology, and environmental compliance. Lessons learned in Rwanda include the need for a strong and aggressive communication strategy—before, during, and after the spraying; the need for ownership of IRS by local leaders; the importance of involving local residents, perhaps through community health workers; the need to involve military and policeman for security sites/areas; the importance of demographic baseline data; and the need to target high transmission foci of malaria. Trends have shown a steady reduction in malaria cases in Kigali, but a lesser decline in the rural villages. The main challenges in IRS have included interference in the operations by rainfall, poor communication between IRS operators and government administration units, communities’ complaints about an apparent increase in numbers of fleas, and pressure from requests to extend the operations to other neighboring sectors not included in the original plan of implementation.

Malaria Elimination in Zanzibar: A Feasibility Assessment

Presenter: Dr. Bruno Moonen, Clinton Foundation

Dr. Moonen focused on the findings of a model that has recently been used to assess the feasibility of malaria elimination in Zanzibar. To date, Zanzibar has achieved a dramatic reduction in malaria cases, mainly through a combination of three interventions: 1) ACT; 2) provision of LLINs among pregnant women and children under five years of age; and 3) IRS using the pyrethroid insecticide lambda-cyhalothrin. The feasibility assessment framework focuses on three elements and corresponding fundamental questions:

1) Technical feasibility: Can complete interruption of malaria transmission in Zanzibar be achieved and sustained using the currently available control tools?
2) Operational feasibility: What measures must be in place to achieve the level of interventions required to reach and sustain elimination?
3) Financial feasibility: What is the cost of a malaria elimination program compared to a sustained control program? How can Zanzibar sustainably finance its malaria interventions?

A comprehensive report on the assessment will soon be available and will serve as a useful tool.
Presentations Narrative and Discussions

for decision making by the ZMCP regarding malaria elimination. It will highlight what still needs to be done in terms of operational research, strategic planning, and financing. According to the mathematical modeling used in the assessment, elimination of malaria in Zanzibar is technically feasible. The model predicts that depending on the level of effective control, malaria elimination can be achieved in 6 to 20 years, but elimination must be maintained. While maintenance of elimination is also technically feasible, the operational and financial feasibility are less obvious due to a host of major challenges.

Concerning financial feasibility, Zanzibar will need to address the challenges of unpredictable funding flows. However, regardless of whether or not Zanzibar decides to pursue malaria elimination or sustained control, consistent financing for the malaria program will have to be secured to avoid resurgence of malaria. This will require a significant change in the approach to malaria funding for Zanzibar to enable long-term financial commitments not tied to the burden of disease.

The feasibility of elimination ultimately depends on strong will—will to mobilize and sustain additional resources; will to overcome enduring systemic challenges; and will to pursue elimination of malaria above other health priorities. Dr. Moonen maintained that whether this strong will can and should be generated, and therefore whether malaria elimination should be pursued, is a decision that can only be made by the Zanzibar Government. It is hoped that the feasibility assessment will be a resource in that process.

IRS Monitoring and Evaluation—Experiences from Kagera Region in Northwest Tanzania: Beyond the Process and Toward the Impact
Presenter: Dr. Fabrizio Molteni, RTI

Dr. Molteni shared findings from the IRS program in Kagera Region, Tanzania. He provided background on the region and discussed the M&E framework. The framework for IRS in Tanzania includes monitoring performance and measuring results. Performance is monitored in terms of inputs (e.g., logistics and management of stock, including fuel, insecticide, and personal protective equipment); process (e.g., advocacy and community sensitization, training, safety); and outputs (e.g., number of structures sprayed, knowledge, and the people that have been protected). Dr. Molteni explained that the results are measured in terms of outcome (e.g., coverage) and impact (e.g., entomological inoculation rate, parasitemia, anemia, as well as morbidity and mortality).

Apart from the three core PMI indicators (IRS coverage, number of residents in structures sprayed, and number of people trained to deliver IRS), RTI also utilizes 14 additional quality management indicators and six extra indicators adopted for Kagera Region. Spray operators collect household data and disseminate it through aggregated reports to the district-level management. Consequently, it is important to keep complete, consistent, and correct data. Overall, health information management tools can be used to provide quality and timely data to monitor and evaluate the various indicators being tracked. There many ways in which output and impact data can be used to improve the overall process for IRS operations. It also is possible to set up a comprehensive M&E framework for IRS implementation in diverse settings and to be able to demonstrate achievements toward the ultimate program goals.

IRS Monitoring and Evaluation: Demonstrating Impact of the U.S. President’s Malaria Initiative IRS over the Last 5 Years
Presenter: Dr. Robert Wirtz, CDC

Dr. Wirtz summarized the impact of the PMI IRS program and highlighted some of the needs and solutions for the next 5 years. He illustrated evidence of the early impact of IRS, using data from Zanzibar. He also cited evidence of impact, showing a decline in mortality of children under five years in Ghana, Rwanda, Senegal, Tanzania, and Zambia, and a more than 50% reduction in malaria parasite prevalence and anemia in the same age group in Zambia during 2006 to 2008. By the third year, PMI implemented IRS programs in 15 African countries and approximately 24.7 million people were being protected under the program.

Dr. Wirtz also discussed quality control of insecticides and formulations (from cradle to grave concept), in view of many counterfeit products on the market, and showed a table of WHO-
recommended insecticides for IRS. He noted that capacity building for insecticide and IRS equipment evaluation can be professionally undertaken by the U.S. Navy Entomology Center of Excellence, as it has uniquely qualified personnel and equipment. New field methods mentioned in connection with quality control and field durability of vector control included the LATH residual insecticide test for IRS, and X-ray fluorometer for measuring deltamethrin in bed nets. Methods for sampling vectors include a new generation of traps and attractants, while new optical or acoustic systems for automated, remote vector behavior and identification are becoming available. Other technologies include tools for vector characterization and new repellents.

Discussion (Q&A)

Questions

- In the Bioko and Zambezia study, were anemia and entomological indicators monitored?
- Should malaria vector control programs aim for universal coverage, with at least one of the interventions or with combined interventions? When will conclusive data be available to facilitate decisions regarding single or combined interventions? There is a need for clear answers since these are costly interventions.
- What range of indicators should be used for M&E of vector control interventions and how frequently should they be measured?
- In Bioko, what will be the way forward regarding the vector control intervention to use considering their low utilization of nets?
- What side effects were found in Rwanda related to IRS?
- What would be the cost implication for malaria vector control in Tanzania, especially if DDT is used for IRS?
- In countries like Zanzibar, where the disease has been controlled and there is capacity to detect and treat cases, will governments be willing to invest additional resources to facilitate elimination?
- Does the model used to assess feasibility of malaria elimination in Zanzibar take into account the declining trends of malaria in other African countries that would normally be associated with reintroduction of cases in Zanzibar? What lessons related to importation of cases can be learned from the successful elimination of malaria in Mauritius?
- Did the feasibility assessment model used in Zanzibar take account of malaria heterogeneity?

Responses

- Measurements of the impact of single and combined interventions on anemia were not made in either Bioko or Zambezia but could still be made for the former location. There was surveillance for entomological indicators but it was not possible to relate results to individual houses and different interventions. It is expected that two new experimental studies in The Gambia and Sudan will generate results that will help to answer the question of whether to use single or combined vector interventions. The studies will measure more indicators than was the case in the Bioko and Zambezia studies.
- Current IRS programs in Africa do not confine themselves to only entomological indicators or those that are required by PMI. As for the frequency of measurement, all the indicators require some baseline measurement, followed by monthly tracking of some of them, e.g., mosquito density, or annual in the case of insecticide resistance.
- Coverage in Bioko can be most effectively achieved with combined interventions. This would lead to greater outcomes and benefits.
- Regarding IRS side effects in Rwanda, two doctors have been trained to monitor side effects, guided by conditions set by the government in 2007. So far there have been no reported severe cases of side effects. Minor effects have been noted, including eye irritations and headaches.
- On the issue of cost implications and reintroduction of DDT in Mainland Tanzania: Insecticides normally constitute 15% of the costs of IRS. DDT no longer commands the cost-effectiveness advantage of the past years, now that there are other less-controversial insecticides that are proving to have equally long efficacy when sprayed in houses. However, it will be important to continue rotating different insecticides to mitigate resistance and also minimize environmental risk.
• The feasibility assessment carried out for Zanzibar will not necessarily be prescriptive of whether the government should aim for malaria elimination or just sustained control. The government needs to undertake a cost-benefit analysis and cast future plans in the context of wider national priorities.

• The declining malaria situation in other African countries was not directly factored into the elimination feasibility assessment model for Zanzibar. As for lessons learned elsewhere, maintenance of elimination in Mauritius has been at great financial cost to the country. Such costs would be many times higher in Zanzibar due to greater chances of importation of malaria cases and a less robust health system.

• Malaria heterogeneity was taken into account in the Zanzibar model, with regard to vector behavior but not geographic variation of disease incidence.

Other Comments and Observations

• Combining LLINs and IRS will be most beneficial if it helps to increase coverage so that each area is protected by either one or the other intervention.

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Session 10. Capacity Building and Training for IRS

Chair: Dr. Jacob Williams, RTI

Presentations Narrative

Need for Capacity Development

Presenter: Dr. Rajendra Maharaj, MRC

Dr. Maharaj observed that existing tools for malaria control would go a long way in protecting populations in Africa from the disease, but a lack of capacity to implement such interventions in a sustainable manner poses a big challenge. Currently, most NMCPs have some infrastructure for program management, but at lower levels, there are many gaps, such as in program planning, entomology, spraying operations, surveillance, M&E, GIS, and management information systems (MIS).

At national and district levels, there is a need for good program managers to coordinate and oversee program implementation, as well as information officers, laboratory managers, clinicians responsible for case management, and officers responsible for public awareness. Insufficient capacity can be linked to poor salaries, heavy workload, lack of career path, and the lure of young people to urban living. National programs first would have to conduct a needs assessment at all levels in order to develop the necessary capacity. Dr. Maharaj noted that although the requirements for a successful malaria vector control program are known, implementation is often limited by lack of capacity, and programs must build the relevant capacity in nearly all countries.

Best Practices in Training Spray Operators

Presenter: Dr. John Chimumbwa, RTI

The purpose of training spray operators is to develop or improve hands-on essential skills and practical knowledge to undertake effective IRS. Dr. Chimumbwa noted that such skills include the ability to identify primary problems and solutions. The goal of the training is to build capacity of government counterparts and partners to enable them to undertake quality IRS and to ensure safe and correct application of pesticides. Trainings include policy level/advocacy workshops to raise awareness of IRS and to ensure ownership of the program; training of trainers for instructors to provide both training and technical capability for IRS; and courses for IRS spray operators. Also, specialized training should be organized for other relevant groups of personnel, including health providers, drivers, store keepers, washers, data entry clerks, IEC mobilizers, supervisors, team leaders, and pump menders.
**Discussion (Q&A)**

- IRS programs usually make a comprehensive attempt to build capacity. However, the issue of capacity building should not only be about skills but also about the number of people who are trained. There is a need for benchmarking to know the numbers needed.

- RTI, under the USAID-funded Integrated Vector Management Task Order II (IVM 2) Project, provides technical assistance resources to institutionalize best practices, conduct operational research, and strengthen the management capacities of country programs. IVM 2 complements the overall strategy of PMI in Africa. An immediate goal under this work area is to develop practical competencies in specific technical areas (e.g., entomology, pesticide management) and in the management of vector control programs (e.g., planning, implementation, and M&E). The first step in the process involves the stock-taking of existing capacities in Africa. Toward this end, a comprehensive review of current institutions and establishments involved in the training of medical entomologists and general vector control in Africa was initiated in April 2008 and is still ongoing. The institutions include universities, research institutes, public health training outfits, NGOs, private sector, and international organizations conducting entomological training in Africa. The purpose of this initial exercise is to document and prepare an electronic listing and profiles on the relevant institutions. Thereafter, a few of them will be selected for further strengthening so that they may serve as nodes for regional and national training in certain IVM skills.

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**Session 11. IRS Communication Strategy**

**Chair:** Ms. Betsy Brown, RTI (formerly)

**Presentations Narrative**

**Approaches for Community Mobilization for IRS**

**Presenter:** Dr. Josephat Shililu, RTI

Dr. Shililu introduced communication in IRS by providing a general background different communication approaches in health delivery and the advantages and limitations of individual communication methods. He used a relational diagram to show how BCC and IEC methods facilitate the core objective of communication, which is to empower and promote change, through a process of learning, sharing, and exchange of information. The importance of a good communication strategy was underscored, since the strategy is what helps to facilitate engagement processes in a structured manner. Good communication strategies comprise a situational analysis, formative research/strengths, weaknesses, opportunities, threats (SWOT) analysis, audience segmentation, strategic approach, message development, communication channels, management for the plan, and M&E.

Communication in health/IRS contributes to all aspects of disease prevention and health promotion; assists in the construction of public health messages and campaigns; helps in disseminating individual and population health risk information; elevates consciousness of health risks and solutions and reinforcing attitudes; increases demand for health appropriate services or decreases demand for inappropriate services; makes information available to assist making complex choices, e.g., selecting treatments/interventions, providers, health plans; influences the public agenda, advocates for policies and programs, promotes changes in socioeconomic and physical environments; and strengthens service provider–consumer relations.

On the specific issue of IRS, messages must be communicated in an organized and systematic manner, with emphasis on key information. Topic areas to be covered when sensitizing communities to IRS issues include overview of the IRS program;
knowledge of malaria; knowledge of IRS; and key messages to households before, during, and after spraying, including how to deal with side effects.

**IRS in Benin: Experience in IRS Communication**

**Presenter: Mr. Seydou Doumbia, RTI (formerly)**

In Benin, RTI and the MOH have developed an IEC strategy plan; developed IEC materials; recruited and trained 253 community mobilizers; utilized five community radio stations to broadcast IEC messages and radio spots in local languages about IRS benefits and precautions to take before, during, and after spraying; worked with existing community structures, including chiefs of villages, traditional and religious leaders, local council members, heads of district, mayors, heads of townships, and members of associations (mostly women's associations); posted banners and posters in the villages being sprayed; deployed IEC mobilizers in each targeted area to go door-to-door to inform the households about the benefits of IRS and the precautions to be taken before, during, and after IRS. IEC materials developed include brochures, leaflets, CDs with IRS songs in local languages, posters, IRS information bulletins, and stickers.

The main success factors of the IRS program in Benin include close collaboration with the NMCP and Ministry of Environment; proactively communicating objectives and results; keeping partners and local authorities informed and updated on IRS progress; building effective relationships with all in-country partners; implementing the program on time; compliance with environmental requirements; and building capacity and transferring operational responsibility.

Mr. Doumbia noted that IEC lessons learned include the following:

- The need to balance ratios between operators and supervisors;
- The importance of regarding household IEC as an integral component of IRS;
- The necessity of using existing traditional communication channels;
- The need to keep partners and local authorities informed and updated on IRS activities using IRS information bulletins; and
- The importance of ensuring involvement of local authorities and community leaders at start-up.

IRS is a military-like operation, and strict discipline among the team members is therefore vital. IRS IEC is only effective with adequate planning and preparatory periods.

**Zanzibar Country Experience: Development of National Malaria Communication Strategy**

**Presenter: Dr. Datius Rweyemamu, University of Dar es Salaam**

Dr. Rweyemamu presented an overview of the Zanzibar malaria communication strategy, which covers all malaria control interventions, and therefore is not specific to IRS. The Zanzibar communication strategy is linked to the wider context of global health and is expected to contribute to achievement of five out of eight Millennium Development Goals. The strategy is also aligned with national development programs on poverty reduction and Tanzania health sector reform. Specific objectives of the national malaria strategic plan are to prevent malaria infection; to promote IVM; to ensure prompt and effective case management; to prevent and control malaria during pregnancy; to provide effective epidemic preparedness and response; to encourage community involvement and participation; and to assess the potential for sustainable elimination.

Dr. Rweyemamu outlined the communication strategy that defines the approaches to be used in communicating messages to audiences and to identify the capacity building needs and functions from national to individual levels. The main partners in the development of the malaria control communication strategy and malaria control in general have included Italian Cooperation, the GFATM, and PMI, through RTI.

Lessons learned during the implementation of the Zanzibar communication strategy include the following:

- The decline of malaria goes hand in hand with emergence of new demands for behavior change.
- When malaria epidemiology changes fast, the communication strategy requires regular revision.
• Involvement of local, national, and international partners in developing the communication strategy increases sense of ownership by all partners.

• Developing a communication strategy that integrates several interventions is important for countries that are experiencing a downward trend of malaria prevalence.

IRS Communication Strategy: Mali Country Experience
Presenter: Dr. Klénon Traoré, Mali NMCP

Dr. Traoré shared the IRS communication strategy for Mali, which incorporates advocacy, social mobilization, and BCC. Communication interventions prior to spraying campaigns include advocacy; developing and printing of IEC/BCC tools for IRS (spots on television and radio); identifying and training of relais (community workers) and spraying operators; training medical staff; organizing a sensitization day for community leaders in the selected IRS sites; and organizing a community mobilization day at the district level. Communication during the spray campaigns includes dissemination of television and radio spots on IRS in targeted districts and visits to homes by community workers. Finally, interventions after spraying include organization of workshops on campaign results at district and national levels and dissemination of IRS information on television and radio, mainly to dissuade people from conducting maintenance work for six months (e.g., painting the walls).

In Mali, there is a strong acceptance of IRS by the community through IEC/BCC interventions. The MOH (e.g., NMCP, regional level, reference health center, and community health center) also effectively participates in the micro-planning, preparatory phases, monitoring, and supervision of the campaign.

IRS Communication Strategy: Uganda Experience
Presenter: Mr. Michael Okia, Uganda NMCP

The Uganda NMCP reintroduced IRS on a large scale in the country in 2006, after more than 40 years. Since there was no institutional memory of IRS, awareness of the intervention was very low, so the program needed to be guided strategically on how to handle the process of introducing IRS amicably without losing the community's trust. Mr. Okia explained that despite considerable support for IRS in Kabale District, community misconceptions and concerns included allegations that the IRS insecticide was not safe; that the fact that you could not see the chemical on the walls meant that the spray operators used only water; that there was a sinister motive behind selecting certain communities for IRS and not others; and a lack of awareness about how households were to prepare for IRS. Furthermore, ongoing public debates caused misconceptions due to confusing IRS with DDT; many people were not aware that less controversial chemicals were also effective for IRS.

Mr. Okia explained that an IRS communication strategy was therefore developed to guide IRS communication to increase the uptake and acceptance of IRS; address critical information gaps regarding the effectiveness of the intervention (myths, misinformation, and misconceptions about IRS); allay community fears and concerns about the safety and efficacy of insecticides used for IRS; and build confidence in communities to fully participate in the exercise. The communication strategy considers the generic communication needs applicable to all spray exercises, and the unique communication issues raised by implementing IRS with DDT, and utilizes a multimedia approach.

Challenges facing IRS in Uganda have included suspicions and politicization of the new IRS program, e.g., communities raised concerns in various areas
of the country, and misinformation about and opposition to DDT use by environmentalist and organic farmers/processors.

Session 12. New Technologies and Future Directions
Chair: Dr. John Chimumbwa, RTI

Presentations Narrative

The Application of GIS for Malaria Control
Presenter: Dr. Michael Gebreslasie, MRC
Dr. Gebreslasie provided background information on GIS and its application to malaria control and IRS. GIS is a system for capturing, storing, editing, integrating, managing, displaying, querying, analyzing, and distributing geographic data. To perform different types of health-related analyses, it is possible with GIS to overlay and integrate data such as population data, socioeconomic data, geodemographics and lifestyle data; environmental and ecologic data; topography and hydrology data; land-use and public infrastructure data.

Application of GIS for mapping malaria incidence/prevalence involves mapping these disease variables over a geographic area, allowing examination of past trends, as well as the present situation. GIS is also used for mapping the population at risk and stratifying risk factors. Dr. Gebreslasie explained that the goal of mapping the associations between malaria cases and environmental variables is to determine if any relationships exist between malaria cases and temperature, rainfall, land use-cover, elevation, demographics (age and gender); or population movement, breeding sites, and control programs. GIS application for malaria risk modeling is future-oriented and can predict areas of malaria risk. Regarding IRS, GIS can help in planning interventions for malaria vector control by defining the IRS targeted area, mapping and enumerating existing targeted structures, quantifying insecticide requirements, and reporting on the intervention activities.

Challenges in using GIS during malaria control work have included lack of accurate data on the disease and how it is reported; nonreporting of case data due to technical problems; difficulties in linking the case data with the GIS systems; the spatial scale of environmental data such as vegetation, topography, land use, demographic data; and inappropriateness of some remote sensing data for many types of locality/village level analyses. In addition, Dr. Gebreslasie noted, at times, weather data are not available at the scale needed for analysis, and some parameters relevant to malaria transmission have not been measured at all, such as wind speed and direction. Challenges could also be related to the technology, or the unavailability of specific computer hardware and GIS software and training, for example. Dr. Gebreslasie suggested a number of possible solutions for challenges with data, technology, and methodology issues.

Zanzibar Malaria Early Epidemic Detection System
Presenter: Ms. Claudia Anderegg, RTI
The Malaria Early Epidemic Detection System (MEEDS) project aims to develop and implement a health facility-based MEEDS for prompt detection of sudden increases in Plasmodium falciparum transmission in Zanzibar. Ms. Anderegg explained that the specific objectives are to facilitate quick reporting of aggregated data (age groups); to detect timely sudden increases in malaria transmission; to inform programmatic decision making; and to advocate for malaria control resources. MEEDS-trained staff use a booklet to record specific indicators, submit the data to a central server by cell phone, and receive a confirmation code. The malaria case register and weekly/quarterly reports provide feedback to health facilities and serve as a way to monitor malaria cases and respond to any possible epidemics. Challenges of MEEDS include difficulties in training new primary health care staff; technical difficulties with cell phone networks currently in use; and RDT stock-outs.

Innovative Payment Schemes for Temporary Workers: The Tanzania Experience
Presenter: Dr. Mahdi Mohamed Ramsan, RTI
Challenges in paying workers involved in IRS operations in many countries include the large number of workers in field operations, spray operators’ inability/ineligibility to open bank
accounts, and accountability and risk associated with handling large cash amounts in remote areas. Dr. Ramsan highlighted the measures undertaken in Tanzania to address these challenges, including coordinating with local banks to open bank accounts for all spray operators in Zanzibar and Mainland Tanzania, as well as submitting the payroll to the banks to transfer payments to respective individual bank accounts, within one day. Potential future innovative payment schemes might also be able to apply phone technologies.

New Products for Prevention
Presenter: Dr. Rajendra Maharaj, MRC

Dr. Maharaj stated that IRS is the most widely practiced vector control intervention in southern Africa since it has the greatest impact in a relatively short time. However, over the past decade, there have been increasing levels of vector resistance to most groups of insecticides, so investments in new products for vector control are needed. Dr. Maharaj conducted a literature survey to find out which new products are coming to the market, such as different formulations of pyrethroids and carbamates that have been developed to offer targeted populations the same level of protection that has been provided by DDT, up to nine months.

Other highlights of current innovative processes and products include potential new active ingredients for insecticides, longer lasting formulations, and house modification such as window screens.

New Directions: Exit Plan and Sustainability—Economic and Ecological
Presenter: Mr. Charles Llewellyn, USAID/Tanzania (formerly)

Mr. Llewellyn opened with a disclaimer that he was neither an epidemiologist nor a medical professional, health economist, or entomologist, and that views expressed in the presentation were his own, not USAID’s, nor PMI’s. He defined sustainability as the probability of an intervention to continue to meet program objectives after external donor funding ends. He compared the cost implications of IRS to those of other interventions including LLINs, ACT, and RDTs, IPTp, and possibly a malaria vaccine in the future.

Following are the comparative estimated costs of achieving malaria control objectives using IRS and other common interventions that he presented:

- IRS: US$2.15 to US$7.00/per person per year (py)
- LLINs: US$8/sleeping space/3 years = US$1.33/py
- ITNs: US$4/sleeping space/2 years = US$1/py
- Drug treatment: US$1/fever case + $1.50/treatment (declines as malaria is controlled; domestically produced ACT cheaper)
- IPTp: very cheap with domestic SP, but only protects 4% of population US$4 to US$10 py

Based on the cost information, Mr. Llewellyn argued that it would be possible to achieve nearly all the malaria reduction objectives with donor funding, but he speculated that when malaria stops killing children, the donor funding will go elsewhere. He estimated that there is only a 10-year window that remains before resources for malaria run out. In conclusion, he stated that

- IRS, being the most expensive intervention, is not sustainable in most African countries;
- IRS should be used as a tool while external donor financing is available, as a “knockdown” strategy;
- Domestic IRS capability should be retained for focal malaria vector control;
- Funds should then switch to more sustainable interventions such as domestic bed nets and ACT; and
- Costs matter.
Real-time Collection and Reporting of Mosquito Larvae and Adult Abundance
Presenter: Dr. Prosper Chaki, Ifakara Health Institute
Dr. Chaki used the Dar es Salaam Urban Malaria Control Programme as an example of an innovative approach to dealing with vast amounts of data generated by the project on a frequent basis. Challenges to the program’s effectiveness include maintaining data quality, coverage, timeliness, need for rigorous external quality control, and flexible surveillance systems. He described a flexible structural framework for data collection and synthesis, including how it has been used to improve quality and reporting time of data. The framework also allows more rapid responses of program managers on a real-time basis.

Malaria Control and Elimination Cross-border Malaria Initiatives
Presenter: Dr. John Govere, WHO
Dr. Govere described several relatively successful cross-border malaria initiatives in southern Africa to underscore the importance of regional collaboration in malaria control. The rationale for malaria control or elimination through cross-border collaboration follows the logic that a regional problem requires a regional solution.

People, mosquitoes, and parasites commonly move across borders, and drug and insecticide resistance strand borders. Intercountry disparity in availability and quality of health-care services should be addressed through collaboration. As countries move to universal coverage and malaria elimination, collaboration in border areas is crucial; cultural similarities of communities at border areas provide a good opportunity for collaboration.

Dr. Govere noted that regional collaboration can facilitate harmonizing of protocols, guidelines, and standards; harmonizing of strategies, case management, vector control, IEC and surveillance; synchronizing the timing of interventions delivery across borders; standardizing services, information, and staff training across border areas; sharing resources and expertise where possible; and mobilizing regional resources.

Current opportunities for cross-border collaboration include increased global and regional support for cross-border initiatives; existence of cross-border collaboration success stories; presence of RBM harmonization success stories; WHO harmonization of malaria treatment and prevention strategies; and recent commitments by certain countries to move from malaria control to malaria elimination.

Examples of cross-border malaria initiatives are mainly among the countries of the Southern African Development Community, including the Lubombo Spatial Development Initiative, the Trans-Limpopo Malaria Initiative in South Africa and Zimbabwe, the Trans-Zambezi Cross-Border Malaria Initiative, and the Trans-Kunene Malaria Initiative.

Range of RTI International’s Vector Control Activities
Presenters: Dr. Jacob Williams and Ms. Mary Linehan, RTI
Dr. Williams and Ms. Linehan discussed RTI’s lead role in PMI-supported work in vector control and neglected tropical diseases (NTDs). The goal of a vector control program is to establish the most efficient, cost-effective, and sustainable program that is responsive to changing local disease eco-epidemiology and that maximizes impact on disease. There is a need, therefore, to continually reorient operations to changing eco-epidemiology and operational settings.

The range of vector control activities that RTI is involved in includes country capacity strengthening—entomology, infrastructure, planning and management competencies; country strategy/policy development (e.g., national IVM strategies, pesticide policies); operational research; development of critical guidance documents and manuals (including needs assessment tool kits, IVM handbook in collaboration with WHO, leading global efforts to harmonize training curricula and institutionalize training courses/videos); review of vector control training capacity in Africa. Among RTI’s future priorities for vector control are co-deployment of IRS-LLINs; field evaluation of options to address increased exophagy and exophily; multidisease vector control delivery vehicles; acceleration of capacity building or core technical and management competencies; and support in reorienting of country programs and vector control policy advocacy.
The USAID-funded NTD Control Program involves mass drug administration (MDAs) for NTDs that can be eliminated or controlled; implementation by governments through health campaigns and school-based distribution; and scale up to national level to treat at-risk populations. The NTD Control Program has been highly cost-effective, with a total of 43 million people treated with over 290 million treatments, costing US$40 million during the first 3 years. Burkina Faso, Ghana, Haiti, Mali, Niger, Sierra Leone, southern Sudan, and Uganda are countries participating in the NTD Control Program, with current scale up to Bangladesh, Nepal, and Togo.

Dr. Williams and Ms. Linehan explained that the Obama Administration is committed to the control of NTDs through the Global Health Initiative, with a focus on elimination, especially of lymphatic filariasis. The program is expected to scale up to 30 countries globally; focus on MDAs, research, drug development, IVM, and morbidity control; build on experience (including Asia), linking malaria and NTD vector control; and find ways for integration to achieve cost-efficiencies, maximize reach, and build and reinforce capacity of country implementers.

Discussion (Q&A)

Dr. Govere sharply disagreed with Mr. Llewellyn’s exit plan, which suggested that IRS is not sustainable in Africa. He emphasized that IRS was sustainable and that one needed to look toward southern Africa to clearly see the impact of the intervention and governments’ commitment.

Closing Remarks

Mr. Lon E. (Bert) Maggart, executive vice president of RTIs International Development Group, thanked the participants and expressed his satisfaction with the topics highlighted at the conference and the current partnership in malaria control in Africa. He reiterated RTI’s commitment to the goal of malaria elimination as a way to improve the human condition.

Dr. Jean Baptiste Tapko, the Tanzania WHO Representative, thanked the organizers for having chosen Zanzibar to host this important meeting. He observed that WHO Director General Dr. Chan had visited Zanzibar at an earlier date to learn from the country’s success in malaria control.

Mr. Robert Cunnane, USAID Tanzania Mission director, observed that despite the complexity of malaria, there is a good chance of successfully fighting the disease in light of the efforts being made to link science with what was happening on the ground. He, however, cautioned that the necessary resources would have to be sorted out in a timely manner in order to ensure sustainability of control programs.

Dr. Mohamed Saleh Jiddawi, principal secretary, Zanzibar MoHSW, thanked the following organizations and individuals: RTI; PMI; USAID; WHO; all the presenters and attendees; and the management of the Kempinski Hotel in Zanzibar. He closed the session on the positive note that malaria is preventable, treatable, and can be eliminated.
PART 2
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The Epidemiological Context of Vector Control in Africa

History of Vector Control Technology
Before 1940, malaria vector control was locally specific and opportunistic, not always feasible, and restricted to areas of special economic or social importance. Since 1940, there have been two main technological revolutions: 1) indoor residual spraying (IRS); and 2) insecticide-treated nets (ITNs), both of which have triggered hopes of malaria elimination or eradication. IRS made effective large-scale malaria control possible for the first time. Among its advantages was the fact that it could be rolled out to the many scattered rural settlements where most people lived. However, IRS was still too logistically demanding for most of Africa (see Figure 1 and 2).

Malaria Epidemiology and the Role of IRS

![Figure 1. Malaria transmission patterns across geographic regions in Africa](image)

<table>
<thead>
<tr>
<th>Rural Lowlands</th>
<th>Northern Fringe and Sahel</th>
<th>Horn of Africa</th>
<th>Southern Africa</th>
<th>Highlands</th>
<th>Urban Areas</th>
</tr>
</thead>
<tbody>
<tr>
<td>Most of tropical Africa, Forest, and savanna. Special issues in irrigated areas</td>
<td>Mauritania, Senegal, Mali, Niger, Chad, northern Sudan</td>
<td>Djibouti, Eritrea, Ethiopia, Somali</td>
<td>Botswana, Comoros, Madagascar highlands, Namibia, South Africa, Swaziland, Zambia, Zimbabwe; southern Angola and Mozambique</td>
<td>Land at or above 1000m ASL</td>
<td>Cities, towns, and large villages</td>
</tr>
<tr>
<td>Transmission during most months of year, sometimes intense. Prevalence of infection at saturation levels</td>
<td>Transmission confined to a short season (may be intense)</td>
<td>Complex epidemiology: Epidemic-prone in populated highlands. Arid areas malarious near water. Some stable endemic areas. Short season</td>
<td>This is the southern fringe of malaria—a large proportion of the at-risk population is exposed to unstable malaria</td>
<td>Limited seasonal transmission; epidemic prone</td>
<td>In hospitable to Anopheles</td>
</tr>
</tbody>
</table>

![Figure 2. Vector control methods for malaria prevention in Africa by geographic stratification](image)

<table>
<thead>
<tr>
<th>Method</th>
<th>General Comments</th>
<th>Rural Lowlands</th>
<th>Northern Fringe and Sahel</th>
<th>Horn of Africa</th>
<th>Southern Africa</th>
<th>Highlands</th>
<th>Urban Areas</th>
</tr>
</thead>
<tbody>
<tr>
<td>IRS</td>
<td>Generally appropriate</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Requires substantial capacity for program management and logistics. Insecticide resistance is absent from most places, but it is a problem in some locations.</td>
<td>Very effective and powerful. IRS probably has stronger short-term impact than ITNs, depending on local balance among vector species and their behavior. Usefulness of IRS in these areas is limited mainly by the prospects for sustained and large-scale coverage, and in the long run, by fears of evolution of resistance.</td>
<td>Very effective. Impact helped by short rainy season, but may sometimes be constrained by exophilic behavior of An. gambiae complex.</td>
<td>Impact helped by short rainy season. Targeted IRS is still the mainstay for malaria control in epidemic-prone areas of Ethiopia. In a few areas, vectors and people are often not in houses.</td>
<td>The mainstay of malaria control, both now and in the past. Malaria is suppressed over large areas by carefully targeting high-risk communities. Resistance management required in some areas (e.g., An. funestus)</td>
<td>Rapid response IRS to interrupt epidemics. Targeted spraying for prevention. Barrier IRS in cordons sanitaires around highlands can protect upland population.</td>
<td>In cities, IRS is used in the periphery as a barrier to prevent vector infiltration from surrounding rural areas: IRS is not appropriate for urban centers, where houses are numerous and breeding sites are few.</td>
<td></td>
</tr>
</tbody>
</table>
History of IRS Versus ITNs in Africa

During the 1950s and 1960s when IRS was popular globally, the intervention was never widely used throughout sub-Saharan Africa. There were large-scale programs in southern Africa and across the Horn of Africa, and smaller efforts in various economically important locations, including Zanzibar. However, the great majority of rural populations exposed to hyper- and holo-endemic malaria transmission remained completely unprotected by any effective form of vector control. This was mainly because of capacity constraints, more than country or place-to-place variations (see Figures 3 and 4).
Finance

IRS requires a quasi-military degree of organization, logistics, and infrastructure, and in most places this simply did not exist. ITNs were developed because of the definite need for a new technology that was easier to implement, but was approximately equally effective to IRS. Thus, ITNs took over as the dominant technology in locations where IRS either had never started or had stopped when malaria was no longer a priority. Countries with strong and very effective IRS programs in the 1980s have continued on with the same technology to date. Because of their superior overall track record with IRS, they resented the suggestion that they should switch to ITNs.

The Global Malaria Program (GMP)/Vector Control Program (VCP) Agenda

The GMP/VCP has a three-pronged agenda, focusing on 1) universal coverage, 2) pyrethroid resistance, and 3) vector control capacity.

Agenda 1: Universal Coverage

ITN universal coverage must take into account the life span of ITNs and country and between-site variation in the rate of physical wear.

The assumptions while using nets as an intervention are that all long-lasting insecticide-treated nets (LLINs) last three years; there are no other types of nets being used; and 3-year term campaigns to replace ITNs give 100% unbroken coverage.

It must, however, be recognized that some nets last much less than three years; some much longer. There are country-to-country or place-to-place variations in condition, life span, and efficacy of nets. Other nets, including old LLINs and new commercial untreated nets, remain in circulation/use.

Agenda 2: Pyrethroid Resistance

Modern malaria control is critically dependent on pyrethroids. It is important to recognize that susceptibility to insecticides is a finite resource, and it will be depleted one way or another. For instance, knockdown resistance (kdr) has been observed in a number of areas. Kdr can easily be detected by polymerase chain reaction, but other new resistance mechanisms may be more threatening. It is therefore important to know, among other factors, whether IRS selects more for resistance than ITNs. While the best form of resistance management may be to “find a new molecule,” financial incentive is often lacking. It should be noted that vector control costing assumes that one new class of insecticides equals US$200 million.
**Agenda 3: Vector Control Capacity**

Building research-driven vector control capacity is essential because it helps answer important questions, such as: Why do the same actions achieve the expected coverage here but not there? Why does the same coverage achieve the expected impact in one location but not another?

The following three phases of vector control precede malaria elimination:

1) **Attack**, using IRS and ITNs;
2) **Pre-elimination**, involving snuffing out remnant foci using fire brigade response for outbreaks (e.g., China, Sri Lanka); and
3) **Consolidation**, reducing receptivity through improved environment management, housing, and land use (e.g., Thailand).

In terms of reducing receptivity, recent declines in malaria reported in Africa could be a result of improved housing and socioeconomic development such as in Thailand. This, and community participation in vector control, is what may eventually make it feasible to eliminate the disease in Africa.

**Topical and Recurrent Issues**

In the fight against malaria, there are many two-sided issues, both topical and recurrent, that must be addressed, such as the following:

- Use of drugs versus vector control;
- Use of horizontal versus vertical malaria control approaches (e.g., primary health care, community participation, decentralization, and technical core);
- Use of DDT versus other chemicals;
- Use of different vector control interventions: IRS versus ITNs (technical consensus must be reached);
- Use of new tools versus better deployment of existing tools;
- Use of campaigns versus routine systems (e.g., ITNs);
- Quick wins versus sustainability (e.g., ITNs);
- Goals aimed at eradication versus control: Elimination is considered good outside Africa, but instils false optimism for Africa; and
- Other “noise” such as silent spring, cancer stories, polychloro biphenyls, Stockholm Convention on Persistent Organic Pollutants, Precautionary Principle, and the World Health Organization’s role

**Elimination or Eradication?**

Several careful trials conducted in 1955–1975 showed eradication to be “not technically feasible” in Africa. This probably still remains true. Elimination, however, is a euphemism for eradication. The concept is sensible with lymphatic filariasis, which has extremely long life cycle; Chagas disease (zoonosis); or malaria in Philippines (i.e., serial local eradication in one island after another). However, “eradication” is not appropriate for malaria in hyperendemic Africa.
Indoor residual spraying (IRS) is the spraying of residual insecticides on interior surfaces of human habitations and other structures that are potentially used as day-time resting places for vector mosquitoes. IRS and long-lasting insecticide-treated nets (LLINs) are the two most widely used and most effective vector control interventions for malaria control in sub-Saharan Africa. IRS is the most standardized and well-defined vector control intervention. It aims at community protection from disease transmission through high levels of coverage (≥ 80%), but has an insignificant role in personal protection with low levels of coverage. IRS also reduces vector density through a knockdown effect and can reduce human-vector contact, depending on the behavior of the insecticide used. Through these effects, IRS is proven to have a quick impact on malaria transmission.

Sub-Saharan Africa carries the highest malaria burden. Effective control of the disease requires application of combined interventions that are intensive and extensive to significantly impact disease transmission. IRS is applicable and effective in all epidemiological settings, as long as considerations are taken, such as vector behavior, susceptibility, and insecticides used; human behavior and activities; environmental factors; and overall feasibility and sustainability of the program. Until 2004–2005, the intervention was applied mainly in seasonal and low-transmission areas of the region, specifically in southern and eastern Africa, to suppress seasonal transmission in order to prevent and control epidemics. Recently IRS was used to target malaria elimination in a number of countries.
Over the past few years, opportunities that have contributed to the expansion of IRS include recognition of IRS as an important malaria control strategy by programs and partners, strong commitment from governments, and availability of resources. However, this encouraging progress is not without challenges. Vector resistance to insecticides is a threat for IRS, as it is for all other insecticide-based interventions. As many countries introduce and expand IRS, critical operational issues such as quality, coverage, and timeliness are becoming challenges in the face of the limited human and technical capacity of malaria control programs. For countries that have successfully expanded IRS with partner support, consolidating efforts and ensuring national capacity building and strengthening systems have been sources of constraint.

It has been evident for some time that IRS plays a decisive role both in low-transmission areas, where elimination can be envisaged, and in areas of moderate or intense transmission, where significant reduction is the immediate objective in order to decrease malaria levels so they no longer pose serious health problems. Consequently, interventions are expected to continue expanding both in low- and high-transmission areas, as countries endeavor to push malaria to pre-elimination/elimination, to achieve universal net access, and to significantly reduce disease transmission.
Partnerships for Vector Control: Learning from the Past, Looking Forward

Dr. James Banda
Roll Back Malaria Partnership Secretariat

Abstract
Vector control scale up, including both long-lasting insecticide-treated nets (LLINs) and indoor residual spraying (IRS), can dramatically reduce malaria morbidity and mortality. At high levels of utilization (greater than 80%), they provide significant community protection against mosquitoes and other disease-carrying insects. The current Roll Back Malaria (RBM) Global Malaria Action Plan (GMAP) aims to reach universal coverage with all malaria control interventions by 2010 and prepare the way for elimination of the disease. This strategy includes comprehensive scale up of both LLINs and IRS. Achieving the target of a 50% reduction in deaths from malaria means that 80% of all populations at risk should have access to and employ effective malaria treatments where appropriate.

Although the RBM Partnership is engaged fully in supporting the GMAP’s implementation, there are ongoing challenges to success that only a robust partnership can address. For example, procurement of vast quantities of nets and insecticides can be complex. Other issues—such as increasing insecticide resistance, acceptance of IRS at the household level, effective use of LLINs, and ongoing debates over DDT and other insecticides—mean that a range of stakeholders and implementing partners must agree on approaches and strategies to overcome bottlenecks, address behaviors, and secure the global political commitment to adequately support this essential aspect of malaria control.

Where We Come From: Learning from the Past
In the early 20th century, malaria was endemic in most countries, with 90% of the world’s population affected by the disease. The beginning of successful efforts to reduce malaria began in 1945 through the use of DDT, e.g., the Sardinian Project in 1946–1950. In 1955, the Global Malaria Eradication Campaign was launched, focusing on vector control using DDT. Malaria was rapidly eliminated in southern Europe, parts of northern Africa, and the Middle East, but insecticide-resistant mosquitoes and drug-resistant parasites began to emerge. Toward the end of the 1960s, funding began to diminish and control efforts were relaxed. As a result, malaria resurged in many areas, such as Sri Lanka. Figure 1 shows the evolution of malaria mortality rates based on different interventions in the 20th century.

We can draw many lessons from past malaria vector control efforts. First, continuous advocacy efforts are needed to ensure high political commitment and ongoing funding. Once begun, indoor residual spraying (IRS) needs to be conducted regularly, alternating insecticides to reduce resistance. Other key success factors include strong coordination at regional levels, alignment of different sectors at national levels, scale up of systems for monitoring resistance to pesticides, and continuous investment in research and integrated vector management.

Between 1998 and 2008, malaria vector control efforts began to significantly change at an international level. The Roll Back Malaria (RBM) Partnership was founded in 1998 by four partners—the World Health Organization (WHO), United Nations Children’s Fund (UNICEF), United Nations Development Programme (UNDP), and World Bank. Today, RBM encompasses all the key actors...
in malaria control and elimination. RBM partners built a solid political commitment at national and international levels and renewed global interest in malaria prevention. International funding to fight malaria increased nearly ten-fold over a decade to US$1.1 billion in 2008. The RBM scale-up strategy showed sharp reductions in morbidity and mortality in Eritrea, Ethiopia, Rwanda, Tanzania, Zambia, and other countries. The Global Malaria Action Plan (GMAP 2008) provided a coordinated road map for malaria control and elimination worldwide.

Today, RBM rallies hundreds of actors from multilateral organizations, such as UNDP, UNICEF, and nongovernmental organizations (NGOs), such as Population Services International, PATH, and the Red Cross. RBM also includes private sector corporations such as Bayer, ExxonMobil, and GlaxoSmithKline; foundations such as The Bill and Melinda Gates Foundation and The William J. Clinton Foundation; donor countries through the auspices of agencies such as U.S. Agency for International Development (USAID), U.K. Department for International Development (DFID), and Australian Agency for International Development (AusAID); and research and academic constituents such as the U.S. Centers for Disease Control and Prevention (CDC), British Medical Journal, and Malaria Journal. The partnership brings together formidable expertise, infrastructure, and funding that enable the global fight against malaria.

Where We Are: Implications for Vector Control

To date, the global malaria burden has been reduced by 50% from 2000 levels, to less than 175–250 million cases and 500,000 deaths. Some 80% of malaria patients are diagnosed and treated with effective antimalarial treatments. In areas of high transmission, a significant number of pregnant women receive intermittent preventive treatment (IPTp).

Presently, the GMAP focuses many actors on a single strategy. The targets include the following:

- By 2010, achieve universal coverage for vector control in endemic areas by ensuring that 80% of at-risk populations are using locally appropriate vector control methods, such as long-lasting insecticide-treated nets (LLINs), IRS, and, in some settings, other environmental and biological measures;
- By 2015, reduce malaria-related deaths to near zero; and
- Beyond 2015, sustain gains and work toward elimination.

The GMAP calls for funding levels of roughly US$5 billion annually for control activities and around US$1 billion annually for research and development efforts.
Although the GMAP sets high targets, there are many tools available for the scale up of malaria vector control such as the following:

- For prevention efforts: LLINs, one treated net for every two people per household; IRS, routine spraying where appropriate; and IPTp, every pregnant woman living in high-transmission settings receiving at least two doses of an appropriate preventive drug during her pregnancy.
- For case management: Prompt parasitological diagnoses by microscopy or rapid diagnostic tests (RDTs); and treatments with effective drugs within 24 hours after first symptoms appear.

Among the tools, LLINs are among the most effective for preventing malaria transmission. High coverage and regular use can reduce all-cause mortality rates in children under age five by nearly 20% in malaria-endemic areas. IRS is also a highly effective tool, especially in high-transmission settings and in managing epidemics. Environmental management and larviciding can be effective and cost-efficient in some areas. Such techniques have been used successfully in India, Mexico, and Central America. These tools will aid in the fight to control and eliminate malaria in this century.

