Improving Vector Control and Surveillance for Malaria and Other Vector-Borne Diseases

More people die from malaria today than 40 years ago.[1] Each year, malaria infects from 300 to 500 million people and causes up to 2.5 million deaths, mostly in young children in sub-Saharan Africa.[2] Malaria morbidity and mortality are both rising in Africa,[3] where they exact a large economic toll that contributes to the continued impoverishment and slow growth of many countries.[4]

The U.S. Agency for International Development (USAID) is working to reduce the burden of this disease by helping countries develop the capacity to prevent and treat malaria more effectively. USAID works closely with the Roll Back Malaria partnership[5] at the global, regional, and country levels. USAID also provides leadership for other global partnerships, invests in new technologies such as malaria vaccine development, and provides technical assistance to help countries increase access to technologies for malaria prevention and effective treatment.[6]

1/ Guerin PJ, P Olliaro, F Nosten, P Druilhe, R Laxminarayan, F Binka, WL Kilama, N Ford, NJ White. Malaria: current status of control, diagnosis, treatment, and a proposed agenda for research and development. Lancet Infect Dis 2002, 2(9):564-73.

2/ WHO/UNICEF. 2003. The Africa Malaria Report 2003. WHO/CDS/MAL/2003.

3/ Snow W, J Trape, K Marsh. The past, present and future of childhood malaria mortality in Africa. Trends in Parasitology, 2001-17, 593-97.

4/ Sachs J, P Malaney. The economic and social burden of malaria. Nature 2002; 415(6872):680-85.

5/ See *http://rbm.who.int/cgi-bin/rbm/rbmportal/custom* for more on the RBM Partnership.

6/ See *www.usaid.gov/our_work/global_health/id/malaria* for more on USAID malaria programs.

USAID uses a wide variety of central and bilateral projects, cooperative agreements, and interagency agreements to implement its malaria program. Within this broad context, USAID has tasked the Environmental Health Project (EHP) with two specific roles:

1. Develop, evaluate, and promote the effective use of vector control methods, in the context of Integrated Vector Management.
2. Support improvements in surveillance, including the collection and use of case reports, environmental and demographic data, and other information to better understand disease distribution patterns and strengthen disease control programs.

This paper summarizes lessons learned through work on these topics from 1999 to 2004. Over this period, EHP has provided assistance to control programs for malaria, visceral leishmaniasis (*kala-azar*), Japanese encephalitis, and dengue fever in Eritrea, Ghana, Kenya, Malawi, Mozambique, Nepal, Uganda, Tanzania, and Zambia and in regional initiatives in Africa, Latin America, and South Asia.

I. Integrated Vector Management

A. Vector Control Options for Malaria

There are four methods for controlling the anopheline mosquitoes that transmit malaria. The two principal methods are

insecticide-treated nets and other materials (ITNs) and *indoor spraying* with a residual insecticide (IRS). These methods kill adult female mosquitoes that alight on the treated surfaces. ITNs and IRS have been proven effective in a variety of environmental and epidemiological settings.

The third method is *environmental management*, which reduces or eliminates the small water pools into which female anopheline mosquitoes lay their eggs. The fourth is *larval control*, which employs chemical or biological pesticides applied to the surface of aquatic habitats to kill mosquito larvae, or synthetic insect-growth regulators to prevent larvae from developing into adults. These methods suppress the overall size of the mosquito population. Although such methods have occasionally been effective over large rural areas, today they are most appropriate in urban and arid areas, where there are relatively few suitable habitats for anopheline larvae.

There are also many personal protection measures that individuals and households use. Smoke from biomass fires, insect coils, repellants, window screens, and insecticide sprays reduce exposure to infective bites for the people who use them. Insecticide-treated nets provide personal protection for the individuals who sleep under them, even when the number of nets being used in the area is too low to produce a significant impact on the mosquito population.

B. Lessons Learned

√ **Lesson:** Integrated Vector Management is now the accepted technical framework for vector control programs for malaria and other vector-borne diseases.

The World Health Organization (WHO) will soon issue a Global Strategic Framework for Integrated Vector Management (IVM). The framework has been developed in consultation with a broad range of experts, including participants from EHP. The document will be disseminated widely and will serve as an essential part of WHO's guidance for planning and implementing vector control programs.

