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What makes a malaria control program sustainable and successful?

Malaria is an extremely devastating and complex disease, and controlling it is neither simple nor easy. Successful and sustainable malaria control programs have an integrated and balanced approach that covers all of the technical, research, and scientific components of malaria control. These programs also have firm political commitments by national governments that ensure sustainable funding and support for malaria control, and policies that are guided by scientific evidence. Perhaps the most important element of malaria control programs is the people on the ground. A collaborative team of professionals is needed, consisting of entomologists, molecular biologists, geographers, statisticians, malaria control managers, accountants, scientists, social scientists, information systems specialists, lab technicians, insectary technicians, vector control managers, field supervisors and medical technicians.

A good example of a successful and sustainable program is the Lubombo Spatial Development Initiative (LSDI) - a tri-lateral agreement between the governments of Swaziland, Mozambique and South Africa to control malaria jointly and regionally. Initial funding for this program was obtained in 1999 from the South African Business Trust and the South African Government. After significant reductions in malaria burden were observed within the first two years, further funding was obtained from the Department of Arts Culture and Science and BHP Billiton (Mozal). Sustained malaria reductions in all three countries were rewarded in 2003 with a multi-country grant from The Global Fund to Fight AIDS, Tuberculosis and Malaria. The LSDI is still receiving funding from The Global Fund, country governments and the private sector, and is seen today as a model for malaria control in Africa.

Understanding the successes and elements of the LSDI can and should guide the development of other malaria control programs in Africa. This document describes the elements of the LSDI that make it so successful: (1) entomology, (2) parasitology, (3) malaria information systems, (4) information, education and communication, (5) geographical information systems, (6) indoor residual spraying, (7) financial management, (8) laboratory capacity, (9) insectaries, (10) logistical management, and (11) monitoring and evaluation. While the main focus of malaria prevention in the LSDI is indoor residual spraying (IRS), improving support and funding for the elements of malaria control described below should be priority for all malaria control programs, including those that rely on insecticide treated nets (ITNs).

In addition to vector control, improving access to malaria treatment and the rational use of safe and effective malaria drugs is a vital component of malaria control. Improved treatment of malaria cases reduces gametocyte carriage and therefore reduces transmission. While malaria treatment is a part of the LSDI, this document focuses on vector control to prevent malaria transmission.

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Elements of the LSDI

1. Entomology

Entomology is an integral part of vector control and is crucial to achieving significant reductions in malaria. Malaria entomologists identify and study the malaria vectors specie composition, vector density, vector biting/feeding patterns, and vector biology and ecology to assist in the selection of the most effective control method for that specific vector. Malaria entomologists monitor the impact of the control method by looking at the malaria vector population density, rate of infections, and the susceptibility of the vectors to the selected insecticide used in IRS.

The following personnel are involved in the entomology component of the malaria control program.

- **Entomologists –** manage all aspects of entomology as described above.
- **Field lab technicians** – install and maintain window traps (used to capture mosquitoes) in order to ensure accurate collections, and collect mosquito samples in the field.
- **Insectary technicians** – breed wild captured mosquitoes to create a first generation colony, which possesses all the biological characteristics of the parents and is used in insecticide resistance testing and bioassays.
- **Field supervisors** – collect mosquito samples from homeowners cooperating in the collection of mosquitoes, and coordinate their compensation.

2. Parasitology

It is essential to understand the disease burden of malaria before implementing a control intervention. A detailed malaria parasite prevalence survey is conducted at baseline to establish the parasite prevalence of the communities being targeted. The presence of parasitological baseline data enables accurate monitoring over time to determine the effect of the interventions on the population. Rapid diagnostic test kits are used to test children under 15 years old in pre-selected sentinel sites to determine their malaria status. The children's households are mapped using Global Positioning System (GPS) coordinates to ensure the correct houses are targeted for follow-up surveys. Hemoglobin and body temperature are informative and easily comparable indicators. Both are collected at baseline from a sample population of children between 2 and 15 years old and again during the post-intervention follow-up survey. The results from the collections are compared to determine changes in parasite prevalence.