The Way Forward: GMAP Implementation

Despite the many types of interventions, there still remain challenges to reaching the GMAP targets. The gap in access to some of the interventions for vector control is a major obstacle in the fight against malaria. In 2006, there were only 82 million nets in use, nine times less than the projected need for 2010 (see Figure 2). Today, the gap is closing since many African countries received enough nets by 2008 to cover greater than 40% of their at-risk populations. Financing is now available to purchase 240 million additional nets in 2009–2010 (source: UNICEF 2009 Malaria and Children, Progress in Intervention Coverage). In 2006, 24 million homes were covered by IRS globally, seven times less than the projected need for 2010 (see Figure 2). Since data on IRS coverage are often limited, RBM recommends including standardized indicators and household survey collection methods in future surveys.

Malaria vector control scale-up efforts come with a heavy cost (see Figure 3). Prevention strategies for all people at risk in 2009 were estimated at US$3.7 billion, with 55% of the cost for IRS and...
45% for LLINs. Funding will need to be sustained at such high levels for many years to come, as IRS is a recurring activity and more nets are needed for distribution in new communities and to replace older, less effective nets.

**IRS as Part of the Global Strategy for Malaria Control**

Currently, 17 countries in sub-Saharan Africa routinely use IRS. In 2008, some 25 million people were protected by IRS in 14 countries. At various points in time, 25 countries across Africa have used DDT for their IRS.

One successful example of cross-border IRS collaboration in Africa is the Lubombo Spatial Development Initiative. The initiative used a two-pronged approach control strategy based on IRS and effective case management. Results show that in South Africa and Swaziland there has been a greater than 90% reduction in malaria incidence (see Figure 4). Similar trends are evident in the adjacent provinces of Mozambique.

In Asia, approximately 16 million households and some 81 million people are covered by IRS. Most countries in Asia have discontinued IRS with DDT. Successful IRS programs are conducted routinely in India, Malaysia, Sri Lanka, and Thailand.

In the Americas, in 2006, IRS covered 268,000 households and approximately 1.3 million people. Because the rate of malaria incidence is much lower across this region, IRS is used only in targeted areas. Between the 1960s and the 1980s, countries in the Americas, used DDT but they are now trying alternative insecticides, e.g., pyrethroids. None of the countries in this region use DDT.

In the Middle East, in 2006, some 1.1 million households were sprayed and approximately 5.6 million people were protected. Similar to the Americas, the Middle East has a lower incidence of malaria and uses IRS with pyrethroids to complement LLIN use.

**Figure 4. Lubombo Spatial Development Initiative**

Map illustrating reductions in the incidence of *Plasmodium falciparum* parasitides in South Africa and Swaziland and prevalence in Mozambique between the baseline in 1999 and survey in 2006.
The Power of Partnerships

The history of malaria control scale up can provide many lessons learned. Malaria vector control can be scaled up in countries where logistical structures exist, such as proper equipment and well-trained staff; where local epidemiology and transmission patterns are well known; and where capacity for regular supervision exists. Scale up success depends on the ability to deploy well-trained spraying teams, to ensure safe insecticide and equipment storage and handling, and to monitor and map sprayed structures.

Ongoing challenges that must still be met include procurement of nets and insecticides, effective use of LLINs, increasing parasite resistance to antimalarial medications and increasing insecticide resistance, acceptance of IRS at the household level, securing global political and financial commitment for supporting IRS, agreement on insecticide use (e.g., ongoing debates on use of DDT), integrating monitoring for insecticide resistance into scaling up LLINs and IRS (e.g., building entomologic capacity at regional, subregional, and national levels), and monitoring impact in high-burden countries in Africa.

There is power in partnerships, including sharing financial burdens and other risks associated with malaria vector control interventions, but partners also jointly reap the gains. Partnerships are effective for monitoring results; storing and distributing insecticide and nets; conducting advocacy and behavior change communication efforts; carrying out in-country planning; mobilizing resources; conducting waste management; executing procurement and supply chain management; and monitoring insecticide resistance, policy, and regulation, all of which further the fight against malaria in endemic countries. RBM continues its outreach for a world free of malaria.
U.S. President’s Malaria Initiative (PMI)

It is important to put into context the U.S. Government’s (USG's) support for malaria control globally. Malaria control is a major objective of the USG’s foreign assistance program. The USG's Global Malaria Control Strategy is grounded in the strategic framework provided by the PMI (2006–2010), and takes into account the specific requirements outlined in the Hyde-Lantos HIV, Tuberculosis, and Malaria Reauthorization Act, an important bill that authorized funding for malaria control from 2010 through 2014. In addition, the USG Global Malaria Control Strategy is consistent with President Barack Obama’s Global Health Initiative (GHI), first announced in May 2009. The strategy commits the USG to provide global leadership in reducing preventable malaria deaths to near zero and to work with host countries and partners toward the long-term goal of eradication.

The PMI is a joint effort between the U.S. Agency for International Development (USAID) and the U.S. Centers for Disease Control and Prevention (CDC). PMI has a goal of reducing malaria-related mortality by 50% in 15 high-burden countries in Africa.

PMI funding began in 2006 with US$30 million to support activities in Angola, Tanzania, and Uganda. In 2007, PMI added four more countries—Malawi, Mozambique, Rwanda, and Senegal—with a budget of US$135 million. In 2008, the eight final PMI countries were added—Benin, Ethiopia, Ghana, Kenya, Liberia, Madagascar, Mali, and Zambia. The budget level for 2008 and 2009 was US$300 million; for fiscal year 2010, it is US$500 million, for a total PMI budget of US$1.265 billion. Separate from the PMI, the USG also supports targeted regional malaria control activities in the Amazon Region in South America and Mekong Region in China, as well as modest assistance to Burkina Faso, Burundi, the Democratic Republic of Congo (DRC), Nigeria, and southern Sudan.

The USG has been a leader in supporting community-based management of malaria and is committed to assisting countries in scaling up these important efforts to extend the reach and access to malaria treatment. Approximately 80% of malaria cases are treated outside formal health facilities, and community-based strategies that increase access to treatment with artemisinin-based combination therapy (ACT) are a critical component of malaria control. PMI supports community-based delivery of ACT in Madagascar, Mali, Rwanda, Senegal, and Zambia, with other countries likely to follow. PMI also is currently supporting collaborations with the private sector in Nigeria and Rwanda to ensure that ACT is available through private sector drug-distribution points, and to decrease the availability of monotherapies for the treatment of malaria on the private sector market.

PMI has contributed to the reintroduction of indoor residual spraying (IRS) as one of the effective tools available for malaria control. PMI also supports procurement and distribution of insecticide-treated nets (ITNs), and does so by supporting free distribution through community-based campaigns or through routine delivery at health clinics, as well supporting distribution of highly subsidized nets through voucher programs (see Figure 1).

PMI and its partners have demonstrated significant progress through year three of implementation. IRS programs have been implemented in all 15 countries, protecting 24.7 million people. PMI procured 12.7 million long-lasting insecticide-treated nets (LLINs), 28.4 million ACTs, 5 million rapid diagnostic tests (RDTs), and 2.3 million intermittent preventive
treatment in pregnancy (IPTp) treatments. Some 35,000 health-care workers were trained in malaria case management, with an additional 14,000 trained in management and prevention of malaria in pregnancy.

In Benin, Ghana, Kenya, Rwanda, Senegal, and Tanzania, recent demographic and health surveys have shown substantial declines in mortality rates among children under five, ranging from 19% to 32% reductions (see Figure 2). Although malaria control cannot account for all of these reductions, the dramatic increases in bed net ownership and usage, the nationwide roll out of ACTs and IPTp across these countries, and the introduction of large-scale IRS supported by PMI and partners over this same period of time, suggests that malaria control played a major role in this reduction.

Figure 3 shows declines in prevalence of malaria and anemia in children under five that have been recorded in Zambia. It also provides evidence of the impact of malaria control efforts by PMI and partners.

PMI also provides significant support to activities that have health systems strengthening and capacity-building objectives in addition to malaria control in PMI countries.

Figure 4 depicts how efforts to strengthen national-, health facility-, and community-level planning and implementation of malaria control interventions can contribute to efforts aimed at strengthening overall health systems.

PMI operates with several management principles. These include accountability and transparency, with
Resource Mobilization for Malaria Vector Control Programs

respect to financial reporting and management; agility to fill gaps as they arise in life-saving commodities through mechanisms, such as the PMI Emergency Commodity Fund; and commitment to documenting and reporting outcomes and impact, using internationally accepted indicators and approaches to data collection and analyses.

Among PMI priorities going forward is continued support for IRS activities across PMI countries, including expansion within countries as resources allow. PMI will also conduct operational research aimed at determining how best to employ IRS and LLINs in a complementary fashion. Encouraging community, national, and international partnerships to ensure sustained acceptance of IRS, as well as providing further support to ministries of health and national malaria control programs in developing and revising country IRS and integrated vector control strategies, will also remain as high priorities for PMI.

The challenges for PMI and for the global malaria community are numerous. These include expanding and improving malaria diagnosis, especially RDTs; delivering ACT in both the public and private sectors; determining how best to employ IRS and ITNs in a complementary fashion; ensuring sustained acceptance of IRS; attaining high ITN usage in areas of high ownership; modifying prevention approaches as malaria incidence rates drop, such as in Rwanda, Zambia, and Zanzibar; and sustaining and expanding achievements.

With regard to the Hyde-Lantos HIV, Tuberculosis, and Malaria Reauthorization Act that prioritizes malaria control as a major foreign assistance objective, the 5-year strategic approach for malaria control states that the USG will continue to provide global leadership in reducing the worldwide malaria burden, with an ultimate goal of eradication. The anticipated funding authorized under this bill between fiscal years 2010 and 2014 totals US$5 billion, a significant further increase when compared to previous years.

The USG 5-year global malaria control strategy, covering fiscal years 2010–2014, outlines plans for further investments to scale up malaria control interventions in the original 15 PMI countries, to achieve a 70% reduction in malaria burden when compared with 2006–2007 baseline data. The strategy also calls for adding up to five additional countries to PMI, including DRC and Nigeria, with the objective of achieving a 50% reduction in malaria burden in these new countries when compared with 2009–2010 baseline data. In Southeast Asia and South America, the strategy outlines plans to strengthen efforts aimed at containing the spread of multidrug-resistant falciparum malaria by supporting antimalarial drug resistance surveillance, building local drug quality-control capabilities, and reducing malaria transmissions in these areas.

On May 5, 2009, President Obama announced that the GHI would be committing US$63 billion over six years to the comprehensive USG Global Health Strategy, including support for HIV, tuberculosis, malaria, maternal and child health (MCH), and family planning programs. The GHI goals are to prevent millions of new HIV infections; reduce mortality of mothers and children under five, thereby saving millions of lives; avert millions of unintended pregnancies through education and family planning options; and eliminate some of the neglected tropical diseases.

Going forward, PMI and the USG Global Malaria Control Strategy are aligned with the GHI principles. These principles are not new. Women-centered programming that targets women to improve malaria outcomes for themselves and their families has continued (and will continue) to be a focus under the strategy. A focus on integration across health (e.g., U.S. President’s Emergency Plan for AIDS Relief, MCH, and other health USG programs) and nonhealth programs, with the objective of increasing impact beyond what the individual programs can do alone, will remain a priority of the strategy. PMI will continue to support country ownership by working under the leadership of national programs and plans, by partnering to further build capacity within national malaria control programs and aiding with strategy and planning efforts. Health systems strengthening will continue to be an integral component of the USG malaria strategy, with PMI continuing to support such activities as strengthening drug management systems, human resource capacity, information systems, laboratory systems, and other areas. PMI also will continue to be committed to improving monitoring and evaluation in order to strengthen national program’s ability to report on implementation, coverage, and impact.
Malaria Control as a Best Practice: Corporate Social Responsibility Program—AngloGold Ashanti Obuasi Limited

Mr. Steven Knowles
AngloGold Ashanti

Abstract
AngloGold Ashanti (AGA) recognizes that malaria is the most significant public health threat to the mine and community in Obuasi, Ghana. AGA implemented an Integrated Malaria Control Programme (MCP) that targets the mine infrastructure, mine housing estates, Obuasi town, private dwellings, and surrounding villages within the Obuasi municipal assembly boundaries.

The Obuasi MCP is made up of the following interventions:

- Indoor residual spraying (IRS);
- Distribution of insecticide-treated nets;
- Environmental management (e.g., screening, lifestyle);
- Information, education, and communication (IEC);
- Early, effective diagnosis and treatment;
- Laviciding of mosquito breeding areas;
- Surveillance, monitoring, and research; and
- Use of repellents.

The MCP’s main focus is to achieve IRS coverage of all structures. Spray operators were recruited from the local community, creating 134 jobs. The first IRS spray round commenced in 2006, with approximately 37,000 households sprayed. The excellent response and acceptance from the community (96% coverage of targeted structures) is attributable to the intensive IEC campaign, using community committees, radio, and other media.

Since 2005, an average decline of 5,800 malaria cases per month (74%) at the mine hospital has been reported. There has also been a corresponding drop in absenteeism at the mine, as well as a significant reduction in medication costs.

The AngloGold Ashanti (AGA) Obuasi Limited Malaria Control Programme

Based in South Africa, AGA is a global gold producer that operates in 22 countries, primarily Argentina, Australia, Brazil, Ghana, Guinea, Mali, Namibia, South Africa, Tanzania, and the United States (with further exploration in China, Malaysia, Philippines, and Laos). Why is a multinational corporation taking on efforts—such as investing in malaria control activities—that are considered the government’s responsibility? Because it makes good business sense.

Mr. Steven Knowles, AGA malaria control program manager, was quoted in the London Financial Times as saying, “The AngloGold Ashanti Malaria Control Programme is the best example of a sustainable corporate social responsibility (CSR) program with a win–win for company and community.” An effective, efficient malaria control program, embracing the community in which the company operates, is the best CSR strategy for a company operating in a malaria-endemic area. In Obuasi, Ghana, where AGA operates a mine, indoor residual spraying (IRS) has not only reduced the burden of malaria in the community, increased school attendance, and won the gratitude of the community and the recognition of the government, but also has reduced absenteeism at the mine, increased productivity, and reduced the cost of malaria medication to AGA employees and dependents. At the corporate level, malaria control generates a return on investments, as well as has the backing of the shareholders.

AGA feels very strongly about CSR and believes that local community involvement and development is a key issue to sustainable operations. As reflected
Resource Mobilization for Malaria Vector Control Programs

The area served by the AGA Integrated Malaria Control Programme (MCP) encompasses the mine, town, and surrounding villages. The initial investment was US$1.7 million, with yearly expenses of US$1.3 million. The program is ongoing with the aim to reduce incidence of malaria by 50% in 2 years. Figure 2 depicts the various activities of the MCP.

Figure 2. MCP activities

<table>
<thead>
<tr>
<th>Laboratory</th>
<th>Field</th>
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<tbody>
<tr>
<td>Mosquito identification</td>
<td>House spraying</td>
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<tr>
<td>Insecticide susceptibility tests</td>
<td>House screening</td>
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<tr>
<td>Mosquito colony maintenance</td>
<td>ITNs</td>
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<td>Bioassays</td>
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<tr>
<th>Disease Management</th>
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<tr>
<td>Diagnosis</td>
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<td>Treatment</td>
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<tr>
<th>Surveillance and Monitoring</th>
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<tr>
<td>Vectors—insecticide resistance</td>
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<tr>
<td>Parasites—drug resistance</td>
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<tr>
<td>HIV—malaria information system (data recording and report production)</td>
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<tr>
<th>IEC and Health Promotion</th>
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<tbody>
<tr>
<td>Information on cause of malaria, how transmission occurs, mosquito biology, personal protection and use of ITNs</td>
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</tbody>
</table>

The MCP activities include vector control through IRS; distribution of insecticide-treated nets (ITNs); application of larvicide at breeding areas (e.g., bodies of water); conducting environmental management using screens in homes; making lifestyle changes such as types of clothing or hours of outdoor activity; performing surveillance, monitoring and evaluation, and research; promoting advocacy of the use of repellents for night shift workers; disseminating community information through education and communication campaigns; and encouraging early and effective diagnosis and treatment when individuals exhibit malarial symptoms.

Does malaria vector control work? Yes: Obuasi has had an average incidence reduction of over 5,800 cases per month, or 75%, since 2005, when AGA initiated vector control activities (see Figure 3).

In February 2009, the fourth year of administering IRS, AGA supported spraying in areas in and around the Obuasi town, mine, and surrounding villages.

in their mission statement, AGA strives to form partnerships with host communities and share their environment, traditions, and values. The company wants local communities to be better off for AGA having been there. AGA also believes that the private sector should be involved and initiate social and environmental projects in the communities in which they operate. In addition to benefiting the people, the reduction of malaria in the Obuasi community and mine, makes good economic sense, and the lessons learned will be used to initiate similar projects in AGA’s other operations. As quoted in the AGA Report to Society 2004, “Malaria remains the most significant public health threat to AngloGold Ashanti operations in Ghana, Mali, Guinea, and Tanzania.”

Malaria can be prevented. There are four main means of malaria prevention: 1) killing adult mosquitoes through IRS and knockdowns; 2) preventing mosquitoes from biting through nets, screening, and repellents; 3) controlling mosquito breeding through larvicide activities and environment management; and 4) prophylaxis with antimalarial drugs.

In 2005, the Obuasi Mine Edwin Cade Hospital saw on average 6,800 malaria patients per month from a workforce of 8,000. Of these, 2,500 were mine employees. With an average of three days off per patient, the absences equate to 7,500 shifts lost per month. Such sick rates, coupled with the slow work rate during recuperation, resulted in a major loss in production. The costs of medication for treatment were in excess of US$55,500 per month. At the government-operated hospital and clinics in Obuasi, reports show an average of 12,000 malaria cases per month (see Figure 1). Malaria patients represent 48% of all cases seen at Obuasi hospitals and clinics. Malaria is the leading cause of death in the area, accounting for 22% of all the reported deaths.

| Figure 1. Malaria medication costs—Edwin Cade Hospital |
|-----------------|--------------|
| 2005 Average monthly cost | 55,000 | 22,000 |
| 2006 Average monthly cost | 26,000 | 9,000 |
| 2007 Average monthly cost | 5,000 | 4,000 |
| 2008 Average monthly cost | 11,000 | 3,000 |
| 2009 Average monthly cost | 10,000 | 2,000 |
The downward trend of cases continued with a 76% reduction of monthly malaria cases since 2005. Some 139,000 structures were sprayed, with approximately 36,000 households covered.

Communities accept IRS and positively respond to the spray campaigns with the dramatic decline in malaria cases. To encourage IRS acceptance, AGA uses committees, radio advertising, talk shows, other media outlets, and public banners as part of a community education program on malaria and prevention efforts. As part of this campaign, the MCP has created 128 jobs in the community for vector control and education activities.

The MCP received international recognition from the Global Business Coalition in Business Excellence, a “Malaria Award,” and two Pan African Health Awards. The U.S. President’s Malaria Initiative (PMI) also provides training and personnel to AGA to assist with IRS implementation. In 2009, AGA received a Global Fund to Fight AIDS, Tuberculosis, and Malaria (GFATM) grant of US$133 million to scale up the Obuasi Model to 40 other districts in Ghana.

AGA has established various national public-private partnerships in Ghana, including alliances with the Ghana Health Service, the National Malaria Control Programme, and the local Obuasi Municipal Assembly, coupled with the benevolent approval of the Ministry of Health (MOH). A private sector-led malaria control program would be impossible without the support and consent of the national government. By the very nature of using insecticides and involving the public, the MOH and the Environmental Protection Agency must approve intervention plans; activities must conform to national malaria operation plans; and consent must be obtained from national malaria staff at the local levels. In Obuasi’s case, AGA is so interlinked with the NMCP that the Obuasi Model has become the basis for the national malaria control plan. AGA is now working with the Obuasi Municipal Assembly and the Environmental Protection Agency, among other governmental entities, to fight malaria together.

### Controlling Malaria Is Our Passion; Saving Lives Is Our Goal

The private sector can play a multifaceted role in combating malaria since companies often have the skills needed to fill gaps left by government interventions. The private sector excels in conducting project management; acquiring source expertise and competent personnel; providing planning and strategy support; developing on-site infrastructure; providing training courses and facilities; implementing financial controls and conducting audits; performing operational and safety audits; and harnessing capacity to implement vector control activities, not limited to the scientific monitoring. Private companies can be the catalyst for national control programs. An ideal program, such as that in Ghana, would involve sharing of resources and intervention goals from the start. The private sector can initiate a control program, set up infrastructure, conduct baseline assessments, start up the program, and ultimately assume most of the risk.

When vector control activity proposals are accepted by a corporate board, the stakeholders expect quick decisions and implementation; M&E efforts with impact assessments; implementation of reporting and progress assessment systems; compliance with operational and financial deadlines; establishment of financial and risk management systems; and

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**Figure 3. Malaria incidence reduction**

<table>
<thead>
<tr>
<th>Lost work days due to malaria</th>
<th>Incidence rate/1,000 employees</th>
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<tr>
<td>2005 Average monthly 6,983</td>
<td>2005 Average monthly 238</td>
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<tr>
<td>2006 Average monthly 4,423</td>
<td>2006 Average monthly 16</td>
</tr>
<tr>
<td>2007 Average monthly 1,206</td>
<td>2007 Average monthly 61</td>
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<tr>
<td>2008 Average monthly 338</td>
<td>2008 Average monthly 46</td>
</tr>
<tr>
<td>2009 Average monthly 282</td>
<td>2009 Average monthly 41</td>
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</table>

The downward trend of cases continued with a 76% reduction of monthly malaria cases since 2005. Some 139,000 structures were sprayed, with approximately 36,000 households covered.
completed, timely deliverables that reflect the positive results of the proposed interventions. Once a malaria control program has a sound base and infrastructure and is successful, efficient, and effective, it may seek international funding for sustainability and scaling up via global funding agencies (e.g., GFATM, World Bank, PMI, nongovernmental organizations, etc). The private sector can continue to provide co-funding and/or in-kind contribution opportunities through infrastructure, training, audits, etc., to maximize resources and impact.
The Role of Vector Control in Malaria Prevention

Vector Control Interventions and Their Effectiveness in Malaria Prevention

Dr. Michael Macdonald
U.S. Agency for International Development/U.S. President's Malaria Initiative

This brief introduction to vector control interventions will touch upon three issues: 1) theory: mathematical models as a guide; 2) practice: biological and programmatic limitations to our interventions; and 3) how we will solve the problems as they arise.

Theory
Infectious disease modeling began with Ronald Ross and his report, *Prevention of Malaria in Mauritius* (full text available online through Google Books). At the very beginning of his mathematical treatment, Ross wrote: "Such calculations as these, which may appear far-fetched to many, but they are useful, not so much for the numerical estimates yielded by them, but because they give more precision to our ideas, and a guide for future investigation."

Ross’s great insight was to the Equilibrium Prevalence, which he described later in his 1910 book, *The Prevention of Malaria*: “a limit must be reached when the new infections exactly balance the recoveries” (164). The factors driving the new infections later became known as “vectorial capacity,” which is the product of the human biting rate, the biting habit, and the expected infective life of the vector, which is a function of the daily survivorship and the duration of sporogony.

Later analyzed in more detail by Professor George Macdonald from the London School of Hygiene and Tropical Medicine, the mathematical models yielded a number of important insights. First, from the sensitivity analysis, it was shown that of the three main vector attributes—1) survivorship, 2) anthropophily, and 3) population density—survivorship has by far the greatest impact. A slight change in survivorship (from indoor residual spraying [IRS] or mass effect of long-lasting insecticide-treated nets [LLINs]) will have an exponential impact on the basic reproductive rate (i.e., the number of new cases arising from an infectious case) because it is raised to the power of the duration of sporogony (n). A change in anthropophily (e.g., from repellents or untreated nets) will have a quadratic impact, while a change in mosquito density (e.g., from larval source management) has only a linear impact.

A second insight relates back to the equilibrium balance that after a one-time reduction in prevalence (e.g., through mass drug administration), there will be only a temporary impact and the prevalence will drift back up to where it was previously. Only a sustained reduction in vectorial capacity will permanently reduce prevalence. In other words, chemotherapy alone will not likely bring us to malaria elimination. Vector control is especially important in light of the emergence of artemisinin resistance in Mekong Region in China.

From Theory to Practice
The first malaria conference in equatorial Africa, held in Kampala, Uganda, in 1950, was a watershed for malaria control in the region. The conference reviewed the data on epidemiology, vector control, therapeutics, and the organization of malaria

<table>
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<th>Vectorial Capacity</th>
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<tr>
<td>( C = \frac{ma^2 p^n}{-Inp} )</td>
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<tr>
<td>human biting rate (ma)</td>
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<tr>
<td>human biting habit (a)</td>
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<tr>
<td>estimated infective life (p^n/Inp)</td>
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control programs. Participants recommended to governments that malaria should be controlled by modern methods as soon as feasible, whatever the original degree of endemicity, and without awaiting the outcome of further experiments. They also noted that the higher the degree of endemicity, the more important it is to establish a sustained program, "so that there may be continuation of the work until the progress of control might allow relaxation without danger of an outbreak of malaria."

There were two additional recommendations from the conference that relate to this discussion. First, the emphasis on the "time-honored and basic principle of malaria control," i.e., that these be adapted to the local conditions; and second that the exuberance for the new chemical toxicants (e.g., DDT) not obscure other methods of control. It should be noted that they did not have pyrethroids and treated materials at that point, but they would have been considered.

We are implementing our vector control measures—whether it is spraying, LLINs, larval control, or some combination—through the framework of integrated vector management (IVM). There continue to be misunderstandings: IVM is not simply throwing a lot of different control methods at a problem and hoping something works. IVM is not simply larval control, and IVM is not a substitute for chemicals. There may be situations where the only control measure one uses is spraying with DDT, and it can be considered IVM. As defined by the World Health Organization (WHO), IVM is "a rational decision-making process for optimal use of resources for vector control." The IVM framework includes the following five key elements:

1) Advocacy, social mobilization, and legislation;
2) Cross-sector collaboration;
3) Integrated approach;
4) Evidence-based decision making; and
5) Capacity building.

One can see that as IRS programs are implemented, some are making progress along each of these five lines, and others less progress.

Nevertheless the U.S. President's Malaria Initiative (PMI)-supported IRS programs have shown phenomenal progress over the past four years, with now more than 25 million people in 15 countries under protection. Prior to PMI, just four years ago, IRS was being implemented in a few countries in southern Africa, including and Eritrea, Ethiopia, Mozambique, and Zambia, and among private sector partners, notably Equatorial Guinea, Ghana,

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REPORT ON THE MALARIA CONFERENCE IN EQUATORIAL AFRICA

Held under the Joint Auspices of the World Health Organization and of the Commission for Technical Co-operation in Africa South of the Sahara

Kampala, Uganda, 27 November - 9 December 1950

The conference emphasizes again the time-honoured and basic principle of malaria control, viz., that measures and methods chosen should be those best adapted to the local conditions, from the standpoint of both economy and efficiency, as determined by careful planning and surveys. The conference also calls attention to the fact that the success of newer chemical toxicants may sometimes obscure possible advantages which might be derived from agricultural, environmental, or naturalistic control-measures.
Mozambique, and Zambia. The many hundreds of people associated with IRS over the past four years should be commended for the rapid learning and tremendous accomplishments shown in this scale up. While we have less information on the social and economic impact of IRS, there has been significant impact on entomological and epidemiological indicators.

It is important to understand the limits of IRS. These can be grouped under technical and programmatic problems. Technically, insecticide resistance is the major threat. Resistance has been documented in a number of countries where PMI is providing support. This is of particular concern in Benin, Ethiopia, Ghana, and Uganda. There are concerns in the other PMI-supported countries, as well as other countries in Africa, but there are less data to indicate a critical problem. Selection pressure for insecticide resistance can come from both public health and agricultural use of pesticides. PMI is working closely with WHO and other partners to develop more robust monitoring and mitigation strategies. Looking forward to 2010, there is optimism that there will be new longer-lasting formulations of insecticides available for IRS, and, before too long, entirely new chemicals. Nevertheless, resistance will inevitably appear for each new insecticide developed.

A second technical problem is related to mosquito behavior, especially early evening and outdoor feeding. This is clearly an issue for vectors in the Americas, including *Anopheles darlingi* and for vectors in China's Mekong Region, including *An. dirus*. We have fewer data for vectors in the Africa, but there are some data, including work done by Dr. Josephat Shilulu in the PMI-supported Eritrea program, showing significant early evening and outdoor biting by *An. arabiensis*. The problem of early evening and outdoor biting by African malaria vectors also is critically important for insecticide-treated net (ITN) strategies.

Programmatic challenges relate first to the overall management of the complex IRS management cycle, and to what we refer to as “optimization”—ensuring that the resources for IRS are first targeted and applied correctly. We have numerous instances where we think IRS needs to be better targeted, especially in urban areas in which transmission has been greatly reduced or eliminated. Quality control will always remain an issue: It takes tremendous effort to ensure the spray is done properly.

ITNs also have their problems—some technical or intrinsic to the net and some programmatic. One technical issue is that nets are sometimes difficult to use, as in the case in Ethiopia in which (with funds from the Global Fund to Fight AIDS, Tuberculosis, and Malaria, not PMI) the rectangular nets purchased were very difficult to hang. According to later research carried out by Carol Baume at NetMark, conical nets were preferred. A programmatic problem associated with nets is proper use, illustrated by the use of polyethelyene nets for fishing in Cambodia.

Larval source management is in many ways more technically demanding than IRS and ITNs. It has been implemented successfully in Dar es Salaam and in some recent operational research settings, but is very often done without monitoring, is misdirected, and can be a waste of money.

A very large problem, especially in the Amazon and Mekong regions, but also in certain settings in Africa, is referred to as the: “Where there is no house problem.” Another issue that requires consideration is providing personal protection for mobile forest workers, homesteaders, and military, as well as occupational exposure for groups such as rubber tappers who are out and exposed to vectors in the early hours of the morning.

**Solving the Problem**

Each vector control intervention has limitations. The key is to understand the limitation for the particular technical programmatic challenge and to solve the problem. Dr. Jose Najera, an iconic figure in the malaria eradication era, stated: “Before DDT, malarialogists were trained to be problem solvers; after DDT malarialogists were trained to be solution implementers” In other words, DDT and IRS were seen by some as a uniform single solution that could fit a wide range of situations without adaptation. We see that as wrong, and there is a continual need to optimize and rationalize vector control, as we are doing with the IVM initiative.
There are a number of new tools on the horizon. In addition to new chemicals and formulations for IRS, there have been advances in the following.

**Remote sensing/satellite telemetry.** In both the Amazon and Mekong regions, malaria is closely associated with deforestation (e.g., *An. darlingi* in Peru), and in the Mekong closed forest cover (e.g., *An. dirus* in Thailand). These are emerging technologies that should help us better target our interventions.

**Repellents.** There also are promising emerging technologies for repellents, as illustrated by a study by Sarah Moore and Sam Darling, using paramethane-diol and lemon grass oil in Peru, offering almost 90% protection from *An. darlingi* biting six hours after applications (compared to only 50% for DEET).

**Hammock nets.** There also has been more work done with treated hammocks. For example, in Venezuela, treated nets reduced parasite prevalence by 83% compared to placebo, and some Benin experimental hut studies with treated polyethylene nets.

**Treated clothing.** This is also a very active area for development, particularly by the U.S. Food and Drug Administration and U.S. Department of Defense, which are developing treated uniforms for the military. These same technologies have been adapted to the commercial sector, e.g., the North American clothing market for camping and fishing. But we hope that this technology also could be used soon for civilian clothing, sheets, blankets, and other treated materials.

**Insecticide-treated plastic sheeting.** Finally, there has been progress for insecticide-treated plastic sheeting in tarpaulins used for emergency housing for displaced persons and, more recently, as durable wall linings that may act similarly to IRS.

It is imperative that we “rationalize and optimize our resources for vector control as we are trying to do through the IVM initiative.” Human capacity is the critical issue. Without trained and supported staff, we are left with “no people, no program.” Through the work of IVM, a framework and institutional foundation exists to build a cadre of public health entomologists and vector control specialists. We need to continue support for capacity building and career structures and develop a new generation of problem solvers.
The Role of Vector Control in Malaria Prevention

IRS in Africa: A Brief Discussion

Dr. John Chimumbwa
RTI International

U.S. President’s Malaria Initiative (PMI) and IRS

The main goal of the PMI is to reduce malaria-related mortality by 50% in 15 target African countries over a 5-year period. The aim is to achieve 85% coverage of targeted populations through effective interventions, such as improving diagnosis followed by effective and prompt treatment with artemisinin-based combination treatment (ACTs); intermittent preventive treatment in pregnant women (IPTp); use of long-lasting insecticide-treated nets (LLINs); and indoor residual spraying (IRS), which involves application of insecticides with residual properties on the interior walls of dwellings where mosquitoes rest.

All these measures are aimed at reducing the burden and impact of malaria on the affected population. There is no one intervention that is a “magic bullet” to malaria prevention and control. It is the sum total—or rational, evidence-based selection—of a single intervention or a combination that result in lowering the disease burden. Malaria transmission does not occur uniformly everywhere, instead there are different epidemiological situations, which demand different prevention and control strategies.

Some years ago, the World Health Organization (WHO) worked out a comparison of the effectiveness of vector control methods in preventing malaria parasite infections. On an arbitrary scale of 1–4, IRS scored the highest when it came to reducing vector densities. Insecticide-treated mosquito nets ranked next, with their physical barrier actions, followed by larviciding (source reduction), and lastly environmental modification. Other transmission prevention tools considered included chemoprophylaxis and mass drug administration, which scored lowest on the scale.

WHO, in its Global Malaria Program (GMP) document, recommended that IRS is suitable for application in all malaria transmission and epidemiological situations, provided it can be applied diligently and closely monitored.

What Is IRS?

IRS is the application of a tiny amount of an insecticide on the inner walls and other surfaces of human habitations where mosquitoes are likely to rest prior to feeding, post blood feeding, or to digest a blood meal and incubate a batch of eggs. IRS relies on the fact that mosquitoes enter human habitations during the night to feed on humans and rest on walls and other surfaces before or after feeding. If these surfaces are coated with an insecticide with residual properties, the mosquitoes will pick up a lethal dose as they rest that will kill them. The killing effect will continue as long as the insecticide retains its efficacy and the mosquitoes remain susceptible to the insecticide.

What IRS Is Not

IRS is not a substitute for any other malaria prevention and control interventions. It should not be promoted as a means to replace other effective interventions, such as insecticide-treated materials, case management, or any other intervention. It is also not the single panacea solution for malaria prevention and control, and not ideal in every malaria epidemiological situation. IRS is an effective means of vector control when used appropriately and judiciously. It is more effective when used as a part of a larger, well-designed, managed, and delivered vector management strategy. As with all chemical-based interventions, environmental safety and due diligence must be maintained when deploying the
intervention. Its impact is more effective when applied in large scale and where coverage of the populations or dwellings is in excess of 85%.

Malaria transmission is a function of numbers of vectors: The more the vector is abundant, the more likely it is to transmit malaria. The life span of a mosquito also has a bearing on the transmission potential of a vector. The longer a mosquito lives, the more likely it is to pick up the disease parasites (plasmodia) infection, develop the infection within itself, and transmit it to the next host. This longevity is in turn governed by a number of factors in the environment, such as temperature, rainfall, humidity, insecticides, etc.

Transmission is also modified by the efficiency of the vector. In Africa, malaria is transmitted by mosquitoes from the genus *Anopheles*. The particular species in this genus, *A. gambiae*, that are present in Africa have been found to be the most efficient transmitters of *Plasmodium* species to the human population. In addition, the behaviors of vector mosquitoes have implications on the transmission of malaria, such as vectors preferring to rest in human dwellings versus those that rest outdoors. Indoor resting increases the interactions between human and vector. Other behaviors, including the preference of human blood over others such as bovine also have implications on malaria transmission.

IRS works by lowering the densities of vectors in a sprayed geographical area; by reducing the contact between the vector and humans; by lessening the life span of the vector; and by altering the behavior of vectors, which leads to lower human-feeding tendencies.

**How Does IRS Control Malaria?**

First, a female mosquito enters a house to feed. After or before biting, it may rest on a sprayed wall from which it picks up a lethal dose of insecticide. IRS kills female mosquitoes before the infective stage of the malaria parasite can develop. It prevents transmission by killing older female mosquitoes. IRS reduces mosquito life span, density, human–mosquito contact, and vectoral capacity. Eventually, it also reduces malaria transmission.

Some of the conditions that favor the deployment of IRS as the vector control tool of choice include where the malaria vector population feeds and rests inside human habitations; where the local malaria vectors are susceptible to approved insecticides of choice; where humans predominantly sleep indoors; where human dwellings are constructed in such a way that they are suitable for application of insecticide; and, most importantly, where the reason for spraying is clearly defined and the population is aware of the reason for carrying out IRS.

Before applying IRS, authorities should define the target population or geographical area; delimit the numbers of structures to be targeted during the campaign; gain acceptability by the local population; and ensure safety, efficacy, and the availability of trained personnel.

**Challenges and Lessons Learned**

The expected achievements through IRS in endemic areas include long-term, effective vector control, resulting in reduced prevalence and human mortality. Key lessons learned from IRS implementation through PMI-supported programs include the following:

- IRS is dependent on weather factors. As such, the factors that drive transmission need to be taken into account to determine the right time to apply insecticide on walls. IRS requires adequate time for preparation to avoid last-minute, rushed preparations.
- Collecting and utilizing baseline data in decision making is an integral aspect of IRS. Information on elements such as vectors, rainfall, susceptibility, and human and vector behavior help to ensure that IRS is conducted successfully.
- It is not possible for one organization or entity to successfully conduct IRS. Successful IRS is dependent on a number of partners working in collaboration and in tandem to ensure that the many moving parts are synchronized.
- Capacity building is an integral aspect of IRS programs. IRS is a science that requires all participating groups to possess skills that enable them carry out their tasks in accordance with professional standards.
• Environmental compliance is another aspect that must be taken into account to ensure the safety of the personnel delivering the intervention, the human population being protected, and the flora and fauna and general environment.

• Advocacy and intensive information, education, and communication for community mobilization is critical. IRS can pose a logistics nightmare (e.g., validation of targets—households or structures and procuring and storing equipment).

• Malaria is preventable and treatable.
Achievements in Malaria Vector Control:
Zanzibar Experience

Dr. Abdullah Suleiman Ali
Zanzibar Malaria Control Programme

Abstract

Introduction
Vector control is used as one of the most effective measures to prevent malaria transmission in Zanzibar. The current selective approaches used include insecticide-treated nets (ITNs), long-lasting insecticide-treated nets (LLINs), indoor residual spraying (IRS), and environmental management.

Methods
The first round of IRS started in 2006 for both Pemba and Unguja islands and targeted 212,454 households, with a set coverage of 80%. IRS operations are ongoing on an annual basis, targeting over 200,000 households per round. Lambda-cyhalothrin 10% WP is the insecticide of choice.

Similarly, the use of ITNs/LLINs is popular, and net re-treatment is regularly conducted in all districts. The current ITN/LLIN policy is aimed at achieving universal coverage. Re-treatment for conventional nets is carried out on a yearly basis.

Larviciding is carried out in small-scale schemes, mainly in well-defined geographical areas. Environmental management is practiced at the village level.

Results
Current ITN/LLIN use for children under five is 81% and 78% for pregnant women. ITN use among the general population is 61%. IRS operations have been conducted successfully, with coverage of over 90% in the targeted households.

Lessons Learned
Involvement of various stakeholders and community groups, including local nongovernmental organizations, is key for achieving set targets for both IRS and LLINs.

In Zanzibar, the main malaria vector is the Anopheles gambiae species complex and is distributed widely on both Pemba and Unguja islands. Plasmodium falciparum is the predominant malaria-carrying parasite, accounting for over 95% of all malaria cases on the islands.

Entomological monitoring is currently ongoing in seven sentinel sites to establish entomological parameters. Since there are vector control guidelines in place, baseline data are being collected. In 2005, a longitudinal survey was conducted in Unguja and Pemba, with the objective of providing entomological baseline data for present and future comparisons. Table 1 shows the improvements made between the 2005 baseline and the ongoing data collection in 2008 and 2009.

Table 1. Entomological indicators

<table>
<thead>
<tr>
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</thead>
<tbody>
<tr>
<td>Human blood index</td>
<td>Analysis ongoing</td>
</tr>
<tr>
<td>Sporozoite rate</td>
<td></td>
</tr>
<tr>
<td>Man-biting rate</td>
<td></td>
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</table>

The main objective of this monitoring period was to measure the impact of interventions in terms of the reduction of disease-transmission potential of the vectors and the actual risk of transmission.
Indoor residual spraying (IRS) is a key vector control activity practiced on both islands of Zanzibar. Prior to IRS operations, teams complete a needs assessment to determine the sprayable areas, survey environmental considerations, and assess the personnel needed. Insecticides and supplies are then procured, and logistics for the spray campaign are arranged. Spray teams are trained and deployed to the spray areas.

IRS requires advocacy campaigns and community involvement to gain support for spraying. During the spray campaign, monitoring and supervision of the sprayers is ongoing, as well as data management to collect accurate numbers of structures sprayed, number of people per household, and amount of insecticide used. After spraying is completed, reports are written and submitted. Used insecticide sachets are properly disposed, and other spray equipment is cleaned and stored at the national warehouse.

Entomological monitoring is conducted at the seven sentinel sites, which are spot-checked twice a month. The Zanzibar Malaria Control Programme also manages an insectary and an animal house for research. Staff collect and enter data and perform analyses for reports.

The Zanzibar IRS program has achieved many significant milestones. In 2006, there was one midyear spray round with ICON WP. In 2007, there were two spray rounds, each with ICON WP, conducted at the beginning and middle of the year. There was one spray round at the end of 2007 that spanned the beginning of 2008. IRS evolved from semiannual to annual rounds.

Zanzibar also promotes the use of insecticide-treated nets (ITNs) and long-lasting insecticide-treated nets (LLINs). The policy for new net distribution includes establishing standards for procurement and storage; distributing LLINs to the households through community involvement; retreating conventional nets with long-lasting insecticide; monitoring and assessing of actual use of nets; and conducting advocacy.

Results show that with the increased IRS and ITN/LLIN interventions, the prevalence and positivity rate for malaria cases has dropped significantly, to below 1%. Spray rounds covered enough of the percentage of structures to interrupt the parasite transmission cycle in Zanzibar (see Figure 1). The disease burden reported for malaria prevalence is currently at less than 1%, according to multiple studies (Malaria Indicator Survey 0.8% [2007]; Tanzania HIV and Malaria Indicator Survey 0.8% [2008]; and cross-sectional survey 0.4% [2009]). The malaria positivity rate dropped from 41% in 2001 to 0.9% in 2008 (see Figure 2).
Conclusion

A number of overarching lessons learned from Zanzibar’s malaria control experience can be shared to bring successful vector control interventions to other regions. Malaria interventions, including case management; information, education, and communication/behavior change communication; vector control; and small- and medium-enterprise funding initiatives, are not independent entities, but need to be executed in coordination as a single a package. Key lessons learned include the following:

- Continued and sustainable funding is crucial for malaria control.
- Entomological field activities are well-accepted by the general community, and mosquito collectors can be selected by the community.
- Households can volunteer to serve at mosquito collection sites.

Figure 2. Malaria prevalence indicators and malaria prevention over time
Insecticide Selection and Management of Resistance in IRS

Management of Pesticides in Vector Control

Dr. Morteza Zaim
World Health Organization

Abstract

Pesticide management refers to regulatory control, proper handling, supply, transport, storage, application, and disposal of pesticides to minimize adverse environmental effects and human exposure.

Capacity strengthening for sound management of public health pesticides has become a priority, especially in Africa. This is due to increasing use of insecticides for vector-borne disease control and personal protection; increasing challenges faced with the management of these chemicals under decentralized health systems; a depleting arsenal of safe and cost-effective insecticides and need to extend the useful life of the existing products; and inadequate national regulatory frameworks and human and financial capacity to regulate the availability, sale, and use of public health pesticides. This poor capacity to enforce the regulatory environment enables the excessive and unsafe use of pesticides, leading to pollutants in food, drinking water, and the environment, and poses significant risk to human health. Substandard, illegal, and counterfeit pesticide products available in the market also are of great concern and undermine expected efficacy and performance and present substantial risk to human health and the environment.

Management of pesticides should cover their life cycle, i.e., from production to use and disposal of waste. It requires a multisectoral and multistakeholder approach, adequate resources and infrastructure, and support by appropriate legislation. In a significant number of countries, pesticide legislation does not properly address regulation of public health pesticides.

Sound management of public health pesticides has to be based on strong post-registration monitoring and evaluation, and on the strategy of judicious use through principles of integrated vector management and insecticide resistance monitoring and prevention.

United Nations specialized agencies, funds, and programs, other intergovernmental organizations, and donor agencies should include capacity strengthening for sound management of public health pesticides within their activities and as a mandatory component of project support to vector-borne disease endemic countries.

The WHO Pesticide Evaluation Scheme (WHOPES) in collaboration with other United Nations agencies, notably the Food and Agriculture Organization and the United Nations Environment Programme, as well as industry and other stakeholders, have been actively involved in capacity strengthening for sound management of public health pesticides through development of guiding documents, norms, and standards, as well as country support. WHOPES acknowledges the financial support of The Bill & Melinda Gates Foundation, which has facilitated, among other things, support to six African countries in the past two years, in development of national action plans for sound management of public health pesticides, based on comprehensive situation analysis, and using a multistakeholder approach. Resource mobilization and increased country support in this priority area of work ranks high on the WHOPES agenda.
Abstract
The U.S. President’s Malaria Initiative (PMI) aims to reduce malaria-related deaths by 50% in Africa through the scale up of key malaria control interventions in 15 African countries. Among the interventions is indoor residual spraying (IRS). IRS is a proven and highly effective intervention for reducing or interrupting malaria transmission. To achieve the desired results, IRS must be conducted using the appropriate insecticide. The review and selection process is conducted in consultation with relevant host government authorities, including the ministry of health and national malaria control program, RTI International, and Liverpool Associates in Tropical Health, based on a set of criteria. As primary criteria, the insecticide
- Must be approved by the WHO Pesticide Evaluation Scheme;
- Must be registered for IRS use in the country;
- Should have a residual efficacy pertinent to transmission season on the major type of wall surface type in the country; and
- Must be effective against the targeted vectors.