In the framework, Integrated Vector Management is defined as "a process for managing vector populations to reduce or interrupt transmission of disease.

"Characteristics of IVM include:

- Methods based on knowledge of factors influencing local vector biology, disease transmission and morbidity
- Use of a range of interventions, often in combination and synergistically
- Collaboration within the health sector and with other public and private sectors that impact on vectors
- Engagement with local communities and other stakeholders
- A public health regulatory and legistlative framework."[7]

In an IVM program, several vector control methods may be used for the same disease, and a particular method may be used to control more than one disease simultaneously. For example, in Nepal during the malaria eradication program from the 1950s to the 1970s, IRS used for malaria also helped control *kala-azar,* which is transmitted by sand flies. The incidence of *kala-azar* accelerated after the malaria program was decentralized and DDT use was discontinued.[8]

There are three motivations for developing and promoting IVM. First, many countries include diverse physical environments in which several of the available vector control methods may be effective. For example, **Kenya** has highlands, coastal areas, cities, and savannah. ITNs and IRS are effective in all of these settings. Environmental management and larval control are effective in cities and potentially in the highlands as well. In a well-run IVM program, program staff at the central and district levels are able to plan, implement, and monitor several types of vector control operations simultaneously,

7/ World Health Organization. Global Strategic Framework for Integrated Vector Management. 2004. WHO/CDS/CPE/PVC/2004.10.

8/ Houston, R., Evolution of a Pilot Strategy to Improve the Management of Kala-azar and Malaria in Nepal. EHP Activity Report 131.

so they can use each method where and when it is most likely to be effective.

A second reason for adopting IVM is to reduce the use of chemical pesticides. Many countries want to gradually reduce their use of insecticides either as a matter of general environmental policy or to contain the cost of vector control programs. IVM can help achieve this goal by exploring and expanding the use of non-chemical methods.

Finally, since in most developing countries only a very small cadre of staff has expertise in medical entomology and vector control, it may be more efficient for them to work as part of a single unit dedicated to vector and pest control (i.e., IVM) that provides support to several disease control programs, rather than assigning them separately to each of the disease control programs or departments. This can create greater opportunities for leveraging experience, sharing expertise, and coordinating control efforts for various disease vectors. In this context, an IVM program might be manifested in the form of vector biology and control units at the central and district levels.

Much of the leadership for adopting IVM as a formal framework has come from the WHO regional offices for Africa (AFRO) and the Eastern Mediterranean (EMRO), and from WHO headquarters' involvement in negotiations of the Stockholm Convention on Persistent Organic Pesticides.[9] USAID and EHP have provided consistent and substantial support for this initiative through involvement in the IVM Partnership for Africa, help to develop a Vector Control Needs Assessment protocol, financial support for meetings of the African Network for Vector Resistance Monitoring, participation on the steering committee of a WHO-UNEP project to support the development of alternative vector control strategies in six African countries that currently use DDT, participation in the WHO Informal Consultation on a Global Strategic Framework for IVM, and other activities. This partnership and consistent engagement have been essential for making progress on IVM policy and implementation.

√ **Lesson:** National malaria control programs want to make greater use of all proven vector control methods.

Insecticide-treated nets have been the principal vector control intervention promoted and used under the Roll Back Malaria partnership, and demand for ITNs has grown quickly over the past five years. Demand for using the other interventions—indoor spraying, environmental management, and larval control—has also grown over this period.

EHP has played a leading role in the investigation of environmental management and larval control methods as part of IVM for malaria control. In **Eritrea**, EHP tested the efficacy of environmentally-safe bacterial larvicides and then designed and implemented a two-year pilot program to develop locally-appropriate protocols for the routine, operational use of larval control.[10] In **Uganda**, EHP has provided technical support to help local government teams test the use of environmental management and larval control methods in Kampala and Jinja.[11] In both countries, initial evidence demonstrates that the methods have reduced mosquito populations and the rate of infective bites in households near the controlled areas. Larger studies and longer periods are needed to determine whether these changes will lead to lower malaria incidence. EHP is also supporting field studies in Dar es Salaam, **Tanzania,** and Kilifi, **Kenya,** to evaluate the potential impact of larval control methods in two coastal cities in Africa and in the Kakamega District of Kenya to evaluate their potential use in highland areas.[12] These studies will continue beyond the end of EHP.