The following personnel are involved in the parasitology component of the malaria control program.

- **Statisticians** – provide statistical support to scientists and researchers conducting field research, and determine the required statistically significant sample size needed at sentinel sites during parasite prevalence surveys.
- **Field supervisors –** sensitize community leaders to the surveys, gain their support, and instill a sense of ownership. In order for a program to be successful, it is critical to have the support of the community leaders and residents.

- **Medical technicians** – perform finger pricks on children to obtain blood for rapid diagnostic testing for malaria, and read/interpret test results.
- **Field scientists –** observe the execution of the surveys to ensure that all activities are conducted scientifically and according to protocol. The results of the surveys are documented and eventually published.
- **Geographers –** geo-locate all surveyed households with a hand-held GPS device. The GPS coordinates are then mapped to establish the spatial variation of malaria within the sentinel sites.

3. Malaria information systems

Sustainable and successful malaria control programs make use of malaria information systems (MIS). An MIS is a computerised central database of malaria cases. Malaria case information is essential to disease management, and makes it possible to accurately and effectively monitor and evaluate interventions. At-risk areas can be easily identified using MIS data, which aids decision makers in directing resources and strategies to the most appropriate areas. Complete and accurate malaria case information is crucial for the planning and implementation of malaria control programs as well as for assessing the efficacy of interventions.

The following personnel are involved in the MIS component of the malaria control program.

- **Information system specialists –** manage and train field-based office staff in operating an MIS, manage data quality control, and provide technical support.
- **Malaria control managers** – coordinate/manage daily program activities using MIS data. MIS data is used in reports to funders and other interested parties to indicate the efficacy of interventions.
- **Statisticians –** monitor/interpret MIS data to establish the significance of outputs.
- **Scientists –** use MIS data in publications.
- **Geographers –** incorporate MIS data into spatial mapping of malaria.

4. Information, education and communication

Information, education and communication (IEC) is an important component of malaria control. Knowledge, attitude and practice (KAP) surveys are used to collect information about the knowledge, attitudes and practices of community residents with respect to malaria. KAP survey results guide the IEC strategy and are used to measure changes in knowledge, attitudes and practices over time. Examples of IEC strategies used include training community health workers, training teachers, community awareness campaigns, posters, flyers, community radio broadcasts and community plays.

The population affected by malaria control programs must be well informed for their support and cooperation to be obtained. Community-based IRS programs rely heavily on the participation of community residents and therefore it is important to maintain a flow of information between the malaria control program management and the residents. Educating residents about malaria and how it is transmitted aids in its prevention. Educated communities tend to take ownership of malaria control and as a result household coverage of IRS and ITN usage are generally higher in these areas. It is important to keep the community residents informed about progress through ongoing communication from the program management. Good communication strengthens relationships and trust and aids in the sustainability of malaria control interventions

The following personnel are involved in the IEC component of the malaria control program.

- **Social scientists –** design the IEC strategy and the materials needed, and administer the KAP surveys.
- **Information systems specialist –** capture data into an IEC database.
- **Field supervisors –** assist with the distribution of IEC materials.
- **Scientists –** monitor and evaluate KAP survey results on an annual basis to determine the level of understanding among community residents.

5. Geographical information systems

Geographical information systems (GIS) introduce a vital spatial component to malaria control programs. GIS provides a mechanism to integrate spatial and statistical datasets and to model possible scenarios to provide an effective planning and management tool. The spatial mapping of malaria is used to create intervention strategies and to allocate resources for disease prevention and control. The mapping of malaria is also used as a tool to assist in logistical planning and field support, and enables malaria control managers and field supervisors to track interventions on the ground.

The following personnel are involved in the GIS component of the malaria control program.

- **Geographers** – collect and map spatial information.
- **Field supervisors –** capture geographical data, such as homesteads, water bodies, health facilities and roads, with a hand-held GPS device. The data is used by geographers to spatially map the geographical characteristics of the area.
- **Malaria control managers –** use the maps as a management tool to coordinate malaria control interventions.
- **Scientists –** interpret the maps and direct health research.
- **Statisticians –** use maps to calculate population size and density in order to estimate the required resources needed for interventions, and assist scientists conducting field research in determining statistically significant sample sizes for their studies.
- **Information systems specialist –** integrate spatial data obtained from maps into an MIS.