The secondary criteria include
- Packaging of insecticides in water-soluble sachets for a single pump charge (8–10L);
- Competitive cost of insecticide;
- Timely delivery of the insecticide to the preferred point of receipt; and
- Representation of supplier in host country.

This paper gives an overview of the principles of how to choose insecticides for IRS in the PMI countries.

Principles of Pesticide Selection
The U.S. President’s Malaria Initiative (PMI) aims to reduce malaria-related deaths by 50% in Africa through the scale up of key malaria control interventions in 15 African countries. Among the interventions is indoor residual spraying (IRS). IRS is a proven and highly effective intervention for reducing or interrupting malaria transmission. To achieve the desired results, IRS must be conducted using the appropriate insecticide. This paper gives an overview of the principles of how to choose insecticides for IRS in the PMI countries.

The Insecticide Selection Process
In PMI programs, the selection process is made up of two steps: 1) technical consultation; and 2) U.S. Agency for International Development (USAID) review and concurrence.

Technical Consultation
The ministry of health or national malaria control program of a given country convenes a technical committee to conduct the insecticide review and selection process. The review and selection process is conducted with technical support from RTI International and its partner(s), in this case Liverpool Associates in Tropical Health. The committee assembles data relevant to the primary criteria (threshold criteria) and technical evaluation criteria, as outlined below. The committee identifies all the candidate insecticides that meet the malaria program’s needs so that subsequent procurement may be conducted among as many insecticides as possible, maximizing the potential benefits of competition among vendors. The committee carefully considers all insecticides within a given class (e.g., pyrethroids), and selects the full class unless specific insecticides within the class are eliminated on the basis of the selection criteria.
The committee then reports the outcome of its deliberations in the form of an Insecticide Selection Memorandum, signed by the committee chair or other government official with clearly designated authority. The memorandum should report the full list of insecticides that have been selected and include a summary of the rationale supporting the committee’s decision. The committee chair then conveys the information to the USAID staff member on the country’s PMI team or other official designated by USAID.

USAID Review and Concurrence
The USAID/PMI team should either recommend and approve the memorandum or return it to the committee chair with comments. When all issues are resolved, concurrence is granted and the approved memorandum is forwarded to RTI for procurement.

Insecticide Selection Criteria
The insecticide for IRS use is selected based on a number of considerations, as discussed in the sections that follow.

### Primary Criteria
The following factors must be satisfied.

**Approved by the World Health Organization (WHO) for Use in IRS**
All insecticides used for public health purposes undergo a process of independent testing. This process is coordinated by the WHO Pesticide Evaluation Scheme (WHOPES). This process ascertains pesticide effectiveness, safety for humans and the environment, and the methods and conditions of their use. The International Code of Conduct on the Distribution and Use of Pesticides (2002) constitutes the WHOPES framework for promoting the safe handling and use, efficacy, cost-effective application, and quality control of pesticide products/formulations used in public health. Currently there are 12 insecticides, which belong to four chemical classes or groups (as shown in Table 1), recommended by WHO for IRS.

**Meets National Registration Requirements**
Individual countries have designated authorities/bodies that provide regulatory service for importation, exportation, manufacture, sale, transport, supply, distribution, and use of pest

### Insecticide Selection Criteria

<table>
<thead>
<tr>
<th>Insecticide compounds and formulations</th>
<th>Class group</th>
<th>Dosage (g/m²)</th>
<th>Mode of action</th>
<th>Duration of effective action (months)</th>
</tr>
</thead>
<tbody>
<tr>
<td>DDT wettable powder (WP)</td>
<td>Organochlorine</td>
<td>1–2</td>
<td>Contact</td>
<td>&gt;6</td>
</tr>
<tr>
<td>Malathion WP</td>
<td>Organophosphates</td>
<td>2</td>
<td>Contact</td>
<td>2–3</td>
</tr>
<tr>
<td>Fenitrothion WP</td>
<td>Organophosphates</td>
<td>2</td>
<td>Contact &amp; airborne</td>
<td>3–6</td>
</tr>
<tr>
<td>Pirimiphos-methyl WP and emulsifiable concentrate (EC)</td>
<td>Organophosphates</td>
<td>1–2</td>
<td>Contact &amp; airborne</td>
<td>2–3</td>
</tr>
<tr>
<td>Bendiocarb WP</td>
<td>Carbamates</td>
<td>0.1–0.4</td>
<td>Contact &amp; airborne</td>
<td>2–6</td>
</tr>
<tr>
<td>Propoxur WP</td>
<td>Carbamates</td>
<td>1–2</td>
<td>Contact &amp; airborne</td>
<td>3–6</td>
</tr>
<tr>
<td>Alpha-cypermethrin WP and suspension concentrate (SC)</td>
<td>Pyrethroids</td>
<td>0.02–0.03</td>
<td>Contact</td>
<td>4–6</td>
</tr>
<tr>
<td>Cyfluthrin WP</td>
<td>Pyrethroids</td>
<td>0.02–0.05</td>
<td>Contact</td>
<td>3–6</td>
</tr>
<tr>
<td>Deltamethrin WP and water dispersable granule (WG)</td>
<td>Pyrethroids</td>
<td>0.01–0.025</td>
<td>Contact</td>
<td>2–3</td>
</tr>
<tr>
<td>Etofenprox WP</td>
<td>Pyrethroids</td>
<td>0.1–0.3</td>
<td>Contact</td>
<td>3–6</td>
</tr>
<tr>
<td>Lambda-cyhalothrin WP and capsule suspension (CS)</td>
<td>Pyrethroids</td>
<td>0.02–0.03</td>
<td>Contact</td>
<td>3–6</td>
</tr>
</tbody>
</table>

**Table 1. WHO-recommended insecticides for IRS against malaria vectors**

*Note: WHO specifications for public health pesticides, for quality control and international trade, are available on the WHO Web site: http://www.who.int/whopes.*
control products and that also mitigate potential harmful effects to the environment. The bodies also ensure that the products conform to all the set requirements for registration in the country.

Susceptibility of Local Malaria Vector Species to the Insecticide
An essential characteristic in the choice of an insecticide is the susceptibility of the malaria vectors in the area of concern. This may vary with time, as resistance can develop as a result of continuous exposure to the insecticide. The assessment of vector susceptibility is done using the WHO bioassay test kit or the U.S. Centers for Disease Control and Prevention (CDC) bottle bioassay. Testing should be carried out to
- Establish the baseline susceptibility of the different vectors in the area;
- Monitor the possible changes throughout the period of insecticide application; and
- Assess the vector’s susceptibility to potential alternative insecticides if there is a need for change.

Residual Efficacy Pertinent to the Transmission Season on the Major Type of Wall Surface in Country
The nature of the sprayable surface plays a major role in the duration of the residual effect of the insecticide. The absorption of the insecticides by the sprayed surfaces may considerably limit insecticide availability on the sprayed surface after a given period of time.

Secondary Criteria
Packaged in Water Soluble Sachets for a Single Pump Charge (8–10L)
The sachet’s solubility in water ensures a good disposal measure since the sachet dissolves with the insecticide in the spray suspension/solution. The sachet solubility further ensures safety while handling insecticides that would be easily blown by the wind during IRS or while transferring the insecticide to the spray tank. The amount of insecticide packaged in each sachet should be adequate for one pump charge, as specified by WHO-recommended dosage requirements. This helps avoid the need to repackage insecticide in the field.

Cost of Insecticide
The amount of active ingredient in the formulation and the cost of shipment should be competitive against others.

Timely Delivery of the Insecticide to the Preferred Point of Receipt
The insecticide supplier must be able to deliver the insecticide to the required point of receipt in the country.

Representation of Supplier in Host Country
The selected insecticide supplier is required to show representation in the country. If issues arise with the insecticide at the field level, communication is easier and faster when using the country representative.

Tendering
A request for quotation (RFQ) is issued to all vendors known to produce the specified class of insecticide, meeting WHOPES-recommended specifications for use in IRS. The RFQ issued to the vendors contains all the requirements that both the insecticide and the supplier should satisfy.

Timing
A lead-time of at least six months from the time the decision to conduct IRS has been made until spraying can actually begin (usually targeted to begin before the rainy seasons) is required. During this period, further resistance monitoring data can be collected and added to the selection criteria. A country-specific Supplemental Environmental Assessment is developed, which includes identification of environmentally sensitive areas where insecticides cannot be used, investigation of storage facilities to establish whether they meet international standards, and country rules on insecticide use are also taken into consideration. A Pesticide Safer Use Action Plan (PERSUAP) is included; standards in the PERSUAP are in accordance with the U.S. or host country regulations, whichever are most stringent. The clearance process takes at minimum 4–6 weeks. Environmental clearance from USAID environmental officers must be obtained before procurement of the insecticide can occur. Further information on pesticide management procedures can be found on the PMI Web site: http://www.fightingmalaria.gov/technical/pest/index.html.
Abstract

Introduction
Insecticide resistance among the major African malaria vector mosquitoes has become a serious problem for many countries on the continent. Resistance to all classes of World Health Organization (WHO)-approved chemicals for vector control is escalating at an alarming rate and may prove to be a stumbling block for accelerated malaria control/elimination in Africa.

Methods
In the past 8–10 years, isolated “spot-check” surveys for vector susceptibility to insecticides have been carried out in numerous African countries, either by national malaria control programs or by commercial entities interested in protecting their operations from the effects of down time, which results in loss of productivity. All of these surveys have used the WHO standard bioassay test procedures and procured kits from the WHO collaborating center in Malaysia. The four classes of insecticides tested were pyrethroids, carbamates, organochlorines, and organophosphates.

Results
Four different vector mosquitoes—Anopheles gambiae S and M forms, An. arabiensis, and An. funestus—were profiled at various localities (not all four species occur at every locality). The results show that different species present various resistance profiles. Different populations of the same species will exhibit various levels of resistance, depending on geographic location. In general, the most serious foci of resistance in Africa are centered on the West African countries of Ghana, Cote d’Ivoire, Benin, and Burkina Faso, where populations of An. gambiae are resistant to almost all insecticides, and An. funestus shows significant resistance to DDT, pyrethroids, and carbamates.

Conclusions
Monitoring of resistance levels in any vector population is critical for every malaria control program in Africa. Policies and strategies for vector control must be based on sound evidence gained from these monitoring and surveillance activities. This has been clearly shown by control programs in Bioko Island, in Equatorial Guinea, and South Africa. In an attempt to promote this concept, the African Network for Vector Resistance (a WHO alliance of interested countries) has facilitated the production of a global database on insecticide resistance, IRbase, that is available for use by all stakeholders. Countries and researchers gathering data on vector susceptibility can contribute to the database online. This database will provide country policy makers with up-to-date information on the status of the vectors in their countries and allow informed decision making on choice of insecticide and implementation strategy.
Integrated Resistance Management in the Control of Disease-Transmitting Mosquitoes

Mr. Mark Hoppé
Insecticide Resistance Action Committee

Abstract
Insecticides have been used extensively since the 1940s to control mosquito vectors and have been a vital component in the fight against malaria. However, resistance among the major mosquito vector species has developed against the four classes of insecticide currently recommended for vector control. As insecticide resistance continues to develop and spread, there is a real danger that these valuable tools will be lost. This paper outlines the principles of insecticide resistance management (IRM), in the vector control context.

Special emphasis is placed on the need to use IRM methods that produce information that enables decision makers within a vector control program to choose the intervention that best fits the principles of IRM. While much energy is being spent on the aim of bringing insecticides with new modes of action to vector control, we must maintain the tools currently available, as well as have a strategy in place to preserve the long-term utility of novel insecticides as they are developed. It is argued that sustainable use of insecticidal vector control interventions can be maintained only through IRM.

Introduction
Insecticides have been extensively used since the 1940s to control the insect vectors of human disease. In the early years of synthetic insecticide use, there was great optimism that not only insect vectors of disease could be controlled, but that diseases such as malaria could even be eradicated.

Despite the initial optimism that synthetic insecticides could rid the world of malaria, it soon became apparent that insects’ ability to develop resistance to the insecticides would challenge this view. Hess stated in 1953, “. . . a breakdown of the effectiveness of insecticides in controlling malaria mosquitoes might be quite disastrous in some areas of the world.” With an insight that is just as relevant today, he goes on to say, “It is hoped that an intensified program of fundamental research on all aspects of this problem may provide a satisfactory solution before any such situation develops.”

Insecticide resistance was not new even then; it was first observed in 1887 that some scale insects were resistant to sprays of kerosene (Hess 1952). In 1914, Melander famously asked whether insects can become resistant to [insecticidal] sprays (Melander 1914). The synthetic insecticides fared no better, with house flies resistant to DDT identified in 1949, only a few years after its introduction (Keiding and Van Deurs 1949). By 2006, there were 7,400 recorded cases of insecticide resistance in 550 different insect species (Onsted 2008). As the majority of the 7,400 cases of insecticide resistance are in agricultural pests, insecticide resistance is of major concern in crop protection. To address these concerns in the crop protection and public health arenas, the private sector manufacturers came together and formed the
Insecticide Resistance Action Committee (IRAC) in 1984. As noted in McCaffery and Nauen 2006, the mission of IRAC is to accomplish the following:

- Facilitate communication and education on insecticide and acaricide resistance; and
- Promote development of resistance management strategies to maintain efficacy and support sustainable agriculture and improved public health by
  - Pooling expertise;
  - Establishing a cross-industry advocacy and lobbying group;
  - Enlisting industry commitment to product stewardship and sustainability; and
  - Fostering communication and education on insecticide resistance management (IRM).

IRAC’s public health activities were strengthened in 2006 with the reformation of the IRAC Public Health Team, consisting of representatives from the private and public sectors (Nauen 2007).

It is estimated that 3.3 billion people, approximately half the world’s population, are at risk of malaria, with an estimated 247 million clinical cases and nearly 1 million deaths in 2006 (World Health Organization [WHO] 2008). Yet with the substantial increase in international initiatives and funding for malaria control seen in recent years, there is still optimism that eradication is a realistic goal (Mendis, et al. 2009). A major focus of the recent vector control initiatives has been on the use of long-lasting insecticide-treated nets (LLINs) and indoor residual spraying (IRS), both of which can significantly impact Plasmodium transmission. However, currently, the WHO Pesticide Evaluation Scheme (WHOPES)-approved LLINs rely on a single class of insecticides, the pyrethroids. IRS is limited to four classes—1) pyrethroids, 2) organophosphates, 3) carbamates, and 4) DDT. The growing specter of insecticide resistance is therefore an extremely serious threat to these proven vector control interventions.

**IRM**

IRAC strongly promotes IRM as an integral part of all insect control programs. IRM programs take actions that reduce an insect population to an acceptable level, to maintain the long-term effectiveness of control interventions employed. Put another way, the aim is to use insecticides in such a way that their effectiveness in a control program is not diminished, allowing their continued use in that program. The emphasis here is on the use of an insecticide in a continuing program, rather than continuous use of a particular insecticide. Integrated vector management (IVM) is defined as “a rational decision-making process for the optimal use of resources for vector control” (Beier, et al. 2008). IRM is therefore an integral part of IVM, as only through the active management of insecticide resistance can the available resources be optimally and sustainably used.

The development of insecticide resistance relies upon the selection of a heritable trait in an insect population that reduces the susceptibility of that population to the insecticide. Thus, insects that possess the heritable trait are more likely to have offspring in the presence of the insecticide than those that do not. If the selection pressure is maintained over a number of generations, the proportion of resistant insects will increase in the population until acceptable levels of control cannot be achieved. The fundamental activity of IRM is therefore to minimize the selection of resistant insects in a population, maintaining their numbers at such a proportion that acceptable control can be achieved.

In the majority of cases, insecticide resistance develops against all members of a class of insecticide that share a common mode of action (MoA). For example, a population of mosquitoes with reduced susceptibility to a particular pyrethroid insecticide will also show reduced susceptibility to all pyrethroids. It is therefore useful to talk about classes, or groups, of insecticide rather than individual insecticidal products. IRAC has worked extensively with industry and non-industry experts to classify all insecticides into a comprehensive MoA classification system. This system groups all insecticides with a MoA, linked to a common target site, into numbered groups. This classification system is updated regularly to include insecticides with new MoAs and increase knowledge in this field.

The IRAC MoA classification for active ingredients recommended for adult mosquito control is shown in Table 1.
Table 1 shows the paucity of insecticide groups available for vector control. Of the 26 groups recognized by the IRAC MoA classification, only two are used for adult mosquito control.

Standard IRM practice is to rotate the use of insecticides with different MoAs, either temporally or spatially. In the crop-protection setting, IRM guidelines have been developed for particular pests and crops that aim to minimize the exposure of successive generations of a pest species to insecticides from the same MoA class. Exposure of successive life stages to insecticides from the same MoA grouping is also discouraged. Such guidelines are published and may form part of an insecticide label. Insecticide use patterns in vector control programs are very different to those in crop protection. Not only are there far fewer classes of insecticide available, but IRS applications and LLINs expose many generations of the mosquito to the same insecticide. IRM as practiced in crop protection is difficult to apply in vector control settings. However, the principles have been applied and shown to reduce insecticide resistance in the field. In a multiyear study sponsored by IRAC in Mexico, the activity of glutathione S-transferase (GST), implicated in the resistance of *Anopheles albimanus* to DDT, was reduced when IRS programs were switched to rotations of alternative MoA insecticides (Penilla, et al. 2006).

**Principles of IRM Applicable to Vector Control**

The choice of insecticide intervention should be based on a number of criteria. However, before any choice of product is made, IRM should be considered. These questions must be asked: Will the product provide sufficient protection of the population from vector mosquitoes in the short term, and how will it impact the ability of the program to protect the population in the long term? To answer these questions, the primary information required is knowledge concerning the resistance/susceptibility status of the vector mosquitoes present, and, ideally, any underlying resistance mechanism present.

Resistance monitoring is therefore a vital component in any vector control program that intends to employ IRM. There are several techniques available for monitoring the susceptibility or resistance levels in mosquito populations, each with their own merits. Resistance monitoring assays fall into three groups: 1) bioassays, which expose live mosquitoes to insecticide residues; 2) biochemical assays, which detect the increased activity of enzyme systems in mosquitoes with a metabolic resistance mechanism; and 3) molecular methods that detect the presence of the genes associated with insecticide resistance and their level of expression. An overview of monitoring techniques can be found in Coleman and Hemingway 2007.

Whilst there has been significant progress in the development of molecular diagnostic tools, in the majority of cases, bioassays are still the most appropriate methodology for monitoring resistance in the field situation. In their basic form, bioassays simply expose field-caught mosquitoes to a residue of an insecticide at a rate that has been predetermined to kill “susceptible” individuals, but not those that are “resistant.” The chosen rate, or discriminating dose, is crucial. It should be set at a dose that identifies a change in the susceptibility status of the mosquito population at such a level that effective management measures can be taken. Ideally, the discriminating dose should be calculated from a baseline study.
of the mosquito species in question. Using the chosen exposure methodology, a dose response is generated from which the lethal concentration (LC) values can be calculated. In crop protection, where there are often large populations of the pest insect readily available, a discriminating dose of twice the LC50 may be used. Such a discriminating dose will identify relatively subtle changes in the susceptibility of the pest population. In vector control programs, especially effective ones, often only small numbers of mosquitoes can be trapped for use in bioassays. A small sample size will not provide a robust result with such a sensitive discriminating dose as twice the LC50, hence a discriminating dose of twice the LC95 is considered to provide a more robust result.

If the discriminating dose is too low, there is a risk that false positive results will be generated, especially with small sample sizes. Conversely, if the discriminating dose is too high, significant levels of resistance may be present in the population before it is detected, as heterozygous resistant individuals may be killed. Halliday and Burnham support this contention in their analysis of the optimal diagnostic dose for monitoring insecticide resistance (1990), and promote the use of dose-response assays, employing a rate range that kills between 50% and 95% of susceptible insects.

Bioassay Methodologies

The WHO diagnostic assay (WHO 1981) is an elegant methodology that uses a specially designed apparatus and insecticide-impregnated papers available from a central source. It attempts to standardize all conditions of the assay, enabling it to be used as a standard diagnostic test. It is widely used, especially in Africa, and the majority of reports of insecticide resistance in *Anopheles* have been generated using this method (Coleman, Sharp, et al. 2006). The WHO diagnostic assay uses a diagnostic dose of twice the LC100. In an effort to standardize the assay, single diagnostic doses have been selected for WHOPES-approved insecticides against the whole *Anopheles* genera, calculating the LC100 from the least susceptible species studied (WHO 1998). However, the data used to generate these diagnostic doses demonstrate the natural differences in susceptibility between *Anopheles* species. Together with a very robust diagnostic dose of twice the LC100, this suggests that the assay may not be sensitive enough to identify developing resistance in some mosquito populations.

The bottle assay developed by the U.S. Centers for Disease Control and Prevention is designed to be a robust and flexible assay that can be undertaken using locally acquired reagents under field conditions. The equipment and reagents used are low cost and readily available in most locations, facilitating resistance monitoring in all vector control programs. Using 250ml glass bottles with screw caps, a known quantity of insecticide (either technical or formulated material) is applied to the inner surface of the bottles using a volatile solvent. Field-caught mosquitoes are aspirated into the treated bottles, and an assessment of mortality or knockdown is made after a given period of time. The assay protocol emphasizes that for each species, and in each region, a baseline study should be undertaken to identify an application rate and exposure period that provides 100% kill, or knockdown, of “susceptible” mosquitoes. Whilst some application rates and exposure times are recommended, these are considered guidelines for developing individual baselines. If a longer exposure time is required to cause 100% kill in a monitoring bioassay, it is assumed the population has developed reduced susceptibility to the insecticide. Promoters of the bottle assay claim that time to knockdown is a more sensitive measure of susceptibility than knockdown or mortality recorded after a given time interval (Brogdon personal communication).

The flexibility of this assay method includes allowing for the addition of synergists to the exposure bottles, either combined with the insecticide, or using a separate bottle to pre-expose the mosquitoes. The WHO diagnostic assay also allows for pretreatment of mosquitoes with synergists. Such studies can provide an indication of whether metabolic resistance is present and, if so, its mechanism.

The flexibility of the bottle assay, however, is at the expense of standardization. If different application rates or exposure times are used at different locations, it diminishes the ability to compare the level of resistance between sites. The age of the mosquitoes and prior field exposure to insecticides can influence knockdown times, as can the environmental conditions under which the assay is undertaken. Likewise, the use of technical or
formulated insecticide may provide differing results. This method is therefore a rapid, simple, and robust method for identifying changes in the susceptibility profile of a mosquito population through time. Without further standardization, it has less utility for comparing between locations or mosquito populations.

The data from all bioassays can be greatly augmented with follow-up studies based on biochemical or molecular techniques. Such further studies can identify particular resistance mechanisms and the proportion of a mosquito population carrying the resistance or differentially regulated genes. Whilst great progress is being made in the development of molecular techniques, they are still largely laboratory based, requiring the return of mosquitoes, or parts of mosquitoes, to a laboratory for analysis (Coleman and Hemingway 2007). In the near future, however, it is anticipated that molecular techniques will move from the laboratory to the field, where they will become increasingly valuable tools for resistance monitoring.

The choice of bioassay used in an IRM program will depend on a number of factors. However, the underlying principle should be to choose an IRM method that produces timely information that enables the decision makers within a vector control program to identify the intervention that best fits their local situation and the principles of IRM. With the widespread distribution of insecticide resistance in some Anopheles populations, this is a matter of identifying relative susceptibility or resistance to the limited number of insecticidal classes currently available.

**IRM: An Example from Crop Protection**

IRM should begin to be implemented before insecticides with new MoAs are brought into widespread use. An example from the introduction of a novel class of insecticides into the crop protection market serves as a model of best practice.

The diamide insecticides, also called anthranilic diamides (IRAC MoA group 28), have been recently brought to the crop protection market by four agrochemical companies. Diamides are classified as ryanodine receptor modulators, a novel target site for insecticides, to which there is no known cross-resistance. Under the auspices of IRAC, the agrochemical companies with rights to this area of chemistry came together to develop an IRM strategy, before the widespread use of this class of insecticide. IRAC formed a Diamide Work Group, which undertook a risk analysis of the likelihood of resistance developing to the diamides in the crops and pests targeted. From this analysis, a global strategy was developed and agreed upon by the four companies, “Insecticide Resistance Management Global Guidelines for IRAC Group 28 (Diamide) Insecticides” (IRAC 2008). These global guidelines are used by local/regional IRAC Work Groups and companies to develop language for their local labels, rotational strategies, and product positioning. Local guidelines cannot be less restrictive but may be more restrictive than the global guidelines.

The IRAC Diamide Work Group developed an agreed upon resistance monitoring bioassay, appropriate for the target insects and this class of insecticide. This bioassay would enable comparable data to be generated by the companies and other interested parties. It is hoped that with the companies all following the recommendations and label requirements that adhere to the principles of the global guidelines, the development of insecticide resistance to this class of insecticides will be greatly delayed.

Whilst there are many differences between insecticide use in crop protection and vector control, there are principles that can be drawn from this example that should influence the introduction of new vector control insecticides. Those seeking to develop new insecticides for vector control should undertake resistance risk analyses to identify the likelihood of resistance developing in a given mosquito population, with a particular use pattern of the new insecticide. An appropriate resistance monitoring bioassay should be developed or recommended, and initial baseline studies undertaken with all mosquito species of major vectorial importance. From knowledge of the susceptibility status of a mosquito population to all approved insecticides, recommendations for use should be made that are consistent with IRM principles. Where there is a risk of cross-resistance due to metabolic mechanisms, this should be taken into account when recommending partners for either temporal or spatial rotations with other MoA insecticides.
Integrated Resistance Management in the Control of Disease-Transmitting Mosquitoes

IRM in an IVM Context

Insecticide resistance develops in an insect population when individuals carrying a heritable trait that allows them to survive exposure to the insecticide pass on these genes. Thus, any activities that control the individuals with the resistance trait will delay the spread of the resistance genes in the population. IRM in the context of IVM, therefore, also includes activities such as habitat management, community education, and mosquito larviciding. Mosquitoes with reduced susceptibility to an insecticide may still be controlled at the recommended label rate. However, exposure to sublabel rate applications may allow these individuals to survive and pass on the resistance genes. Sublethal exposure may arise in IRS due to poor choice of product, under-dosing during application, or poor application technique. In each case, the residuality of the product may not be sufficient, delivering a sublethal dose before the next scheduled spray round. LLINs may also deliver sublethal doses within their expected lifetime due to poor product choice or inappropriate storage, use, or washing. These factors that reduce the efficacy of a vector control program can lead to a shift in the resistance status of the mosquito population, and should be avoided through informed product choice and effective IRS application, LLIN distribution, and education.

There is an assumption in the implementation of IRM programs that the gene, or genes, that confer resistance are only selected for in the presence of the insecticide. However, care must be taken to identify the source of the selection pressure. Mosquitoes are not only exposed to insecticides in the course of vector control programs; agricultural use of insecticides can be a significant route of exposure. Adults can be exposed to residues on crop plants, and larvae via insecticide run-off into their aquatic habitat; a correlation has been shown between agricultural usage and mosquito resistance (Diabate, et al. 2002). Hydrocarbons in the form of petroleum products spilled, or otherwise, finding their way into mosquito larval habitats, also have been implicated in pyrethroid cross-resistance (Djouaka, et al. 2007). Domestic use of insecticides for mosquito or general pest control can also be a significant route of exposure in some locations. Hence, the cessation of use of an insecticide in vector control may not remove all the selection pressure for the genes that confer resistance. As part of an IRM program, actions should be taken to minimize the exposure of mosquitoes to these alternative sources of selection pressure.

Summary of IRM Best Practices

Choice of Insecticide Intervention

- Undertake a susceptibility resistance monitoring study to identify the resistance profile of the mosquito population.
- Where resistance is identified, it is ideal to elucidate the resistance mechanism.
- If differing resistance profiles are identified in a local/regional mosquito species complex, base insecticide choice decisions on the species that is the most important local vector.
- Identify significant alternative sources of insecticide exposure, e.g., agriculture; if the mosquitoes in the target region are found to be susceptible to more than one class of insecticide, ideally, weight should be given to the class to which they have minimal exposure from alternative sources.
- In the absence of resistance/susceptibility data, the rotation of products between IRAC MoA classes will reduce selection pressure for resistance development. If no alternatives are available and there is no evidence of cross-resistance, rotation between subgroups can be considered.

Choice of Insecticide Product

- Where a choice exists, choose a product with WHOPES approval.
- For IRS products, choose the product that offers the greatest residual control on the surfaces that will be treated. IRS products should also be chosen on conformity to WHO specifications and uniformity of quality.
- For LLINs, choose the net that provides the best insecticidal effectiveness under field use. This should include insecticidal activity and physical robustness.
- Choose products with clear and explicit use directions and appropriate text and pictograms, supporting correct use or application.
• Choose products that minimize waste or the need to dispose of contaminated materials, i.e., unit dose or easily measured products, appropriate for the spray equipment used.
• Choose products that will have a sufficient shelf life, to enable the program to be undertaken when they are delivered to the field.
• Where they exist, follow IRM recommendations for product use.

Application/Dissemination
• Ensure spray operators are trained in the correct application of the chosen insecticide product.
• Ensure spray application equipment is maintained and calibrated, delivering the correct residual application.
• Ensure product label rates are being used.
• Dispose of any unused insecticide spray according to the product label and local regulation. Prevent unused spray from contaminating water courses or mosquito breeding sites.
• LLIN users should be informed of the correct way to use, store, clean, and repair their nets.
• Only use products that are within their “use-by” date.
• Maintain detailed records of product usage, including product, batch, application equipment used, and treated area.
• Continue resistance monitoring throughout program.

Conclusions
IRM should be an integral part of all vector control programs. Using insecticides in such a way that maintains their effectiveness in an integrated vector control program is a stewardship responsibility of the commercial companies that market them. It is also a stewardship duty of those who design and implement vector control programs.

Bibliography


Emerging Solutions to Waste Management and Disposal in the PMI IRS Program

Mr. Tito J. Kodiaga
RTI International

Introduction
Indoor residual spraying (IRS) is the organized, timely spraying of an insecticide on the interior walls of houses or dwellings. It is particularly effective in preventing malaria epidemics and designed to interrupt malaria transmission by killing adult female Anopheles mosquitoes. IRS has been used for decades and has helped eliminate malaria from many areas of the world, particularly where mosquitoes are indoor-resting and malaria is seasonally transmitted.

Several formulations of insecticides are available for IRS. The World Health Organization (WHO) has approved the following classes of pesticides that have proven effective in killing Anopheles mosquitoes: pyrethroids, carbamates, organochlorines, or organophosphates. Table 1 illustrates the different insecticides recommended under the WHO Pesticide Evaluation Scheme (WHOPES).

Waste Generation in IRS
Two types of wastes are generated during the IRS process: 1) liquid and 2) solid.

Liquid Waste
During implementation of IRS activities, waste water is generated on a daily basis during the Triple Rinse\(^1\) of spray cans, when spray operators clean themselves, and when personal protective equipment (PPE)—such as overalls, coverings, and gloves—is washed. This wash water is contaminated with insecticide; indiscriminate, unsound, and improper disposal of IRS wastes can pollute the environment and cause adverse risks to human health through exposure.

Note: WHO specifications for public health pesticides, for quality control and international trade, are available on the WHO Web site: http://www.who.int/whopes.

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1 Seven barrels, drums, and containers of approximately 200L capacity each are placed in a line. Every other container is filled with water (e.g., first container is empty; second container is filled with water; third container is empty; fourth and sixth containers are filled with water; and the fifth and seventh containers are empty).
Equipment is washed above the soak pit, or a washing bay/area is prepared, to avoid potential contamination of surrounding soils. All liquid waste from all insecticides other than DDT are channeled into soak pits. Some countries use hard plastic sheets to avoid contamination while washing PPE and rinsing pumps, while others have constructed concrete cement bays. See examples in Figures 1 and 2.

**Figure 1. A soak pit in Senegal**

![Image of a soak pit in Senegal](image1.png)

**Figure 2. A rinsing area and soak pit in Benin**

![Image of a rinsing area and soak pit in Benin](image2.png)

**Solid Waste**

During IRS, solid waste is generated, which includes empty insecticide sachets, damaged and/or used gloves or respiratory masks, material-covering sheets, used rinse barrels, and contaminated materials (e.g., sawdust and soil used as secondary containment for accidental spills). These substances could pose health and environmental hazards if not disposed in an acceptable and environmentally sound manner.

**Potential Adverse Impacts of IRS Wastes on the Environment and Human Health**

**Exposure During Disposal, Including Progressive Rinsing**

Waste disposal is a key issue in IRS interventions, especially when decontaminating containers and cans and disposing effluent waste produced during washing and progressive rinsing. Solid waste disposal is also a key issue of concern during the final stage of the IRS process. Both burying and dumping waste can lead to dermal exposure among residents who come in contact with soil or water in which the insecticide was disposed. Ingestion exposure can occur from drinking contaminated water. When excess effluent seeps into the soil, pesticide may contaminate groundwater that also may be used as a water supply for household wells. Residents may then become exposed to the contaminated water through ingestion or dermal contact when the water is used for cleaning or drinking.

The indiscriminate disposal of liquid waste into the environment is likely to contaminate water bodies, soil, and vegetation and can adversely impact aquatic resources, flora, and fauna that come into contact with the contaminated media (see Figure 3).