9/ Stockholm Convention on Persistent Organic Pesticides, entered into force 17 May 2004; see *http://www.pops.int*

10/ Novak, R., and J. Shililu. Eritrea: A Pilot Program to Use Larval Control for Preventing Malaria. Activity Report (forthcoming).

11/ Lindsay, S. and T. Egwang. Uganda: Reducing urban malaria using environmental management in Kampala and Jinja. EHP Activity Report (forthcoming).

12/ Fillinger, U., S. Lindsay, A. Githeko, M. Kiama, and G. Killeen. Pilot Studies of Anti-Larval Methods for Controlling Malaria in Africa. EHP Activity Report (forthcoming)

USAID's modest investments in operational research on larval control methods have catalyzed other, larger investments for developing and demonstrating these techniques. The U.S. National Institute of Allergies and Infectious Diseases recently awarded three large grants for multi-year studies of anopheline larval ecology and control in Africa. The principal investigators for two of the three awards are key contributors to EHP's work, and the third has had a key role in malaria transmission and intervention studies in Kisumu, funded by USAID and implemented by the U.S. Centers for Disease Control and Prevention.

Demand for expanding the use of indoor spraying (IRS) is rising throughout Africa and elsewhere. For example, **Zambia** is using a large portion of its Global Fund award to expand IRS coverage in five key cities, an effort for which EHP is providing technical assistance. **Mozambique** has sought funds from USAID to expand IRS coverage in major cities, as part of a malaria control support project that EHP helped design. **Eritrea** is using funds from the U.N. Environment Program to rationalize its use of IRS and, over the long term, reduce its use of DDT as part of an IVM program for malaria. In **Kyrgyzstan**, WHO is using funds provided by USAID to support IRS operations for malaria.

Three factors are contributing to the growth in demand for IRS. First, it has been effective in reducing malaria transmission, cases, and deaths in operational control programs implemented at scale in various settings. Second—and probably most important—the Global Fund is providing many countries with access to the substantial level of funding required to pay for IRS programs. Finally, the Stockholm Convention on Persistent Organic Pesticides includes an exemption allowing signatories to use DDT for public health purposes. This recent development, coupled with the long-standing policies, guidance, and programs from WHO to support the judicious use of IRS, has caused participants in the Roll Back Malaria partnership to provide greater and more open support for countries that wish to expand the use of IRS.

√ **Lesson:** Professional training and experience in entomology and vector control are critical for running an Integrated Vector Management program that makes appropriate use of all available control methods.

EHP has made important contributions to staff development in **Eritrea**, **Zambia** and **Nepal** and to training field entomology staff in conjunction with the larval control studies in **Kenya** and **Tanzania**. Based on work done in these settings, EHP has prepared training materials and approaches for building in-country capacity to implement IVM for malaria control, including:

- Building field and laboratory capacity for essential research and surveillance
- Building operational capacity for malaria vector control interventions
- Building capacity for data management, analysis, and use.

However, the lack of a sufficient number of skilled, experienced and dedicated staff with adequate program support is the most important constraint for scaling up coverage with vector control interventions in Africa.

In **Eritrea**, much of the population has been mobilized under arms for the last 20 years, creating a generation gap between the senior, experienced managers and the young, newly trained apprentices. The program is effective and successful, but operates on a very thin margin at constant risk of losing critical expertise. Through a series of operational research studies and improvements in surveillance, field staff have been trained in basic entomological methods and larval control techniques. EHP has also contributed to the training and improved supervision of a new cadre of Environmental Health Technicians. Despite these advances, program staffing remains thin. The recent death of a zonal program manager has compromised the continuity and integrity of malaria control activities in that zone.

In **Zambia,** frequent turnover among the central malaria program staff and multiple

other duties has hampered their ability to provide technical support to the districts for planning and implementation of Global Fund resources for expanding the use of IRS. Moreover, at the district level, the lack of dedicated trained staff and vehicles led to problems with supplies and logistics, reporting, quality of spray operations and safe handling of pesticides. Experienced staff were spread too thin to provide effective oversight. Although the problems are clear and program leaders are motivated, the shortage of experienced staff is a finite problem that cannot be overcome quickly.