6. Indoor residual spraying

IRS is a malaria control intervention targeted at the mosquito vector. Trained spray operators equipped with hand-held pumps spray the inside surface of the walls of houses with residual insecticide. The insecticide dries and forms a crystalline deposit on the sprayed surface. The main aim of IRS is to kill and/or repel the mosquito so that it will not bite and transmit malaria to the residents. Contact with the human vector is thus prevented causing a break in the malaria transmission cycle. The most successful IRS programs make use of local men and woman and are referred to as community-based. By recruiting local men and woman, community residents feel a sense of ownership for the program, local jobs are created, and resistance to spraying is reduced since the spray operators are known in the community.

In addition to spray operators, the following personnel are involved in the IRS component of the malaria control program.

- **Vector control managers –** oversee the training of spray operators, coordinate IRS field operations, manage quality control of spraying and insecticide storage “leakage control”.
- **Fields supervisors –** recruit local men and woman as spray operators and sensitize the communities through local leadership.
- **Geographers –** use maps to direct the spray teams IRS operations within the communities.
- **Malaria control managers –** coordinate all IRS activities including ordering and transporting all materials and equipment to the spraying locations, and inform funders and stakeholders of program progress.

7. Financial management

Successful and sustainable malaria control programs have proper financial management that guarantees the appropriate use of funds. Most malaria control programs rely on donor funding. Sound financial management of donated funds is crucial to ensure the sustainability of funding over time. Accountants play an important role in the timely procurement of commodities, such as insecticide, vehicles, spray pumps and personal protective clothing for spray operators, to avoid interruptions in spray operations.

The following personnel are involved in the accounting component of the malaria control program.

- **Accountants –** manage all procurements and provide financial reports to funders, external auditors and malaria control managers.
- **Malaria control managers** – manage the program accountants and incorporate the financial reports into the annual reports.

8. Laboratory capacity

Insecticide resistance is a critical problem facing vector control interventions today. A well-equipped laboratory enables malaria control programs to keep abreast of possible insecticide resistance build-up ensuring the sustainability of the entire program. Apart from the WHO susceptibility testing, laboratory personnel conduct malaria vector identification.

The following personnel are involved in the laboratory component of the malaria control program.

- **Lab technicians –** prepare and document mosquito samples for the WHO susceptibility and PCR insecticide resistance testing.
- **Molecular biologist -** conduct all insecticide susceptibility and resistance testing.

9. Insectaries

A well-equipped insectary is needed to support the entomology component of malaria control. An insectary provides entomologists and laboratory personnel with live first generation mosquitoes that are hatched from wild captured mosquitoes. These mosquitoes are used for insecticide resistance testing, which is a key component of malaria control.

The following personnel are involved in the insectary component of the malaria control program.

- **Entomologists** – conduct all insecticide resistance testing with insectary mosquitoes.
- **Field lab technicians –** collect mosquito samples in the field.
- **Insectary technicians –** manage the mosquito colonies, and breed wild captured mosquitoes to create a first generation colony, which possesses all the biological characteristics of the parents and is used for insecticide resistance testing and bioassays.

10. Logistical management

Malaria control is field-based, and requires considerable logistical management and support to coordinate all of the above-mentioned activities. Many malaria control programs fail to recognize the importance of logistics. The entire malaria control team should be involved in all logistical aspects of the program, and an experienced malaria control manager is needed to coordinate and manage all of the activities.

11. Monitoring and evaluation

Monitoring and evaluation (M&E) of malaria interventions is an integral part of an integrated and comprehensive malaria control program. It is essential to measure changes in indicators over time in order to determine the efficacy of interventions and the impact on parasite prevalence. M&E must be included in the malaria control budget and funded by national governments where possible in order to limit the reliance on external funding. Surveillance systems are needed to ensure complete and accurate M&E.