**Figure 3. Possible disposal exposure routes**

```
<table>
<thead>
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<th>Process</th>
<th>Media</th>
<th>Exposure Pathway</th>
<th>Receptor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Burying</td>
<td>Groundwater</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dumping</td>
<td>Soil</td>
<td>Ingestion</td>
<td>Resident</td>
</tr>
<tr>
<td></td>
<td>Rain event</td>
<td>Dermal</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Surface Water</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
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**Reuse of Pesticide Containers**

Reuse of pesticide containers occurs when best practices for disposal are not followed. Pesticides, especially those bought in bulk amounts, come in large, screw-top containers made of extremely durable materials (e.g., plastics and metals); as a result, the desire to reuse containers is strong.

Sturdy pesticide containers might be improperly reused to store water or dry food, such as millet or flour, leading to ingestion and dermal exposure from consuming contaminated water and or food. A conceptual model for improper reuse of pesticide containers is presented in Figure 4.

Additionally, after daily spraying ends, buckets and basins are used for washing and rinsing. If reused for
other purposes, these containers can cause exposure to people and result in adverse effects.

**Figure 4. Possible exposure routes from disposal of insecticide containers**

<table>
<thead>
<tr>
<th>Process</th>
<th>Exposure Pathway</th>
<th>Receptor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Food/Drink Storage</td>
<td>Ingestion</td>
<td>Resident</td>
</tr>
<tr>
<td>Other Storage</td>
<td>Dermal</td>
<td>Resident</td>
</tr>
</tbody>
</table>

**RTI’s Standard Operating Procedures (SOPs) for Waste Disposal**

The purpose of SOPs for RTI’s effluent and solid waste disposal is to outline uniform and standard procedures for disposal of IRS waste in all the PMI countries, in an environmentally sound and internationally accepted manner for pesticide disposal.

**Liquid Waste SOP**

The liquid waste disposal SOP includes factors such as considerations that must be for locating IRS effluent disposal facilities, standard designs for disposal facilities (e.g., soak pits and evaporation tanks), and construction materials recommended. It also addresses personal health and safety while in the facilities and how to decommission the facilities once operations are terminated.

**Solid Waste SOP**

The SOP for solid waste disposal is also aimed at ensuring that all the countries have in place a hands-on guide, providing them with the reference and direction for the disposal of the wastes in accordance with regulations issued by WHO and the Food and Agriculture Organization (FAO).

This SOP details the standard requirements for storage of IRS solid waste before eventual disposal. It also outlines the process for selecting an in-country incinerating facility, including selection criteria, steps to take when in-country incinerating facilities are unavailable, personal health and safety during disposal, responsibilities of different actors, and proof of destruction.

**RTI’s Approach to IRS Liquid Waste Disposal**

RTI disposes all effluent waste at source through evaporation tanks for DDT and soak pits for all other liquid wastes (e.g., pyrethroids, organophosphates, and carbamates). For DDT, all the liquid effluent is trapped and evaporated to prevent any potential entry into the general environment. Soak pits enable filtration/absorption of pesticides and biodegradation within the limited confines of the pits through technically constructed layers (see Figure 5). Both soak pits and evaporation tanks must be constructed in environmentally sound locations, away from flood-prone areas, steep gradients and slopes, and water sources.
RTI’s Approach to IRS Solid Waste Disposal and Current Country Status

In selected countries, RTI presently stores waste (e.g., sachets, used gloves, containers, covering sheets, and face masks) in warehouses, pending identification of a facility that meets the internationally acceptable standards for pesticide waste disposal.

Incineration of IRS solid waste is a procedure and requirement followed by RTI in all countries that implement IRS. Incineration is recommended by the United Nations Environment Programme (UNEP), WHO, and FAO for waste disposal, particularly for primary and secondary packaging materials and contaminated single-use clothing.

WHO and FAO jointly note that in relation to disposal of pesticides, “Pyrethroids can be incinerated without major limitations in an appropriate high-temperature incinerator with emission control equipment or in an appropriate cement kiln.” They also contend that “High-temperature incineration is currently the most widely established and economical disposal option,” compared to alternative options such as base-catalyzed dechlorination, gas phase chemical reduction, or plasma arc.

RTI’s Approach to Identifying and Approving Sites for Incineration

RTI considered other viable IRS solid waste disposal options before settling on incineration. This decision was guided by availability of technology in each country and the cost of disposal when using other options. Before any incineration facility is used, RTI seeks concurrence from the host governments, specifically the ministries of health and environment (environmental protection agencies), as well as approval from the U.S. Agency for International Development (USAID) Mission. This is to ensure that RTI has an agreement in place, indicating that the wastes have been disposed in an appropriate manner and with concurrence from all the critical parties.

Undertaking Due Diligence for Incinernators

One of the key steps that RTI undertakes when selecting in-country incinerators for waste disposal is to inspect the host country’s existing incinerators. The inspection aims to ascertain the extent to which the they meet and satisfy the incineration requirements for disposal of pesticide wastes, especially in relation to temperature requirements, flue gas emissions, and general health and safety concerns at the time of disposal.

According to WHO and FAO, incinerators recommended for this kind of waste disposal must satisfy the following key requirements:

- A recommended combustion temperature of between 1,100°C and 1,300°C;
- A required after-burner, with a residence time of at least two seconds; and
- Emission control, including particulate matter filters.

Ash and slag produced by high-temperature incineration of pesticides are, in principle, considered inert unless determined otherwise. This assessment is to ensure that RTI does not use in-country incinerators that are not accredited or licensed by the respective environmental government agencies for disposal of hazardous wastes and that do not conform to the specified UNEP/WHO/FAO standards, which would otherwise cause potential environmental impacts and could lead to possible liability threats.

In cases where certain countries do not have waste incineration guidelines or approved/registered and licensed incinerators, RTI uses the UNEP/FAO/WHO standards as the criteria for selecting appropriate facilities.

Alternately, cement kilns or furnaces are also considered ideal for disposal, particularly in countries where cement factories or copper furnaces (e.g., Ghana, Tanzania, and Zambia) are available. RTI’s SOP recommends their use based on and subject to agreement by the private entities that own such facilities.

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When undertaking due diligence, there is a likelihood that certain countries might not have incinerators that meet specified requirements. In these cases, RTI ultimately facilitates and makes arrangements to have wastes shipped to neighboring countries. This is a tedious and slow process because of the unusually lengthy intergovernmental negotiations required in adhering to the Basel Convention, which guides transboundary movement of hazardous wastes; however, it remains the only reasonable option.

The IRS program works collaboratively with ministries of health in the respective countries, most of which have hospital incinerators specifically for disposing internally generated health-care wastes. Some of these incinerators meet the minimum requirements and present a potential option for disposing IRS wastes. When this option is pursued, the facilities are inspected and verified as meeting the standard FAO/WHO guidelines before RTI decides to use them.

**Waste Incineration Process**

As part of the SOP for solid waste disposal, whenever a facility is identified and approved by the environmental regulatory agency as fit for incinerating IRS wastes, RTI ensures that the following steps are followed before the actual incineration occurs:

1. RTI officially requests, via a written letter of “No Objection” from the host environmental regulatory agency, to use the identified facility. This letter is accompanied by an attachment highlighting the facility’s specifications and justification as to why it meets the standards.

2. Following approval of the request, RTI staff ensure that the wastes are packaged in a truck (meeting transport requirements for hazardous wastes), with loaders outfitted in full PPE, and in the presence of staff from the ministries of health and environment.

3. Personnel from RTI and the ministries of health and environment accompany the waste to the facility, and the incineration process is documented on a form that notes the waste type, quantity, date, and time, and includes a photograph.

4. If the facility is licensed and hence authorized to issue a certificate of destruction, then this certificate is mandatory. However, if it is not licensed but has been approved by the environmental agency, then a signed letter showing satisfaction with the destruction is issued by the environmental agency.

**Challenges**

1. One of the biggest challenges encountered so far in solid waste disposal is the lack of availability of incinerating facilities that meet the FAO/UNEP standards, as described above. In certain countries such as Madagascar, Mali, and Liberia, suitable incinerators have yet to be identified.

2. When shipment of wastes to another country is the only option, the second challenge is the intergovernmental negotiations to satisfy the Basel Convention requirements for transboundary shipment.

3. In some countries, appropriate facilities like cement kilns are owned by private players. Authorization to use such facilities for waste incineration has proven to be another challenge.

**Conclusion**

RTI is making every effort to identify in-country incineration facilities that comply with and meet international standards for pesticide waste disposal. The use of in-country incinerators is a practice that ensures sustainability and reduces costs, and in cases where private facilities are used, promotes public-private partnerships. Thus far, progress in identifying in-country incinerators has yielded fairly good results; however, certain countries like Ethiopia, Liberia, Madagascar, and Rwanda still present a challenge.

RTI also has created a database of every facility currently in use to incinerate wastes. The database includes company profiles (if a private facility) and detailed specifications of the incinerators, including contact addresses. After every IRS round, RTI tabulates the entire amount of solid waste generated, by category and in terms of quantity, as part of the tracking and control approach for empty insecticide sachets.

For DDT countries, where transboundary shipment is mandatory, RTI is offering technical advice and facilitation between the specific countries to ensure fulfillment of the Basel Convention requirements.
Introduction
Impregnated materials such as treated nets and indoor residual spraying (IRS) play an important role in malaria prevention. The use of insecticide applications involves various health and environmental risks for the targeted population and operators. With IRS, the risk of contaminating the environment primarily involves insecticides applied, residue disposal methods, cleaning equipment used in the field, and solid waste disposal systems.

In Senegal, lambda-cyhalothrin (a pyrethroid) was selected after the National Malaria Control Programme (NMCP) and Ministry of the Environment and Nature Conservation approved and authorized its use. ICON 10% WP was used in the first year, and the 10% CS formulation was used during the other IRS campaigns.

A waste disposal system was implemented, according to the standards defined by the World Health Organization’s Food and Agriculture Organization (FAO), to mitigate unfavorable environmental and health impacts by removing or reducing them to an acceptable level. The specific objectives were to reduce pollution of groundwater and surface waters and to minimize the population’s and nontarget fauna’s exposure to insecticides.

Method
Storage
The selection of storage areas is subject to validation by the Plant Protection Directorate, Directorate of Environment and Classified Factories (DEEC), the health district, and RTI International. At the local or district level, secondary storage sites are required for IRS, where a small amount of insecticide, personal protective equipment (PPE), etc., can be stored and where operators can meet at the beginning and end of the working day. A central warehouse was established in Dakar and in each health district. There is one main storage area and 7–8 secondary storage sites, according to the number of IRS sectors.

The following are the minimum safety standards:
- Each insecticide storage room is managed by a trained storekeeper, with an education level equal to or higher than a first cycle educational diploma.
- Storage rooms are secured with a solid double-locking door and subject to advance authorization for access; the roofs are sealed so that rain water can not seep.
- Storage rooms are located away from people, animals, sources of water, wells, and drainage systems.
- Warehouses are easily accessible for delivery vehicles.
- A thermometer, fire extinguisher, and other equipment appropriate for emergency situations are kept on hand in both storage rooms and warehouses.
- Insecticides are stored on pallets, with a maximum of five boxes stacked one over the other.
- Insecticides, empty packaging, barrels, and buckets are stored in warehouses to reduce contamination.
- A general register is used for inventory, which tracks inputs, outputs, and quantity of insecticide, empty bags, pumps, replacement parts, PPE, and other stored materials.
- Showers, soap, and clean water are available to operators, to ensure that they can bathe after operations.
Supply
Before spraying commences, team leaders provide spray operators with six pesticide sachets, each to be used during the spray day. Every sachet has a code number for tracking. Once back from spraying, every spray operator returns empty, as well as full, pesticide sachets to their team leaders. Team leaders collect all the empty and full sachets from the teams and take stock of the quantity with the storekeeper before signing the record card. The storekeeper then updates the stock book and arranges the remaining unused sachets in the storeroom.

Storage of Contaminated Solid Wastes
The storekeeper completes the daily collection card of contaminated solid wastes, including empty sachets. These empty sachets are arranged in the storeroom for contaminated solid wastes. Masks are resupplied daily and gloves every 10 days. Empty pesticide containers and used masks and gloves are collected and stored in plastics bags and stowed in storerooms for solid waste disposal. Empty bags that contained the sachets also are arranged in storerooms for solid waste (see Figure 1).

Table 1. Totals of various solid wastes collected

<table>
<thead>
<tr>
<th>Material</th>
<th>Velingara</th>
<th>Nioro</th>
<th>Richard Toll</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of empty sachets</td>
<td>Delivered</td>
<td>17,927</td>
<td>19,877</td>
</tr>
<tr>
<td></td>
<td>Returned</td>
<td>17,882</td>
<td>19,870</td>
</tr>
<tr>
<td></td>
<td>Lost</td>
<td>45</td>
<td>7</td>
</tr>
<tr>
<td>Number of masks</td>
<td>Delivered</td>
<td>8,960</td>
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</tr>
<tr>
<td></td>
<td>Returned</td>
<td>6,093</td>
<td>6,152</td>
</tr>
<tr>
<td></td>
<td>Lost</td>
<td>2,867</td>
<td>611</td>
</tr>
<tr>
<td>Number of pairs of gloves</td>
<td>Delivered</td>
<td>925</td>
<td>883</td>
</tr>
<tr>
<td></td>
<td>Returned</td>
<td>815</td>
<td>640</td>
</tr>
<tr>
<td></td>
<td>Lost</td>
<td>110</td>
<td>243</td>
</tr>
</tbody>
</table>

Figure 1. Contaminated solid wastes packaged in plastic bags and empty pesticide boxes in a storeroom

At the end of the campaign, all solid wastes are transported to the Dakar warehouse by vehicles adapted for the carriage of such waste (see Table 1). In the Dakar warehouse, 227 boxes full of contaminated solid waste are stored, as well as empty boxes. In the 2007 campaign, 43 boxes were used, and 184 in 2008. On the locked door of the contaminated solid waste storage location, pictograms are posted that include the words “No Smoking” and “Do Not Enter” (see Figure 2).

Figure 2. Exterior and interior view of the central warehouse

Management of Contaminated Liquid Wastes
Each center has
- Two pump technicians;
- Drums and buckets exclusively for face and hand washing or constructed/renovated showers for daily baths for spray teams;
- Containers exclusively used for washing coveralls;
- Detergent to wash the coveralls;
- Seven drums for progressive rinse;
- One plastic can for each drum; and
- Functional soak pits.

Soak Pits
The site for the soak pit is selected by the environmental authority. The soak pits are usually situated at the highest point at the IRS depot/storage site and away from the natural path of run-off water. Usually an area of 3m by 3m (9 sq.m) is excavated to a depth of one meter. The bottom of the pit is packed with hard coal or charcoal, followed by sawdust (where feasible) and stone aggregate. The area is then fenced off to keep out domestic animals and children.
Because there is no loose soil, overalls can be washed here. This soak pit is also good for drying overalls, by laying them either on top of the stones or over the fencing (see Figure 3).

**Progressive Rinse of Sprayers**

Cleaning of spraying equipment can easily be a source of environmental contamination with harmful effects to human health. For environmentally sound cleaning of the sprayers, a progressive rinsing system is implemented (see Figures 4 and 5).

For end-of-day cleaning, pump technicians carry out the following tasks:

- Empty the remaining solution from the sprayer into drum 1.
- Tap 1L of water into drum 2 and pour it in the pump.
- Close the sprayer, shake it, and then pour the liquid into drum 3.
- Fill the pump half full with water from drum 4.
- Close the pump; clean the sprinkling system, pipes, internal filters, and the nozzle; and pour the contents of the spray into drum 5.
- Fill the pump half full with water from drum 6 for the third flushing and clean the strainer, nozzle, and external parts of the sprayer.
- Rinse water is poured into drum 7.

The next day, pumps are filled with the solution in drum 1 and rinse water from drums 3, 5, and 7. The returned solutions and pump rinse water are 100% recycled.

Only rinse waters and residual ICON collected in the last spray day are poured into the soak pit area (around 1,600L were poured into the 22 soak pit areas during the 2009 IRS campaign). Soak pit ground areas then are leveled and covered with concrete.

**Incineration of Contaminated Solid Wastes**

Approval to incinerate the 2007, 2008, and 2009 IRS contaminated solid wastes was obtained by the DEEC on July 14, 2009. The Regional Hospital Centre of Louga incinerator was chosen for the incineration operation. A training session on hygiene and safety for handling contaminated solid wastes was conducted by the RTI environmental officer for personnel involved in the incineration process.
The incineration started on July 29, 2009, in Louga at 1,150°C for the main chamber and 1,000°C for the secondary chamber (see Figures 6 and 7). The following incineration times were observed: 2 hours for empty ICON sachets and 1:45 minutes for other contaminated items. During the process, incineration operations were managed by maintenance workers; supervision was ensured by the hospital hygienists. Inspection was carried out by the representatives from the DEEC and the RTI environmental officer.

As of September 2, 2009, 1,050kg of contaminated solid wastes that included masks, gloves, and empty ICON sachets were incinerated. The incineration ashes were transferred to the ash dump built for this purpose. The analysis results issued by CERES Locustox (a laboratory approved by the DEEC) indicated that the incineration ash samples were free of lambda-cyhalothrin. Table 2 shows harmful effects registered following the 2008 IRS application.

### Challenges
To improve the system for IRS waste disposal, the following must be done:

- Reinforce the control of ICON sachets traceability to maintain a 100% collection rate.
- Supply the incinerator’s technical support center with spare parts.
- Support acquisition of an atmospheric analyzer for air quality control during smoke release from the chimney.

### Conclusion
A good partnership has been developed among RTI, government partners (e.g., the ministries of Health, Environment, and Agriculture and universities), beneficiary populations, and nongovernmental organizations (e.g., Christian Children's Fund, Plan International, etc.). This multisector collaboration has strengthened IRS, which contributed to the reduction of malaria morbidity and mortality in Senegal, without adverse effects to the environment.
References
Training of Trainers’ Manual for Vector Control and IRS in Malaria Control, WHO 2009, adapted to Senegalese context.

Implementation of the cadre plan of IRS environmental and social management on 2008, presented for the IRS evaluation by RTI/IRS Program Senegal. RTI Senegal.
Introduction
The U.S. Agency for International Development’s (USAID) identified Benin as a second-wave country to receive funding under the U.S. President's Malaria Initiative (PMI). USAID and the Benin National Malaria Control Program (Programme National Intégré de Lutte contre le Paludisme [PNILP]) identified four epidemic-prone districts—1) Akpro-Misserete, 2) Dangbo, 3) Adjohoun, and 4) Seme-Podji, in Ouémé Region—for indoor residual spraying (IRS) activities. In 2008, USAID and the PNLP agreed to focus spraying activities in Ouémé.

RTI International provides strategic, technical, management, and operations support for IRS activities in the above-mentioned districts. Malaria is the leading cause of morbidity in Benin, with an average rate of 65.8 cases per 1,000 people, accounting for 35% of outpatient visits (1.6 million recorded visits in 2001). The national health management information system (Système National d’Information et de Gestion Sanitaires [SNIGS]) indicates that in 2005, about 900,000 malaria cases and 1,581 malaria deaths were reported. This data, however, seriously underestimates true malaria cases and deaths. Roll Back Malaria (RBM) estimated that in 2004 there were about 3 million cases of malaria, and the World Health Organization (WHO)-convened Child Health Epidemiology Reference Group (CHERG) estimated that in the year 2000, between 10,000 and 13,000 malaria deaths occurred in children under five years of age.

Benin Country Malaria Control Strategy
- Case management of simple and severe malaria
  - Case management of malaria in health center: Availability of artemisinin-based combination therapy (ACT) in all health centers.
  - Case management of simple malaria in the community: Availability of ACT at the community level.
- Prevention
  - Long-lasting insecticide-treated net (LLIN) distribution;
  - Indoor residual spraying (IRS);
  - Intermittent preventive treatment in pregnant women (IPTp); and
  - Larvicides for vector control.
- Observation
  - Epidemiological surveillance;
  - Malaria drug efficiency;
  - Entomological surveillance; and
  - Pharmacovigilance.
- Monitoring and evaluation (M&E)
  - Periodic assessment for malaria data collection;
  - Supervision to support the local medical staff; and
  - SNIGS annual report publication.
• Communication
  – Contract with local radios; and
  – Television campaign to promote malaria drugs

• Community
  – Nongovernmental organization (NGO) and local stakeholder involvement in malaria control activities (e.g., IRS operations, information, education, and communication [IEC] campaigns).

**IRS Commodity Management and Supply**

A total of 4,400 kg of bendiocarb was procured for spray operations. The quantification was based on the field reconnaissance and data provided by the Ministry of Health (MOH). WHO-approved Hudson X-Pert compression sprayers were procured for each spray operator, with an extra 10% stock as backup for emergency and repair situations. Two sets of personal protective equipment (PPE), in accordance with WHO specifications, were provided to each spray operator and team leaders. Table 1 provides a summary of PPE procured.

<table>
<thead>
<tr>
<th>Table 1. PPE procured for IRS operations</th>
</tr>
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<tbody>
<tr>
<td>Compression Sprayers X-Pert, Model 67462AD 4 Gallon</td>
</tr>
<tr>
<td>Compression Sprayer Repair Kits for Item 1, Model</td>
</tr>
<tr>
<td>Compression Sprayer Nozzles Tip T-JET 8001, Model</td>
</tr>
<tr>
<td>Compression Sprayer Filters Nylon X-Pert, Model 152-356</td>
</tr>
<tr>
<td>Heavy Duty Gloves</td>
</tr>
<tr>
<td>Respirator Masks</td>
</tr>
<tr>
<td>One-piece Coveralls</td>
</tr>
<tr>
<td>PVC Gumboots</td>
</tr>
<tr>
<td>Lightweight Helmet and Face Shield</td>
</tr>
<tr>
<td>Pregnancy Test Kits 8 x 25</td>
</tr>
<tr>
<td>Reflective Jackets—Green</td>
</tr>
<tr>
<td>Reflective Jackets—Red or Orange</td>
</tr>
<tr>
<td>Medical First Aid Kits—10 Person/Kit</td>
</tr>
<tr>
<td>Barrel</td>
</tr>
<tr>
<td>Bendiocarb</td>
</tr>
</tbody>
</table>

To ensure better follow-up and maintenance, the PPE was marked “PNILP/Pulverisation Intra Domiciliaire.” PPE distribution per district is shown in Table 2.

<table>
<thead>
<tr>
<th>Table 2. PPE Distribution in each district</th>
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<tbody>
<tr>
<td>Districts</td>
</tr>
<tr>
<td>Aprons</td>
</tr>
<tr>
<td>Boots</td>
</tr>
<tr>
<td>Hard Hats</td>
</tr>
<tr>
<td>Pumps</td>
</tr>
<tr>
<td>Gloves</td>
</tr>
<tr>
<td>Respiratory Masks</td>
</tr>
</tbody>
</table>

**Management and Supply**

IRS operations were managed at the Porto Novo warehouse. Prior to the start of operations, the warehouse was divided into five sections to ensure that all the environmental rules and regulations were followed and to best control the operation’s flow. The first section of the warehouse was used as the central warehouse in which the pesticide and PPE were stored; the remaining four sections were designated for each of the districts. Each district’s storage was managed by a district logistician responsible for withdrawing materials from the central warehouse and tracking and documenting the movement of materials on forms. The district logisticians received pesticide on a weekly basis from the central warehouse manager. The PPE was allocated according to the size of the district and distributed to the group and team leaders after they signed a receipt form.

At the end of each day, empty sachets were collected by the district group leader, recorded on M&E forms, and given to the district logistician in the presence of the logistics manager. Both logisticians counted all the empty sachets and sealed them in barrels. All solid waste, including masks and gloves, were also sealed in barrels.
Selection of the Pesticide: Ficam M (Bendiocarb)

Many studies conducted in Benin have demonstrated a decrease in efficacy of pyrethroid-treated nets and IRS on *Anopheles* mosquitoes in zones of strong resistance, in southern Benin. As a result, there is a need to identify a non-pyrethroid, e.g., a carbamate or an organophosphate insecticide, for use in IRS against populations of pyrethroid-resistant *An. gambiae*.

To address this issue, a study was carried out to select a pesticide for IRS in Benin. The study compared the effect of two pyrethroids K-Othrine WG 250 (deltametrin 250g/kg) and Fendona 5WP (alpha-cypermethrin 50g/kg); two organophosphates Sumithion 40 WP (fenitrothion) and Master Quick ZC (mixture chlorpyriphos 250g/l + deltamethrin 12g/l); and one carbamate (bendiocarb 800g/kg).

During the 4-month evaluation, three insecticides Sumithion 40 WP (fenitrothion), Master Quick ZC (mixture chlorpyriphos 250g/l + deltamethrin 12g/l), and bendiocarb 800g/kg proved to be good candidates to combat pyrethroid-resistant *An* mosquitoes. Despite the short efficacy duration, bendiocarb was chosen because Master Quick ZC IRS formulation had not received WHOPES authorization for commercial use, and Sumithion 40 WP had some side effects and an odor.

Methods

Two IRS rounds were conducted in Benin, from July 3 to August 23, 2008, and March 10 to April 28, 2009. Residential structures were sprayed with sachets of bendiocarb. Total sachets used was 42,993 (22,984 for the 2008 campaign and 22,009 in 2009). During IRS operations, spray operators also collected data on mosquito net use in each district.

Results

In 2008, IRS operations lasted 44 days in the four targeted districts. Figure 1 shows IRS per district in 2008. Of the 151,783 structures targeted by 265 spray operators, 142,814 were sprayed and 521,738 people were protected (82,498 pregnant women and 42,101 children under five years). A total of 20,984 sachets of bendiocarb were used during this first round of IRS. In terms of mosquito net use, according to residents interviewed, LLINs were used more often than ordinary nets—a total of 88,838 LLINs and 83,011 ordinary nets.

In 2009, IRS operations lasted 42 days and required 22,009 sachets of bendiocarb. Figure 2 shows IRS per district in 2009. A total of 205 spray operators covered 156,233 structures out of 157,146 structures identified, protecting a total population of 512,491. In total, 130,710 people reported sleeping under LLINs, including 29,169 pregnant women and 56,185 children under the age of five. The total number of mosquito nets found in the four districts was 130,710.
Environmental Compliance

In IRS, the use of insecticide poses potential risks for spray operators, beneficiaries, and the environment. To minimize these risks, the various actors (particularly the spray operators, washers, drivers, storekeepers, service engineers, and other personnel working with pesticides) were trained on the proper handling of bendiocarb and the precautions to take during IRS operations. Moreover, each spray operator, washer, and storekeeper was equipped with PPE, consisting of a long-sleeved shirt, helmet, face shield and mask, pair of robust boots, and resistant gloves.

Conclusions

After two rounds, IRS appears to be a very good approach in integrated vector management control in Benin. The MOH, local stakeholders, and technical and finance partners are all mobilized to identify resources for expanding IRS to 13 others districts in 2010. To cover 15 out of 77 districts in Benin, the Government of Benin is currently seeking US$13.75 million.
Critical Steps in Implementing IRS Programs

Dr. Robert Ssengonzi
RTI International

Abstract
Implementing large-scale indoor residual spraying (IRS) for malaria prevention and control is a complex, multi-stage, and multi-pronged effort that requires adequate planning, capacity building, and infrastructure strengthening. It also requires appropriate timing of spray activities to ensure that the IRS program has a significant impact on reducing the malaria vector population in targeted communities. This paper highlights some of the critical steps that are necessary for a successful IRS program, using examples from past and ongoing activities in sub-Saharan Africa.

Introduction
Malaria is a health problem of enormous magnitude and socioeconomic impact in sub-Saharan Africa. It remains the leading cause of morbidity and mortality across the continent. Malaria vector control through indoor residual spraying (IRS) is one of the four key interventions recommended by the World Health Organization (WHO) to prevent and manage malaria. Depositing the standard dose of insecticide on potential mosquito-resting surfaces such as walls, ceilings, and eaves of residential structures through IRS helps control malaria by keeping the vector population at a minimum. After application of IRS, mosquitoes pick up a lethal dose of the chemical when they rest or land on the sprayed surfaces.

Implementation of large-scale IRS programs requires technical expertise, preparation, and adherence to protocols and guidelines around the following five key operational components: 1) IRS implementation capacity; 2) procurement and logistics; 3) IRS infrastructure; 4) safe and judicious use of insecticide during spraying; and 5) research, monitoring, evaluation, and compliance. This paper highlights the critical steps to follow in order to implement a successful large-scale IRS program.

Phase 1. Pre-spray Period
IRS Planning
A successful IRS program starts with timely planning during the pre-spray period. This includes conducting a baseline assessment of the major malaria vectors in the target communities, resting behaviors and house-resting densities of the identified vectors, and effectiveness of the various insecticides against those vectors. The assessment should also examine the type of wall substrate prevalent in residential homes in the targeted areas, together with the geographical terrain and rainfall patterns.

The planning process then moves toward a determination of the technical, financial, logistic, human capacity, and operational needs required to conduct successful IRS activities against the identified vectors. Early commencement of the planning process leads to timely ordering and procurement of all necessary commodities, training of spray personnel, and preparation of spray operation centers. It is recommended that this process commence at least six months before the start of the actual IRS activities. This duration can be shorter in subsequent spray rounds since some of the information already would be available. Micro-planning sessions should be held to discuss the data collected and review modalities for efficient execution of activities, as well as to cost out the spray program with the inclusion of stakeholders at various levels (e.g., national, province, district, community, village).
**Pesticide Selection**

This step builds on the entomological assessment that is conducted in target areas and leads to selection of a pesticide that would not only be effective against the malaria vectors, but also would be in compliance with the prescribed guidelines for pesticide use in the focus country. Pesticide selection should be made through transparent, rational, and evidence-based process to avoid misunderstanding. Key criteria to consider include susceptibility status of the vectors; registration status of the insecticide for IRS use in the focus country; duration of insecticide effectiveness on the wall substrates—taking into consideration local climatic conditions and compared to the duration of malaria transmission in the target areas; safety profile of the insecticide; and cost of the insecticide.

**Procurement and Logistics**

IRS programs are time sensitive and require a significant amount of commodities that must be procured during the pre-spray season. In addition, there is need for a robust logistics and commodity management system to be used during the implementation stage. The first critical step related to this component is to develop a procurement and supply plan that is most appropriate to the nature and needs of the particular IRS program. The plan should clearly delineate the necessary tasks and path to be followed, to maintain efficient procurement cycle times and to provide inventory and storage management throughout the spray season. The quantities of commodities procured should be based on the logistical assessment and should follow a competitive bidding process that would ensure delivery of the best quality products at a reasonable cost. Mechanisms should be put in place to ensure that all commodities are shipped, handled, and delivered safely. All commodities should be stored in warehouses that are compliant with recommended guidelines.

**Systems and Infrastructure for IRS implementation**

It is important to establish strong IRS operational systems and infrastructure ahead of spray activities. This includes recruiting spray personnel and providing sufficient knowledge and skills-based training to them; preparing operational centers (e.g., storage facilities, wash areas, and bath shelters) according to environmental and technical guidelines; conducting information, education, and communication (IEC) campaigns to mobilize the communities to be sprayed; and establishing an information system for capturing data on spray performance.

**Phase 2. During-spray Period**

If program planning, infrastructure development, and other preparatory activities are done properly during the pre-spray stage, they would culminate in an efficient implementation of IRS activities during the spray period. During the spray period, focus should be put on conducting activities in a timely manner and in accordance with technical and operational guidelines. The following sections describe key steps in this implementation stage.

**Adherence to Technical Standards during Implementation**

All spray activities should be done according to established technical standards and guidelines. First, the program should deploy an optimal number of personnel to cover the planned activities. Second, all spray personnel involved in the IRS program should be provided with appropriate personal protective equipment (PPE) that suits their roles, to avoid exposure to themselves, other spray personnel, the community residents, and the environment. Spray pumps, PPE, and other chemicals to be used should meet national and international technical standards and must be approved for public health use by the respective national agencies.

**IEC Activities**

IEC and social mobilization activities do help in increasing citizens’ knowledge about IRS, as well as support for and interest in IRS activities. However, for IEC activities to be effective, they must be conducted in a manner that reaches the highest number of the target population and in a format that allows for dialogue. It is also recommended that IEC activities are conducted throughout the spray period to keep the target population engaged and sensitized on their roles in IRS implementation, to proactively address possible community resistance and manage any adverse events. IEC can be done in different formats, including use of radio shows, community meetings, and printed visual materials. These forums can also be used to provide status updates of IRS implementation during the spray period.
Compliance Inspections
The program should conduct compliance inspections during the spray period to ensure that the recommended amount of insecticide is deposited on the sprayable surfaces of the target households. It should also ensure that the operations are conducted in full adherence to standards and that waste is properly managed. The inspections should also assess whether household members who reside in the sprayed homes actually comply with guidelines on preparation of homes for spraying, time required to wait before re-entering homes, and protection of household pets, poultry, and livestock during the spray activity.

Program Research, Monitoring, and Evaluation
Besides the entomological assessments and compliance inspections/audits, program monitoring information should be collected on the residential housing units, population residing in the units in each focus area, and coverage information (number and type of residential structures sprayed) during the spray period. Additionally, household interviews and focus group discussions can be conducted with various population segments—such as women, men, youth in school and out of school, and health workers—to identify perceptions and attitudes toward IRS. The interviews also provide feedback from the community about the spraying exercise in target districts. Results generated can be used to assess progress in program implementation and to make adjustments as necessary to enhance efficiency.

Phase 3. Post-spray Period
This period should be used to conduct post-spray compliance inspections; manage and properly dispose IRS-related waste; develop and disseminate IRS status and coverage reports; and review/inform specific IRS operational guidelines, to make them more responsive to the needs of the target population.

Post-spray Inspections
Assessments and inspections done during this stage will ensure that all equipment, commodities, and remaining insecticide after the spray program are cleaned, inventoried, properly stored, and compliant with environmental and technical guidelines.

Waste Management and Disposal
It is recommended that waste is minimized during the spray period and that all waste generated is properly separated between contaminated and uncontaminated categories. Contaminated waste should be disposed in an internationally accepted and recommended method, according to the Food and Agriculture Office (FAO) guidelines, such as incineration after the end of the spray period.

IRS Status Reports and Dissemination Meetings
Spray reports should provide relevant information that can be used to assess program performance and guide future implementation. Such information includes warehouse usage reports; safety reports, including any reports of adverse events (e.g., pesticide poisoning); environmental monitoring reports, as specified in the environmental assessment; quantity of chemical used; population protected; and costs incurred in the spray round. Dissemination meetings should be held at various levels (e.g., community, district/province, and national) and involve a wide range of partners—government, civil society groups, and the community—to review and discuss successes, challenges, and solutions associated with implementing an IRS program. These forums can also be used to deliberate on changes that may be needed to improve the performance of future IRS activities.

Promoting Local Ownership at All Stages of the Implementation Process
Successful IRS programs call for strong collaboration and partnership at all levels of the implementation continuum. They also require local partners’ active involvement and ownership of the implementation process. It is recommended that efforts be taken to strengthen the capacity of local government officials to participate in the coordination and implementation of IRS at the earliest opportunity. This approach will also lead to more efficient use of available resources.
Collaboration in IRS Scale-Up: Recent Experience in Ghana

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Ghana National Malaria Control Program
Dr. Paul Psychas
U.S. Centers for Disease Control/U.S. President’s Malaria Initiative, Ghana

Introduction

An interesting and perhaps instructive aspect of Ghana’s recent experience with scaling up indoor residual spraying (IRS) for malaria control is the successful, four-way collaboration between

- The Government of Ghana (Ministry of Health [MOH]/National Malaria Control Program [NMCP] and the University of Ghana);
- A private mining company (AngloGold Ashanti [AGA]);
- A U.S. bilateral program (the U.S. President’s Malaria Initiative [PMI]); and
- A multilateral program (the Global Fund to Fight AIDS, Tuberculosis, and Malaria [GFATM]).

This paper discusses the chronology and geography of this collaboration and present highlights of recent experience. It begins with a review of the country’s malaria situation and strategic framework and concludes with a brief examination of the way forward as Ghana seeks to aggressively scale up IRS for malaria control. Napoleon Graham, RTI International, and Steven Knowles, AGA, provided background documents that contributed greatly to this review; their contributions are gratefully acknowledged.

Malaria Situation

In Ghana, malaria has long been the leading cause of mortality, health facility attendance, and loss of work days and productivity [1-4]. Malaria is hyperendemic in all parts of the country, and Ghana’s entire population of 23 million is considered at risk. Transmission is year-round, but marked seasonal variation occurs in northern Ghana, associated with the prolonged dry season in October–April [4-6]. Malaria is the leading cause of mortality and morbidity, accounting for 36% of hospital admissions according to Ghana Health Service (GHS) records. Malaria-attributable deaths were estimated at over 25,000 for 2006, with over 90% occurring in children under five years of age [7]. Encouragingly, the 2008 DHS documented a 30% decrease in all-cause under five mortality since 2005 [8]. Major vectors in Ghana are Anopheles gambiae and An. funestus. Also prevalent are A. melas, on the coast, and A. arabiensis, in the north [4]. In rural areas, infective bite rates (EIRs) of 200–300 or more per person per year are common, and DDT resistance is widespread.

Evolving Strategic Framework for Malaria Control

Consistent with the international Roll Back Malaria (RBM) strategy, Ghana’s national strategy places priority on rapid scale up of long-lasting insecticide-treated nets (LLINs); artemisinin-based combination therapy (ACT), including home-based management; intermittent preventative treatment in pregnancy (IPTp); and IRS [7,9]. The National Malaria Control Strategic Plan 2008–2015 sets the goal of attaining 85–90% coverage of these major interventions by 2015, thereby reducing disease burden by 75% [4]. With support from GFATM, United Nation’s Children’s Fund (UNICEF), PMI/the U.S. Agency for International Development (USAID), and other partners, remarkable gains have been made, although significant gaps remain. Between 2003

Note: The views expressed are the authors’ own, and do not necessarily represent the view of the governments of Ghana and the United States.
and 2008, household insecticide-treated net (ITN) coverage significantly increased from 3% to 33%, and IPTp coverage increased from <1 to 41% of pregnant women [8]. Public health facilities are prescribing ACTs at rates >90%; however, due to access constraints and the ready availability of other medications through informal and private sector channels, the proportion of all febrile children under five receiving an ACT was just 12% in 2008 [8, 10].

In 2006, the World Health Organization (WHO) recommended scale up of IRS in areas of hyperendemic transmission such as Ghana [11]. Although IRS had been previously undertaken in Ghana, it was only conducted sporadically and on a limited scale. The national strategy now calls for aggressive scale up to cover 33% of all districts in the country. The national Integrated Vector Management Policy also embraces complementary methods, such as insecticide-treated curtains/wall linings, environmental management, and selective larviciding [12].

Policy priorities in malaria control include targeting of vulnerable populations, promoting equity in access, and promoting public-private partnerships. Ghana’s MOH/NMCP has a receptive attitude to would-be collaborators in malaria control, provided they work within the national and RBM strategies and adhere to standards. The Malaria Vector Control Oversight Committee was established in June 2009 to enhance collaboration and strengthen MOH/NMCP oversight.

**Summary of the Geography and Chronology of IRS Scale Up**

The map of IRS activity in Ghana shows a patchwork of programs across a diverse landscape, as summarized in Figure 1 and Table 1. In the southern forest zone, AGA has covered Obuasi Municipality in Ashanti Region since 2005. Newmont, Red Back, and other mines have begun implementing IRS at scattered locations in southeastern Ghana. A PMI-funded program has covered five contiguous districts

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**Figure 1. The geography of IRS scale up in Ghana**

PMI covers five districts in N. Region since 2008 (+3 more by 2010, not shown).

AngloGold Ashanti covers Obuasi in Ashanti since 2006.

Global Fund/AGA will cover up to 40 districts by 2015. (See key below.)

Lab facilities in Navrongo (GHS), Obuasi (AGA), Tamale (PMI) and Accra (Noguchi) support entomologic and epidemiologic monitoring.

Mines, plantations, and tourist resorts in Ashanti and W. Region will help support IRS operations.

Year 1  Year 2  Year 3  Year 4 and 5

Source: AGA and PMI
in Northern Region since 2008 and is expanding to eight districts in 2010. This program has been implemented by RTI, in collaboration with GHS. From 2010 to 2013, a GFATM grant will expand IRS into 35 additional districts, with AGA as the grant’s principal recipient and implementer.

Following is a brief chronology of how this unusual arrangement came to pass:

1950–1970s: Early IRS experience: Arial spraying was also done.

1980s–2005: Limited IRS by small operators and private researchers.

2005: AGA commenced IRS in Obuasi, as a central feature of its integrated malaria control program, which attracted many visitors, including President Kufuor in 2006. AGA offered its state-of-the art malaria control facilities for use by the MOH and other institutions.

July 2007: NMCP, AGA, PMI, and WHO collaborated on a GFATM Round 7 application for IRS. The application was not successful, but much was learned.

December 2007: A PMI program was launched in December 2007 and immediately funded a joint RTI/GHS program in the Northern Region, in support of the national strategy. AGA assisted with training and community outreach. The first spray round was conducted in May–July 2008 [13–14].

July 2008: The Ghana Country Coordination Mechanism submitted a revised GFATM Round 8 application for a US$130 million, 5-year program [15]. This time, AGA was designated as the principal recipient. The NMCP, PMI, and WHO collaborated in the program design and proposal writing, incorporating the best practices and lessons learned from the IRS pilots. The application was successful.

August 2009: The PMI pilot concluded its second spray round in six districts and confirmed plans to expand into two additional districts for the coming year [16,17].

November 2009: GFATM Round 8 grant was awarded. Implementation plans are based on AGA and PMI experience. Spraying will commence in July 2010.

The increased IRS activity has relied on the country’s laboratories, insectaries, and research facilities to support the necessary entomologic and epidemiologic monitoring. The key facilities—located in Navrongo (GHS), Obuasi (AGA), Tamale (PMI), and Accra (Noguchi Memorial Research Institute)—are receiving increased funding through the IRS programs, so that in-country laboratory capacity can keep pace with the increasing demand. All facilities have benefitted significantly from the technical guidance and local malaria control expertise of the Noguchi Memorial Institute for Medical Research at the University of Ghana-Legon.
Highlights of Recent Experience

AGA Malaria Control Program in Obuasi

This influential and well-regarded malaria control program has implemented comprehensive IRS, complemented by targeted larviciding in peri-urban areas, and increased use of ITNs and ACTs. The program has been characterized by the following:

- High standards in planning, training, community education, spray operations, environmental compliance, and entomologic monitoring.
- State-of-the-art malaria control facility on the grounds of an international mining operation.
- Active leadership role in promoting the Obuasi Model of IRS elsewhere.

Demonstrating impact has been a key to AGA influence. The company’s main health facility reported a remarkable and sustained 75% decrease in malaria cases between 2005 and 2008 (Figure 2). Anemia and parasitemia studies conducted in school children in the target area have demonstrated up to 50% reduction since the program commenced [unpublished data]. Reduction of malaria burden in the company’s work force has been remarkable (Figure 3). In Figure 2, the impact in the years 2007–2009 would have been magnified somewhat by the change in malaria case definition from largely empiric to largely laboratory-confirmed; nonetheless, the overall trend is obvious.
Program success has inspired mines in Ghana, Tanzania, and Guinea to adopt IRS. The program has exemplified the two pillars of effective IRS practice, i.e., community acceptance on the one hand, and well-trained, highly motivated spray operators, on the other hand. In October 2009, Ghana secured a large GFATM grant for implementation of IRS in 35 additional districts by 2013, with AGA as the grant’s principal recipient.

PMI in Northern Region
The PMI-funded program has demonstrated that large-scale, public sector IRS can be established safely and rapidly in Ghana, even in remote and deprived districts, where roads are poor and infrastructure limited. The scale is greater than ever seen in Ghana, as evidenced by the following statistics [10, 13]:

- Year 1 reached 601,000 people in five districts (target was 500,000);
- Year 2 reached 708,000 people in six districts; rooms sprayed: 284,800;
- Excellent community acceptance (>92% sprayable structures covered);
- More than 720 implementers trained; management capacity built at district, regional, and national levels; and
- Simultaneous operations at 22 sites; remotest areas were covered first (before rains cut them off).

The PMI program has been characterized by a strongly collaborative approach. The NMCP has been particularly pleased with RTI’s transparency, the PMI contractor, and its high level of interaction with partners. Key collaborators have included the MOH, GHS, NMCP; regional health authorities; regional technical staff (e.g., malaria focal person and regional biologist); District Health Management Teams; the Ghana Environmental Protection Agency (EPA); AGA; the Noguchi Institute of Medical Research; district assemblies; traditional and opinion leaders; and community members.

As depicted in Figure 4, a visit to a typical operational site highlights this collaboration. An unused GHS building was seconded as a district spray operations site. The spray teams shown were hired in local communities, at rates negotiated with GHS, from candidates nominated by district. Implementation was overseen by district and national RTI staff. Monitoring visits were conducted by NMCP and PMI staff from Accra. Community mobilization efforts relied on existing GHS health volunteer networks. Specially trained information, education, and communication (IEC) implementers were deployed for the spray season. Community

Figure 4. PMI/GHS operational site in Savelugu-Nanton District, Northern Region

Source: NMCP
volunteers visited every house, complementing radio spots and talk shows in English and local languages (Dagbani and Mampruli). The social cohesion of rural communities and the influence of chiefs were used to advantage. These activities more than compensated for the logistical challenges of the most rural terrain, such that coverage rates have approached 100% in several districts (e.g., 99% in Karaga and 95% in East and West Mamprusi; see Figure 5). Continual learning and quality improvement is a strength of this pilot program.

The Way Forward

As Ghana aims to further scale up IRS, there would appear to be consensus that the major stakeholders should make good upon the following intentions:

1) All IRS implementers will maintain high standards of operator performance, community engagement, and environmental compliance.

2) The NMCP, aided by the new Malaria Vector Control Oversight Committee, will aim to refine and enforce its draft standard operating procedures for IRS. It will refine strategies for capacity building and insecticide resistance management.

3) The NMCP and the committee will foster improved coordination among existing programs, while also providing oversight and guidance to newly emerging partners (e.g., sanitation and larviciding companies).

4) The Government of Ghana will assume more responsibility with each new IRS round, at all levels, including
   – MOH, GHS, and NMCP;
   – District authorities;
   – District disease control officers;
   – Regional authorities (Northern Region is showing the way); and
   – Environmental managers.

5) The major IRS programs will continue to cooperate and to learn from each other.
   – The PMI-funded program has been encouraged to demonstrate IRS impact in terms of malaria burden and entomologic parameters. The program plans to conduct operational research in 2010–2012 to validate its one-spray-round per year approach, looking at trends in parasitemia among school children.
   – The AGA/GFATM program has been encouraged to enhance its transparency and increase interaction with partners such as the EPA. This will tend to occur naturally, as it absorbs the activities in Obuasi Municipality. The Malaria Vector Control Oversight Committee provides a suitable platform for open review of all partner and regulator activities.
   – As the GFATM/AGA program implementation rolls out, there will be important opportunities for joint investment (e.g., training, entomologic facilities, etc.), and for harmonization of monitoring and evaluation indicators.

6) Programs would need to design strategies to cope with increased outdoor biting, if entomologic data shows sustained trends.

Figure 5. IRS coverage rates year 2 (% of sprayable structures sprayed). Sprayable structures are defined in the PMI program as “rooms where people sleep.” This excludes food stores, outdoor cooking areas, animal shelters, shops, schools, churches, etc.

Source: RTI
Conclusion