Training, supervision, and staff retention will remain critical challenges for improving vector control for some time. Ad hoc, competitive efforts by various institutions to provide training in malaria entomology and vector control in Africa have not substantially increased the availability of skilled staff at the operational level of malaria control programs. A comprehensive regional strategy is needed for building capacity in IVM.

II. Surveillance

EHP has devoted substantial funding and effort to improving surveillance for malaria in Eritrea and several high-priority vector-borne diseases in South Asia. The general lesson from this large body of work is:

√ **Lesson:** In areas prone to epidemics of malaria and other vector-borne diseases, understanding the local distribution of the disease and its relation to environmental and demographic factors will help public health officials improve the prevention and control activities they direct.

In **Eritrea**, EHP helped the ministry of health improve malaria surveillance by performing each of the following steps and analyses:

- Supported the design and implementation of a national malaria prevalence survey
- Supported planning for a network of malaria sentinel surveillance sites
- Disaggregated data on malaria cases and program interventions by week and reporting facility for the past six years to make more detailed analyses possible
- Prepared software to help zonal malaria officers extract malaria data routinely from the ministry's health management information system
- Assembled data on diverse environmental variables (rainfall, soil type, vegetation index, etc.) that might be useful in explaining the distribution of malaria
- Analyzed data from the prevalence survey to identify relationships between malaria prevalence and potentially relevant environmental variables, and used results from the analysis to prepare a detailed map of malaria stratification in Eritrea
- Used the disaggregated historical data to identify site-specific thresholds for defining and detecting malaria epidemics
- Used insights from the preceding work to prepare a manual on epidemic detection, preparedness and response for Eritrea's National Malaria Control Program
- Analyzed historical climate and rainfall patterns for Eritrea and related these to malaria incidence over the same period, to prepare epidemic forecasting models that are specifically tailored to the several climatic zones of the country.

In **South Asia**, EHP worked with disease control officials in **Nepal**, **India**, **Bangladesh**, and **Bhutan** to reach agreements on standardizing surveillance protocols for Japanese encephalitis, kala-azar, and resistance to anti-malarial drugs. Over the course of five years, EHP organized five regional meetings, several bilateral (cross-border) meetings between adjoining countries, developed and maintained a web-site (*www.bbin.org*), and sustained ongoing dialogue and collaboration with officials of the national ministries, the Southeast Asia Regional Office of WHO (SEARO), and various universities and research institutes that are resources within the region. The four key accomplishments from this work are:

- A multi-country agreement to standardize the case definition, diagnostic protocols, and reporting conventions for Japanese encephalitis

- A regional agreement to use standard protocols for evaluating *in vivo* resistance to anti-malaria drugs
- The first coordinated studies of anti-malarial drug resistance in adjoining districts of West Bengal and Nepal
- A bilateral agreement between adjoining districts in India and Nepal to share information on incidence, trends, and interventions for kala-azar, and to coordinate both the timing and content of public information campaigns on both sides of the border to ensure the maximum effect of the kala-azar campaign.

EHP has prepared a set of useful guidelines for improving malaria surveillance in areas of of seasonal and low transmission that are epidemic-prone.[13]

Future Directions

Looking forward, the following are priority actions for advancing integrated vector management and malaria surveillance:

Developing and field testing approaches for engaging community organizations in an effective partnership with the operational and regulatory personnel of government departments (health and local government) to implement environmental management and larval control interventions.

Developing greater capacity in malaria control programs for collecting, managing, and analyzing malaria case reports and environmental data that are useful for planning malaria control operations.

Organizing and implementing regional training programs, professional associations, and technical assistance networks that can operate over the long term to build and sustain the human resource capacity needed for effective vector control programs.

13/ Graves, P. Improving Malaria Surveillance in Areas of Low and Seasonal Transmission. EHP Strategic Report (forthcoming).

Key Documents

A Pilot Program to Use Larval Control for Preventing Malaria. Activity Report (forthcoming)

Evolution of a Pilot Strategy to Improve the Management of Kala-azar and Malaria in Nepal. Activity Report 131

Improving Malaria Surveillance in Areas of Low and Seasonal Transmission. Strategic Report (forthcoming)

Pilot Studies of Anti-Larval Methods for Controlling Malaria in Africa. Activity Report (forthcoming)

Uganda Final Report. Activity Report (forthcoming)

WHO Global Strategic Framework for Integrated Vector Management. Activity Report (forthcoming)