Alternative malaria control interventions

Insecticide treated nets

ITNs are a well-established malaria control intervention receiving considerable funding from the international community. ITNs are not a main component of the LSDI or other malaria control programs in the Southern Africa Development Community region; however, their importance in malaria control programs in other regions should not be overlooked. The impregnation of mosquito nets with an insecticide was an important development in malaria control. The insecticide used in the nets has a repelling effect on mosquitoes as well as a knockdown effect, whereby the mosquitoes die when they come into close contact with the impregnated nets. Mosquitoes are attracted by the carbon dioxide and body odors emitted by humans when they sleep. Pyrethroids are the preferred insecticide for bed net impregnation due to their repellency and toxicity to insects, and their relative safety to humans who come into close contact with them. ITN research is ongoing and as a result the effectiveness and quality of ITNs have changed considerably in the last few years, such as improvement in the durability and expected lifespan of ITNs.

There are many different models used in the delivery of ITNs, but monitoring and evaluation of ITN programs remains weak. Many people do not consistently sleep under an ITN, mosquito nets requiring insecticide re-treatment are not always re-treated, and ITNs are often misused (e.g. for catching and drying fish). Too much emphasis is placed on outcomes, such as the number of ITNs distributed, and not enough emphasis is placed on the impact of ITNs on malaria transmission.

Larvae control

Larviciding has been used as a method of vector control since the start of the century to kill mosquito larvae before they reach the adult stage. Early liquid larvicide compounds, such as petroleum oils, paraffin and other hydrocarbons, played an important role in the development of new environmentally friendly larvicide compounds. The early compounds were found to cause damage to ecological and aquatic systems. The development of organophosphates, synthetic pyrethroids and bacterial larvicides such as *bacillus thuringiensis israelensis* (Bti) was a marked breakthrough in mosquito larval control.

In the late 1970s, the efficacy of bacterial larvicides (Bti) against mosquito larvae that breed in non-polluted water was discovered and became incorporated into several larvicide programs around the world. The use of bacterium *B. sphaericus* (Bsph) against mosquitoes that breed in polluted water has increased in the past decade. Both (Bti) and (Bsph) are highly effective and target specific mosquito larvae. In addition, (Bti) and (Bsph) have an excellent safety record for humans, animals and fish, and the products are cost effective.

Environmental manipulation measures

Clearing vegetation is a method of controlling mosquito populations, which is still done today. It removes the shelter that mosquitoes use in the daytime and causes the evaporation of standing water, which mosquitoes use as breeding sites. Although clearing vegetation to control malaria has been successful there is the danger that the environmental changes might suit the breeding habits of other mosquito species.

Planting certain vegetation like eucalyptus and other trees has been used to dry up stagnant water and get rid of potential mosquito breeding sites. This form of environmental manipulation has worked well and is still used throughout Africa to control malaria. Other plants, such as muskgrass (*Chara*), floating leaf (*Brasenia*) and bladderwort (*Utricularia*), are known to prevent mosquitoes from breeding and can also be planted as an environmental manipulation strategy to get rid of surface water.

Drainage is a very effective method of eliminating mosquito breeding sites. Small scale drainage schemes can be developed rather easily due to the small volume of water involved, which will eventually evaporate once the water is drained. Planning and construction of major drainage schemes requires trained personnel due to the complex nature of topographical features and water flow. Drainage as a malaria control method is still used in Africa today. However, it is not seen as a first-line defense against malaria transmission due to the ecological destruction of the drained areas, the cost involved in draining operations, and the fact that the many *Anopheles* vectors prefer to breed in small collections of water, like cattle hoof prints, as apposed to large bodies of water.

Conclusion

Although malaria is a preventable and entirely curable disease, malaria control is highly complex. Ensuring sustainable malaria control requires considerable investment in numerous elements that make up a sound, evidence-based malaria control program. The perception that malaria control is simple and easily accomplished by residents sleeping under an ITN is false. Unfortunately some donor funded programs as well as private initiatives focus greatly on the delivery of commodities such as ITNs to the exclusion of other interventions and activities. In order to create long-lasting effective malaria control programs, there must also be investment in health systems and human and logistical capacity.