Ghana is poised to implement its policy of aggressive scale up of IRS. In the coming years, this will place enormous demands on logistics, coordination, training, epidemiologic and entomologic monitoring, etc. Yet recent experience suggests that Ghana can face this future with confidence. There is a diversity of successful IRS implementation experience in the country to build on. Moreover, there is proven willingness of the key partners (public and private) to collaborate selflessly and effectively in the common cause of malaria control (Figure 6).

Figure 6. Collaborators in IRS at the Ghana NMCP Office, High-Level Conference on Aid Effectiveness Site Visit, Accra, September 2008

Depicted, from left to right:
Ghana Global Fund CCM Chairperson
Mr. Frank Boateng
WHO Ghana Malaria Advisor
Dr. F. Owusu-Antwi
Ghana Health Service Director General
Dr. Elias Sory
USAID Director Ms. Henrietta Fore
Ghana NMCP Manager
Dr. Constance Bart-Plange
RTI Ghana Chief of Party
Napoleon Graham and RTI staff
AGA staff members

Source: PMI Ghana
References


Malaria is one of the major causes of disease burden in Madagascar, with confirmed out-patient visits in health facility centers reported at 19% in 2006 and 4.9% in 2008. It is the second cause of mortality at health facility centers in Madagascar. The Programme Nationale de Lutte contre le Paludisme promotes vector control through the use of indoor residual spraying (IRS).

IRS was implemented in the central highlands after a serious epidemic in 1988, followed by blanket coverage of this epidemic-prone area from 1993 to 1997. Since 1998, spraying activities have been focused only in some residual clusters within the central highlands.

Methods
Madagascar’s malaria elimination strategy includes combined and integrated strategies that are implemented based on epidemiological evidence. IRS is an important component of this strategy. IRS operations in 2008 were carried out with the technical and financial support of the

- Global Fund to Fight AIDS, Tuberculosis, and Malaria, Round 7, for 26 districts; and
- U.S. President’s Malaria Initiative in seven districts.

In Madagascar, IRS is implemented

- Before the transmission and epidemic season in November; and
- Across the entire central highlands and fringes in eight regions, covering 33 districts and 525 communes.

Results
Results from IRS operations in 2008 achieved the following targeted indicators:

- 96.1% of structures targeted were sprayed; and
- 96.9% of population targeted was protected.

Conclusions
Successful IRS operations were carried out in Madagascar due to

- Support from local authorities at different levels;
- Collaboration of other ministry, community, political and religious leaders;
- Effective community participation; and
- Collaboration of health agents at different levels.
Introduction

The global strategic plan for Roll Back Malaria (RBM) recommends that by 2010, 80% of the at-risk population should be protected from malaria by using effective vector control measures. To achieve this goal, there is a need to scale up all effective components of integrated vector management (IVM), which includes long-lasting insecticide-treated nets (LLINs), indoor residual spraying (IRS), environmental management, and larval control.

Evidence has shown that at 85% coverage of targeted populations and structures, IRS remains the most effective intervention that rapidly reduces malaria transmission. Reports from the pilot trials showed that IRS is feasible, effective, and acceptable in Nigeria.

There have been reports of poor utilization of insecticide-treated nets (ITNs) despite the scale up for impact in the country. It, therefore, is necessary to use IRS to complement the use of ITNs, particularly in areas of high malaria prevalence and where there is evidence of poor utilization of ITNs.

Resulting from the realization of IRS’s effectiveness in malaria control, the National Malaria and Control Programme (NMCP) is determined to scale up IRS (and other malaria control interventions) in Nigeria to achieve global elimination. The broad objective of using IRS in Nigeria is to reduce malaria transmission by decreasing malaria vector life span and population density. It is expected that the IRS program will protect 20% of the total households in Nigeria by 2013.

IRS Initiation in Nigeria

As part of the IRS initiation process in Nigeria, two pilot trials were conducted in 2006 and 2007, in collaboration with the private sector, Syngenta, Harvestfield, and Dizengoff West Africa, in five local government areas (LGAs). The LGAs in which the pilot trials were conducted and insecticides used are shown in the Table 1.

Table 1. IRS pilot LGAs

<table>
<thead>
<tr>
<th>State</th>
<th>LGA</th>
<th>Insecticides used</th>
<th>Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Borno</td>
<td>Damboa</td>
<td>Lambda-cyhalothrin, bifenthrin, alpha-cypermethrin</td>
<td>2006</td>
</tr>
<tr>
<td>Lagos</td>
<td>Epe</td>
<td>Lambda-cyhalothrin, bifenthrin, alpha-cypermethrin</td>
<td>2006</td>
</tr>
<tr>
<td>Adamawa</td>
<td>Madagali</td>
<td>Deltamethrin, bendiocarb</td>
<td>2007</td>
</tr>
<tr>
<td>Ogun</td>
<td>Remo North</td>
<td>Deltamethrin, Bendiocarb</td>
<td>2007</td>
</tr>
</tbody>
</table>

The pilot trials were evaluated by the World Health Organization (WHO), which revealed the following: IRS was feasible in Nigeria; insecticides tested were effective, and IRS was recommended for scale up. The results of the pilot trials and the attendant recommendations encouraged the NMCP to scale up IRS implementation in Nigeria.
IRS Structures
The pilot trials were followed by a series of activities that culminated in the first IRS operation in 2009. To provide clear direction and guidance, IRS policy, guidelines, and implementation plans were developed in collaboration with RBM partners with major inputs from WHO.

An IRS management structure was established at all levels across the states, supported by the World Bank Malaria Booster Project for proper management of IRS in Nigeria, and represented various ecological zones. Vector control officers at the national, state, and LGA levels were identified, and their roles and responsibilities were clearly stated.

Realizing that the states lack the capacity to successfully plan and implement IRS, notable entomologists were therefore identified from universities and research institutes to engage as principal investigators (PIs) in collaboration with the states. Their terms of reference include conducting entomological baseline surveys, monitoring insecticide resistance, liaising with the state to implement IRS, and documenting results.

Scale Up and Targets for IRS in Nigeria
The use of IRS shall be expanded progressively to protect 20% of the total households in the country by the year 2013. Scale up of IRS in Nigeria is indicated in Table 2.

Selection of LGAs for IRS
One LGA in each of the identified states was selected for initial IRS implementation. The strategy involves expanding to other LGAs in the state, based on availability of resources, and is expected to provide lessons learned and best practices for scale up. The LGAs selected are shown in the Table 3.

Procurement of Equipment and Materials
Insufficient equipment and materials were procured for total coverage of the LGAs selected. The insecticides only covered about 2–3 wards, depending on the LGA’s size. Table 3 shows the distribution of procured materials to the selected LGAs.

<table>
<thead>
<tr>
<th>Table 2. Scale up of IRS in Nigeria</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Year</strong></td>
</tr>
<tr>
<td>Proportion of households to be covered</td>
</tr>
<tr>
<td>Number of households to be covered</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Table 3. States and LGAs selected for IRS</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>State</strong></td>
</tr>
<tr>
<td>Akwa Ibom</td>
</tr>
<tr>
<td>Anambra</td>
</tr>
<tr>
<td>Bauchi</td>
</tr>
<tr>
<td>Gombe</td>
</tr>
<tr>
<td>Jigawa</td>
</tr>
<tr>
<td>Kano</td>
</tr>
<tr>
<td>Rivers</td>
</tr>
<tr>
<td>Total</td>
</tr>
</tbody>
</table>
Training

Training manuals for managers and spray operators were developed in 2007 and introduced to state RBM managers and state vector control officers. This was followed by a training of trainers (TOT) for state RBM managers, state IRS officers, and state malaria training officers. The TOT was facilitated by WHO consultants, Bayer Environmental, Hudson X-Pert, Syngenta, Harvestfields, and Dizengoff West Africa. The training for supervisors, team leaders, and spray operators was carried out at the ward level, with the participation of Syngenta, Harvestfields, and Dizengoff West Africa. Trainings were also conducted for baseline entomological data collection and house enumeration.

Advocacy and Community Mobilization

Advocacy visits were made to state ministry officials, at which time their support for IRS was solicited. The National IRS Team, in collaboration with the state support teams, paid advocacy visits to LGA officials and communities to enlist their support.

The community was involved from the outset. Several community meetings and dialogues were held during which community members were educated on the IRS operation, safety of the insecticides to be used, and their responsibilities. Community development committees were involved in the selection of the youth engaged in entomological baseline data collection, house enumeration, and spraying.

Baseline Data Collection

A pre-entomological baseline data-collection meeting was held at the Nigerian Institute for Medical Research, Lagos. Representatives of the NMCP, state malaria control program managers, state IRS officers, PIs, and resource persons attended the meeting. The meeting’s objective was to orient PIs, state malaria control program managers, and state IRS officers; develop standard operating procedures and protocols for the baseline data collection; and develop next steps for IRS implementation in the states.

Since most universities lack modern equipment such as a polymerase chain reaction machine for molecular analysis, PIs were restricted to only assessing the indoor resting density of anopheline mosquitoes and susceptibility of the local anopheline mosquitoes to the proposed insecticides for IRS.

The mosquitoes collected through pyrethrum spray catch were sent to the Nigerian Institute for Medical Research, Lagos, for further analysis. In addition to the orientation meeting, PIs and state IRS officers were further trained at the Nigerian Institute for Medical Research, Lagos.

The entomological baseline data collection was designed to be carried out monthly for a period of six months (July–December 2009), to provide comprehensive data.

House Enumeration

Households for spraying were enumerated and issued spray IRS cards, which were hung on secured places in the houses. Households were instructed on the importance of the spray cards. Maps were produced by geographic information systems (GIS) and enumeration of houses conducted using geographic positioning systems (GPS).

Spray Operation

Three of the states—Akwa Ibom, Kano, and Anambra—have not completed the spray operations. Baseline surveys started in all the seven states in July 2009.

The training of supervisors, team leaders, and spray operators in Gombe, Bauchi, and Rivers preceded the spraying operations. The training involved participation of the state team, NMCP representatives, and RBM private partners (Syngenta, Harvestfields, and Dizengoff West Africa), particularly in Rivers State. Training was conducted for four days. Participants were drilled on spraying techniques, how to fill out the spray cards, use of data capturing forms, and proper waste management. Medical examinations were conducted for all personnel engaged in the spray operation to ascertain their fitness. Certificates were awarded to all trained personnel at the end of the training. Mock sprays were carried out in a few households in identified communities.

Supervision, Monitoring, and Daily Debriefing Meeting

The spraying operation was supervised and monitored by national representatives, state, and LGA IRS teams, as well as the recruited supervisors. The monitoring was carried out using checklists and reports from the field, including problems...
encountered, collated, and discussed at the daily debriefing meetings.

**Bauchi State Post-spraying Activities**

Post-spraying activities include the following:

- Conduct bioassays on walls using the WHO Bioassay Cones to assess the
  - Quality of spray (day 1 after spraying, on the third and sixth months); and
  - Residual effect of insecticides on sprayed walls.
- Monthly assessment of indoor resting density of anopheline mosquitoes in randomly selected households.
- Administration of questionnaire to find out opinion about the efficacy of the spraying and other related issues.

**Strengths**

- The participation of the private sector (Syngenta, Harvestfields, and Dizengoff West Africa) in the training and presentation of certificates provided a boost for the recruited personnel.
- Collaboration with research institutes and universities strengthened the operation.
- The kick-off ceremony, which included media events, held by the executive governors in some states, led to increased awareness of IRS.
- Support from the states, LGAs, and community development committees was a clear demonstration of the positive impact of collaboration among various levels of government.

**Weaknesses**

- Spraying was conducted during the rainy season in some areas, causing several delays and hindering movement. Households could not take their property outside when it was raining.
- The rains interfered with GPS use for mapping because the technology relies on satellite images.
- Engagement of private companies for house enumeration using GPS was quite expensive and delayed the enumeration exercise, as only one or two GPS were used. Use of GPS will be more expensive and laborious, considering the expansion of IRS in future years. The procurement of GPS and PDAs will be more cost-effective.
- Poor quantification occurred because some states selected more wards than the available quantity of insecticides to cover selected areas. As a result, this might not achieve the desired mass effect.

**Challenges**

- Most households did not prepare their houses for spraying, which led to delays.
- Complaints were made by spray operators, requesting increases in their daily allowance in one of the states.
- Some spray operators refused to return the protective clothing provided to them in Rivers State.
- NMCP staff felt that retrieving the protective clothing from the spray operators was not hygienic. They proposed buying cheaper protective clothing materials and giving them to spray operators after each spraying cycle.

**Recommendations**

1. Ensure that spraying operations end before the onset of the rainy season.
2. Procure materials and equipment in a timely manner.
3. Procure GPS and PDAs for house mapping to drastically reduce cost and develop capacity for sustainability.
4. Conduct intensive advocacy for community leaders and community mobilization, as they are needed to improve the IRS acceptance by community members.

**Conclusion**

Community acceptance of IRS is apparent and encouraging. Evidence strongly indicates that there is great potential for the successful implementation of IRS in Nigeria. However, resources are needed for the program to achieve the 20% target (i.e., 6,000,000 households) of IRS coverage in order to eliminate malaria by 2013.

Appropriate planning, effective coordination, supervision, monitoring, and commitment are also essential ingredients for the success of the National IRS Campaign in Nigeria. Sustainability of IRS largely depends on community empowerment. As such, there is a need to leverage the existing community structure.
Developing a Seamless Partnership in Planning, Procuring, and Providing IRS Products

Ms. Jean Benedict
Crown Agents

What We Do: Integrated Supply Chain Solutions, Which Lead to Sustainable Supply Chain Systems and Capacity in Partner Countries

- Procurement: Actively seek out new vendors with quality products and delivery capacity.
  - Develop and maintain relationships with leading manufacturers of chemicals, spray pumps, and protective clothing worldwide.
  - Regularly meet with major chemical manufacturers to discuss industry developments and logistics issues relevant to Africa country deliveries.

- Logistics and Distribution: Competitive shipping, delivery, and clearing/forwarding services provided by senior logistics team in Nairobi, the United States, and the United Kingdom.
  - Manage deliveries from vendors in the United States, Europe, and Africa to field sites/district warehouses in Africa.

- Payroll/Cash in Transit Service: Delivery of cash stipends to indoor residual spraying (IRS) laborers in the field.

- Renovation Design/Engineering and Construction Procurement: Design and construction of evaporation tanks and district warehouse facilities.

Importance of Supply Chain Systems to Health Programs

- Development of a reliable, secure, and cost-effective supply of drugs and health-care products is essential.
  - Right product: Selection that meets specific country settings.
  - Right condition: Quality assurance and secure delivery.
  - Right cost: Efficiency savings through integrated procurement and logistics services.
  - Right place: Delivery coordination with spray teams and field managers.
  - Right time: Planning for rainy season deadline is key.

Box 1. Crown Agents supply chain fundamentals

<table>
<thead>
<tr>
<th>FUNDAMENTAL 1. Value-for-Money Procurement</th>
<th>Result Expected: Greater participation, both local and international, in the procurement procedures and greater competition, which leads to better value for money.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Analyze Market Conditions to Optimize the Success of the Procurement Activity</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>FUNDAMENTAL 2. Procurement Planning</th>
<th>Result Expected: The procurement activity supports overall project implementation, budgeting, and draw down process and goods. Services and works are delivered to the correct specification, at the right place, and at the right time.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plan, Schedule, and Prioritize Procurement Functions</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>FUNDAMENTAL 3. Logistics Management</th>
<th>Result Expected: Logistics coordination takes place seamlessly and supports overall project implementation, by ensuring that goods are delivered to the correct specification, at the right place, and at the right time.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Schedule and Carry Out Door-to-Door Delivery</td>
<td></td>
</tr>
</tbody>
</table>
• Development of strategic partnerships with other donors, government partners/malaria control programs, WHO Pesticide Evaluation Scheme, and manufacturers.

Where We Are on IRS Supply Chain Management: “Buy and Supply” Stages

• Subcontract with RTI International to provide outsourced procurement and logistics services on a task order basis.

• Receive task orders for purchasing and delivery requirements on average approximately 6–8 weeks before products are due in country.

• Submit budgetary requirements/response to task orders within one week.

• Issue public tenders for goods on the same day that the budget is approved.

• Close tenders within one week; perform evaluations within one week.

• Manage vendors and provide procurement transparency, best price, and best practice at all stages of the process, including logistics and shipping.

• Reduce order and delivery times in half, in most cases.

• Reduce cost of shipping and delivery.

Model Procurement Plan

• For projects such as IRS, where time is of the essence, it is critical to have a plan in place and agreed upon by all stakeholders, as early as possible, to facilitate a smooth supply chain process.

• Crown Agents has developed a model procurement plan for IRS based on years of practice and experience with other donor-funded projects that will save time and involve all partners in the process with an agreed-upon schedule of commitments for IRS commodities and delivery.

  – Plan includes: What will take place and when; intended and agreed outcomes; each stakeholder’s responsibilities in contributing to the realization of the outcomes; and provision for ensuring sites are suitable to receive and store commodities and that local staff are available for training.
Ordering and planning in advance could allow for new products to be tested and a wider range of cost-competitive choices to be sourced.

**Moving Forward Toward Innovation: Integrated Service Structure and Planning**

**Step 1: Engagement**
- Active engagement in the strategic planning process at the country level to develop forecasts and help source and manage warehouse capacity on the continent.
- Formation of a Nairobi Working Group to review operational plans, determine and forecast needs, and collect data for annual procurement plan.

**Step 2: Development of Model Procurement Plan**
- Sound planning is essential if appropriate goods and equipment are to arrive when and where they are needed.
- Through involvement at the design stage, we can contribute our product, price, and marketplace knowledge to help develop procurement budgets and highlight any potentially disruptive elements, such as long delivery times.
- Procurement plan can act as a management tool to be developed and used by all stakeholders (see Figure 1).

**Step 3: Supply Management**
- Development of reserve commodity stock and proper management in vendor-leased and public warehouse facilities.
- Development of procurement plan and quantification across all IRS program countries will allow Crown Agents to negotiate global indefinite quantity contracts (IQCs) with vendors and store reserve stock in vendor-leased warehouses on the continent for up to nine months in advance of orders.
- Support of logistics consultancy can help build sustainable capacity within partner governments in warehouse management, inventory control, and distribution planning and implementation.

**Step 4: Benefits of Improved Planning**
- Global plans and framework agreements will allow programs greater command of market dynamics (e.g., improved prices, relationships with suppliers, etc.).
- Logistics methodology changes to lower cost options (e.g., sea freight becomes more viable with greater lead times).
- Proper storage and stock analysis could revolutionize the capacity of local governments to mobilize quickly and effectively to spray at the optimal times of the year.

![Figure 1. Model procurement plan](image)

**INNOVATION = QUALITY + COST CONTROL**
Combining Indoor Residual Spraying and Insecticide-Treated Net Interventions

Immo Kleinschmidt, Christopher Schwabe, Murugasampilay Shiva, Jose Luis Segura, Victor Sima, Samuel Jose Alves Mabunda, and Michael Coleman

London School of Hygiene and Tropical Medicine, London, United Kingdom; Medical Care Development International, Silver Spring, Maryland; Global Malaria Programme, World Health Organization, Geneva, Switzerland; Ministerio de Sanidad y Bienestar Social, Malabo, República de Guinea Ecuatorial; Ministerio da Saúde, Maputo, Mozambique; Malaria Research Programme, South African Medical Research Council, Durban, South Africa; Liverpool School of Tropical Medicine, Liverpool, United Kingdom

The paper can be found on the following pages.
Combining Indoor Residual Spraying and Insecticide-Treated Net Interventions

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Abstract. Does scaling up of malaria control by combining indoor residual spraying (IRS) and long-lasting insecticidal nets (LLIN) enhance protection to populations? Results from a literature search and from recent household surveys in Bioko, Equatorial Guinea, and Zambezia, Mozambique, are presented. Five out of eight previous studies reported a reduced risk of infection in those protected by both interventions compared with one intervention alone. Surveys in Bioko and Zambezia showed strong evidence of a protective effect of IRS combined with nets relative to IRS alone (odds ratio [OR] = 0.71, 95% confidence interval [CI] = 0.59–0.86 for Bioko, and OR = 0.63, 95% CI = 0.50–0.79, for Zambezia). The effect of both interventions combined, compared with those who had neither, was OR = 0.46, (95% CI = 0.76–0.81) in Bioko and 0.34 (95% CI = 0.21–0.56) in Zambezia. Although the effects of confounding cannot be excluded, these results provide encouragement that the additional resources for combining IRS and LLIN are justified.

INTRODUCTION

Malaria control and elimination interventions are being scaled up and intensified in current efforts to attain World Health Assembly, Roll Back Malaria, and Millennium Development universal access and coverage targets, to reduce and interrupt disease transmission in countries. The major malaria intervention tools now include long-lasting insecticidal nets (LLIN), artemisinin-based combination therapy (ACT), indoor residual spraying of insecticide (IRS), and intermittent preventive treatment in pregnancy (IPT). Since 2007, there have been increasing global efforts toward sustainable scaling up of malaria control to bring about rapid reductions in transmission and move toward long-term goals of malaria elimination and global eradication.

Insecticide-treated nets (ITNs) and IRS have each been shown to be highly effective methods of malaria vector control in their own right. A recent review of the evidence of cost and consequences of large-scale vector control for malaria concluded that both ITNS and IRS are highly cost-effective vector control strategies. ITNs have been the mainstay of vector control in many countries in which the disease is endemic and where infrastructure limits or precludes the implementation of IRS. Despite extensive evidence of their proven efficacy in reducing malaria morbidity and mortality, ITN ownership and use remains low in many of these countries.

In 2006, the World Health Organization (WHO) recommended that, where appropriate, IRS with dichloro-diphenyl-trichloroethane (DDT) or other insecticides should be a central part of national malaria control strategies. Synthetic pyrethroids are safe alternatives to DDT especially in modern housing surfaces and in low and seasonal transmission areas. Where malaria vectors are resistant to DDT or pyrethroids, more expensive, shorter duration insecticides have to be used (carbamates and organophosphates). In Africa, sustained IRS has historically been used mainly in the southern part of the continent, where it has been successful in controlling malaria and reducing transmission. With current efforts to scale up malaria control in Africa, IRS has been introduced in a number of countries with initially high levels of transmission. However, IRS requires more complex and costly operational delivery systems than ITNs and claims of sustained high coverage often remain unproven.

In some countries where more resources have become available, malaria control programs have deployed both IRS and LLIN in the same malaria risk areas. The reasons for this combined approach are 1) to reduce transmission and hence the malaria burden of disease more rapidly than may be feasible with one method alone; 2) to increase overall coverage of vector control protection, for example when full IRS or ITN coverage is difficult to sustain; and 3) to delay the emergence of insecticide resistance by using different classes of insecticide for IRS and LLINs.

This study reports on a review of current evidence on whether the use of both interventions in combination versus one method alone affords enhanced protection to exposed populations. Results of a literature search and of analysis of recent household survey data from Bioko, Equatorial Guinea, and from Zambezia province, Mozambique, are presented.

METHODS

Forty articles or reports were identified searching the databases Ovid/Medline and Ovid/Global Health for publications that mentioned both IRS and nets in the same report. Eight of these studies compared health or entomologic outcomes between areas or individuals using mosquito nets in IRS-treated houses, and IRS or mosquito nets alone. Nine were reports on studies in which a comparison was made between areas using nets and areas using IRS, either in terms of efficacy or in terms of cost-effectiveness. The remaining articles dealt with aspects of malaria vector control not directly relevant to the question of combined use of IRS and mosquito nets. There were no reports of studies in which combined interventions and use of one intervention alone were randomly allocated either to individuals or to houses or to areas. None of the published reports gave any assessment of combined vector control coverage achieved in areas benefiting from the use of both methods together.
Data from five household surveys undertaken between 2006 and 2008 in Bioko, Equatorial Guinea, and in Zambezia, Mozambique were analyzed to estimate the combined effect of IRS and nets on prevalence of infection, compared with IRS alone. In each of these surveys rapid diagnostic tests (RDT) were used to determine infection with *Plasmodium falciparum* in children 2 to < 15 years of age. Questionnaires were used to record whether the house in which the child lived had been sprayed with insecticide in the previous 12 months, whether the child had slept under a mosquito net the night before the survey, and what household goods and services were available in the house. The condition of nets as to whether they were new, or had recently been treated with insecticide, or were LLIN was determined in only some of the surveys, and we report on these separately.

The three surveys in Bioko were carried out in 2006, 2007, and 2008 as part of monitoring and evaluation of the Bioko Island Malaria Control Project (BIMCP). Bioko is situated in the equatorial tropics in the Gulf of Guinea with high rainfall throughout most of the year. The BIMCP introduced IRS in 2004 with initially a single round of pyrethroids, followed from 2005 onward by two rounds per year of bendiocarb. LLINs were distributed by the BIMCP to cover all sleeping areas in all households in 2007, though nets had previously been distributed on a smaller scale and their use was monitored in surveys from 2006. All BIMCP surveys were carried out on randomly selected households in 18 sentinel areas that cover almost the entire Island. Households were selected from sampling frames constructed by listing all houses in sentinel areas using personal digital assistants (PDA) or from census enumeration lists. All children between 2 and < 15 years of age in selected households who were present at the time of the survey were tested for *P. falciparum*.

The surveys in Zambezia, Mozambique in 2006 and 2007 were carried out through the malaria decision support system project (MDSS), based at the Medical Research Council of South Africa. Zambezia province is situated in south-central Mozambique and is characterized by seasonal rainfall from November to June. Surveys were conducted at 19 sentinel sites established in 2006 for monitoring and surveillance of the malaria control program. Before 2006 the only vector control intervention in the area was mosquito nets. IRS was introduced in 2006, initially by the national malaria control program and later supported by Presidents Malaria Initiative.

Permission to carry out the surveys was obtained from the Ministry of Health and Social Welfare in Equatorial Guinea, and from the Ministry of Health Ethics Committee in Mozambique. Informed consent was obtained from a responsible adult in each participating household, and from children who were tested, where appropriate.

For each of the five surveys, prevalence of infection was calculated for four groups of children: 1) those whose house had not been sprayed in the past year and who did not sleep under a net the night before the survey, 2) those whose house had been sprayed in the past year but who did not sleep under a net, 3) those who did sleep under a net but whose house had not been sprayed in the past year, and 4) those who slept under a net in a dwelling that had been sprayed. For each survey the odds ratio (OR) of infection with *P. falciparum* for those protected directly by IRS combined with nets relative to those who were protected by IRS alone was calculated separately for those sites in which parasite prevalence was under 35%, and for those sites in which prevalence was 35% and over. Sentinel sites were specified as the primary sampling units in statistical analysis that allowed for complex survey designs in the statistical package Stata.

For the most recent survey data for each of the two programs (2008 for Bioko and 2007 for Zambezia) multiple variable logistic regression was used to assess whether sleeping in an IRS-treated house and sleeping under a net were independently associated with infection status of a child, and whether these associations were the result of confounding by the wealth status of the house. For the analysis of the 2008 data from Bioko net use was restricted to mean ITN or LLIN use (rather than any net) since the status and type of each net was known and because the number of ITN/LLIN users was sufficiently large. For the analysis of the 2007 data from Zambezia net use was taken as any mosquito net, because treatment status of nets was not verified by interviewers. For the Bioko analysis whether the house had electric lights was used as a proxy indicator of household wealth; similarly, for the Zambezia data whether the household had a radio was used as a proxy indicator of household wealth. The logistic regression models were also used to test whether there was modification (interaction) of the effect of IRS treatment by the effect of sleeping under a net/ITN, and vice versa.

**Funding sources.** The BIMCP is funded by a consortium led by Marathon Oil Corporation (Houston, TX). The MDSS is funded by the Innovative Vector Control Consortium.

**RESULTS**

The three surveys in Bioko and two in Zambezia show ORs of < 1 for prevalence in children protected by both IRS and nets relative to IRS alone (Table 1). There was generally moderate to strong evidence of this effect across both high and low prevalence sites. Pooling the data for each project, there was strong evidence of a protective effect of IRS combined with nets relative to IRS alone (OR = 0.71, 95% CI = 0.59–0.86, *P* = 0.001 for Bioko, and OR = 0.63, 95% CI = 0.50–0.79, *P* < 0.001 for Zambezia).

Multiple variable analysis showed that living in an IRS-treated house had a protective effect on infection corresponding to an OR of 0.68, 95% CI = 0.48–0.94 in Bioko and of 0.49, 95% CI = 0.28–0.88 in Zambezia, regardless of whether the child was also sleeping under an ITN/net or not (Table 2). Similarly, sleeping under an ITN/LLIN or any net had protective effects on infection (OR = 0.68, 95% CI = 0.48–0.97 for ITN/LLIN on Bioko, OR = 0.70, 95% CI = 0.54–0.90 for any net in Zambezia) regardless of whether the child simultaneously slept in an IRS-treated house or not. In Bioko, there was no evidence of an association between infection and the house having electric lights; including this variable in the model did not alter the effects of IRS and ITNs, respectively (not tabulated). In Zambezia there was only weak evidence of an association between infection and the household having a radio, and including this variable in the model did not alter the effects of IRS or net use, respectively. There was no evidence of interaction between the effects of IRS and of ITNs in Bioko (*P* = 0.976) or between IRS and nets in Zambezia (*P* = 0.493).

Previous studies that compared IRS combined with ITN vector control with one method alone give contradictory results. Some studies reported that there was no incremental benefit.
in terms of lower risk of infection, lower incidence of cases, or lower vector abundance and infectivity associated with the use of ITNs/LLINs, or untreated nets in areas that had been IRS treated. Other studies do report evidence of lower risk of infection for children who used nets (treated or untreated) and lived in an IRS-treated house, compared with those living in an IRS-treated house without nets. Rowland and others reported substantially lower rates of \emph{P. falciparum} and of \emph{Plasmodium vivax} infections in Afghan refugee clinic attendees who claimed using ITNs, compared with those admitting not using any nets, in villages in which spraying had also been carried out. Yadav and others reported reductions in malaria incidence and prevalence of infection in Indian villages that were supplied with either treated nets or untreated nets compared with villages that were not supplied with nets in an area in which the standard control strategy consisted of IRS alone using DDT.

Protopopoff and others, reporting on a combined IRS and LLIN intervention in Burundi found that LLINs combined with IRS had an incremental effect in reducing the density of \emph{Anopheles} mosquitoes when compared with IRS alone, but had no observable effect in reducing the number of infective bites per house. The authors argue that high coverage with effective IRS had already reduced sporozoite rates to such a low level that nets were unable to make any additional impact.

In the same intervention in Burundi, the effect of IRS and LLINs on prevalence of infection was studied by Protopopoff and others. Although there was strong evidence of an overall intervention effect in IRS-treated areas, there was no indication that those who also slept under nets in the IRS-treated areas had any additional protection against infection compared with those who did not sleep under a net (OR = 0.49, 95% CI = 0.60–1.31 for the 1- to 9-year-old group). The authors argue

### Table 1
Prevalence of infection in children 2 to < 15 years of age in Bioko, Equatorial Guinea, and Zambezia, Mozambique between 2006 and 2008 by indoor residual spraying (IRS) status of house and whether the child slept under a mosquito net the night before the survey.

<table>
<thead>
<tr>
<th>Study</th>
<th>Survey year</th>
<th>Low or high prevalence sites</th>
<th>Unprotected</th>
<th>IRS only</th>
<th>Net only</th>
<th>IRS + net</th>
<th>Number in sample</th>
<th>Odds ratio IRS + net relative to IRS only</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bioko</td>
<td>2006</td>
<td>low</td>
<td>28 (22–36)</td>
<td>21 (16–27)</td>
<td>21 (15–28)</td>
<td>13 (10–17)</td>
<td>4094</td>
<td>0.56 (0.43–0.72); P &lt; 0.001</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2006</td>
<td>high</td>
<td>56 (41–70)</td>
<td>51 (45–57)</td>
<td>39 (30–49)</td>
<td>38 (27–50)</td>
<td>902</td>
<td>0.59 (0.36–0.96); P = 0.036</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2007</td>
<td>low</td>
<td>25 (19–32)</td>
<td>20 (15–25)</td>
<td>32 (21–45)</td>
<td>19 (14–26)</td>
<td>2064</td>
<td>0.99 (0.75–1.30); P = 0.92</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2007</td>
<td>high</td>
<td>52 (40–64)</td>
<td>43 (35–51)</td>
<td>51 (36–65)</td>
<td>30 (25–34)</td>
<td>785</td>
<td>0.56 (0.41–0.76); P = 0.001</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2008</td>
<td>low</td>
<td>26 (15–42)</td>
<td>22 (15–31)</td>
<td>24 (19–31)</td>
<td>17 (14–21)</td>
<td>3012</td>
<td>0.74 (0.53–1.06); P = 0.003</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2008</td>
<td>high</td>
<td>61 (51–70)</td>
<td>53 (52–54)</td>
<td>45 (39–52)</td>
<td>35 (18–56)</td>
<td>476</td>
<td>0.48 (0.20–1.15); P = 0.094</td>
<td></td>
</tr>
<tr>
<td>All Bioko</td>
<td>2006</td>
<td>low</td>
<td>33 (20–31)</td>
<td>25 (19–33)</td>
<td>30 (26–36)</td>
<td>19 (15–24)</td>
<td>11,775</td>
<td>0.71 (0.59–0.86); P = 0.001</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2006</td>
<td>high</td>
<td>31 (23–40)</td>
<td>32 (24–41)</td>
<td>40 (26–55)</td>
<td>19 (16–24)</td>
<td>693</td>
<td>0.52 (0.33–0.81); P = 0.006</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2007</td>
<td>low</td>
<td>76 (65–85)</td>
<td>58 (44–71)</td>
<td>77 (68–85)</td>
<td>49 (32–67)</td>
<td>1450</td>
<td>0.71 (0.51–0.99); P = 0.045</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2007</td>
<td>high</td>
<td>48 (34–51)</td>
<td>32 (31–34)</td>
<td>30 (6.9–71)</td>
<td>23 (15–35)</td>
<td>286</td>
<td>0.63 (0.38–1.03); P = 0.064</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2008</td>
<td>low</td>
<td>76 (66–84)</td>
<td>64 (53–73)</td>
<td>67 (47–82)</td>
<td>53 (42–63)</td>
<td>2147</td>
<td>0.63 (0.49–0.84); P = 0.003</td>
<td></td>
</tr>
<tr>
<td>All Zambezia</td>
<td>2006</td>
<td>low</td>
<td>52 (40–64)</td>
<td>43 (35–51)</td>
<td>51 (36–65)</td>
<td>30 (25–34)</td>
<td>785</td>
<td>0.56 (0.41–0.76); P = 0.001</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2006</td>
<td>high</td>
<td>25 (19–32)</td>
<td>20 (15–25)</td>
<td>32 (21–45)</td>
<td>19 (14–26)</td>
<td>2064</td>
<td>0.99 (0.75–1.30); P = 0.92</td>
<td></td>
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<tr>
<td></td>
<td>2007</td>
<td>low</td>
<td>48 (34–51)</td>
<td>32 (31–34)</td>
<td>30 (6.9–71)</td>
<td>23 (15–35)</td>
<td>286</td>
<td>0.63 (0.38–1.03); P = 0.064</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2007</td>
<td>high</td>
<td>61 (51–70)</td>
<td>53 (52–54)</td>
<td>45 (39–52)</td>
<td>35 (18–56)</td>
<td>476</td>
<td>0.48 (0.20–1.15); P = 0.094</td>
<td></td>
</tr>
</tbody>
</table>

* IRS = indoor residual spraying; ITN = insecticide-treated net; OR = odds ratio; CI = confidence interval.
† Adjusted for effect of sleeping in an IRS-treated house.
‡ Proxy for wealth of household.
§ Electric lights and household radio not included in multiple variable models due to absence of effect as confounder, and large P values.
* No evidence of effect modification (interaction) between IRS and net use effects (P = 0.493).
++ Adjusted for effect of sleeping under any net.
†† No evidence of effect modification (interaction) between IRS and ITN use effects (P = 0.976).

### Table 2
Effects of sleeping in an IRS-treated house, sleeping under net/ITN, unadjusted, and adjusted for each other and effect of proxy for wealth status of household on infection with \emph{Plasmodium falciparum} in children 2 to < 15 years of age in Zambezia province, Mozambique, and Bioko, Equatorial Guinea.

<table>
<thead>
<tr>
<th>Study</th>
<th>Percent infected</th>
<th>Number</th>
<th>OR</th>
<th>95% CI</th>
<th>P value</th>
<th>Adjusted OR</th>
<th>95% CI</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bioko, 2008 Living in IRS-treated dwelling#</td>
<td>29</td>
<td>496</td>
<td>1.00</td>
<td></td>
<td>1.00</td>
<td>0.49‡</td>
<td>0.94</td>
<td>0.024</td>
</tr>
<tr>
<td></td>
<td>Yes</td>
<td>21</td>
<td>2631</td>
<td>0.65</td>
<td>0.46–0.92</td>
<td>0.017</td>
<td>0.48–0.94</td>
<td>0.024</td>
</tr>
<tr>
<td>Slept under ITN#</td>
<td>76</td>
<td>860</td>
<td>1.00</td>
<td></td>
<td>1.00</td>
<td>0.68‡</td>
<td>0.97</td>
<td>0.033</td>
</tr>
<tr>
<td></td>
<td>Yes</td>
<td>20</td>
<td>2267</td>
<td>0.66</td>
<td>0.46–0.94</td>
<td>0.025</td>
<td>0.48–0.97</td>
<td>0.033</td>
</tr>
<tr>
<td>Electric lights§</td>
<td>22</td>
<td>1076</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Yes</td>
<td>22</td>
<td>2051</td>
<td>1.02</td>
<td>0.62–1.66</td>
<td>0.940</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Zambezia, 2007 Living in IRS-treated dwelling††</td>
<td>71</td>
<td>827</td>
<td>1.00</td>
<td></td>
<td>1.00</td>
<td>0.49‡</td>
<td>0.88</td>
<td>0.019</td>
</tr>
<tr>
<td></td>
<td>Yes</td>
<td>55</td>
<td>1617</td>
<td>0.50</td>
<td>0.28–0.87</td>
<td>0.018</td>
<td>0.28–0.88</td>
<td>0.019</td>
</tr>
<tr>
<td>Slept under net††</td>
<td>64</td>
<td>1622</td>
<td>1.00</td>
<td></td>
<td>1.00</td>
<td>0.70‡</td>
<td>0.90</td>
<td>0.009</td>
</tr>
<tr>
<td></td>
<td>Yes</td>
<td>55</td>
<td>822</td>
<td>0.71</td>
<td>0.53–0.95</td>
<td>0.025</td>
<td>0.54–0.90</td>
<td>0.009</td>
</tr>
<tr>
<td>Household has radio§</td>
<td>64</td>
<td>991</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Yes</td>
<td>58</td>
<td>1453</td>
<td>0.77</td>
<td>0.59–1.01</td>
<td>0.056</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
that the absence of an additional effect may be caused by high IRS coverage (90%) recorded by spray managers.

A study by Nyarango and others\(^{20}\) evaluating a combination of malaria control measures in Eritrea concluded that "combining ITN use with IRS or other vector control measures did not confer added value to the outcome in malaria mortality and morbidity."

In a study on a malaria epidemic during civil unrest in Burundi, Protopopoff and others\(^{19}\) described a vector control intervention consisting of IRS and ITN campaigns. The evaluation of this intervention showed no difference in prevalence of infection between sprayed and non-sprayed areas, but a reduced prevalence of infection in individuals sleeping under ITNs in one of the two zones in which IRS was deployed.

A study analyzing district level data from Eritrea\(^{21}\) found that ITN use and IRS were independently associated with reductions in malaria cases in multiple variable regressions after adjusting for differences in climate implying that combined use of IRS and ITNs did provide additional protection, compared with their single use. Table 3 summarizes the studies that have compared IRS combined with mosquito nets versus one intervention alone.

**DISCUSSION**

On the basis of previously published studies, the evidence of the effect of using IRS in combination with ITNs (or nets) compared with one method alone has been varied with some studies showing a positive combined effect and others no combined effect. Because none of these studies have been able to fully control for confounding effects, and none were based on experimental study designs, it is not possible to draw firm conclusions regarding the benefits of a combined vector control strategy based on ITNs and IRS.

For example, some of the studies (Rowland, Yadav) show a lower incidence of malaria cases in those using nets combined with IRS compared with those given IRS alone, but the additional protection of the nets may have been because of patchy or ineffective spray programs that were not monitored separately. This may also explain the effect observed in the epidemic outbreak in Burundi in 2000,\(^{26}\) in which there were no differences in prevalence of infection between individuals in IRS-treated and untreated houses but a reduced prevalence of infection in individuals sleeping under nets. These results could be explained as being caused by poor implementation of spraying, which despite reported high coverage in some cases, showed no benefit.

The results from Bioko and from Zambezia make a more convincing case for the combined use of IRS and treated nets. In Bioko, overall prevalence of infection had decreased from 26% (95% CI = 21–33) in 2007 to 22% (95% CI = 17–28) in 2008 in the 2 to < 15 year age group, possibly because of an increase in the proportion protected by both methods (IRS + any net in 2007, IRS + ITN in 2008) from 18% in 2007 to 62% in 2008.

Those who lived in IRS-treated houses in 2008 were overwhelmingly less likely to be infected compared with those who were not living in such houses (OR = 0.68, 95% CI = 0.48–0.94) regardless of whether they slept under a net or not, whereas those sleeping under ITNs were similarly better off (OR = 0.68, 95% CI = 0.48–0.97) regardless of whether they slept in an IRS-treated house or not. Those benefiting from

---

**Table 3**

<table>
<thead>
<tr>
<th>Study</th>
<th>Country and time period</th>
<th>Case control study</th>
<th>Effect size</th>
<th>How effect was measured</th>
<th>Effect of nets/ITNs combined with IRS vs. IRS only</th>
</tr>
</thead>
<tbody>
<tr>
<td>Protopopoff(^{19})</td>
<td>Burundi, 2002–2005</td>
<td>Vector density and infectivity (all ages); Prevalence, 1–9 years</td>
<td>Significantly reduced</td>
<td>Household survey</td>
<td>Treated household</td>
</tr>
<tr>
<td>Protopopoff(^{19})</td>
<td>Burundi, 2002–2005</td>
<td>Vector density</td>
<td>No effect</td>
<td>Net use</td>
<td>Treated</td>
</tr>
<tr>
<td>Protopopoff(^{19})</td>
<td>Burundi, 2000</td>
<td>Prevalence (all ages); Vector density</td>
<td>No effect</td>
<td>Net use</td>
<td>Both</td>
</tr>
<tr>
<td>Nyarango(^{20})</td>
<td>Eritrea, 1999–2003</td>
<td>Incidence and prevalence</td>
<td>Significant reduction</td>
<td>Household survey</td>
<td>Yes</td>
</tr>
</tbody>
</table>

**Notes:**
- ITN = insecticide-treated net; IRS = indoor residual spraying; OR = odds ratio.
- One zone only.
- Includes data from Kleinschmidt and others.\(^{22}\)

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*Previously unpublished* implies data from Kilborn and others.\(^{23}\)
the combined effect of both measures had an odds of infection equivalent to the multiplicative effect of the two measures \((OR = 0.46, 95\% CI = 0.26–0.81)\) relative to those unprotected by either method.

In Zambezia, there was some evidence of an overall increase in prevalence at all sites combined from 52\% in 2006 to 62\% in 2007 in children 2 to <15 years of age \((P = 0.053)\). However, those who lived in IRS-treated houses in 2007 were considerably less likely to be infected compared with those not living in such houses with an \(OR = 0.50, 95\% CI = 0.28–0.87\), whereas the protective effect of sleeping under a net had an \(OR = 0.71, 95\% CI = 0.53–0.95\), relative to those who were unprotected by a net. The effect of both measures combined was again multiplicative with an \(OR = 0.34, 95\% CI = 0.21–0.56\), relative to those who were unprotected.

Because there was no random allocation of vector control measures in these studies, individuals not receiving either of the two interventions may be viewed as a control group consisting of those who either did not comply, or who were missed by the control program. Although they may be thought of as unrepresentative and socio-economically different, our analysis does not support this view. In both Bioko and Zambezia, the results appear to be unaffected by potential confounding by the proxy indicators that we used for the wealth status of the household. Nevertheless, in observational studies the effect of confounders cannot be ruled out, and prevalence of malaria infection or incidence of disease can be influenced by many other factors including access to diagnosis and treatment, and the perception of risk by net users or health providers. More rigorous studies should randomly allocate study clusters to single or combined vector control so that confounding factors can be balanced between study arms.

It would be plausible if in combined IRS and ITN use the effect of one method alone was modified by the presence of the other. However, in the 2007 Zambezia and 2008 Bioko surveys there was no evidence of such interaction, i.e., the effect of one intervention was neither reduced nor magnified by the presence of the other.

All of these results need to be interpreted with caution, however, because community effects are likely to be substantial when ITN and/or IRS coverage is high. In Bioko in 2008, 95\% of children less than 5 years of age were sleeping either in a house that had been IRS-treated, or under an ITN. In such circumstances risk of infection is substantially reduced for everyone, regardless of whether they slept under a net or whether their individual house was sprayed. Mass effects of IRS and ITN vector control extending to those not sleeping under nets and not living in sprayed houses therefore complicates the interpretation of data from observational studies.

It is noteworthy that studies in which infection status was analyzed in relation to protection by IRS or net use at individual level, did show evidence of a beneficial effect of IRS + net use, relative to IRS alone. The strongest evidence comes from our data (Table 1), which show that in most surveys in Bioko and Zambezia, infection prevalence was not only lower in children benefiting from the combined vector control measures compared with those benefiting from IRS alone, but that IRS alone was also beneficial compared with those not receiving any intervention. The lower prevalence in the IRS + net group is therefore an additional benefit because of the nets, and not simply the effect of a functioning intervention added to a primary non-functioning one.

**CONCLUSION**

Future studies that address the question of whether combined use of ITNs and IRS provide additional protection, need to ensure that each intervention is effective on its own in a particular setting by including program implementation indicators that are adequately and independently monitored. This can be a challenge for IRS implementations that use ineffective insecticides, or suffer from poor spray applications or low coverage because such program deficiencies cannot be readily measured through household surveys. Poor ITN implementation, however, can be gauged more easily from household survey responses.

Because combined interventions are more costly than single ones, their sustainability needs to be taken into account when they are implemented. In some countries it may be sensible to use combined IRS and LLIN for a limited period, and switch to LLIN alone once transmission rates have been reduced to previously defined targets.

Despite the limitations that are inherent in non-experimental studies, the analysis reported in this study provides remarkably consistent evidence of added protection offered to individuals who sleep under a mosquito net or ITN in an IRS-treated house in settings with as different climatic conditions as those in Bioko and in Zambezia. This suggests that in areas where funding is adequate to offer a combined approach as a means of accelerating the transmission reduction process, or in areas where malaria control is challenging because of very high transmission intensities, or where high vector control coverage using one method alone has remained illusive or where preparation for elimination is a medium term goal, the option of combining these two vector control interventions should be considered. At the same time, there is an urgent need to back up our evidence with rigorous randomized controlled studies.

There is a growing global demand for sustainable scaling up of malaria control and for elimination. This will have to balance the need for equity in delivery of cost-effective malaria control interventions against the demands for more intensified malaria control including combinations of vector control interventions. Because the implementation of IRS combined with LLIN means increases in cost, it is important that the deployment of such additional resources is based on good evidence of their efficacy, and on cost-effectiveness estimates of costs per person protected, per infection averted, and per life saved. Such information can only come from well-designed prospective multi-country studies in different transmission settings.

Received January 30, 2009. Accepted for publication April 22, 2009.

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REFERENCES


Added Value of Combining IRS and LLINs: Results from Experimental Hut Studies

Dr. Sarah Panvec-Moore
Ifakara Health Institute and Liverpool School of Tropical Medicine

Abstract

Background
Effective implementation of indoor residual spraying (IRS) and long-lasting insecticide-treated nets (LLINs) is crucial to successful malaria control. Studies suggest that IRS and LLINs have similar impact at equivalent coverage levels; however, limited information is available to permit selection of one or a combination of these interventions.

Methods
A standard experimental hut assay was performed using a readily transportable kit form experimental hut, with interception traps designed to capture Afrotropical malaria vectors entering and exiting the huts. Assays measured the following: 1) reductions in proportions of mosquitoes entering treated versus control huts (deterrence); 2) time spent in huts by mosquitoes (contact irritancy); and 3) mosquito mortality (toxicity). Combinations of IRS included ICON CS, Fendona WP, Actellic WP, DDT WP, and Dieldrin (positive control). LLINs, Permanet, and Olyset, were tested singly and in combination.

Results
Combining ICON CS with Olyset provided the greatest protection from exposure to Anopheles arabiensis mosquitoes, reducing exposure by 47%, not through deterrence but through toxicity. Combining ICON CS with Permanet gave 46% protection, with 11.5% toxicity. Both Permanet and Olyset used singly gave excellent protection—35% and 27%, respectively—through a combination of deterrence and toxicity. Combining LLINs with deterrent IRS insecticides reduced the toxicity of both types of LLINs, which could reduce community protection.

Introduction
Effective implementation of indoor residual spraying (IRS) and long lasting insecticide-treated nets (LLINs) are crucial to the success of malaria control. However, we do not know how these interventions can drastically reduce malaria transmission. For Anopheles gambiae and other African malaria vectors, we do not know the mode of action (MoA) of the insecticides used for IRS and LLINs, which may be spatially repellent; irritant; or toxic [1], leading to different degrees of individual, household, or community protection. Studies suggest that IRS and LLINs have similar impact at equivalent coverage levels [2]; however, limited information is available to permit a data-based selection of one or a combination of these interventions, especially when their behavioral MoA is considered.

The modification of malaria vector behavior through deterrence and irritancy has long been known [3], and may have a crucial effect on malaria control programs [4]. Although contact toxicants such as Dieldrin have had a dramatic impact on malaria transmission [5], there is much evidence that insecticides with a deterrent MoA also can drastically reduce malaria transmission at high-coverage levels [6-8]. A recent study in Bioko, where deltamethrin was used in IRS, showed significant reduction in the sporozoite rate, even though mosquito numbers were not significantly reduced [9]. This reduction may be attributed to reduction in man-vector contact by keeping mosquitoes out of the house [10], which provides personal protection. Alternatively, it may be a consequence of reduced vector survival because the mosquito is forced to continue seeking a host when it has been repelled from a house, which provides community-level protection by killing the vector indirectly (Figure 1). This induced mortality has been termed foraging-related mortality [11].
It is important to distinguish between these MoAs, and select treatments with appropriate action, when considering local vector behavior. For instance, in an area where vectors do not rest indoors, a contact toxicant LLIN may be more appropriate than IRS. In an area where vectors bite early in the evening, bed nets may be limited in their efficacy, and a deterrent IRS may provide more effective protection. In addition, it is essential to select appropriate combinations of interventions to maximize both household-level and community-level protection by using additive or even synergistic combinations of insecticides.

**Methods**

**Study Site**

This study was conducted in Lupiro, Ulanga District, Tanzania, approximately 40km south of Ifakara Town at 8.4°S and 36.7°E. The village borders a perennial swamp, cleared for rice cultivation, with high densities of *An. arabiensis* [12]. Annual rainfall is 1,200–1,800mm, and the annual temperature is 20°–32.6°C.

**Hut Design and Construction**

Approximately 75% of homes in Tanzania are constructed from mud bricks and thatch [13]. Hut design was based on the mode measurements of mud-brick houses in the study village: 6.5m x 3.5m x 2m high to and 2.5m at the roof apex. The average eave gap was 10cm. Each hut had two windows on both long sides and a single door.

Experimental hut design was based on that of Achee and Grieco [14], modified to reflect east African house design and to maximize portability (Figure 2). The huts sit on a cedar platform, raised 40cm off the ground by metal supports, with individual water troughs to prevent ants from ascending and with a canvas “skirt” suspended from the platform to prevent mosquitoes flying beneath the hut. The
interlocking frame was constructed using galvanized steel pipe, bolted together and to the platform. The walls were made of cedar lattice panels skinned with canvas (Elastic Manufacturing Ltd, Tanzania) for lightweight waterproofing and were hung from the frame with steel brackets. The roof was constructed of corrugated steel, overlaid with grass to reduce inside temperatures to levels comparable with local houses.

An internal set of frames overlaid with chicken wire that are covered with mud—prepared and applied in the traditional manner—*ku_gandika ma_umpe_*—are hung inside to mimic the inner surface of local adobe huts, but the panels can be removed for incineration using an air curtain burner (Air Burners LLC, Florida).

**Trap Design and Construction**

**Eave Traps**
The eave traps are designed to collect mosquitoes entering or exiting the huts on all four sides at the same time, with the option of hourly sampling. The traps individually connect to the eave gap between the top of the wall and the roof. Each eave interception trap (EIT) is a net box design supported on a collapsible steel framework 100 cm x 40 cm x 40 cm, with a “letter-box” opening. A 15 cm-deep net collar on the front outside of the trap attaches to the Velcro on the walls to form an unbroken surface to the trap opening. Velcro on the collar also enables traps to be linked together to form a contiguous line of traps. Each trap has two aspirator holes to remove trapped mosquitoes. Traps are constructed from black fiber-glass shade netting (Elastic Manufacturing, Tanzania) as it is strong, durable, UV-resistant, and designed to maximize airflow.

**Window Traps**
The window traps are modified versions of the Muirhead Thompson Trap, with a “letter box” entrance, constructed from the same netting, piping, and wood blocks as the EITs. The collapsible metal frame measures 55.5 x 45.5 x 55.5 and fits into the window aperture, attached by Velcro.

**Baffle**
A shade-net baffle modified from Smith and Hudson [15] was placed to allow mosquito entrance on all four sides of the hut, but reduce egress. The baffles measure 100 cm long and 50 cm deep, and connect to the roof by nylon cord and to the wall by Velcro. The sides are shaped to fit to adjacent traps and to the roof to create a contiguous seal.

**Trap Set-Up**
Both EITs and window traps are reversible. Therefore the traps were set up in a continuous entrance, exit, baffle arrangement (Figure 3 and 4).

**Treatments**
Nine huts were used for the study; five were sprayed with one of the IRS treatments (Table 1), and four were not sprayed. Bed nets were rotated between huts on a nightly basis (Table 2). N.B. Data for Icon Life are not included in the results. Experiments ran between 19.00 and 07.00 hours, with two volunteers in each hut. Volunteers were not rotated between huts, therefore hut–volunteer combination was treated as a single bias in the statistical analysis.
Outcomes

- Reductions in proportions of mosquitoes entering treated versus control huts show spatial repellence; and
- Mortality of those mosquitoes that enter huts.

Statistical Analysis

Data were analyzed with generalized estimating equations using SPSS 16. Outcome variable for analysis one was mosquito density and for analysis two was proportion of dead mosquitoes within each hut. “Hut” was used as the subject and “day” as the within-subject variable. The independent variable was treatment. Data were analyzed separately for Olyset and Permanet to measure the added benefit of adding an IRS treatment to each LLIN. Therefore, each LLIN was treated as the reference group in the analysis.

Table 1. IRS and LLINs used in the evaluation

<table>
<thead>
<tr>
<th>Compound</th>
<th>Trade Name</th>
<th>Mode of action</th>
<th>Dose</th>
<th>Note</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lambda-cyhalothrin</td>
<td>ICON CS (Syngenta)</td>
<td>Irritant</td>
<td>0.03g/m²</td>
<td>Widely used for IRS in PMI countries (WHOPIES approved)</td>
</tr>
<tr>
<td>DDT</td>
<td>DDT 750 WP (Avima)</td>
<td>Excitopellent (deterrent)</td>
<td>2.0g/m²</td>
<td>Widely used for IRS in PMI countries (WHOPIES approved)</td>
</tr>
<tr>
<td>Alpha-cypermethrin</td>
<td>Fendona WP (BASF)</td>
<td>Irritant</td>
<td>0.03g/m²</td>
<td>Used as a control (WHOPIES approved); used as a model irritant control</td>
</tr>
<tr>
<td>Pyrimiphos-methyl</td>
<td>Actellic (Syngenta)</td>
<td>Contact Toxicant</td>
<td>2.0g/m²</td>
<td>Tested as a potential replacement IRS due to low toxicity (WHOPIES approved)</td>
</tr>
<tr>
<td>Dieldrin (&gt;90% purity (Sigma Aldridge))</td>
<td>Contact toxicant</td>
<td>1.0g/m²</td>
<td>Not WHOPIES registered. Used as a model contact toxicant control</td>
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Table 2. Sample rotation of LLINs

<table>
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<tr>
<th>Days</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>DDT</td>
<td>Lamda CS</td>
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<td>Dieldrin</td>
<td>Actellic</td>
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<td>No IRS</td>
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<tr>
<td>1</td>
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<td>Olyset</td>
<td>Icon Life</td>
<td>Permanet</td>
<td>Olyset</td>
<td>Icon Life</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
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<td>Permanet</td>
<td>Olyset</td>
<td>Icon Life</td>
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<td>Olyset</td>
<td>Icon Life</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
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<td>Permanet</td>
<td>Olyset</td>
<td>Icon Life</td>
<td>Permanet</td>
<td>Olyset</td>
<td>Icon Life</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Icon Life</td>
<td>Permanet</td>
<td>Olyset</td>
<td>Icon Life</td>
<td>Permanet</td>
<td>Olyset</td>
<td>Icon Life</td>
<td></td>
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<tr>
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<td>Icon Life</td>
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<td>9</td>
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<td>Olyset</td>
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<tr>
<td>11</td>
<td>Olyset</td>
<td>Icon Life</td>
<td>Permanet</td>
<td>Icon Life</td>
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<td>Olyset</td>
<td>Icon Life</td>
<td>Permanet</td>
<td>Olyset</td>
</tr>
</tbody>
</table>
**Ethical Considerations**

Participants were recruited on written informed consent and provided with free weekly malaria screening and treatment, if parasite-positive. Participants wore gum boots, trousers, and jackets to prevent mosquito bites. Ethical approval was granted by IHRDC/IRB/No.A-019-2007, NIMR/HQ/R.8a/ Vol. W710 and LSHTM 5552.

**Results**

The greatest effect (46.5%) was shown by a combination of ICON CS and Olyset LLIN, although this protection was through deterrence alone (Figure 5 and Table 3). ICON CS with Permanet provided a similar level of protection, although this combination killed 12% of mosquitoes, as did Fendona in combination with Permanet. Both Olyset or Permanet LLINs, used in the absence of...
IRS, provided significant protection (27% and 35%, respectively), with Permanet consistently providing more toxicity than Olyset. Actellic was the only IRS treatment that showed contact toxicity either when used alone or in conjunction with an LLIN.

Combining LLINs and IRS significantly increased deterrence in the case of ICON CS and Olyset (Table 4), which will result in greater household protection or community protection at high-coverage levels. However, combining Olyset with the irritant insecticides ICON CS and DDT significantly reduced the mortality of mosquitoes (Table 5), presumably as a result of decreased contact between the mosquitoes and the LLIN or IRS. In combination with Olyset, Actellic significantly increased mosquito mortality (Table 5). Combining Permanet with IRS did not significantly improve either its deterrency or killing effect (Table 6).

Currently in Tanzania, the National Malaria Control Programme (NMCP) and U.S. President’s Malaria Initiative (PMI) are using a combination of universal coverage with Olyset LLINs and targeted use of ICON CS in malaria elimination and control.

### Table 4. Median mortality of *An. arabiensis*

<table>
<thead>
<tr>
<th>Toxicity (%)</th>
<th>Mean mortality</th>
<th>Lower ci</th>
<th>Upper ci</th>
<th>p value</th>
<th>Odds ratio</th>
<th>Lower ci</th>
<th>Upper ci</th>
<th>p value</th>
<th>Lower ci</th>
<th>Upper ci</th>
<th>p value</th>
<th>Odds ratio</th>
<th>Lower ci</th>
<th>Upper ci</th>
</tr>
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<tbody>
<tr>
<td>Olyset only</td>
<td>38.270</td>
<td>32.770</td>
<td>43.760</td>
<td>0.096</td>
<td>1.207</td>
<td>0.967</td>
<td>1.505</td>
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<tr>
<td>Alpha-cypermethrin &amp; Permanet</td>
<td>43.130</td>
<td>31.720</td>
<td>54.540</td>
<td>0.037</td>
<td>1.354</td>
<td>1.018</td>
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<tr>
<td>Lambda-cyhalothrin &amp; Permanet</td>
<td>43.630</td>
<td>32.810</td>
<td>54.450</td>
<td>0.030</td>
<td>1.370</td>
<td>1.030</td>
<td>1.821</td>
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<td>1.381</td>
<td>1.039</td>
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<td>46.180</td>
<td>34.880</td>
<td>57.490</td>
<td>0.011</td>
<td>1.450</td>
<td>1.090</td>
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<tr>
<td>Permanet only</td>
<td>47.580</td>
<td>41.180</td>
<td>53.990</td>
<td>0.001</td>
<td>1.437</td>
<td>1.161</td>
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<td>36.360</td>
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<td>35.010</td>
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<tr>
<td>Dieldrin only</td>
<td>55.670</td>
<td>46.290</td>
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<td>1.707</td>
<td>1.284</td>
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### Table 5. GEE predicted relative ratio of *An. arabiensis* in huts with Olyset only versus Olyset plus IRS

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<thead>
<tr>
<th></th>
<th>Reduced entry</th>
<th>Reduced mortality</th>
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</thead>
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<tr>
<td></td>
<td>p value</td>
<td>Odds ratio</td>
<td>Lower ci</td>
<td>Upper ci</td>
<td>p value</td>
<td>Lower ci</td>
<td>Upper ci</td>
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<tr>
<td>Lambda-cyhalothrin &amp; Olyset</td>
<td>0.032</td>
<td>0.663</td>
<td>0.456</td>
<td>0.965</td>
<td>&lt;0.0001</td>
<td>0.714</td>
<td>0.366</td>
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</table>

### Table 6. GEE-predicted relative ratio of *An. arabiensis* in huts with Permanet only versus Permanet plus IRS

<table>
<thead>
<tr>
<th></th>
<th>Reduced entry</th>
<th>Reduced mortality</th>
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<td>Upper ci</td>
<td>p value</td>
<td>Odds ratio</td>
<td>Lower ci</td>
</tr>
<tr>
<td>Lambda-cyhalothrin &amp; Permanet</td>
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<td>0.778</td>
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<td>2.126</td>
<td>1.373</td>
<td>3.293</td>
<td>N.S.</td>
<td>1.069</td>
<td>0.856</td>
</tr>
<tr>
<td>DDT &amp; Permanet</td>
<td>N.S.</td>
<td>0.982</td>
<td>0.634</td>
<td>1.522</td>
<td>0.001</td>
<td>0.691</td>
<td>0.553</td>
</tr>
<tr>
<td>Alpha-cypermethrin &amp; Permanet</td>
<td>N.S.</td>
<td>0.932</td>
<td>0.537</td>
<td>1.289</td>
<td>N.S.</td>
<td>0.960</td>
<td>0.769</td>
</tr>
<tr>
<td>Pyrimiphos-methyl &amp; Permanet</td>
<td>0.004</td>
<td>1.893</td>
<td>1.222</td>
<td>2.932</td>
<td>N.S.</td>
<td>1.103</td>
<td>0.884</td>
</tr>
<tr>
<td>Permanet only</td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
epidemic zones. Data show that this combination is optimum, provided spray coverage is sufficient to provide community-level effects. Actellic is an organophosphate and may provide a useful alternative to pyrethroids, when used in combination with LLINs due to its excellent contact toxicity.

References
Introduction: Framework for Monitoring and Evaluation (M&E) of IRS and Indicators in Kagera Region

Kagera Region, made up of 2.4 million people, is located in northwest Tanzania on the shores of Lake Victoria. Malaria prevalence is the highest in the country, with 41% prevalence in children under the age of five years (Tanzania HIV/AIDS and Malaria Indicator Survey 2008). Malaria transmission varies from stable perennial to unstable and highly seasonal, according to the climatic and geographic variations.

A first phase of indoor residual spraying (IRS), funded by the U.S. President’s Malaria Initiative (PMI) was initiated in 2007 as a response to malaria epidemic control in unstable transmission areas.

In this phase, 100,000 households were targeted in Karagwe and Muleba districts. Three to four complete IRS rounds were performed between 2007 and 2009, with an overall spray coverage of over 90%. In this period, malaria indicators in health facility-based sentinel surveillance (HFBSS) sites decreased three to fourfold. Following the excellent performances and demonstrated impact on the disease, in 2009, the Tanzania National Malaria Control Programme (NMCP) and PMI decided to extend the IRS campaign to the remaining high-malaria transmission areas of the region. Therefore, an additional 340,000 house structures were targeted and spray operations were carried out. In Kagera Region, overall spray coverage in 2009 reached 94%.

Tracking processes, measuring outcomes, reporting findings, and evaluating impact are critical for appropriate management of IRS programs. A simple but comprehensive framework for M&E of the IRS campaign has been introduced in Kagera Region. The framework is based on a continuum of indicators collected before, during, and after the IRS operation, with the aim of monitoring the performances and measuring the results (Figure 1).

Figure 1. M&E framework for IRS
The implementation of the framework requires appropriate data collection and prompt analysis. Simple tools for collection, recording, reporting, processing, and analyzing data are essential for effective information management. Several input, process, and output indicators are needed for monitoring the performances of the IRS operations. Other outcome and impact indicators, mainly epidemiological and entomological, are needed to measure the results. To be effective, the information system should have an upward and downward flow.

Apart from the three core PMI indicators, RTI utilizes 14 additional quality management indicators (see Table 1). Among these 17 indicators, only one is meant to measure results (IRS coverage), and no one is measuring impact. A few more indicators were introduced into the M&E framework adopted in Kagera to monitor other missed parameters: IRS logistics, reasons for IRS refusal, community satisfaction, net coverage, and impact indicators.

### Flow of Information, Levels, and Magnitude of Data Handling in Kagera Region IRS Campaign

**IRS Performance Monitoring**

Performance monitoring is by far the most demanding activity of data collection, reporting to the next supervisory level and, finally analysis and utilization of information (Table 1). During the IRS campaign in Kagera, spray operators (level 1) collected daily data, recorded them in appropriate forms, summarized them at the end of the work day, and submitted forms to their team leaders (level 2). Aggregated data from each team leader were submitted to the team supervisors (level 3); after verification and compilation, daily reports were submitted to the site managers (level 4). The final aggregated reports were submitted by site managers to the district data management unit (level 5).

In 2009, in Kagera, approximately 61,500 forms, totaling 12 million records, were filled out manually in the three operational levels. They were then electronically entered in the data management unit. Afterward, the data for selected levels (2 and 4) were entered into a spreadsheet (1.75 million records). The data entry template was provided for automatic consistency and a completeness check. Inconsistent data forms were returned to the previous level for verification, correction, and then resubmitted. The provided electronic spreadsheet included a dashboard, with tables and charts, that was automatically updated daily.

**Training Performance Monitoring**

Selected community members temporarily recruited for the operations in Kagera in 2009 included approximately 1,800 people—operators, team leaders, store assistants, pump technicians, suit/equipment washer, and guards. All of them have been trained by their direct overseers for an average of six days in the 28 IRS operation sites (level 1). The technical overseers, team supervisors, and site managers were trained at the district level by regional

### Table 1. IRS Indicators

<table>
<thead>
<tr>
<th>A. Core IRS Indicators (PMI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. IRS coverage</td>
</tr>
<tr>
<td>2. Number of residents of sprayed structures</td>
</tr>
<tr>
<td>3. Number of people trained to deliver IRS</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>B. Quality Management Indicators (RTI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Average time the family/goods remain outdoors following IRS application</td>
</tr>
<tr>
<td>2. Percentage of households in which residents sweep the floor upon reentry following IRS</td>
</tr>
<tr>
<td>3. Percentage of households in which a respondent reports accurate knowledge of IRS messages</td>
</tr>
<tr>
<td>4. Percentage of operators who fully implement best practices (% FC)</td>
</tr>
<tr>
<td>5. Supervisory ratio describes the number of team leaders and spray operators reporting to each supervisor</td>
</tr>
<tr>
<td>6. Number of storage facilities from which the logistics manager has received a current Storekeeper’s Weekly Report</td>
</tr>
<tr>
<td>7. Number of insecticide sachets in stock</td>
</tr>
<tr>
<td>8. Percentage of remaining insecticide requirement available</td>
</tr>
<tr>
<td>9. Percentage of empty sachets returned</td>
</tr>
<tr>
<td>10. Percentage of empty sachets disposed</td>
</tr>
<tr>
<td>11. Proportion of health facilities with adequate stocks of insecticide antidotes and treatment medications in target communities</td>
</tr>
<tr>
<td>12. Proportion of health facilities at which health workers have been trained to treat cases of pesticide poisoning and exposure</td>
</tr>
<tr>
<td>13. Percentage of female spray operators tested for pregnancy during spray operations</td>
</tr>
<tr>
<td>14. Percentage of spray operators who reported adverse health events attributable to pesticide exposure</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>C. Additional Indicators Collected in Kagera IRS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Fuel consumption per vehicle</td>
</tr>
<tr>
<td>2. Average sachets of insecticide per house structure</td>
</tr>
<tr>
<td>3. Reasons for spray refusal</td>
</tr>
<tr>
<td>4. Community satisfaction/dissatisfaction</td>
</tr>
<tr>
<td>5. Ownership of net</td>
</tr>
<tr>
<td>6. Use of net</td>
</tr>
</tbody>
</table>
and national facilitators (level 2). Training indicators were collected in the IRS operation sites, using a standardized format and then aggregated by district.

**Insecticide Use Monitoring**
Insecticide sachets distributed individually to each spray operator were individually recorded each day before departure to the spray areas. At the end of each day, unused sachets and used empty sachets were then counted and recorded on the individual spray operator cards and submitted to the next supervisory level. The aggregated data by spray team were verified and sent to the data management unit by the site managers. Daily use of insecticide, rate per house structure, and insecticide stock level was constantly monitored.

**Transport Performance Monitoring**
Fuel consumption is the main concern in monitoring vehicle performances. The provided log sheets were submitted weekly to the data management unit to calculate the mileage and fuel provided. Fuel consumption rate was then monitored for each vehicle.

**Information, Education, and Communication (IEC) Performance Monitoring**
This process is based on administrative rather than IRS operational levels. The final target is to perform house-to-house visits for registration and dissemination of educational messages. In Kagera, we set up a system starting from the household level (440,000). Hamlet leaders (4,074), assisted in some districts by two selected people per hamlet (3,968), were involved in the process (level 1). Each household visited was recorded, and aggregated data were compiled at the village level (642) by the village council executive officer (level 2). Following the administrative level’s set-up, the reports reached the 144 wards (level 3) and the seven districts (level 4).

**Data Collection Tools**
Various data collection tools were used during the operation. Four different data collection forms were used by spray teams, according to the level. Individual medical examination and treatment cards were designed and provided to all operation sites; log sheets and logbooks were provided to all drivers; and an electronic spreadsheet that included the weekly summary was compiled by the data management unit. Aggregated weekly insecticide movement summaries, collective issue vouchers for personal protective equipment (PPE), team daily insecticide movement cards, bin cards, ledgers, and issue vouchers were the main data collection, recording, and reporting tools used in the operation sites and warehouses. In addition, supervisory checklists were provided and filled out by team leaders and team supervisors; standard training reports were filled out by facilitators at all levels. Forms for three levels of sensitization were filled out by hamlet, village, and ward leaders, reporting information from each household, hamlet, and village respectively.

**Data Management Unit**
All of the collected information was handled by one dedicated person at the district level, assisted and supervised by one RTI staff member.

---

**Table 2. IRS performance monitoring**

<table>
<thead>
<tr>
<th>Level</th>
<th>Tool/Media</th>
<th>Staff units</th>
<th>Frequency of reporting</th>
<th>Magnitude of information flow (30 reporting days)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Level 1: Operators</td>
<td>Paper (manual)</td>
<td>1,725</td>
<td>Daily</td>
<td>51,750</td>
</tr>
<tr>
<td>Level 2: Team leaders</td>
<td>Paper (manual)</td>
<td>203</td>
<td>Daily</td>
<td>6,090</td>
</tr>
<tr>
<td>Level 3: Supervisors</td>
<td>Paper (manual)</td>
<td>97</td>
<td>Daily</td>
<td>2,895</td>
</tr>
<tr>
<td>Level 4: Site managers</td>
<td>Paper (manual)</td>
<td>28</td>
<td>Daily</td>
<td>840</td>
</tr>
<tr>
<td>Level 5: District IRS management unit</td>
<td>Paper (filing)</td>
<td>7</td>
<td>Daily</td>
<td>61,575</td>
</tr>
<tr>
<td></td>
<td>Spreadsheet (electronic)</td>
<td></td>
<td></td>
<td>6,930</td>
</tr>
<tr>
<td>Level 6: Regional IRS management unit</td>
<td>Spreadsheet (electronic)</td>
<td>3</td>
<td>Daily</td>
<td>21</td>
</tr>
</tbody>
</table>
Monitoring Performances: Generating and Using Input, Process, and Outputs Indicators

The intention of this paper is not to provide a complete set of evidence, witnessing the effectiveness and impact of IRS in Kagera, but to indicate the process used to monitor performances and measure results related to IRS operations. Selected examples of the methodology used and the outputs of the system are described below.

Inputs

This is the relatively easy piece of work in terms of IRS monitoring but extremely important in terms of effective management. Before the actual spray, quantification of necessary items, timely procurement, and delivery to the several IRS operation sites in the right quantity and at the right time depend enormously on correct and precise information. At the start of operation, PPE were issued to the teams and recorded. During the operation, critical items—such as insecticide—are issued to the teams daily and properly recorded. This daily monitoring prevents leakage/pilferage. Another input indicator constantly monitored is fuel consumption of the hired vehicles, to avoid misuse of resources.

Process

Documenting the process to deliver appropriate messages regarding IRS to the communities is the most demanding part in monitoring the implementation process. The system was set up to verify that the several thousand community sensitizers involved in IEC activities were following instructions given by their direct supervisors and to verify the number and proportion of households reached with educational messages about malaria and IRS. Therefore, number of households visited and their willingness to participate in IRS were recorded.

Less demanding was the documentation of the training process. Training facilitators compiled a standard preprinted report format that included all necessary indicators.

Outputs

The main output indicators monitored during spray operations in Kagera included the quality management of spray, appropriate safety procedures used by operators, number of house structures found and sprayed, people living inside, number of nets found, and community awareness and knowledge about IRS and practices regarding what they were supposed to do before, during, and after the spraying of their houses. Operator cards and supervisor checklists provided the aforementioned indicators.

Measuring Results: Generating and Using Outcomes and Impact Indicators

Outcomes

Outcomes are relatively easy to monitor, given that the right denominator is provided. Unfortunately, identifying an appropriate denominator is not an easy task. The cardinal outcome indicator for IRS is the spray coverage defined as the percentage of sprayable structures found in the target area that were sprayed. The problem with the denominator is principally semantic and secondarily operational. The terminology currently used refers to an easy to describe, but difficult to understand, concept for the average spray operator: “sprayable structure.” The key definition of “sprayable structure” is a free-standing building in which people sleep.

In practical terms, it was very frustrating during the registration and spray operation to consistently match the expected number of structures to be sprayed and the ones reached and reported. Available information in the village from a previous census is generally imprecise, with variations ranging from 5% to over 25%. Information gathered in the previous IRS rounds is also discouraging. Administrative boundaries are quite volatile, and in some areas, population mobility is high. The concept of “building in which people sleep” has been found to have several interpretations among community members and spray operators and is influenced by cultural norms and practices. The term “found” is also equivocal:
All sprayable structures found are included in the denominator, but what about the unfound structures? We observed different behaviors among spray teams toward the “hard-to-reach areas.” Sometimes houses in remote rural areas are not “found,” meaning that they are ignored and hence unrecorded.

Apart from the above-described drawbacks and other difficulties in reporting aggregated data, we managed to monitor the outcomes daily and, most importantly, by level. A prompt reporting of the actual outcomes during the operation can provide valuable information on the progress of the operation. In Kagera, we generally use a trajectory with the expected cumulative outcome from the first to the last day of operations (Figure 2). Two curves/lines are plotted in a chart to describe the desired coverage: The first line is set at 85% and the second at 100%. If the daily cumulative performance is positioned between the two lines, it means that the operation is going on according to the expected targets. If the performance curve is below the 85% line, the outcome is below the set target; therefore action is needed. In Kagera, we managed to monitor outputs and outcomes up to the 28 IRS operational sites level.

Impact

People may argue that measuring impact is not directly related to IRS implementation and that it is a result of several interventions and weather conditions. In Kagera Region, we found it very useful to collect impact-related indicators to verify if the activity produced the desired effect: reduction of Anopheles mosquito population and eventually reduction in malaria morbidity and mortality. Therefore, from the beginning of IRS operations, RTI and its partners gathered entomological, parasitological, and health facility-based morbidity indicators.

Entomological Monitoring

Since district and regional health departments lack the necessary entomological competence to perform the monitoring, we decided to initiate a partnership with the National Institute for Medical Research (NIMR)-Mwanza Centre. NIMR performed baseline data collection in selected sentinel sites and provided some follow-up surveys. Main indicators selected to verify impact are mosquito abundance, species,
sporozoite/blood meal rate, and resting behavior. Other important collected indicators, related more to the effectiveness of the intervention, included insecticide susceptibility and bioassay.

Longitudinal entomological monitoring, rather than baseline cross-sectional surveys, should provide the necessary data to monitor the eventual impact on malaria vectors. Establishing longitudinal entomological monitoring is the only way forward. This type of investigation requires collection of samples from sites at regular intervals and prompt analysis. Capacity building of district- and community-based personnel is of paramount importance in order to perform regular longitudinal monitoring, and a competent entomological laboratory is needed to process samples. RTI is currently working with partners to set up an effective longitudinal entomological monitoring operation in the Lake Zone.

Malaria Prevalence in the Community

Malaria prevalence in the community should be considered the impact "gold standard" indicator, but to be representative, it usually needs expensive and demanding cross-sectional population studies. In Kagera Region, we set up an alternative cheap and easy-to-establish sentinel population surveillance to monitor proxy indicators, reflecting the prevalence of malaria in identified strata of the population. We decided to use pregnant woman and children under five years of age as a sentinel population. Since antenatal clinic attendance and measles vaccination coverage is quite high in the region (more than 90%), we selected as specific population surveillance targets pregnant woman, attending the clinic for the first time, and children below one year of age who were eligible for measles vaccination. The advantage of sentinel population is that it can provide information in a prospective longitudinal way rather than cross-sectional. In Kagera, we selected the existing 17 rural health centers, the second level of the health care delivery system in Tanzania, and their service population (see Figure 3). Health centers have better staffing compared to dispensaries, the first level health-care facilities, and the additional work required by the longitudinal survey is absorbed by the existing staff.

The system, even if not representative of the entire population, is providing useful indicators of the intensity of malaria infection in the area (Figure 3). Continuous monitoring of malaria parasitemia in the sentinel population is a simple way to

Figure 3. Sentinel population surveys, proportion of malaria parasites in children under five years of age attending RCH clinic for measles vaccination
measure disease trends, seasonal variations, and local variation/diversity within the locations. Rapid diagnostic tests (RDTs) for malaria are used to screen the sentinel population.

Malaria Morbidity and Mortality
A network of HFBSS sites has been established between 2006 and 2009 in Tanzania (5) and Zanzibar (7). These sentinel sites have been selected to provide quality and timely monthly malaria indicators. The standard health management information system (HMIS) tools have been slightly modified to accommodate information not included in the routine system. Some data have been collected retrospectively for 10 years. The sentinel sites are providing valuable programmatic indicators for malaria case management and epidemiological indicators to measure impact of malaria control activities in the area. Rubya Designated District Hospital in Muleba District is one of the five national sentinel sites in Mainland Tanzania. RTI in collaboration with NMCP, district, and hospital authorities started collecting regular daily data in 2007 and officially established the site in August 2008. Since then, regular monthly data are provided (see Figure 4).

Discussion
The Kagera experience demonstrates that there are many indicators to address, and all of them are relevant. The aim of collecting the massive amount of indicators outlined in Table 1 is to use them. Each indicator, or set of indicators, has its own purpose and cannot be isolated from the entire context. The purpose of three core PMI indicators (see Table 1, A1–A3) is to provide spray coverage, estimate the number of people protected by IRS, and demonstrate the efforts to increase the capacity of host country institutions to implement IRS. The purpose of the standard RTI indicators (see Table 1, B1–B14) is to monitor the quality of the IRS management in the area. Indicators B1, B2, and B3 reflect the quality of IRS communications and community awareness; indicators B4 and B5 indicate the quality of IRS training and implementation and the effectiveness of supervision. The set of indicators from B6 to B10 reflects compliance with stock management and record-keeping requirements, while B11–B14 suggest that the safety in IRS operations is adequate. The additional indicators used in Kagera Region (see Table 1, C1–C6) suit the local implementation requirements being raised by specific needs: tracking the use of consumables, eventually responding to misuse (indicator C1 and C2), and verifying the attitude of the targeted communities (C3 and

Figure 4. HFBSS, Rubya Designated District Hospital, Muleba District: Positive malaria tests and malaria test positivity rates, 2006–2009
Indicators C5 and C6 have been added to monitor the progress of the national net distribution campaign and to verify that IRS does not discourage the usage of nets in the population.

Eventually, all indicators are relevant and should be used to monitor performances, measure results, and ultimately to improve the management. The major challenge is the collection, recording, reporting, and analysis of consistent, meaningful, and quality information. The process is involving a multitude (several thousand) of people at the community level without specific basic training in data management. Maintaining good quality data management needs a high level of commitment and skills from the management staff. Consistency checks and verification of completeness of submitted information is of paramount importance.

High IRS coverage may lead (if the vector population is resting indoors and susceptible to the insecticide used) to a dramatic reduction of malaria transmission. Measuring IRS outcomes can provide an anticipation of a possible decline of malaria burden, but this is just an assumption if it is not corroborated by solid impact data. Experiences from Kagera suggest that it is not only possible but even recommended to include the collection of impact data into routine IRS implementation frameworks. The same experience shows the feasibility of this approach by establishing ad hoc population surveillance and HFBSS to monitor biological markers of malaria infection.

The massive amount of data generated during an IRS campaign should be timely and competently handled. The established data management units at district and regional levels provided the necessary support. These data management units are sometimes overwhelmed by the large amount of data flowing in and by providing regular real-time analysis of “millions” of records and feedback to the IRS management. Follow up on and feedback to staff engaged in collecting and reporting information should be provided to maintain quality and reliable flow of data.

Conclusions

The Kagera experience described in this paper demonstrates that it is possible to set up a comprehensive M&E framework within IRS implementation. Input indicators must be used in the preparation phase to determine the resources needed. Process and output indicators must be used regularly during the implementation to monitor the quality of IRS activities and to take appropriate action when it is needed. Daily and weekly reporting are recommended in this stage. Finally, our experience suggests that we should be strategic in generating smart outcome data and meaningful and evocative impact data to measure the achievements of the set targets and to demonstrate that we are moving in the right direction toward achieving the program’s ultimate goal.
PMI Progress through Year Three
The U.S. President’s Malaria Initiative (PMI) began supporting indoor residual spraying (IRS) in 2006. By 2009, IRS has been implemented in 15 PMI focus countries, protecting 24.7 million people.

There are decreased slide positivity rates for the malaria parasite. Demographic health surveys in Ghana, Rwanda, Senegal, Tanzania, and Zambia show a decline in the malaria-related mortality rate of children under five years of age.

In Zambia, an over 50% reduction in malaria prevalence and anemia in children under five years of age was reported between the years 2006 and 2008. Figure 1 shows the frequency of positive malaria smears in children under the age of two in Zanzibar between 2005 and 2007.

Figure 1: Evidence of early impact: Frequency of positive malaria smears in children under age 2, Zanzibar, 2005–2007

Quality Control of Insecticides and Formulations
The quality of insecticides and their formulations must be regularly confirmed to avoid substandard or counterfeit insecticides and formulations. Insecticides must be World Health Organization Pesticide Evaluation Scheme (WHOPES) approved (see Table 1).

Field methods for IRS quality control and field durability include the following:

- Liverpool Associates in Tropical Health and Innovative Vector Control Consortium have developed a new insecticide quantification kit, which should facilitate on-site quantification of bioavailable residues from walls in a much more cost-effective and simple format. The kits work with alpha-cyano pyrethroids and DDT.
- X-ray fluorometers are used to detect the amount of deltamethrin in Permanets.

New Vector Surveillance Methods
New vector surveillance methods are now available. Instead of using the traditional human landing collections, traps and attractants should be used for vector collections. Optical or acoustic systems could be used for automated, remote vector behavior and species identification. For vector characterization, the standard PCR and TaqMan assays are effective. Spectroscopic methods such as near infrared spectroscopy (NIRS) are used to determine parameters such as age, species, and vector status.
<table>
<thead>
<tr>
<th>Insecticide compounds and formulations</th>
<th>Class group</th>
<th>Dosage (g/m²)</th>
<th>Mode of action</th>
<th>Duration of effective action (months)</th>
</tr>
</thead>
<tbody>
<tr>
<td>DDT wettable powder (WP)</td>
<td>Organochlorine</td>
<td>1–2</td>
<td>Contact</td>
<td>&gt;6</td>
</tr>
<tr>
<td>Malathion WP</td>
<td>Organophosphates</td>
<td>2</td>
<td>Contact</td>
<td>2-3</td>
</tr>
<tr>
<td>Fenitrothion WP</td>
<td>Organophosphates</td>
<td>2</td>
<td>Contact &amp; airborne</td>
<td>3–6</td>
</tr>
<tr>
<td>Pirimiphos-methyl WP and emulsifiable concentrate (EC)</td>
<td>Organophosphates</td>
<td>1–2</td>
<td>Contact &amp; airborne</td>
<td>2–3</td>
</tr>
<tr>
<td>Bendiocarb WP</td>
<td>Carbamates</td>
<td>0.1–0.4</td>
<td>Contact &amp; airborne</td>
<td>2–6</td>
</tr>
<tr>
<td>Propoxur WP</td>
<td>Carbamates</td>
<td>1–2</td>
<td>Contact &amp; airborne</td>
<td>3–6</td>
</tr>
<tr>
<td>Alpha-cypermethrin WP and suspension concentrate (SC)</td>
<td>Pyrethroids</td>
<td>0.02–0.03</td>
<td>Contact</td>
<td>4–6</td>
</tr>
<tr>
<td>Cyfluthrin WP</td>
<td>Pyrethroids</td>
<td>0.02–0.05</td>
<td>Contact</td>
<td>3–6</td>
</tr>
<tr>
<td>Deltamethrin WP and water dispersable granule (WG)</td>
<td>Pyrethroids</td>
<td>0.01–0.025</td>
<td>Contact</td>
<td>2-3</td>
</tr>
<tr>
<td>Etofenprox WP</td>
<td>Pyrethroids</td>
<td>0.1–0.3</td>
<td>Contact</td>
<td>3–6</td>
</tr>
<tr>
<td>Lambda-cyhalothrin WP and capsule suspension (CS)</td>
<td>Pyrethroids</td>
<td>0.02–0.03</td>
<td>Contact</td>
<td>3–6</td>
</tr>
</tbody>
</table>

Note: WHO specifications for public health pesticides, quality control, and international trade are available on the WHO Web site: http://www.who.int/whopes.
Abstract
Communication is a process of learning that involves exchange of information, with an ultimate aim to empower, promote, and change. A communication strategy entails planned actions targeted at achieving objectives to address, improve, and solve problems by utilizing communication methods, techniques, and media. A comprehensive communication strategy should encompass elements such as situational analysis, audience segmentation, communication objectives, strategic approach, message development, channels and tools, management plan, and monitoring and evaluation.

Health communication contributes to all aspects of disease prevention and health promotion. It assists in the creation of public health messages and campaigns, influences the public agenda, and overall encourages norms that benefit health among community members.

Communication channels used in the implementation of indoor residual spraying (IRS) include word of mouth, print media (e.g., brochures and posters), electronic media (e.g., radio and television), and edutainment (e.g., songs and drama). IRS messages need to be communicated in a systematic and organized manner, covering program overview, knowledge of malaria and IRS, and key messages to households. It is critical to counter myths and misconceptions, ensure quality of communication, and maintain confidentiality to build trust, all with a view of promoting community acceptance and demand for IRS.

Background
The success of malaria control programs across Africa depends on correct and consistent use of insecticide-treated nets (ITNs), acceptance of indoor residual spraying (IRS), and adherence to treatment and prevention therapies. Experiences over the decades have taught us the importance of communication and community participation to attain sustainable shifts in the behaviors of individuals and communities concerning malaria treatment and prevention.

Current malaria control strategies rely mostly on individuals and communities taking action to hang bed nets and sleep under them, treat symptoms of malaria with antimalarial drugs, and support vector management practices, including IRS. These strategies can only succeed when communities understand the causes of malaria and their role in combating the disease. As such, communication is vital for communities to understand and take action, and for those working in malaria control, to introduce the most appropriate action at the community level. Advocacy should take place at all levels to raise awareness of taking appropriate actions for malaria control.

Information, education, and communication (IEC), sometimes referred to as behavior change communication (BCC), is an interactive process with communities, aimed at developing tailored messages and approaches using a variety of communication channels to promote positive behaviors. Strategically designed communication can play a key role in malaria control. Communication strategies are generally called for whenever there is a need to change awareness, knowledge, attitudes, social norms, skills, or expectations.
IEC/BCC seeks to strengthen all the strategic components of the malaria control programs by supporting the delivery of cost-effective interventions. IEC/BCC combines strategies, approaches, and methods to enable individuals, families, groups, organizations, and communities to play active roles in achieving, protecting, and sustaining their own health. Embodied in IEC/BCC is the process of learning that empowers people to make decisions, modify behaviors, and change social conditions. The influence of social, cultural, economic, and environmental conditions on health are also taken into consideration in the IEC processes. To achieve success in the implementation of key strategies, including IRS, there is need to implement an effective communication strategy in malaria control and prevention.

### Communication Strategy

A communication strategy is a well-planned series of actions aimed at achieving certain objectives through the use of communication methods, techniques and approaches. The purpose of designing a communication strategy is to address, improve, and solve problems by utilizing a variety of communication techniques. A communication strategy defines a high-level plan on how members of a malaria control program will communicate during the course of the operations. It includes details of who, what, when, where, why, and how in terms of communications. A good strategy needs to encompass the following key elements: situational analysis; formative research and strengths, weaknesses, opportunities, and threats (SWOT) analysis; audience segmentation; strategic approaches; communication objectives; message development; management of communication strategy; and monitoring and evaluation (M&E).

Situational analysis is aimed at clearly identifying the purpose of the strategy. It helps point out the exact issues or problems to be addressed by the campaign. For example, using sources such as demographic health surveys, knowledge, attitude, and practice (KAP) research reports, and documented best practices on malaria prevention, control, and treatment can shed some light on past/current situation; identify issues to be addressed; and identify gaps and areas of improvement.

Through formative research, the key audience and stakeholders should be identified. The research will also help identify the strengths of the malaria prevention and control program, weaknesses, opportunities available, and potential threats to the program. The target audience of a malaria/IRS communication campaign often has different demographic characteristics and interests, hence the need for audience segmentation. A single communication approach cannot have an effective and equal impact on all groups within the target population of a campaign due to differences in characteristics and interest. There is need to classify the population into different groups of identical interest, positions, or even demographic features once information on the population has been obtained.

A country-specific national malaria strategy provides the framework for the prevention, control, and treatment of malaria. For example, the Kenya National Malaria Strategy (2001–2010) outlines the broad framework that guides communication on malaria in Kenya and identifies issues that need to be addressed to promote key behaviors and to build a supportive environment to sustain those behaviors. Based on this, communication objectives that reflect the country-specific national malaria strategy are developed. If the strategy proposes IRS and use of ITNs as interventions for malaria prevention and control, specific communication objectives need to be addressed under each of these approaches. For example, one of the objectives of the Kenya Malaria Communication Strategy (2006) is “To increase the proportion of households with knowledge and skills on the application of IRS and its demand among epidemic prone districts.” This clearly stipulates the action: “increased knowledge and skills” and the target audience: “households.”

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2. PSP-One AND Behavior Change Communication (BCC) 2006.
Message development is a critical element to generating effective communication strategies and should always include the key messages to be used in the campaign. The messages must be short but at the same time capture the essential themes of an intervention. Based on the audience characteristics and segmentation, the appropriate channels of communication have to be spelled out. The channels may include radio, television, posters, billboards, and interpersonal communication, among others. Depending on the objectives of a campaign, particular channels may be more appropriate. Sometimes a combination of channels produces better results. There is a need to set timelines for implementation, as well as indicating the roles played by partners. Financial and other resources required must be indicated. A phased approach can be used to implement the communication strategy, where specific, planned activities take place at different times.

Overall, it is essential to monitor progress toward the achievement of the communication strategy objectives and in tracking project performance. The key aspects of an M&E framework include monitoring the implementation of activities, as well as assessing the outcomes and the contribution of communication activities to the overall national malaria strategy at regular intervals. It is important to appoint a communication person to oversee the application of the communication plan and to work with other actors.

**Role of Communication in Health**

Communication in health care is increasingly recognized as a necessary element to improve personal and public health by influencing individual and community decisions. Health communication contributes to all aspects of disease prevention and health promotion, and it is relevant in a number of contexts, including assisting in the construction of public health messages and campaigns, helping in dissemination of individual and population health risk information, helping elevate consciousness of health risks and solutions, and reinforcing attitudes. Communication enhances demand for appropriate health services and makes information available to assist in making complex choices such as selecting treatments/interventions, providers, and health plans. It also influences the public agenda, advocates for policies and programs, and promotes changes in socioeconomic and physical environments. Improvements in the delivery of public health and health-care services and enhancement of social norms that benefit health and quality of life rely on effective communication. The success of IRS programs will therefore largely depend on how best our communication is structured.

**IRS Communication Channels**

IRS for malaria control uses a variety of communication approaches to reach out to the community and stakeholders. These include interpersonal communication, print media, electronic media, and edutainment.

Interpersonal communication involves relationships between people, e.g., individual discussions, group discussions, and community meetings. In Kenya, the PMI-funded districts use door-to-door and group mobilization to reach the community with messages. This includes conducting advocacy-related activities with key stakeholders from the provincial administration, line ministries, and malaria control partners and implementers. Interpersonal communication provides an opportunity to discuss and receive feedback, reinforces the messages, and allows for clarity and checking of messages disseminated, as well as allows for flexibility, such as change in language used to ensure good communication.

Print media or one-way communication involves use of brochures, fliers, banners, and posters, among others. The advantages of using print media include the following: they act as a permanent record of information; transfer of meaning is not a function of time or space; they allow for message preparation; there is less chance of misunderstanding; and they serve as a reference for those receiving the materials. This form of communication is, however, impersonal. There is absence of prompt feedback and people do not always read the materials. There is a tendency to litter the environment after reading the materials. This medium also does not take into consideration illiterate populations.
Electronic media involves radio and television in the dissemination of messages. They have the potential to reach out to wider audience. When using these media, messages should be customized to various audiences, ensuring simplicity, as well as appropriateness of the language (either local/national), and checked for accuracy. Frequently airing spots reinforces the message conveyed.

Evaluations conducted in Kenya show that mass media are a popular way to sensitize communities on IRS because most families in low-resource settings own a radio. Significant resources are required for a successful mass media campaign, which is a prohibitive factor. Reach is selective to only those who own radio or television and/or understand the language used. In addition, a convenient means of receiving feedback also is lacking. Production and time allocated to disseminate content is limited by costs.

Edutainment is a relatively new form of communication that is gaining popularity in BCC. It aims to educate and entertain at the same time, engages the community, and encourages message retention, as real life situations are used to bring out issues. This form of communication reaches both literate and illiterate people since it involves the use of song, dance, drama, theater, and skits. It is important that the edutainment group maintain a balance between entertainment and information dissemination and ensure consistency to avoid message distortion.

For a successful IRS program, messages need to be communicated in an organized and systematic manner with emphasis on key information. When sensitizing the community on IRS, it is important that people first get to know the program and gain basic knowledge of malaria and IRS; this is followed by the key messages that will enable them to prepare for spraying. Maintaining a consistent and organized flow of information enhances comprehension of the link between the IRS and malaria control and builds support and ownership of the program. It is important to also ensure that the key messages to households are standardized and accurately and consistently disseminated. This is why in Kenya, each mobilizer is issued a laminated mobilizer guide, which they are required to keep and refer to at all times. The mobilizer guide instructs the mobilizer in how to disseminate information to the household and lists key information on how households should prepare their houses before, during, and after spraying.

**Lessons Learned from IRS Campaigns**

Communication is a key component of the IRS program, and certain factors need to be considered when disseminating messages to the community. The following points are derived from Kenya’s IRS experiences (in 2008 and 2009) and communications reference material:

- Messages should be disseminated in a systematic and organized manner to avoid confusion.
- Language used should be simple and easily understandable to avoid misconceptions and misunderstanding.
- It is important to respect and embrace people and their culture. By getting to know them, one is able to know how best to approach them with information and to counter resistance.
- It is important to address all myths, misconceptions, and misinformation about malaria or IRS. Most of the time, misunderstandings are brought about by fear of change or new innovations or ideas; therefore, effort must be made to identify the source and target audience to discuss the issues. This goes a long way in building support.
- Identify pre-existing community structures and resources (e.g., provincial administration, community leaders, community-based organizations, government ministries, and manpower) to enhance communication and sustainability.
- Maintain confidentiality whenever interacting with the community members, since that builds trust.
- Highlight the benefits of IRS intervention to beneficiaries; only then will they be convinced and/or accept and support the program.

• All messages that are developed need to be pre-tested with the target audience so that they are relevant and acceptable to the consumers.

• Research must be undertaken to understand the community and its priorities and systems and the intervention's impact on them, to determine the best way to achieve good results, allow for continuous improvement, and foster community ownership.

• Diversify sensitization and communication strategies to empower the community and achieve wider coverage and greater impact.

Conclusion
Community mobilization and IEC are important in IRS success. The quality of communication affects the quality of a relationship and/or impact of the message, which affects IRS program success. Even with good communication, everyone understands messages differently; therefore, there is need for massive, repetitive, intense, and persistent use of a varied number of communication channels to get the message across.
Malaria is the leading cause of morbidity in Benin, with an average incidence rate of 65.8 per 1,000. The disease accounts for 35% of out-patient visits and makes up 1.6 million recorded health center visits in 2001. As one of the second wave of countries to benefit from the U.S. President’s Malaria Initiative, U.S. Agency for International Development, and Programme National de Lutte contre le Paludisme (National Malaria Control Programme) identified four epidemic-prone districts in Benin—1) Adjohoun, 2) Akpro- Misserete, 3) Dangbo, and 4) Seme-Podji, in the region of Ouémé—for indoor residual spraying (IRS) activities. RTI International was tasked with providing strategic, technical, management, and operations support for IRS activities in Benin. The Benin IRS project has completed two IRS rounds—the first round from July 3 to August 23, 2008, and the second round from March 10 to April 28, 2009.

In the first IRS round, the program achieved 94% coverage of all residential structures in the four districts, where 142,814 out of 151,783 structures found were sprayed. This effort led to the protection of 521,738 residents against malaria infection for up to four months. For the second round, 156,233 structures out of 157,146 structures found were sprayed, protecting a total population of 512,491, representing a 99% coverage rate.

This paper shows how information, education, and communication (IEC) is a critical component of IRS and was an important factor in the Benin IRS campaigns. IEC improved the target population’s knowledge and understanding of the benefits of IRS. IRS mobilization more specifically informed recipients of the precautions to be taken before, during, and after IRS. The IEC campaign focused on providing immediate information about malaria prevention and IRS to its primary audiences and strived to create long-term sustainability through its secondary and tertiary audiences.

insecticide-treated nets (LLINs), rapid diagnostic tests (RDTs), artemisinin based combination therapy (ACT), and sulfadoxine-pyrimethamine (SP) for intermittent preventive treatment in pregnant women (IPTp). The GOB’s overall goal is to reduce malaria morbidity and mortality by 50% by the year 2010.

In 2007, Benin was selected by the U.S. Agency for International Development (USAID) as 1 of 8 countries to receive funding during the third year of the U.S. President’s Malaria Initiative (PMI). To support the GOB in its strategy for malaria control, PMI developed a strategy for indoor residual spraying (IRS) in collaboration with the GOB. Since vector control is an effective method for malaria prevention, IRS is included in the PNLP’s 2006–2010 malaria strategic plan.

**Benin IRS Program**

As one of the second wave of countries to benefit from the PMI, USAID and PNLP identified four epidemic-prone districts: 1) Adjohoun, 2) Akpro-Misserete, 3) Dangbo, and 4) Seme-Podji, in the region of Ouémé, for IRS activities (see Figure 1). In 2008, the PMI and PNLP agreed to focus spraying activities in these four districts and then develop a long-term IRS strategy, expanding coverage across Benin and with support from other donors.

RTI International provides strategic, technical, management, and operations support for IRS activities in Benin. The Benin IRS project has completed two IRS rounds—the first round from July 3 to August 23, 2008, and the second round from March 10 to April 28, 2009. During these two IRS rounds, about 94% and 99%, respectively, of eligible structures were sprayed in the four pilot communes.
Information, Education, and Communication (IEC) Activities and Community Involvement

The IEC component is one critical aspect of IRS. IEC improves the target population’s knowledge and understanding of the benefits of IRS. Mobilization more specifically informs the recipients of the precautions to be taken before, during, and after IRS. Throughout the community mobilization process, the RTI team worked in close collaboration with the ministries of Health, Environment, Communication, and Interior.

Objectives of IEC

The objective of IEC in Benin is to ensure that each household is correctly informed about the benefit and precautions during IRS. More specifically, IEC aims to

- Inform beneficiaries about the positive benefits of IRS in controlling and preventing malaria and malaria-related deaths;
- Inform beneficiaries about their roles before, during, and after the spray operations;
- Inform key stakeholders and beneficiaries about safety issues related to the environmental and health effects of using insecticides; and
- Ensure that each household is correctly informed about the benefit and precautions during IRS.

Process

To meet the overall objectives of the IEC campaign, PNLP and RTI developed an IEC strategy plan in collaboration with the PNLP. Once developed, the IEC strategy plan was approved in a workshop that included a number of malaria partners and was led by the PNLP. The IEC strategy was approved by the Ministry of Health (MOH) at the national and district level. After the strategy was approved by the PNLP, IEC materials were developed by RTI in collaboration with the PNLP. The IEC materials were approved by the MOH at the national and district level so that they could be used by IEC mobilizers. To facilitate IEC, the following activities were conducted:

- Recruited and trained 253 community mobilizers.
- Utilized five community radio stations to broadcast IEC messages, skits, and radio spots developed in local languages, about the benefits of and precautions to take during IRS.
- Worked with existing community structures, including chiefs of villages, traditional and religious leaders, local council members, heads of districts, mayors, heads of townships, and members of associations (mostly women’s associations).
- Displayed banners and posters in the villages being sprayed.
- Deployed IEC mobilizers in each targeted area to go door-to-door to inform the households about the benefits of IRS and the precautions to be taken before, during, and after IRS.

IEC Materials and Activities

The IRS IEC campaign focused on providing immediate information about malaria prevention and IRS to its primary audiences (see Tables 1 and 2). The campaign strived to create long-term sustainability through its secondary and tertiary audiences. IEC activities began three weeks prior to the start of IRS. In Benin, IEC activities included community mobilization, mass mobilization, and community radio broadcasts.

Table 1. IEC materials produced during IRS round 2

<table>
<thead>
<tr>
<th>IEC materials</th>
<th>Number of materials distributed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brochures</td>
<td>160,000</td>
</tr>
<tr>
<td>Leaflets</td>
<td>145,000</td>
</tr>
<tr>
<td>Stickers</td>
<td>145,000</td>
</tr>
<tr>
<td>T-shirts</td>
<td>1,439</td>
</tr>
<tr>
<td>IRS Info bulletins</td>
<td>2,800</td>
</tr>
<tr>
<td>CD of IRS songs</td>
<td>60</td>
</tr>
<tr>
<td>IRS bags</td>
<td>675</td>
</tr>
<tr>
<td>Posters</td>
<td>60</td>
</tr>
</tbody>
</table>

Table 2. IEC activities conducted during IRS round 2

<table>
<thead>
<tr>
<th>IEC activities</th>
<th>Number conducted</th>
</tr>
</thead>
<tbody>
<tr>
<td>IRS radio shows</td>
<td>75</td>
</tr>
<tr>
<td>Interviews with local officials and village and religious leaders</td>
<td>300</td>
</tr>
<tr>
<td>Broadcasts</td>
<td>2,139</td>
</tr>
<tr>
<td>Debates</td>
<td>36</td>
</tr>
<tr>
<td>Media communication</td>
<td>69</td>
</tr>
<tr>
<td>Radio spots</td>
<td>3,695</td>
</tr>
<tr>
<td>Interviews and testimonials after houses are sprayed</td>
<td>695</td>
</tr>
</tbody>
</table>
Community Mobilization
The RTI team held numerous meetings in collaboration with the PNLP, department of Ouémé, and the chief doctors of the four targeted districts to talk to local officials about IRS strategy and goals and gain their support. Meeting participants included districts leaders, chiefs of villages, and representatives of nongovernmental organizations (NGOs) working in the targeted districts. Once support from local officials was obtained, the chiefs held a series of meetings for community members to select IEC mobilizers. Mobilizers were chosen based on their experience in other health projects or activities, their reputation as active members of the community, and literacy skills. With support from community leaders and village chiefs, 253 IEC mobilizers were recruited, trained, and equipped with bags containing leaflets, posters, and other IEC documents.

One week prior to the beginning of spray operations, IEC mobilizers went door-to-door to visit each household, distribute leaflets, and inform households about the benefit of IRS and the precautions to be taken before, during, and after spraying. At the end of each visit, stickers were glued to the door of each household visited and signed by mobilizers to indicate that a house had been visited. These stickers were signed by the team leader and supervisor after a house had been sprayed and inspected.

Household IEC
Household IEC included organizing concerts at the district level. During these concerts, well-known musicians sang in local languages about the benefits of IRS and village, traditional, and religious leaders spoke about IRS. Public reminders were issued by the village announcer, who travelled around the village right before dawn to deliver information about the spray schedule.

Community Radio Broadcast
Five community radio stations were contracted to broadcast IRS information seven times per day. The contract included radios spots, shows, and sketches that were all broadcast at prime times during the day throughout the spray operations.

Coordination with Spray Operations
The coordination of IEC activities with spray operations is crucial to the success of IRS. In addition to pre-spray messages, mobilizers passed through each household 24 to 48 hours prior to the start of spray operations to remind the population about the spray schedule. During spray operations, each mobilizer was responsible for visiting every household in the village at least twice.

Supervision of IEC Activities
Throughout spray operations, supervision of IEC mobilizers was conducted by 43 head nurses from the townships. Data collection forms were used by head nurses to collect the number of communication materials distributed (e.g., leaflets, posters, T-shirts, booklets, bags, CDs of IRS songs, and stickers placed on each household) by IEC mobilizers. The stickers provided proof that a mobilizer had passed through a household to discuss the benefits of IRS and to confirm that a household was then sprayed. Head nurses also collected the number of IRS plays performed by associations and games played by the communities that demonstrated what to do before, during, and after IRS.

IRS Info Bulletins
In addition to community mobilization, a news bulletin, IRS Info, was developed and distributed throughout the spray operations, highlighting key activities that occurred during IRS. Throughout the IRS spray operations, a total of seven IRS Info bulletins were developed and distributed to all partners working in malaria control, to keep them informed of the progress made on IRS.

IRS Launching Ceremonies
IRS operations were officially launched by the Beninese minister of Health and USAID Mission director. Health and community officials at national and districts levels attended the ceremonies and visited the field to observe the spray operators’ work.

Results
The PNLP, with RTI’s technical assistance, conducted two IRS campaigns in 2008 and 2009, covering four districts. In 2009, IRS operations lasted for 42 days and required 22,009 sachets of bendiocarb insecticide. The spray team consisted of 205 spray operators, 41 team leaders, and 19 supervisors. The supervision team consisted of PNLP supervisors, hygiene agents from Ouémé-Plateau Department, chief doctors, and technicians from the Ministry of Environment (MOE). In the first round, the program achieved 94% coverage of all residential
structures in the four districts, where 142,814 out of 151,783 structures identified were sprayed. This effort led to the protection of 521,738 residents against malaria infection for up to four months. For the second round, 156,233 structures out of 157,146 structures were sprayed, protecting a total population of 512,491, representing a 99% coverage rate (see Figures 2 and 3).

Figure 2. Coverage and acceptability rate in round 2

![Graph showing coverage and acceptability rate in round 2]

Figure 3. People protected by IRS in round 2

![Graph showing people protected by IRS in round 2]

An innovative approach unique to the Benin IRS program is the use of women’s associations, under the supervision of PNLP and RTI, to hang LLINs in targeted households in flooding zones that are not eligible for IRS. To ensure that every household was covered, the IRS team chose to work with local women’s associations to hang LLINs in each household and to explain to household members the benefits of using bed nets. In 2009, some 32,826 LLINs were distributed in 31,667 households in 64 villages located in flood zones.

Success Factors

The following factors contributed to the success of IRS in Benin:

- Work in close collaboration with the PNLP, MOH, and MOE. The Benin IRS team worked daily in close collaboration with NMCP in Cotonou, PNLP representatives in the district, and MOE throughout the operations, including supervision conducted daily by Service d’Hygiene and the MOE.
- Communicate objectives and results proactively to all the team members.
- Implement operations on time.
- Build effective relationships with in-country partners.
- Comply with environmental requirements.
- Demonstrate and maintain technical quality.
- Build capacity and transfer operational responsibility.
- Keep partners and local authorities informed and updated on IRS progress. Representatives from USAID/Benin, MOH, and WHO visited IRS sites numerous times, as they felt part of the process.

Lessons Learned

- Balance ratios between operators and supervisors.
- Make household IEC an integral component of IRS.
- In community mobilization, ensure involvement of local authorities and community leaders in IRS activities from the onset.
- Use traditional channels of IEC.
- Ensure effective coordination between IEC activities and spray operations.
- Keep partners and local authorities informed and updated on IRS activities, e.g., use of IRS *Info Bulletins*.
- Ensure discipline throughout the operation and among the team. IRS is military-like operation action.
- Ensure adequate planning and preparatory periods for successful implementation of IRS operations.
- Ensure host government buy-in to IRS activities.
In Mali, malaria-induced fever is responsible for 37.5% of out-patient consultations in health facilities (Système Local d’Information Sanitaire 2008). Children under five and pregnant women are most vulnerable to malaria. To reverse the disease’s trends, access to malaria control interventions, notably preventive measures such as indoor residual spraying (IRS), have greatly improved in Mali. IRS activities led by the U.S. President’s Malaria Initiative started as a pilot project to reinforce the Ministry of Health’s (MOH’s) capacity in implementing IRS. Two districts were selected, Bla and Koulikoro. The IRS program’s objectives were to cover 85% of structures targeted to be sprayed; protect 85% of the population in the two districts; and protect 85% of the population living in the structures identified.

**Advocacy**
To achieve a quality round of IRS, it is very important to plan comprehensive advocacy, social mobilization, and communication strategies. The participation and support of local decision makers, individuals, family members, and communities is instrumental to the success of an IRS campaign. Advocacy should be conducted at different levels to obtain various leaders’ support. Advocacy activities should be done in coordination with health services and administrative authorities, religious leaders and local elected bodies, nongovernmental organizations (NGOs), and local media. Advocacy messages include the burden of malaria on the community; effectiveness of the IRS campaign in reducing the morbidity; social and economic benefits in eliminating malaria; safety of environment; and use of insecticides.

**Social Mobilization**
Social mobilization activities are designed to obtain the support of various groups, institutions, and organizations. During early contact with individuals and groups, they are asked about their points of view; they are then assigned specific tasks for their participation. Social mobilization tasks include providing informing about the campaign during important meetings and social, cultural, and sport events; providing personnel, financial resources, storage facilities, and other resources; radio broadcasting; and launching the campaign through community-wide events.

**Behavior Change Communication (BCC)**
A BCC campaign should reach all targeted populations, particularly individuals who are not aware of IRS or who are simply busy. Clear messages should be developed and disseminated through appropriate methods to reach individuals that could influence the larger population. Communication channels include media such as radio or television, interpersonal communication, and associations and networks, e.g., the RECOTRADE, an association of traditional communicators.

Though the communication strategy planning process is integral to a successful IRS campaign, it is only the first step. The campaign then needs to be carried out. Before the spraying campaign, there should be teams working on advocacy; developing and printing information, education, and communication (IEC)/BCC tools for IRS (e.g., television and radio spots); and identifying and training relais (community mobilization workers).
Other activities include identifying and training spray pump operators; training medical staff at the community and referral health centers, including head nurses at the health posts; organizing a sensitization day for community leaders in the selected sites on IRS; and organizing a community mobilization day event at the district level.

During the spraying campaign, community workers disseminate television and radio spots on IRS in targeted districts and visit homes to further IEC/BCC efforts. After the campaign, workers organize workshops on campaign results at district and national levels and disseminate the results and ongoing IRS materials that cover topics such as preventing people from conducting maintenance work on or painting walls before the six-month insecticide effectiveness expires or the next spray campaign passes.

**Results**

The results of the 2009 IRS campaign in Mali achieved 95.4% coverage of sprayed structures in the two targeted districts; 97.5% coverage of the population in the two districts; 94.9% coverage of pregnant women in the two districts; and 96.4% coverage of children under five years old in the two districts. The BCC campaign boosted IRS acceptance by communities. The MOH’s effective participation (including the regional level of the Programme National de Lutte contre le Paludisme, reference health centers, and community health centers) in the microplanning, preparatory phases, and monitoring and supervision of the campaign was also critical. In addition, the Ministry of Environment offered support in the training and supervision of activities through regional and district services.

The administrative aspects of the campaign also garnered support from the local communities at district and community levels. An advocacy workshop explained the IRS activities to the local leaders, particularly the selection, recruitment, and compensation of people involved in spraying operations at the community level.

**Challenges**

Though the 2009 campaign had many positive results, there were also some constraints. One challenge was the slowness in starting up IEC activities. In future campaigns, one solution would be the organization of a week-long promotion of *relais* activities.

**Conclusion**

Overall, the population—including local, district, and regional leaders—were pleased with the results achieved during IRS operations, as well as the communication activities. Mobilization and behavior change were very crucial elements of success in Mali’s IRS operations.
Applications of GIS for Malaria Epidemiology in Africa

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Medical Research Council

Introduction

Malaria is a major cause of morbidity and mortality in Africa, and is a leading cause of death, especially among children in many African countries. Malaria often occurs in specific, local geographic areas. These areas do not respect political or jurisdictional boundaries. More than 47 countries or territories in Africa are malarious areas that bear most of the global malaria burden (World Health Organization [WHO] 2008). New technologies—such as geo-informatics technologies, geographic information systems (GIS), global positioning systems (GPS), and remote sensing—offer new opportunities for the rapid assessment of malaria-endemic areas, the provision of reliable estimates of populations at-risk of malaria infection, prediction of malaria distribution, modeling of malaria risk, and guidance on intervention strategies such as indoor residual spraying (IRS), so that scarce resources can be allocated in a cost-effective method.

GIS are automated systems for capturing, storing, retrieving, analyzing, and displaying spatial data (Maguire 1994). GIS are integrating systems that bring together ideas developed in many areas, including agriculture, botany, computing, surveying, zoology, and geography. The component parts of GIS include not just a database, but also spatial or map information and some mechanism to link them together. Recently, GIS has emerged as an innovative and important component of many projects in public health and epidemiology.

Applications of GIS in malaria epidemiology include the mapping of malaria incidence and prevalence data at different geographic scales, the identification and prediction of suitable habitats for malaria parasites and intermediate mosquito vector species, and the modeling of malaria risk areas. Other prominent applications have included the guidance of malaria control interventions. There have been limitations in previous work conducted in some parts of Africa and outlines potential new applications of GIS techniques, namely quantitative GIS modeling, Web-GIS, and the utilization of emerging satellite information. These new technologies hold the promise to further enhance malaria risk mapping and malaria epidemic prediction. Current research must overcome some of the remaining challenges of GIS applications for malaria, so that further and sustained progress can be made to control and eliminate this disease from Africa, as stipulated by Roll Back Malaria (RBM) partnerships.

In Africa, the application of GIS technologies to malaria study dates back to the late 1990s. Particular emphases have been placed on mapping incidence/prevalence, identifying mosquito habitats, and forecasting transmission risk in relation to environment. Various applications of GIS that have furthered our understanding of malaria and its control approaches in Africa.

GIS have been used in studies of vector-borne diseases and have been proposed as a potential tool for vector-borne disease control. Together with remote sensing technology, these tools provide a new approach for epidemiologic studies and control efforts of vector-borne diseases.
GIS and IRS for Mapping Malaria Incidence and Prevalence

Typically, the purpose of using geo-informatics is that maps provide an added dimension to data analysis, which helps in visualizing the complex patterns. Snow et al. (1999) recognized that accurate mapping of malaria cases is an important tool for efficient handling of the malaria control program. Mapping the incidence/prevalence of malaria over a geographic area is the basic application for focusing on examining past trends, as well as the present situation. This usually does not include any statistical analysis, with the exception of correlation incidence/prevalence with population in order to calculate population at risk (MARA). Table 1 summarizes different studies that applied GIS technologies for malaria incidence/prevalence mapping. For each study, the aim, country, method employed, and data sources are provided.

GIS for Assessing the Association between Malaria Cases and Environmental Factors

GIS also enhances an interdisciplinary approach to the solution of problems. It goes beyond conventional mapping and spreadsheet tables, helping scientists discover and visualize new data patterns and relationships that would have otherwise remained invisible. GPS and remote sensing support this through their unique multifaceted, real-world data capturing capability. GIS compile these data sources into layers, each covering a single aspect of reality. GIS then link these layers by spatially matching them and query and analyze them together to produce new information and hypotheses. It is possible, for example, to overlay and integrate the population, environmental, ecological, climate, and malaria data layers to assess the relationships between malaria incidence and different types of environmental and/or ecological variables. The study by Oesterholt et al. (2006) showed that local malaria transmission in a defined spatial zone is restricted to the rainy season and strongly associated with proximity to the river. Table 2 summarizes the different studies that applied GIS technologies for assessing the association between malaria cases and environmental variables. For each study, the aim, country, method employed, and data sources are provided.

Modeling Malaria Risk

Risk modeling uses many of the same variables studied and their associations with the malaria cases discussed above. The statistical relationships are established between malaria cases and (the dependent variable) and a range of environmental/ecological variables (independent variables) in an effort to predict future cases of malaria. Table 3 summarizes the different studies that applied GIS for

<table>
<thead>
<tr>
<th>Reference</th>
<th>Study Aim</th>
<th>Study Area</th>
<th>Method</th>
<th>Data Sources and Parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pietro et al. (2007)</td>
<td>Map and stratify malaria epidemic area based on</td>
<td>Eritrea</td>
<td>Clustering and mapping</td>
<td>Monthly clinical malaria cases</td>
</tr>
<tr>
<td></td>
<td>incidence</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Abdisalan et al. (2008)</td>
<td>Map malaria distribution in low malaria transmission area</td>
<td>Somalia</td>
<td>Bayesian geo-statistical models</td>
<td>Rapid diagnostic tests to examine the presence of ( P. falciparum ) parasites</td>
</tr>
<tr>
<td>Oesterholt et al. (2006)</td>
<td>Map spatial and temporal variation of malaria transmission</td>
<td>Tanzania</td>
<td>Malaria cases mapped by residence and season and distance to breeding site</td>
<td>Demographic malaria cases mosquito light traps</td>
</tr>
<tr>
<td>Bøgh et al. (2007)</td>
<td>Map malaria transmission risk</td>
<td>Gambia</td>
<td>Filed survey and Landsat™ data to map entomological inoculation rates (EIR)</td>
<td>Anopheles gambiae breeding habitats; location of settlements</td>
</tr>
<tr>
<td>Craig et al. (2007)</td>
<td>Mapping of historical malaria prevalence Botswana</td>
<td>Univariate logistic regression</td>
<td>Bayesian geo-statistical model</td>
<td>Malaria prevalence extracted from MARA</td>
</tr>
</tbody>
</table>

Note: Bøgh et al. (2007) emphasized the importance of malaria distribution maps for designing interventions and/or vaccine trials. The same authors used a combination of field data, satellite remote sensing images, and GIS modeling to develop a high-spatial resolution map of malaria EIR in Gambia. Their study detailed that \( A. gambiae \) habitats were mapped by classification of a LANDSAT™ satellite image with the overall accuracy of 83%. Using meteorological, demographical, entomological, and parasitological data, a study was carried out in a single village in northern Tanzania to map malaria epidemiology (Oesterholt et al., 2006). GIS were utilized to map malaria cases identified through passive case detection at the local health center, and the incidence/prevalence of cases by season and distance to the main breeding site were also calculated using GIS analysis. Similarly, Craig et al. (2007) applied GIS for mapping historic malaria cases in Botswana, using malaria cases reported at the local health center.
modeling malaria risk areas, assessing the association between malaria cases and environmental variables. For each study, the aim, country, method employed, and data sources are given.

**GIS for IRS Planning**

Incorporating GIS into a malaria control program enhances the intervention program’s capacity to plan, manage, and report on its malaria control activities. GIS is also useful for monitoring and evaluating IRS. It helps to clearly define IRS targeted and eligible households, which is important for several reasons. First, through the planning process, enumerating IRS households makes it possible to quantify the allocation of spray personnel, simplify the spray schedule, and estimate the duration of spray activities. The most obvious use of mapping and enumerating structures is the quantification of insecticides. Rather than using general estimations or guesswork in counting structures, GIS provides accurate counts of structures.

**Limitations in Using GIS for Malaria Research and Control in Africa**

**Lack of qualified staff.** Staffing is a common issue that has most frequently occurred in Africa. The fact that GIS is a relatively new technology means that staff with GIS training and skills are in high demand but scarce.

**Data.** GIS users have faced this problem for decades in the majority of Africa countries. The spatial scale of the existing spatial data is not appropriate for many types of analyses. Remote sensing data and meteoro logical data are not usually available at the scale needed for analysis. While it may be appropriate for country-wide analysis, it is not for local/village analysis, because small features such as ponds and localized wetlands are generalized in most available data.

**Cost of hardware and software.** The cost for software licenses and maintaining both hardware and software is far too expensive for most African countries.

**Conclusion**

GIS provides a powerful means of capturing, storing, and displaying spatial information. It would be a useful tool for evidence-based decision making in malaria control. This technology has been used in identifying risk areas and risk factors, stratification for malaria interventions, allocation of limited resources in a cost-effective manner, and forecasting of epidemics or identification of outbreaks. Nonetheless, several important issues remain to be addressed and require further study to refine the tools and broaden their applicability. This paper underscores that optimal use of GIS for malaria control purposes requires a sound understanding of the epidemiology and recognition of the inherent problem of pattern and scale in ecology.
References


new technologies and future directions

zanzibar malaria early epidemic detection system

ms. claudia anderegg
rti international

introduction and background

In 2003, the Revolutionary Government of Zanzibar implemented the free provision of artemisinin-based combination therapy (ACT) to confirmed and suspected cases of malaria in all public health facilities. Following this decision was an increase in the use of ACT as a first line treatment, a rise in coverage with insecticide-treated nets (ITNs), and the completion of four indoor residual spraying (IRS) campaigns during 2005–2008. The approach of using various intervention strategies decreased the malaria positivity rate in Zanzibar from 41% in 2003 to less than 1% in 2007 (World Health Organization 2008) (see Figure 1).

While malaria prevalence has been reduced to unprecedented low levels—less than 1% (2008 Tanzania HIV/AIDS and Malaria Indicator Survey)—the persistence of malaria transmission in surrounding areas (e.g., Mainland Tanzania and Kenya) leaves Zanzibar vulnerable to sudden outbreaks of malaria and a resurgence of endemic malaria transmission. As a result, improved malaria surveillance and epidemic response capabilities are required to prevent malaria resurgence in Zanzibar. To fulfill these needs, in 2008, the Zanzibar Malaria Control Programme (ZMCP), in collaboration with the U.S. President’s Malaria Initiative (PMI), developed and implemented the Malaria Early Epidemic Detection System (MEEDS).

objective

The objective was to develop and implement a health facility-based MEEDS for prompt detection of sudden increase in *P. falciparum* transmission in Zanzibar. Specifically, this initiative aimed to

- Facilitate quick reporting of aggregated data (age groups);

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**Figure 1: Slide positivity rate in relation to intervention coverage (%) in Zanzibar, 2003–2007 (source ZMCP)**
• Detect sudden increases in malaria transmission;
• Inform programmatic decision making;
• Predict demand for services and service provision needs; and
• Advocate for malaria control resources.

Methods
MEEDS was implemented in 10 primary health care units (PHCUs), five each in Pemba and Unguja (see Table 1). PHCUs offer basic curative and preventive out-patient services for children and adults.

Table 1. Initial Zanzibar MEEDS Sites

<table>
<thead>
<tr>
<th>Primary Health Care Unit</th>
<th>District (Island)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Makangale</td>
<td>Micheweni (Pemba)</td>
</tr>
<tr>
<td>Konde</td>
<td>Micheweni (Pemba)</td>
</tr>
<tr>
<td>Mzambarauni</td>
<td>Wete (Pemba)</td>
</tr>
<tr>
<td>Kengeja</td>
<td>Mkoani (Pemba)</td>
</tr>
<tr>
<td>Jadida</td>
<td>Wete (Pemba)</td>
</tr>
<tr>
<td>Gamba</td>
<td>North B (Unguja)</td>
</tr>
<tr>
<td>Matemwe</td>
<td>North A (Unguja)</td>
</tr>
<tr>
<td>Donge Michagani</td>
<td>North B (Unguja)</td>
</tr>
<tr>
<td>Bumbwini</td>
<td>North B (Unguja)</td>
</tr>
<tr>
<td>Jambiani</td>
<td>South (Unguja)</td>
</tr>
</tbody>
</table>

After the successful implementation of MEEDS in 10 PHCUs, the system was scaled up to 52 facilities, 25 in Pemba and 27 in Unguja. The selection criteria for the sites were as follows:

• Inclusion of all geographic locations in Zanzibar (representation from each district);
• Higher coverage in areas with a higher malaria burden (Roll Back Malaria Indicator Survey, Zanzibar, 2007);
• Inclusion of one facility at each district with a low number of malaria cases (i.e., control site);
• Availability of malaria diagnostic capacity;
• Catchment service population; and,
• Staff capacity.

Data Flow
MEEDS relies on mobile phone-based, weekly reporting of malaria indicators, which are reported in the patient register (i.e., health management information system [HMIS]) (see Figure 2).

The indicators included in MEEDS are the following:
• Total number of out-patient visits (for <5 years of age and ≥5 years of age separately);
• Total number of malaria tests\(^1\) performed (for <5 years of age and ≥5 years of age separately); and
• Total number of positive test results (for <5 years of age and ≥5 years of age separately).

**Health Facility**

On a daily basis, staff at each health facility enter data on the indicators into a specially designed booklet. In addition to completion of the MEEDS booklets, each confirmed malaria case is entered into the Malaria Case Register (MCR), which collects information about the treatment and travel history of each case. The data entered into the MCR are not reported to the national level, but are used by the ZMCP for evaluation of data accuracy and travel history surveys.

The aggregated data from the MEEDS booklets are sent weekly through SMS to a secure central server (e.g., Selcom) (see Figure 2, number 1).

**Central Server**

The SIM card in each MEEDS phone contains a customized menu (e.g., Selcom Wireless in Dar es Salaam), which allows the health facility to send the weekly report to the central server. The server generates a backup of the submitted data and is linked with a secure Web site. A basic evaluation of the incoming data is generated for each health facility on the Web site. The data on the Web site can be downloaded if needed for further evaluation.

**District Level**

After the health facility sends their SMS to the central server, it generates an SMS for the District Health Management Team (DHMT, see Figure 2, number 2), including the numbers respective to all indicators. District medical officers can immediately follow-up with sites that fail to report.

**National Level**

The secure server allows responsible staff at ZMCP, representatives at the Ministry of Health and Social Welfare, and defined stakeholders to have access to the weekly aggregated data (see Figure 2, number 3). With the downloaded data, ZMCP and stakeholders produce the MEEDS biannual, quarterly, and weekly reports.

• **Biannual reports**\(^2\) (see Figure 2, number 4). Evaluation of all collected information for the national level and stakeholders. The first biannual report includes data from the 52 MEEDS facilities for 2008 and through week 26 of 2009. It captures a total number of 492,248 out-patient cases and 116,333 malaria test results. During this period, 3,003 positive test results were reported. The overall positivity rate for 2008 was 2.4% and 2.8% for weeks 1–26 of 2009. The malaria testing rates increased between 2008 and 2009, following the re-training of clinic staff to reinforce the need to screen all patients with a current or history (past 48 hours) of fever. The number of reported malaria cases increased between 2008 and 2009, but this likely resulted from an increase in the number of confirmed malaria cases through an increase in the number of tests performed.

• **Quarterly reports** (see Figure 2, number 5). A short feedback report is provided to the health staff of the MEEDS facilities and the DHMT for each district. The reports contain data from the last three months and include an evaluation of the total number of out-patient cases, overall positivity rates, and completeness of reporting for each health facility.

• **Weekly reports** (see Figure 2, number 6). The objective of the weekly report is to evaluate and monitor the weekly incoming data for decision making (rapid response guidelines for malaria reported cases in Zanzibar).

**Supervision**

**MEEDS Data Accuracy Study**

In September 2009, a total of 20 MEEDS facilities (12 in Unguja and 8 in Pemba) were included in a supervision study to evaluate the accuracy of the data that have been submitted to the national level.

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\(^1\) In 50 MEEDS sites, malaria rapid diagnostic tests (RDTs) were used. Two sites are using microscopy.

Evaluation of MEEDS Data Accuracy

Data were compared for malaria cases reported to MEEDS January 1 through July 30, 2009 (Weeks 1–31).

- Data (collected on a weekly basis) from the MEEDS Web site were compared with the facility’s MEEDS booklets and the MCRs.
- Daily reports from MEEDS booklets for 40 preselected dates (every fifth day, beginning on January 1, 2009) were compared with data in the facility’s HMIS register.

Feedback to MEEDS Sites

Staff in charge of the MEEDS sites were presented with a copy of the first quarterly MEEDS report.

Findings

MCRs

- Completion of MCRs requires improvement. Only 46% of confirmed malaria cases reported during the first two quarters of 2009 were found in the MCRs at the Unguja facilities.
- Completion of MCRs requires improvement, with 82% of confirmed malaria cases reported during the first two quarters of 2009 found in the MCRs at the Pemba facilities.

MEEDS Data Accuracy

Unguja. Overall data accuracy was good, with 89% accuracy (see Table 2) between data records for all the Unguja sites that were evaluated. There were minimal to no discrepancies in the numbers of confirmed malaria cases reported to MEEDS. Improvement is needed in reporting of negative RDT results and all-cause visits.

Pemba. Accuracy of data submitted to MEEDS by Pemba sites requires improvement. None of the sites had accuracy rates across the records over 90%, with Pemba’s total at 83% (see Table 3). There were minimal to no discrepancies in the numbers of confirmed malaria cases reported to MEEDS. Improvement is needed in reporting of negative RDT results and all-cause visits.

In response to these results, the checklist for supervision visits was updated, and regular supervision visits were planned for each quarter.

Discussion

MEEDS was implemented in 2007, and a significant amount of information concerning the malaria situation in Zanzibar could be collected. However, the system is young and improvements are necessary. The findings from the data accuracy study showed that supervisory visits to reporting health facilities should be planned on a regular basis to give an opportunity for health staff to address questions and difficulties in the normal MEEDS data reporting process.

Some of the health facilities had a problem with sending the weekly reports due to network issues. The solution to this problem will involve changing networks for these facilities to a wireless company with a wider coverage in these areas.

Next steps in the implementation include reprinting the new MCR booklets and training health staff at each facility on how to obtain and document detailed information about the travel history of each malaria case. Travel history will assist with determining whether a malaria infection occurred within Zanzibar or outside of the islands. This clarification will be important for planning and decision making for malaria elimination.

To evaluate the performance of RDTs at the health facilities, an RDT-blood slide proficiency reading is planned in 10 MEEDS sites (five in Unguja and five in Pemba).
Innovative Payment Schemes for Temporary Workers: The Tanzania Experience

Dr. Mahdi Mohamed Ramsan
RTI International

Introduction
Since 2006, the U.S. Agency for International Development (USAID) has provided technical and financial support to the Tanzania National Malaria Control Programme (NMCP) and Zanzibar Malaria Control Programme (ZMCP) under the U.S. President's Malaria Initiative (PMI). Under a Cooperative Agreement with USAID, RTI International provides technical support and assistance to the NMCP and ZMCP through the Malaria Control in Mainland Tanzania and Zanzibar Project. RTI assists with indoor residual spraying (IRS), environmental compliance, epidemiological surveillance, malaria epidemic early detection, urban malaria control in Dar es Salaam, implementation planning, and behavior change communication in Zanzibar.

IRS logistics preparations are complex and require at least six months of pre-spray organization before IRS operations commence. The RTI team, working closely with local partners, developed several innovative systems and on-the-job training activities to ensure streamlined and quality IRS operations.

RTI's Innovative Payment System in Tanzania
One of the major challenges in IRS is the recruitment and payment of seasonal local spray operators. Cash costs associated with field operators (e.g., staff and transport) total almost 35% of operations expenditures (see Figure 1). Among the many challenges involved in handling and disbursing cash payments in the field are the efficiency and timeliness of the process, as well as security.

Figure 1. Breakdown of IRS operations expenses in Karagwe District
Owing to various circumstances, including conditions imposed by banks, most operators are not eligible to open bank accounts. As a result, RTI, in collaboration with local partners, developed a system to pay seasonal local spray operators through direct-deposit payments into individual, personal, local accounts. This method replaced the old system of direct cash payments to spray personnel on a weekly basis, which was disruptive to IRS activities. The process and time involved in issuing cash payments to spray operators often caused a 1–2 day delay in operations. Moreover, carrying and handling large sums of cash in the field created significant security concerns for the RTI team.

To facilitate the direct deposit payment process, RTI hires a finance manager and logistics specialists in all the spray sub-stations to handle financial payments, manage local accounts, and ensure timely payments.
Malaria Control and Elimination Cross-Border Collaboration

Dr. John M. Govere
World Health Organization

The increasing inter-country population movement and the global call for malaria elimination have increased the importance of malaria cross-border collaboration. Inter-country disparity in availability and quality of health-care services, cultural similarities of communities at border areas, and business and employment opportunities increase cross-border movement of people and mosquitoes, and malaria parasites. This movement may also result in cross-border movement of drug and insecticide resistance. In southern Africa, countries with lower malaria burdens, due to sustained IRS programs, normally initiate cross-border malaria collaborations with bordering countries. Implementation of cross-border malaria control collaboration in southern Africa has shown that cross-border collaboration reduces malaria burden in participating countries.

In cross-border collaboration, participating countries agree to harmonize protocols, guidelines, standards, and strategies, as well as to synchronize timing of interventions delivery across borders; standardize services and information at cross-border areas; conduct joint staff training at cross-border areas; share resources and expertise where possible; and mobilize regional resources. The importance of malaria cross-border collaboration has been widely recognized and accepted, and is now receiving global and regional support and financial investment.

The Lubombo Spatial Development Initiative (LSDI), a regional malaria control collaboration between Mozambique, South Africa, and Swaziland, is the most successful cross-border malaria control collaboration initiative in southern Africa. The initiative is administered by the Medical Research Council, Durban, South Africa. The LSDI has been in operation for eight years, focusing on malaria control in Mozambique, with remarkable reduction of malaria burden in Mozambique and ripple effect in Swaziland and South Africa.

There are three other active cross-border malaria control initiatives in southern Africa, which include the Trans-Limpopo, Trans-Zambezi, and Trans-Kunene. The Trans-Limpopo Malaria Initiative involves South Africa and Zimbabwe. The initiative was established in 2001 by two bordering provinces—Matabeleland South (Zimbabwe) and Limpopo (South Africa)—with the aim of sharing information and strengthening programs on both sides of the border to achieve malaria elimination in the two provinces. The Trans-Zambezi Cross-Border Malaria Initiative is a convergence of five countries—Angola, Botswana, Namibia, Zambia, and Zimbabwe. The initiative is driven by the Southern African Development Community, with the aim of increasing access to interventions among hard-to-reach communities. The Trans-Kunene Malaria Initiative involves southern Angola and northern Namibia. Implementation of this initiative started in 2009, by harmonizing interventions across border provinces.

As the volume of cross-border population increases and countries move toward universal coverage of malaria interventions and malaria elimination, cross-border collaboration becomes critical. Malaria is a regional problem and requires a regional solution.
The goal of any vector control program is to establish the most efficient, cost-effective, and sustainable program that is responsive to changing local disease eco-epidemiology (e.g., vector, human, and ecosystem) and operational settings, and that maximizes impact in reducing disease burden. Despite dramatic increases in malaria control funding over the last decade, disease-endemic countries still face significant difficulties in establishing and sustaining effective programs. This is largely due to inadequate in-country technical and managerial capacities to generate the critical entomological and epidemiological information required that inform program implementation and management. Most countries also lack appropriate institutional and policy frameworks.

RTI International provides a broad range of vector control services aimed at strengthening country capacities and competencies to control vector-borne diseases, particularly malaria. Currently, RTI is conducting these services through the following U.S. Agency for International Development (USAID)-funded projects: Indoor Residual Spraying (IRS) Projects 1 and 2, a component of the U.S. President’s Malaria Initiative (PMI); Malaria Control in Mainland Tanzania and Zanzibar Project; Tanzania Vector Control Scale-Up Project; Integrated Vector Management of Malaria and Other Vector Borne Diseases (IVM Project); and the Neglected Tropical Disease (NTD) Control Project.

**IRS Project**

The IRS Project’s operations are conducted through a strategy that increases the role and responsibilities of countries as capacities/competencies are strengthened. Opportunities for seamless and ongoing hands-on field training/experience are therefore provided, such as the following:

- Countries are supported to build capacities for program planning, conduct monitoring and evaluation (M&E); and collaborate in micro-planning, field implementation and supervision, and management of IRS operations.
- Various training activities are conducted for all categories of IRS workers (e.g., spray operators; storekeepers; environmental monitoring/human health safety supervisors; information, education, and communication [IEC]/behavior change communication [BCC]; etc.).
- Infrastructure support includes establishing disposal and waste minimization facilities (e.g., evaporation tanks, soak pits) and insectaries.

**IVM Project**

The IVM Project provides technical assistance resources to institutionalize best practices, conduct operational research, and strengthen the management and technical capacities of country programs. The objective is to facilitate efficient and sustainable management of disease vectors. The IVM Project complements the PMI’s overall strategy. Two strategic approaches (global/regional and country) are utilized.

At the global and regional level, the IVM Project

- Partners with the World Health Organization (WHO) in setting the global IVM agenda, clarifying the IVM concept, providing advocacy and technical support to countries for development of core competencies in program planning, implementation, and M&E; and transitioning to integrated approaches.
• Cosponsors annual IVM stakeholder meetings with WHO, which bring together vector-borne disease endemic countries, academia/research institutions, multilateral/international agencies, and industrial/private sectors to review experiences and strategize on implementation.

• Serves on specialized committees such as the Vector Control Committee of the Malaria Eradication Agenda (MalERA) and provides input to other high-level, ad hoc scientific meetings

• Provides technical and/or financial investment for developing critical manuals, including Guidelines for Assessing the Management and Organizational Capacity of National Malaria Control Programs, a rapid assessment tool kit coauthored with the Health Systems 20/20 project. The tools are aimed at facilitating self-evaluations by national malaria control programs (NMCPs) to identify key management and organizational capacity needs, to meet the challenges arising from the scale up in funding and implementation. A review of vector control training capacity in Africa lists existing institutions, training programs organized, and resources and technical expertise at these institutes. The IVM Handbook is being drafted under the auspices of WHO, to serve as a user-friendly and comprehensive practitioner’s source book.

At the country level, the IVM Project works closely with NMCPs to review and strengthen national vector control strategies and policies, by conducting vector control needs assessments and developing national IVM strategies; establishing insectaries, ELISA-based laboratories, and entomological sentinel systems; and conducting basic and advanced entomology technician training to create a critical mass of trained personnel within regions and districts for entomological monitoring and surveillance. The IVM Project is mobilizing industry partners and international implementing agencies in ongoing public-private partnerships to accelerate entomological capacity strengthening and priority operational research (e.g., co-deployment of IRS, long-lasting insecticide-treated nets [LLINs], options for addressing the problem of increasing exophagy, maximizing multidisease vector control delivery vehicles, and evaluation of new vector control tools).

**NTD Project**

The NTD Project supports the supply of safe and effective drugs for mass drug administration (MDA) programs in countries, targeting local elimination or control of NTDs (onchocerciasis, lymphatic filariasis, trachoma, schistosomiasis, and soil-transmitted helminthiasis). The drugs are mostly donated by pharmaceutical industry partners. The project facilitates national scale up of treatment of populations at-risk, the integration of disease treatment, and government ownership and leadership. MDAs are implemented by governments through health campaign and school-based distribution. Between 2006 and 2009, approximately 43 million people were reached in Burkina Faso, Ghana, Haiti, Mali, Niger, Sierra Leone, South Sudan, and Uganda. Over 290 million treatments were distributed at a total program cost of US$40 million.

The NTD Project will expand to cover 30 countries globally. The U.S. Government remains committed to eliminating the targeted diseases, especially lymphatic filariasis. While the project’s focus will remain primarily on MDAs, it will also extend to research and drug development, IVM, and morbidity control. Efforts will build on experiences in linking malaria and vector control of other NTDs. Future efforts will therefore include exploring opportunities for achieving cost-efficiencies, maximizing reach, and building and reinforcing the capacity of country implementers. In addition, the project will explore how IRS can help to accelerate local elimination of NTDs, the potential use of NTD programs to facilitate LLIN distribution, and other community mobilization programs (e.g., home-based management of fever), as well as coordination/integration of program monitoring with vector control programs.
Presenter Biosummaries

A

**Dr. Abdullah Suleiman Ali**  
Zanzibar Malaria Control Programme (ZMCP)

Dr. Abdullah Suleiman Ali serves as manager of the ZMCP, where he supports efforts toward malaria control and elimination in Zanzibar.

**Dr. Chioma Amajoh**  
Nigeria National Malaria Control Programme

Dr. Chioma Amajoh has more than 20 years of experience managing and providing technical leadership for the design and implementation of integrated vector management, particularly indoor residual spraying (IRS), insecticide-treated nets, and long-lasting insecticide-treated nets. She is currently a temporary consultant for the World Health Organization. Previously, she was a member of a team that drafted the IRS Regional Framework/Guidelines in 2006. In 2000, Dr. Amajoh served on a committee that drafted the technical document for the Abuja Declaration at the African Summit on Roll Back Malaria.

**Dr. Birkinesh Ameneshewa**  
World Health Organization-Africa Regional Office (WHO-AFRO)

Dr. Birkinesh Ameneshewa is the vector control operations officer at WHO-AFRO. Dr. Ameneshewa is a medical entomologist, with more than 15 years of experience in managing disease vector control programs at national and regional levels. She serves as the officer responsible for coordinating technical support to countries in the design and management of vector control programs. She is skilled and has sound experience in conducting situation analysis, needs assessment, planning, implementation, and monitoring of vector control programs in the context of integrated vector management. She also is apt in designing and developing vector control policies and strategies and in capacity development of vector control programs.

**Ms. Claudia Anderegg**  
RTI International

Ms. Claudia Anderegg is a technical advisor for RTI’s Tanzania Vector Control Scale-Up Project, funded by the U.S. Agency for International Development through the U.S. President’s Malaria Initiative. In this role, she works with the Zanzibar Malaria Control Programme. Ms. Anderegg previously worked with the Tanzania National Malaria Control Programme of Tanzania. She earned a master’s degree in epidemiology from the Swiss Tropical Institute in 2009. Her master’s thesis focused on routine malaria monitoring in Tanzania.

Dr. Kathryn Aultman  
The Bill & Melinda Gates Foundation

Dr. Kathryn Aultman is responsible for the Vector Initiative in malaria and neglected and other infectious disease strategies. She manages a portfolio of grants that explore and develop new paradigms for vector control, including spatial repellents, auto-disseminated larvicides, and attractant-baited traps, among others. Although successful in agriculture, these paradigms are new to public health and must be established in initial proof of principle studies. She also supports and manages a set of grants that support vector control broadly, including support for regulation, prequalification, judicious use of public health pesticide products (PHPPs), and understanding and mitigating insecticide resistance. Dr. Aultman leads the development of an overall vector strategy, working within the Foundation and the community to develop a conceptual framework that will help guide investments in this field.

Prior to joining The Bill & Melinda Gates Foundation in 2005, Dr. Aultman spent 15 years at the U.S. National Institutes of Health (NIH). While at NIH, she managed a portfolio of basic, applied research grants in vector biology, and created a partnerships program that supported a consortia of industry and academia to develop novel PHPPs—all focused on disease-endemic countries. Before joining the NIH, Dr. Aultman was an AAAS Science and Diplomacy fellow at the U.S. Agency for International Development (1988–1989). She holds a bachelor’s degree in biology and chemistry from the University of New Orleans and a PhD in biochemistry from Louisiana State University.

B

**Mrs. Aba Baffoe-Wilmot**  
Ghana National Malaria Control Programme (NMCP)

Mrs. Aba Baffoe-Wilmot is a principal medical entomologist at the NMCP within the Ghana Health Service (GHS). For over 30 years, she has worked as a senior vector control manager at GHS and has been involved in research and control of malaria, trypanosomiasis, yellow fever, lymphatic filariasis, and leishmaniasis. She was instrumental in placing Ghana’s malaria control efforts on the world map through the country’s participation in the Roll Back Malaria initiative, establishing a public-private partnership for the sustainable marketing of insecticide-treated materials, and linking insecticide-treated net distribution to measles vaccination campaigns, to achieve high, equitable, and rapid coverage at a low cost.
Dr. James Banda
Roll Back Malaria (RBM) Partnership Secretariat

Dr. James Banda joined the RBM in 1998 as an adviser on health systems and sector-wide approaches (SWAPs). He has since served in various capacities, achieving major goals such as the introduction and promotion of 5-year strategic planning, 3-year operational planning, and integrated business planning. As head of the Partnership Facilitation Team, Dr. Banda leads the global alignment of implementation support to in-need countries, as well as provides expert advice on results-oriented health service delivery.

With more than 20 years’ experience in health systems reform in Zambia, Dr. Banda’s work has focused on translating policy into action. Prior to taking up his post at RBM, Dr. Banda served at various capacities in the Zambia Ministry of Health. Major projects included strengthening of district hospitals within district health systems, decentralizing health services management to hospital and district health management boards, and building the first ever SWAP. Dr. Banda holds a master's degree in public health from The Johns Hopkins University, in Baltimore, MD.

Ms. Jean Benedict
Crown Agents

Ms. Jean Benedict is a regional manager and a senior business development professional for Crown Agents, where she supports new business ventures in Africa for the company. Ms. Benedict managed the Crown Agents Indoor Residual Spraying (IRS) Project office in Nairobi from 2007–2010. She designed the cash-in-transit model that is used to provide cash stipends to the spray operators in Kenya and Mozambique. An economist by training, Ms. Benedict has been an advocate of improving and streamlining the management and productivity of project operations, competitive vendor sourcing, and financing arrangements for the IRS Project in Africa.

Prior to joining Crown Agents, she worked for the U.S. Agency for International Development's (USAID's) Regional East Africa Mission in Kenya. She also has worked for USAID as a private-sector advisor in Lilongwe, Malawi. Ms. Benedict has lived, traveled, and worked in Cote d’Ivoire, Ghana, Guinea, Kenya, Malawi, Mozambique, Senegal, Tanzania, and Uganda. Ms. Benedict has a master’s degree in international economics and Chinese studies from the The Johns Hopkins University Nitze School of Advanced International Studies, in Washington, DC.

Ms. Dian Bobola
RTI International (formerly)

Ms. Dian Bobola served as the procurement manager in support of RTIs Indoor Residual Spraying (IRS) Project. She is a seasoned procurement professional, with over 25 years of experience. She has a strong background in purchasing management, negotiations strategies, procurement, commodity management, internal audit, supplier relations, materials management, and negotiation. Ms. Bobola has specialized skills and experience in subcontracts administration and extensive knowledge of applicable regulations that enabled her to lead and support the broad spectrum of activities related to the IRS Project.

Dr. Prosper Chaki
Ifakara Health Institute (IHI)

Dr. Prosper Chaki joined IHI in 2006, and has since been working with community-based urban malaria vector control. Dr. Chaki coordinates and conducts monitoring and evaluation activities for programmatic surveillance of malaria vectors. He investigates the influence of specific environmental and interventional determinants to operational programs, with particular focus on mosquito ecology and larval source management. Dr. Chaki also researches the epidemiological impact of larval control through microbial larvicide application and effective community engagement strategies for sustainable vector control interventions in urban settings. Dr. Chaki studied at the Liverpool School of Tropical Medicine.

Dr. John Chimumbwa
RTI International

Dr. Chimumbwa is a Zambian national with a PhD in malaria epidemiology from the University of Natal. He has more than 20 years of experience working to combat malaria. In addition to malaria and vector control expertise, Dr. Chimumbwa is skilled in training, capacity building, and program monitoring and evaluation. He serves as director of RTIs Indoor Residual Spraying (IRS) Project, funded by the U.S. Agency of International Development through the U.S. President's Malaria Initiative (PMI). Dr. Chimumbwa also acts as the RTI Nairobi Regional Office director.

Dr. Chimumbwa is the overall technical leader of the IRS Project, overseeing all aspects of IRS country operations and programs across 13 PMI countries. He ensures that IRS country program activities are completed on time and meet quality standards. Dr. Chimumbwa also approves work plans and technical standard operating procedures; manages host country and local donor relationships and PMI teams for all country programs; and supervises 13 chiefs of party.

Dr. Awa Marie Coll-Seck
Roll Back Malaria (RBM) Partnership Secretariat

Dr. Awa Coll-Seck was appointed executive director of RBM in 2004. RBM is the global framework for coordinated action against malaria, mobilizing resources to fight malaria, forging consensus among more than 500 partners, and supporting countries to make the money work. RBM is composed of malaria-endemic countries, their bilateral and multilateral development partners, the private sector, nongovernmental and community-based organizations, foundations, and research and academic institutions. The Partnership was launched in 1998 by the World Health Organization, United Nations Children's Fund, United Nations Development Programme, and World Bank.

Dr. Coll-Seck is a professor of infectious diseases and expert in public health and tropical medicine. Before leading RBM, she served as minister of health of the Republic of Senegal, president of the Assembly of the Ministries of Health of the West African Health Organization, director of the Policy, Strategy and

Dr. Maureen Coetzee  
University of Witwatersrand/National Institute for Communicable Diseases  
Dr. Maureen Coetzee is the director of the Malaria Entomology Research Unit, based in the School of Pathology at the University of the Witwatersrand. This unit is affiliated with the National Institute for Communicable Diseases at the National Health Laboratory Services in Johannesburg, South Africa, where her laboratories are based. She is also the holder of a DST/NRF Research Chair in Medical Entomology at the University of the Witwatersrand. She has worked on malaria vector mosquitoes for 35 years and published over 120 papers in peer-reviewed journals and several chapters in books. Her research covers the taxonomy, systematics, genetics, and insecticide resistance of malaria vector mosquitoes in Africa.

Mr. Robert Cunnane  
U.S. Agency for International Development (USAID)  
Mr. Robert Cunnane serves as mission director for USAID/ Tanzania. Mr. Cunnane has worked for USAID for 18 years, with most of his service overseas in East Africa. Prior to his work in Tanzania, Mr. Cunnane served as USAID deputy director in Indonesia from 2005–2008. Other posts include USAID/ Uganda, overseeing health, HIV/AIDS, and education programs; USAID/Tanzania as the supervisory health officer; and USAID/Bangladesh as a health officer. Before joining USAID, Mr. Cunnane was a research associate at The John Hopkins University from 1989 to 1991; he was a country representative for Project Concern Indonesia from 1985 to 1989. Mr. Cunnane received a bachelor of science degree in public health from the University of Massachusetts and a master of public health degree in international health from the University of California, Los Angeles.

Mr. Seydou Doumbia  
RTI International (formerly)  
Mr. Seydou Doumbia served as chief of party of RTI's Indoor Residual Spraying (IRS) Project in Benin, funded by the U.S. Agency for International Development (USAID) through the U.S. President's Malaria Initiative. In addition to overseeing all project activities, he managed relationships with USAID, the Ministry of Health, the National Malaria Control Programme (NMCP), and other local stakeholders. He also provided substantive technical advice on malaria prevention to the NMCP. Mr. Doumbia is a former USAID/West Africa employee, where he served as a senior reproductive health, child survival, and infectious diseases specialist. In that role, he co-managed regional reproductive health, family planning, and child survival interventions in West Africa. Mr. Doumbia has also served as country director for Management Sciences for Health's USAID-funded Supply Chain Management System for HIV/AIDS Project in Côte d'Ivoire and as country director for Population Council's activities in Mali.

Dr. Michael Gebreslasie  
Medical Research Council (MRC)  
Dr. Michael Gebreslasie is a senior scientist in MRC's Malaria Research Programme unit and a member of Group on Earth Observation. Dr. Gebreslasie has several years of experience in geo-information science research and applications, in forest environmental management. His current areas of interest include spatial data quality, spatial and temporal dynamic modeling of environmental, and ecological variables with applications to malaria epidemiology. He holds a degree in geography from the University of Asmara, Eritrea; a master's degree in applied environmental science from the University of KwaZulu-Natal, South Africa; and PhD in geography from University of KwaZulu, Natal.

Dr. John Govere  
World Health Organization (WHO)  
Dr. John Govere has worked on malaria vector control, with a focus on indoor residual spraying (IRS). His experience includes 19 years in Zimbabwe and seven years in South Africa. In 2002, Dr. Govere joined WHO, where he was responsible for supporting malaria vector control in Southern African Development Community countries for six years. In 2006, he began supporting malaria vector control efforts in 17 countries in East and Southern Africa. Dr. Govere holds a PhD in medical entomology and parasitology.

Dr. Emmanuel Hakizimana  
Rwanda Ministry of Health (MOH)  
Dr. Emmanuel Hakizimana, a medical entomologist, was appointed as regional technical assistant entomologist within the Malaria Unit of the Rwanda MOH in 2007. In this role, he coordinates vector control interventions. From 2000 to 2007, he was the head of the Department of Vector Control at the
Programme National Intégré de Lutte contre le Paludisme. At that time, Dr. Hakizimana played a major role in promoting malaria vector control tools in Rwanda, particularly indoor residual spraying for malaria epidemic management and bed nets for target groups with high exposure to malaria.

Dr. Victoria Haynes
RTI International

Dr. Victoria Haynes has served as RTI’s third president since 1999. Her career spans 32 years of technology leadership, management, and new business development. She began her career at Monsanto Company in 1977, holding a number of senior management positions, including director of technology in the company’s plastics division until 1992. Prior to joining RTI, she worked for seven years at Goodrich Corporation as vice president of Research and Development and later as chief technical officer and vice president of the company’s advanced technology group.

Mr. Mark Hoppé
Insecticide Resistance Action Committee’s Public Health (IRAC)

Mr. Mark Hoppé served as the chairperson of the IRAC Public Health Team. IRAC is a specialist technical group of CropLife International, the agrochemical industry’s trade association. Mr. Hoppé is employed by Syngenta Crop Protection in Switzerland, where he manages teams involved in the research and development of insecticides for vector control and other non-agricultural uses. With over 20 years of work in insecticide research and development and technical management, primarily in the public health sector, Mr. Hoppé has extensive experience of insecticide development. This includes discovery of novel insecticides and design and field evaluation of formulated material and final products, within industry and in partnership with academic institutes and nongovernmental organizations.

Mr. Hoppé holds a bachelor of science degree and a master of business administration degree from the University of Bath, in the United Kingdom.

Dr. Yacoubou Imorou Karimou
Benin Programme Nationale Intégré de Lutte contre le Paludisme (PNILP)

Dr. Yacoubou Imorou Karimou is the coordinator of the PNILP in Benin. Dr. Imorou Karimou previously worked for the Ministry of Heath, most notably, on the Stockholm Convention on Persistent Organic Pollutants and the monitoring of workers’ health. He also held positions at the National Hospital Center and University of Cotonou. Dr. Imorou Karimou holds a certificate in occupational health studies and completed supplementary studies in malariology.

Dr. Mohamed Saleh Jiddawi
Zanzibar Ministry of Health and Social Welfare

Dr. Mohamed Saleh Jiddawi is the principal secretary of the Zanzibar MoHSW, where he supports efforts toward malaria control and elimination in Zanzibar.

K, L

Dr. Immo Kleinschmidt
London School of Hygiene and Tropical Medicine (LSHTM)

Dr. Immo Kleinschmidt is a senior lecturer in the Tropical Epidemiology Group at the LSHTM. He holds a PhD in malaria epidemiology from the Swiss Tropical Institute. His main area of work focuses on the design and evaluation of interventions against malaria. Projects he has worked on or is working on include the Equatorial Guinea and Bioko Island Malaria Control projects (since their inception in 2003); Lubombo Spatial Development Initiative in Mozambique; Malaria Decision Support System of the Innovative Vector Control Consortium; and Impact of Insecticide Resistance on the Effectiveness of Malaria Vector Control in Sudan.

Mr. Steven Knowles
AngloGold Ashanti (AGA)

Mr. Steven Knowles is the Malaria Control Programme manager for AGA, one of the largest international gold mining companies. He is an occupational hygienist by profession, specializing in malaria control programs. Mr. Knowles is a proponent of integrated malaria control programs that utilize all available interventions. He has several years of experience in implementing malaria control programs for the private sector, including the sugar industry in South Africa and in Mozambique, Mozal Aluminum Smelter, Illovo Sugar, and Mozambique Tobacco Company.

Mr. Knowles served on the private sector’s component of the unique malaria control project, the Lubombo Spatial Development Initiative, a joint Mozambique, South Africa, and Swaziland project. The Initiative was funded by the Global Fund to Fight AIDS, Tuberculosis, and Malaria and the respective country governments, with the aim of opening up previously malarious areas for tourism and development.

Mr. Tito Kodiaga
RTI International

Mr. Tito Kodiaga serves as RTI’s indoor residual spraying (IRS) regional environmental compliance manager. He manages environmental compliance activities for RTI’s IRS Project, across the U.S. President’s Malaria Initiative’s 15 countries. He was part of the team that prepared the Environmental Monitoring Protocol and Quality Assurance Procedure to monitor the adverse impacts of DDT use in IRS countries.

Mr. Kodiaga was instrumental in the development of key standards and operational procedures for identifying solid waste incinerators in IRS countries. He provided training and capacity building in environmental assessment and monitoring, including health and safety to relevant government ministries in the region. He also provided technical guidance and leadership to Tanzania and Zambia in developing nationwide environmental impact assessments in IRS, an approach since embraced by the U.S. Agency for International Development and replicated in countries scaling up IRS. Prior to joining RTI, Mr. Kodiaga directed a private environmental engineering company whose clients included the World Bank and other international donors.
Ms. Mary Linehan
RTI International

Ms. Mary Linehan serves as the operations director of RTI’s Neglected Tropical Disease Control Program, funded by the U.S. Agency for International Development. She has 19 years of experience in international health, with extensive Asia regional experience, including 12 years’ residence in Nepal, Indonesia, the Philippines, Thailand, and Vietnam. Her background includes managing operations research, malaria surveillance technical assistance activities, and indoor residual spraying (IRS) in Kenya, Tanzania, and Zanzibar, for RTI’s IRS project. She was the study manager of a study comparing the efficacy of Coartem® with the current first-line therapy for uncomplicated malaria and for malaria prevalence studies in two districts of Nepal.

Dr. Jonathan Lines
World Health Organization (WHO)

Dr. Jonathan Lines is a geneticist specializing in insecticide resistance in Anopheles mosquitoes with the London School of Hygiene & Tropical Medicine. He is a senior associate for the Malaria Consortium and often serves as a consultant. He is an active leader in vector control and prevention in WHO’s Global Malaria Programme and a prolific author, with over 85 publications on various research aspects of malaria vector control.

Mr. Charles Llewellyn
U.S. Agency for International Development (USAID)

Mr. Charles Llewellyn served as the U.S. Agency for International Development’s (USAID’s) Health and Population team leader in Tanzania. In this role, he managed the U.S. President’s Malaria Initiative, Family Planning and Reproductive Health, and Maternal and Child Health portfolios. Prior to arriving in Tanzania in 2005, Mr. Llewellyn served as the USAID health officer in Bangladesh, Bolivia, Ghana, and Nepal, and two years as a personal services contractor in USAID/Peru. He also worked in the Global Health and Asia Near East Bureaus in USAID/Washington, for a total of 25 years with USAID.

Mr. Lon E. (Bert) Maggart
RTI International

Mr. Bert Maggart has over 42 years of leadership experience in both small groups and large, complex organizations. He completed his military career as the commanding general, Fort Knox, KY. Since his military retirement, Mr. Maggart has held various leadership positions at RTI. In his current role as executive vice president of International Development, Mr. Maggart is responsible for 68 contracts, 274 international staff, and 1,147 cooperating country nationals in 38 countries that generate US$288 million in revenue annually.

In his previous position as senior vice president of Operations, Mr. Maggart was responsible for coordinating the day-to-day operations of the institute, including facilities; domestic and international security; and regional offices. Mr. Maggart also served as director of the Center for Semiconductor Research, where he was responsible for overseeing research in heterojunction bipolar transistors, plasma technology, wafer bonding, thermoelectrics, and radiation hardening. In addition, Mr. Maggart was the interim senior vice president of Engineering, with oversight of technology programs in fuels, environmental science, chemical analysis, filtration, aerospace, agricultural science, and technology assisted learning.

Dr. Rajendra Maharaj
Medical Research Council (MRC)

Dr. Rajendra Maharaj is director of the MRC’s Malaria Research Programme in South Africa. He has more than 18 years’ experience in malaria entomology, including large-scale malaria control through indoor residual spraying (IRS). He designed, managed, and evaluated IRS projects in more than eight African countries.

Dr. Maharaj has worked extensively with malaria control programs at national and international levels. His focus is on building capacity within local institutions and national programs in developing countries. He also has experience in monitoring and evaluation, especially in using geographic information systems. Dr. Maharaj is currently involved in examining new formulations of insecticides for more effective vector control.

Dr. Fabrizio Molteni
RTI International

Dr. Fabrizio Molteni has worked in Tanzania’s health sector for over 20 years. He currently serves as deputy chief of party and senior technical advisor of RTI’s malaria control programs in Tanzania and Zanzibar, the Malaria Control in Mainland Tanzania and Zanzibar Project and the Tanzania Vector Control Scale-Up Project, both funded by the U.S. Agency for International Development through the U.S. President’s Malaria Initiative.

Dr. Molteni provides technical advice to the Tanzania National Malaria Control Programme (NMCP) and the Zanzibar Malaria Control Programme (ZMCP). Stationed at the NMCP, he is responsible for coordinating NMCP working groups on malaria diagnosis; overseeing artemisinin-based combination therapy (ACT) drug management and ACT communication campaigns;...
developing medium-term strategic plan evaluation surveys in Mainland Tanzania and Zanzibar; providing technical assistance during malaria outbreaks; and coordinating subcontracted malaria research work. Dr. Molteni oversees monitoring and evaluation (M&E) units and develops M&E guidelines specific to the program’s malaria control activities. Previously, he served as resident advisor for three years to the Integrated Malaria Control Program, funded by the Italian Cooperation. He holds an MD and MMed degree, specializing in tropical diseases, from Univerista degli Studi, in Milan, Italy.

**Dr. Bruno Moonen**  
The William J. Clinton Foundation

Dr. Bruno Moonen is the regional malaria manager for the Clinton Health Access Initiative, and is based out of Nairobi, Kenya. From 2000 to 2003, Dr. Moonen worked for Médecins sans Frontières in the Democratic Republic of Congo, Kenya, Somalia, and Southern Sudan. After obtaining a master of science degree in epidemiology, he consulted for Epicentre (nutritional surveys and program evaluations), United Nations Children’s Fund (vaccination campaigns), and Roll Back Malaria. He also served as a malaria technical adviser with MERLIN for the Global Fund to Fight AIDS, Tuberculosis, and Malaria (GFATM) in Sudan.

Over the past three years, he has been involved in writing GFATM malaria proposals for Chad, Somalia, and most recently the Comoros. He currently is managing the Southern Africa Malaria Elimination Support Team, a collaboration between The William J. Clinton Foundation and the Global Health Group of the University of San Francisco, which provides technical assistance to the national malaria control programs in Botswana, Namibia, South Africa, and Swaziland. He also was responsible for coordination of the feasibility assessment for malaria elimination in Zanzibar.

**Hon. Sultan Mohamed Mugheiriy**  
Zanzibar Ministry of Health and Social Welfare

Hon. Sultan Mohamed Mugheiriy was appointed Zanzibar’s minister of Health and Social Welfare in 2005. Prior to his current role, Minister Mugheiriy was the deputy minister of Health and Social Welfare (2004–2005) and the deputy minister of Education, Culture, and Sports (2000–2004). He spent six years as the program manager for the Zanzibar Malaria Control Programme (ZMCP), and served as assistant chief parasitologist and entomologist for ZMCP from 1984 to 1991. He received a master’s degree in public health from the University of North Carolina, Chapel Hill, and a certificate in law from the University of San Francisco, which provides technical assistance to various national and international institutions to develop their capacity and conduct technical support supervision on vector-borne disease control interventions in Uganda.

**Dr. Shiva Murugasampillay**  
World Health Organization (WHO)

Dr. Shiva Murugasampillay has served as a WHO medical officer in the Vector Control and Prevention unit of WHO’s Global Malaria Program in Geneva since 2005. From 1997 to 2005, he served as the WHO team leader for the WHO Inter-country Southern Africa Malaria Control Program in Harare for 10 countries in southern Africa. Prior to working at WHO, Dr. Murugasampillay was the chief epidemiologist and director of the Department of Epidemiology and Disease Control for Zimbabwe's Ministry of Health, from 1989 to 1997. He is registered as a recognized public health medicine specialist in the United Kingdom and Zimbabwe, specializing in communicable and tropical disease control program development at both the country and international levels.

**Mrs. Rodaly Muthoni**  
RTI International

Mrs. Rodaly Muthoni provides technical assistance in entomological monitoring and surveillance and strategic advice to national governments on the rational choice of insecticides for use in indoor residual spraying (IRS). Mrs. Muthoni has extensive experience in the use of insecticides for IRS, having worked as the vector control supervisor and environmental health manager in Kenya’s refugee camps. She holds a master of science in applied medical entomology.

**N, O, P**

**Hon. Shamsu Vuai Nahodha**  
Revolutionary Government of Zanzibar

Now in his second term, Hon. Shamsu Vuai Nahodha has served as chief minister in Zanzibar for 10 years. He holds a bachelor of arts degree in education from Dar es Salaam University and completed post-graduate studies in international relations.

**Dr. Michael Okia**  
Uganda National Malaria Control Programme (NMCP)

Dr. Michael Okia is a senior entomologist with the Uganda NMCP, which is part of the Ministry of Health. He has more than 30 years of experience in vector-borne disease control and research, with a special focus on malaria and trypanosomiasis vector control, including planning; implementation; and monitoring their control in Uganda. Dr. Okia also has worked with various national and international institutions to develop their capacity and conduct technical support supervision on vector-borne disease control interventions in Uganda.

**Dr. Sarah Panvec-Moore**  
Liverpool School of Tropical Medicine (LSTM)

Dr. Sarah Panvec-Moore is a lecturer in the disease control and vector biology unit of LSTM. She is seconded on a full-time basis to the Ifakara Health Institute in Tanzania, to conduct research, training, and capacity building. She is a vector ecologist, specializing in the chemical ecology and control of Anopheles mosquitoes. She has 10 years’ experience in the evaluation of tools to kill and repel mosquitoes, especially those that feed and rest outdoors. Dr. Panvec-Moore works on devising methods to attract mosquitoes, to monitor their numbers for evaluation of control programs, and to trap and kill mosquitoes, as well as designs methods of repelling mosquitoes to protect individuals, households, and communities. All of these projects involve rigorous field evaluation of methods to reduce mosquito-borne disease transmission and a strong social science component to ensure that technologies developed are compatible with the needs and wishes of the communities that use them. Dr. Panvec-Moore has worked in South America, China, and Tanzania.
Dr. Rodolphe Donatien Rakotobe  
**Madagascar Programme Nationale de Lutte contre le Paludisme (PNLP)**

Dr. Rodolphe Donatien Rakotobe has served as the national coordinator of indoor residual spraying (IRS) in Madagascar since 2008, as part of the PNLP. After obtaining his doctorate of medicine in 1984, he practiced for 10 years in a medical center, providing clinical services to the local population. He then served as a medical inspector and chief of service in a health district, which is the hub of the Ministry of Health in Madagascar. Since 2001, he has served as chief of medical service (technical assistant to the regional health director) and chief of service for the Mobile Health Team, all while acting as regional manager for the PNLP and inter-regional coordinator of IRS. Dr. Rakotobe received his diploma of special studies in public health in 2000.

Dr. Mahdi Mohamed Ramsan  
**RTI International**

Dr. Mahdi Mohamed Ramsan, MD, PhD, currently serves as chief of party of RTI’s malaria control programs in Tanzania and Zanzibar, the Malaria Control in Mainland Tanzania and Zanzibar Project and the Tanzania Vector Control Scale-Up Project, both funded by the U.S. Agency for International Development through the U.S. President’s Malaria Initiative.

Over the past several years, he has provided management oversight and technical leadership for two indoor residual spraying (IRS) rounds in Tanzania's Muleba District, reaching 36,000 households in each round. In addition, three spray rounds have been conducted in Zanzibar, reaching 200,000 households in each round and resulting in malaria rates that have dropped from 20% to nearly zero since 2005. The malaria control project in Zanzibar has been hailed as a model, with many of the lessons learned now being applied in other IRS countries.

Prior to joining RTI, Dr. Ramsan served as a technical advisor to the Zanzibar Malaria Control Programme. He has eight years of experience conducting field research, and has worked with the World Health Organization on projects targeting malaria, soil-transmitted helminthiasis, and schistosomiasis in Afghanistan, Ethiopia, India, Nepal, and Zanzibar.

Dr. Datius Rweyemamu  
**University of Dar es Salaam**

Dr. Datius Rweyemamu serves as a senior technical consultant for RTI International on the Malaria Control in Mainland Tanzania and Zanzibar Project, funded by the U.S. Agency for International Development through the U.S. President’s Malaria Initiative. Dr. Rweyemamu is a medical sociology consultant, with practical field, academic, and research expertise, and an enriched capacity to work within and with governments, nongovernmental organizations, and international and national research and development institutions. He has developed several strategic plans for both national and international organizations. He also serves a lecturer at the University of Dar es Salaam, where he teaches sociology courses and social science research.

Dr. Rweyemamu has published on adolescent sexuality and communication, and is currently involved in a study on male involvement in gender and health issues in Tanzania. He holds a PhD in sociology from the University of Dar es Salaam.

Dr. Josephat Shililu  
**RTI International**

Dr. Josephat Shililu serves as chief of party for RTI’s Kenya Indoor Residual Spraying Project. He has extensive experience in capacity building, research, and project management and operations research. Dr. Shililu previously worked as a resident advisor for vector ecology and control for National Malaria Control Programme in Eritrea under the U.S. Agency for International Development-funded Environmental Health Program.

Dr. Shililu has served as a lecturer in the Department of Zoology at Jomo Kenyatta University of Agriculture and Technology for over 18 years. He has conducted research on malaria vectors at the International Center of Insect Physiology and Ecology, Nairobi, and has 33 publications to his credit in refereed journals. He has mentored several doctoral and master’s degree candidates. Dr. Shililu holds a PhD in entomology from Kenyatta University, Kenya.

Dr. Robert Ssengonzi  
**RTI International**

Dr. Robert Ssengonzi serves as RTI’s Africa Regional Integrated Health Programs director and is a senior research health specialist, medical demographer, and certified public accountant. Dr. Ssengonzi has over 18 years of experience in project management, training, monitoring and evaluation, and research of HIV/AIDS, malaria, and reproductive health programs.

He is intimately familiar with public health programming in sub-Saharan Africa. Dr. Ssengonzi has played a key role in the planning and start up of large-scale indoor residual spraying activities in Uganda. Currently, he provides project management and technical oversight on several RTI projects in Uganda funded by the U.S. Agency for International Development, U.S. Centers for Disease Control and Prevention, and the U.S. Department of Defense.

Dr. Jean Baptiste Tapko  
**World Health Organization (WHO)**

Dr. Jean Baptiste Tapko is the WHO representative for Tanzania, regional adviser for blood safety for the WHO African Region, and chairman of the Reclassification Committee at the WHO-Africa Regional Office. In addition to his specialization in hematology, he also holds post-graduate degrees in virology, parasitology, immunology, and molecular biology. Before joining WHO, Dr. Tapko was a senior lecturer of hematology at the Faculty of Medicine/Yaoundé Cameroon and a lecturer at the Faculty of Medicine in Marseille, France. His research and publications are in the field of HIV (epidemiology and treatment), hematology, and blood transfusion safety.
Dr. Klenon Traoré
Mali Programme National de Lutte contre le Paludisme (PNLP)
Dr. Klenon Traoré is the Mali PNLP director and works closely with the U.S. Agency of International Development, U.S. President’s Malaria Initiative, and RTI International to implement indoor residual spraying in Mali.

Dr. Oladapo Walker
World Health Organization-Africa Regional Office (WHO-AFRO)
Dr. Oladapo Walker was appointed as the WHO-AFRO inter-country team coordinator for east and southern Africa in 2008. Dr. Walker spent the past 15 years at WHO, in roles such as advisor for operational research in the Regional Programme for Malaria Control, WHO representative to Uganda, and program manager of technical cooperation with countries in the Regional Directors Cabinet. A WHO-trained epidemiologist, Dr. Walker also is a professor of pharmacology and therapeutics and a public health clinical pharmacologist (malariology).

Dr. Jacob Williams
RTI International
Dr. Jacob Williams serves as director of the Integrated Vector Management Project at RTI. He is a public health expert with over 20 years of experience in vector-borne disease control and related health systems strengthening. Dr. Williams has supported regional and country programs across Africa, Asia, the Middle East, the Pacific and the Americas on policy, capacity building, and program implementation. He served 12 years with the World Health Organization (WHO), where he worked with the Global Malaria Program, the Joint WHO/Food Administration Organization/United Nations Environment Programme/United Nations Centre for Human Settlements Panel of Experts on Environmental Management for Vector Control, and the WHO Center for Environmental Management. Dr. Williams was a lead WHO staff member in the Stockholm Convention negotiations on the use of DDT for malaria vector control. He also served as a lecturer in zoology and ecology with the University of Ghana.

Dr. Robert Wirtz
U.S. Centers for Disease Control and Prevention (CDC)
Dr. Robert Wirtz currently serves as chief of the Entomology Branch in the CDC’s Parasitic Diseases Division. In this role, he directs branch activities to reduce the threat of arthropod-borne diseases to humans, with a focus on vector control in malaria, lymphatic filariasis, and Chagas disease; insecticide resistance; analysis of insecticides and antimalarial drugs; and implementation and evaluation of insecticide-treated bed net and indoor residual spraying programs. He also coordinates technical assistance and oversight for vector control in 15 African and seven Latin American countries, in support of the U.S. President’s Malaria Initiative and Amazon Malaria Initiative, respectively. Prior to his role at the CDC, he was the assistant chief of the Department of Entomology at Walter Reed Army Institute of Research, in Washington, DC.

Admiral Timothy Ziemer
U.S. Agency for International Development/U.S. President’s Malaria Initiative (PMI)
Admiral Timothy Ziemer was appointed in June 2006 to lead PMI, a historic US$1.2 billion, 5-year initiative to control malaria in Africa. Announced by President George W. Bush on June 30, 2005, PMI is a collaborative U.S. Government effort led by the U.S. Agency for International Development (USAID) in conjunction with the U.S. Department of Health and Human Services through the U.S. Centers for Disease Control and Prevention, the U.S. Department of State, the White House, and other agencies. PMI aims to reduce malaria-related deaths by 50% in 15 countries, by achieving 85% coverage of proven preventive and curative malaria interventions. As coordinator, Admiral Ziemer reports to the USAID administrator, with direct authority over both the PMI and USAID malaria programs.

Admiral Ziemer previously served as executive director of World Relief, which provides disaster response, community development, maternal and child health, HIV/AIDS, agricultural assistance, and micro-credit programs in over 30 countries. World Relief is operational in the United States, resettling refugees and providing immigration services through 24 affiliate offices across the country.

Dr. Morteza Zaim
World Health Organization (WHO)
Dr. Morteza Zaim is the team leader of the WHO Unit of Vector Ecology and Management and the scientist in charge of the WHO Pesticide Evaluation Scheme (WHOPES). His field studies and research have mainly focused on mosquito ecology and management, especially relating to malaria vectors. He served as the member of the WHO Panel of Experts on Vector Biology and Control (1986–1996). He also served as professor of Medical Entomology and Vector Control in the School of Public Health in Tehran, 1979–1996. He received a master of science degree and PhD in medical entomology from Ohio State University and Michigan State University, respectively.
Pan African Malaria Vector Control Conference
25–29 October, 2009
Zamani Zanzibar Kempinski Hotel
Zanzibar, Tanzania

Sunday 25 October 2009
SESSION 1: Welcome, Registration, and Conference Opening
Chair: Mr. Napoleon Graham, RTI International Master of Ceremonies
Location: ZanziBar (Main Reception Area)
Afternoon Arrival, Registration, and Logistics for Presenters
Ms. Vera John, Ms. Eve Van Devender
Ms. Maritoni Enraca Kostic: Finances; Mrs. Heidi Huber-Early: Travel arrangements
Ms. Claire Ng’aru, Mr. Chris Davis: Media contacts
Location: Zamani Conference Room
17:00 Opening Ceremony
Dr. Oladapo Walker, World Health Organization-Africa Regional Office (WHO-AFRO)
Dr. James Banda representing Dr. Awa Coll-Seck, Roll Back Malaria (RBM) Partnership Secretariat
Admiral Timothy Ziemer, U.S. President’s Malaria Initiative (PMI)
Dr. Victoria Haynes, RTI
Hon. Sultan Mohamed Mugheiry, Zanzibar Ministry of Health and Social Welfare (MoHSW)
Hon. Shamsu Vuai Nahodha, Revolutionary Government of Zanzibar, representing President Karume of Zanzibar and the Revolutionary Government of Zanzibar
Location: Zamani Beach Club
18:00 Welcome Buffet Reception
* Please meet in the main lobby after the Opening Ceremony to transfer to the Zamani Beach Club. Traditional Zanzibar music provided by the Tamarine Band.

Monday 26 October 2009
SESSION 2: Malaria Epidemiology and the Role of IRS
Chair: Dr. Mohamed Saleh Jiddawi, Zanzibar MoHSW
Location: Zamani Conference Room
08:00 Review Agenda and Objectives for the Conference
Ms. Rosemary Mwakitwange, Master of Ceremonies
*Press will be on site through lunch time.
08:20 The Epidemiological Context of Vector Control in Africa
Presenter: Dr. Jo Lines, WHO
08:40 Overview of Indoor Residual Spraying in Southern Africa
Presenter: Dr. Rajendra Maharaj, Medical Research Council (MRC)
09:00 Indoor Residual Spraying in Different Epidemiological Settings
Presenter: Dr. Birkinesh Ameneshewa, WHO-AFRO
09:20 Discussion, Q&A, Lessons Learned, and Recommendations
Presenter: Session Chair, All
## Location:
Zamani Terrace

<table>
<thead>
<tr>
<th>Time</th>
<th>Activity</th>
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<tbody>
<tr>
<td>09:40</td>
<td>Group Picture</td>
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<tr>
<td>10:00</td>
<td>Morning Coffee and Tea Break</td>
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<td>*Press will be able to talk to speakers during the break time.</td>
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### SESSION 3: Resource Mobilization for Malaria Vector Control Programs
Chair: Dr. Awa Coll-Seck, RBM Partnership Secretariat

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<tr>
<th>Time</th>
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<tbody>
<tr>
<td>10:20</td>
<td>Partnerships for Vector Control: Learning from the Past, Looking Forward</td>
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<tr>
<td></td>
<td>Presenter: Dr. James Banda, RBM Partnership Secretariat</td>
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<td>Presenter: Admiral Timothy Ziemer, PMI</td>
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<td>11:00</td>
<td>Resources for Evolution &amp; Innovation</td>
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<td>Presenter: Dr. Kathryn Aultman, The Bill &amp; Melinda Gates Foundation</td>
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<td>11:20</td>
<td>Overview of CHAI Malaria Support</td>
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<td>Presenter: Dr. Bruno Moonen, The William J. Clinton Foundation</td>
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<td>11:40</td>
<td>Malaria Control as a Best Practice: Corporate Social Responsibility Program—AngloGold Ashanti Obuasi Limited</td>
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<td>Presenter: Mr. Steven Knowles, AngloGold Ashanti</td>
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<td>12:00</td>
<td>Discussion, Q&amp;A, Lessons Learned, and Recommendations</td>
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<td>Presenter: Session Chair, All</td>
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<td>*Press will be able to ask questions as part of this session.</td>
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<tr>
<th>Location:</th>
<th>Cloves Restaurant</th>
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<tbody>
<tr>
<td>12:20</td>
<td>Lunch</td>
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<td>*Press will return to Stone Town after lunch.</td>
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### SESSION 4: The Role of Vector Control in Malaria Prevention
Chair: Dr. Shiva Murugasampillay, WHO

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<th>Time</th>
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<tbody>
<tr>
<td>14:00</td>
<td>Vector Control Interventions and Their Effectiveness in Malaria Prevention</td>
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<td>Presenter: Dr. Michael Macdonald, PMI</td>
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<tr>
<td>14:20</td>
<td>IRS in Africa: A Brief Discussion</td>
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<td>Presenter: Dr. John Chimumbwa, RTI</td>
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<tr>
<td>14:40</td>
<td>Achievements in Malaria Vector Control: Zanzibar Experience</td>
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<td>Presenter: Dr. Abdullah Suleiman Ali, Zanzibar Malaria Control Programme (ZMCP)</td>
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<tr>
<td>15:00</td>
<td>Discussion, Q&amp;A, Lessons Learned, and Recommendations</td>
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<td>Presenter: Session Chair, All</td>
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<td>15:20</td>
<td>Afternoon Coffee and Tea Break</td>
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### Location: Kiwengwa Conference Room
15:40 Country Poster Session

Presenters: National Malaria Control Programme (NMCP) Representatives and RTI IRS Chiefs of Party. An informal session to view the country posters and ask NMCPs about their specific country programs.
**Tuesday 27 October 2009**

**SESSION 5: Insecticide Selection and Management of Resistance in IRS**  
**Chair:** Dr. Robert Wirtz, U.S. Centers for Disease Control and Prevention (CDC)  
**Location:** Zamani Conference Room

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<tr>
<th>Time</th>
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<tr>
<td>08:00</td>
<td>Management of Pesticides in Vector Control</td>
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<td>Presenter: Dr. Morteza Zaim, WHO</td>
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<tr>
<td>08:20</td>
<td>Principles of Pesticide Selection</td>
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<td></td>
<td>Presenter: Mrs. Rodaly Muthoni, RTI</td>
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<tr>
<td>08:40</td>
<td>Tracking Insecticide Resistance in Africa</td>
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<td>Presenter: Dr. Maureen Coetzee, University of the Witwatersrand/National Institute for Communicable Diseases</td>
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<tr>
<td>09:00</td>
<td>Integrated Resistance Management in the Control of Disease-Transmitting Mosquitoes</td>
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<td>Presenter: Mr. Mark Hoppé, Insecticide Resistance Action Committee</td>
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<td>09:20</td>
<td>Discussion, Q&amp;A, Lessons Learned, and Recommendations</td>
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<td>Presenter: Session Chair, All</td>
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<tr>
<td>09:40</td>
<td>Morning Coffee and Tea Break</td>
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**SESSION 6: Safe Use of Insecticides**  
**Chair:** Dr. Michael Macdonald, USAID/PMI  
**Location:** Zamani Conference Room

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<th>Time</th>
<th>Session</th>
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<tr>
<td>10:00</td>
<td>Emerging Solutions to Waste Management and Disposal in the PMI IRS Program</td>
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<td>Presenter: Mr. Tito Kodiaga, RTI</td>
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<td>10:20</td>
<td>Panel: Country Experiences in Waste Disposal</td>
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<td>Presenters:</td>
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<td></td>
<td>• Senegal Country Experiences in Waste Disposal due to Pyrethroid Use in IRS—Dr. Abdoulaye Diop, Senegal Programme Nationale de Lutte contre le Paludisme (PNLP);</td>
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<td>• IRS in Benin: Experience in Four Epidemic-Prone Districts—Dr. Yacoubou Imorou Karimou, Benin Programme Nationale Integre de Lutte contre le Paludisme;</td>
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<td></td>
<td>• Waste Disposal in Indoor Residual Spraying: Individual and Environmental Protection—Dr. Shiva Murugasampillay, WHO</td>
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<td>11:00</td>
<td>Discussion, Q&amp;A, Lessons Learned, and Recommendations</td>
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<td>Presenter: Session Chair, All</td>
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<td>11:30</td>
<td>Lunch</td>
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**SESSION 7: IRS Implementation**  
**Chair:** Ms. Julie Wallace, PMI  
**Location:** Zamani Conference Room

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<th>Time</th>
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<tr>
<td>13:00</td>
<td>Critical Steps in Implementing IRS Programs</td>
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<td>Presenter: Dr. Robert Ssengonzi, RTI</td>
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<td>13:20</td>
<td>Collaboration in IRS Scale-Up: Recent Experience in Ghana</td>
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<td>Presenter: Mrs. Aba Baffoe-Wilmot, Ghana NMCP</td>
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<td>13:40</td>
<td>Indoor Residual Spraying in Madagascar: Experiences in Central Highlands and Fringes</td>
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<td>Presenter: Dr. Rodolphe Donatien Rakotobe, Madagascar PNLP</td>
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<td>14:00</td>
<td>Preliminary Report on Indoor Residual Spraying in the Seven World Bank Malaria Control Booster Projects in Nigeria</td>
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<td>Presenter: Dr. Chioma Amajoh, Nigeria NMCP</td>
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<td>14:20</td>
<td>Discussion, Q&amp;A, Lessons Learned, and Recommendations</td>
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<td>Presenter: Session Chair, All</td>
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<td>14:40</td>
<td>Afternoon Coffee and Tea Break</td>
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SESSION 8: IRS Commodity Supply and Management
Chair: Dr. Jacob Williams, RTI

Location: Zamani Conference Room

15:00  Nuts and Bolts of IRS Supply Chain Management
       Presenter: Ms. Dian Bobola, RTI

15:20  Developing a Seamless Partnership in Planning, Procuring, and Providing IRS Products
       Presenter: Ms. Jean Benedict, Crown Agents

15:40  Discussion, Q&A, Lessons Learned and Recommendations
       Presenter: Session Chair, All

Wednesday 28 October 2009

SESSION 9: IRS Monitoring and Evaluation—Measuring Impact
Chair: Dr. Peter McElroy, CDC-Tanzania

Location: Zamani Conference Room

08:00  IRS Monitoring
       Presenter: Dr. John Chimumbwa, RTI

08:20  Combining Indoor Residual Spraying and Insecticide-Treated Net Interventions
       Presenter: Dr. Immo Kleinschmidt, London School of Hygiene and Tropical Medicine (LSHTM)

08:40  Added Value of Combining IRS and LLINs: Results from Experimental Hut Studies
       Presenter: Dr. Sarah Panvec-Moore, Ifakara Health Institute (IHI)/LSHTM

09:00  Rwanda Country Experience in Using IRS and ITNs
       Presenter: Dr. Emmanuel Hakizimana, Rwanda Ministry of Health

09:20  Malaria Elimination in Zanzibar: A Feasibility Assessment
       Presenter: Dr. Bruno Moonen, The William J. Clinton Foundation

09:40  IRS Monitoring and Evaluation—Experience from Kagera Region in Northwest Tanzania: Beyond the Process and Toward the Impact
       Presenter: Dr. Fabrizio Molteni, RTI

10:00  IRS Monitoring and Evaluation: Demonstrating Impacts of the U.S. President’s Malaria Initiative’s Indoor Residual Spraying Over the Last 5 Years
       Presenter: Dr. Robert Wirtz, CDC

10:20  Discussion, Q&A, Lessons Learned, and Recommendations
       Presenter: Session Chair, All

Location: Zamani Terrace

10:40 am  Morning Coffee and Tea Break

SESSION 10: Capacity Building and Training for IRS
Chair: Dr. Jacob Williams, RTI

Location: Zamani Conference Room

11:00  Need for Capacity Development
       Presenter: Dr. Rajendra Maharaj, MRC

11:20  Best Practices in Training Spray Operators
       Presenter: Dr. John Chimumbwa, RTI

11:40  Discussion, Q&A, Lessons Learned, and Recommendations
       Presenter: Session Chair, All

Location: Cloves Restaurant

12:00  Lunch
### SESSION 11: IRS Communication Strategy
**Chair:** Ms. Betsy Brown, RTI

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<th>Time</th>
<th>Presentation Topic</th>
<th>Presenter/Institution</th>
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<tr>
<td>13:20</td>
<td>Approaches for Community Mobilization for IRS</td>
<td>Dr. Josephat Shililu, RTI</td>
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<td>13:40</td>
<td>IRS in Benin: Experience in IRS Communication</td>
<td>Mr. Seydou Doumbia, RTI</td>
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<td>14:00</td>
<td>Zanzibar Experience: Development of National Malaria Communication Strategy</td>
<td>Dr. Datius Rwiyemam, RTI</td>
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<td>14:20</td>
<td>IRS Communication Strategy: Mali Experience</td>
<td>Dr. Klenon Traoré, Mali PNLP</td>
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<td>14:40</td>
<td>IRS Communication Strategy: Uganda Country Experience</td>
<td>Dr. Michael Okia, Uganda NMCP</td>
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<td>14:40</td>
<td><strong>Discussion, Q&amp;A, Lessons Learned, and Recommendations</strong></td>
<td>Session Chair, All</td>
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**Location:** Zamani Conference Room

**15:20**  
**Afternoon Coffee and Tea Break**

### SESSION 12: New Technologies and Future Directions
**Chair:** Dr. John Chimumbwa, RTI

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<th>Time</th>
<th>Presentation Topic</th>
<th>Presenter/Institution</th>
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<tr>
<td>15:40</td>
<td>New Technologies</td>
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<td>• Application of GIS for Malaria Control in Africa—Dr. Michael Gebreslasie, MRC</td>
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<td>• Zanzibar Malaria Early Epidemic Detection System—Ms. Claudia Anderegg, RTI</td>
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<td>• Innovative Payment Schemes For Temporary Workers: The Tanzania Experience—Dr.</td>
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<td>Mahdi Mohamed Ramsan, RTI</td>
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<td>• New Products for Prevention—Dr. Rajendra Maharaj, MRC</td>
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<td>16:30</td>
<td>New Directions</td>
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<td>• Exit Plan and Sustainability: Economic and Ecological—Mr. Charles Llewellyn, USAID/ Tanzania</td>
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<td>• Real-time Collection and Reporting of Mosquito Larvae and Adult Abundance—Dr.</td>
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<td>Prosper Chaki, IHI</td>
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<td>• Malaria Control and Elimination on Cross-Border Collaboration—Dr. John Govere, WHO</td>
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<td>• Range of RTI International’s Vector Control Activities—Dr. Jacob Williams and Ms. Mary Linehan, RTI</td>
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<td>17:00</td>
<td><strong>Discussion, Q&amp;A, Lessons Learned, and Recommendations</strong></td>
<td>Session Chair, All</td>
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<td>17:20</td>
<td><em>Roundtable discussion of key outcomes and recommendations with key speakers</em></td>
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**Location:** Zamani Conference Room

**17:30**  
**Summary of Key Outcomes and Recommendations**  
Presenter: Dr. Clifford Mutero, Meeting Rappatuer

**17:40**  
**Closing Ceremony**  
Presenters:  
• RTI—Mr. Bert Maggart  
• WHO-Tanzania—Dr. Jean-Baptiste Tapko  
• PMI/USAID Tanzania—Robert Cunnane  
• Vote of Thanks—Dr. Mohamed Saleh Jiddawi, Zanzibar MoHSW
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<tr>
<td>8:00</td>
<td>Optional Visit to Zanzibar IRS Field Sites</td>
<td>Field trip leaders: <em>Dr. Abdullah Suleiman Ali, ZMCP; Dr. Mahdi Mohamed Ramsan, RTI</em>&lt;br&gt;Participants will be able to sign up to visit Option 1 or Option 2 listed below&lt;br&gt;&lt;br&gt;<strong>Option 1 (20 people)</strong>&lt;br&gt;- Kombeni Primary Health Care Unit, MEEDS&lt;br&gt;- IRS warehouse&lt;br&gt;- ZMCP entomology laboratory&lt;br&gt;- Group discussion and wrap up&lt;br&gt;&lt;br&gt;<strong>Option 2 (20 people)</strong>&lt;br&gt;- ZMCP entomology laboratory&lt;br&gt;- Kombeni Primary Health Care Unit, MEEDS&lt;br&gt;- IRS warehouse&lt;br&gt;- Group discussion and wrap up</td>
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<tr>
<td>11:00</td>
<td>Open Time for Lunches and Shopping in Stone Town</td>
<td><em>Meet back at the vans for transport to the airport. Please check out of hotel ahead of time and bring luggage in vans.</em></td>
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