Handbook for Integrated Vector Management in the Americas

Pan American Health Organization

World Health Organization
REGIONAL OFFICE FOR THE Americas

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Abbreviations

CD	Directing Council
DDT	dichloro-diphenyl-trichloroethane
DTU	discreet typing unit
IPM	integrated pest management
IRS	indoor residual spraying
IVM	integrated vector management
GIS	geographic information system
LLIN	long-lasting insecticide treated net
NGO	nongovernmental organization
PAHO	Pan American Health Organization
VBD	vector-borne disease
WHO	World Health Organization

Glossary

Adulticide: A chemical or biological insecticide targeting vectors in the adult stage.

Arbovirus: Any of the viruses transmitted by arthropod vectors; a contraction of "arthropod-borne virus."

Arthropod: Invertebrate animals that form the most diverse group in the animal kingdom. Their bodies are covered by an exoskeleton or cuticle, and they have segmented bodies and jointed appendages. Arthropods include arachnids, insects, and crustaceans.

Biological control: Use of living organisms or their products to control vectors. The organisms used include viruses, bacteria, fungi, and fish, among others.

CD48/13: Mandate of the Pan American Health Organization (PAHO) (resolution CD48.R8, document CD48/13) from 2008 entitled *Integrated Vector Management: A Comprehensive Response to Vector-borne Diseases*.

Chagas disease (or American Trypanosomiasis): A systemic parasitic disease caused by the protozoan flagellate *Trypanosoma cruzi*. *T. cruzi* is transmitted to humans and other mammals by hemiptera insect vectors of the subfamily Triatominae, reduviid bugs with various popular names such as kissing bugs, bedbugs, cone-nosed bugs, and blood suckers.

Chemical control: Application of chemicals (insecticides) to control vectors in the larval and adult phases.

Chikungunya: An emerging disease caused by an alphavirus (the chikungunya virus or CHIKV), which is transmitted through the bite of a mosquito, mainly *Aedes aegypti* and *albopictus*.

Circadian variation: Peak times of insect bite activity, during the day or at night.

Dengue: An infectious disease caused by dengue virus (DENV). It belongs to the *Flavivirus* genus in the *Flaviviridae* family in the arbovirus group. There are four serotypes: DENV-1, DENV-2, DENV-3 and DENV-4. It is primarily transmitted by the *Aedes aegypti* and *Ae. albopictus* mosquitoes.

Discrete typing unit (DTU): Classification unit to describe the genetic lineage of *T. cruzi*.

Entomopathogenic fungus: A fungus that infects insects and reproduces in the organism, causing death. Some recognized fungi are *Metarhizium anisopliae* and *Beauveria bassiana.*

Environmental management: Management of environmental factors to prevent or minimize propagation of the vector and reduce human contact with the vector-pathogen. It may entail environmental modification (permanent environmental change) or environmental manipulation through physical or mechanical means (recurring actions to temporarily achieve inhospitable conditions).

Extra-domiciliary spraying: Application of insecticide to the exterior surfaces of dwellings (chicken houses, granaries, barns, etc.).

Focal treatment: Application of mosquito larvicide, recommended for household water storage containers that cannot be protected, destroyed, eliminated, or otherwise treated.

Impregnated mosquito net: Mosquito net or bed net impregnated with pyrethroid insecticide, used to prevent contact between people and mosquitoes and thus control the transmission of disease.

Insect growth regulator (IGR): Natural or synthetic product that impedes the growth and development of mosquitoes in the early stages, thereby blocking their natural maturation cycle.

Insecticide resistance: Ability of insects to survive exposure to a standard dose of insecticide. It may be the result of a physiological or behavioral adaptation.

Integrated vector management: A rational decision-making process to optimize the use of resources for vector control, which enhances the effectiveness and efficiency of national and subnational vector control programs.

Leishmaniasis: A disease transmitted by the genus *Lutzomyia*, with various species of parasites and different reservoirs and vectors involved in transmission. It is caused by protozoans of the genus ***Leishmania*** that are transmitted by several species of phlebotomine sand flies. There are three different clinical manifestations: cutaneous, mucocutaneous, and visceral (the most serious form that affects the internal organs).

Lymphatic filariasis: A parasitic infection produced by worms (nematodes) that can cause changes in the lymphatic system. In the Americas, *Wuchereria bancrofti* is the only pathogenic species and is transmitted by mosquitoes of the genus *Culex* (primarily *C. quinquefasciatus*), the most common vectors.

Malaria: Disease caused by parasites of the genus *Plasmodium*, transmitted through an infected mosquito bite. Only mosquitoes of the genus *Anopheles* transmit malaria. The parasites *P. vivax* and *P. falciparum* are most common in malaria, while *P. malariae* and *P. ovale* are less common and have a smaller distribution area.

Natural enemy: An organism in the natural environment that preys on larvae or adult vectors.

Onchocerciasis (river blindness): A parasitic disease caused by the filarial worm *Onchocerca volvulus* and transmitted to humans by black flies of the genus *Simulium*. It causes serious dermatological and ophthalmic problems that can even lead to blindness.

Perifocal treatment: Treatment of all mosquito-infested containers (whether or not they contain water) by spraying the interior and exterior surfaces, leaving them completely covered with insecticide residue. Fumigation extends to any surface within a 60 cm radius of the container. Non-potable water in containers is also treated.

Receptivity analysis: Analysis of community acceptance of the intervention measures.

Release of genetically modified mosquitoes: Technique that consists of releasing into the environment mosquitoes that have undergone some type of genetic engineering that renders them unviable or sensitive to control measures.

Release of irradiated mosquitoes: Technique that consists of releasing into the environment mosquitoes that have been irradiated with gamma rays, rendering them sterile.

Release of mosquitoes with endosymbiotic bacteria: Technique that consists of releasing into the environment mosquitoes infected with a bacterium that theoretically can immunize them against infection.

Schistosomiasis: A trematode parasitic infestation of the genus *Schistosoma*. The only form present in the Americas is intestinal schistosomiasis caused by *Schistosoma mansoni*. In order to complete its life cycle, the *S. mansoni* requires a final host—a human being (since there is no other significant animal reservoir)—and an intermediate host—a fresh water snail of the *Biomphalaria* genus.

Thermal spraying: Treatment of an area with hot aerosols. It is applied with foggers that turn a low-concentrate solution into a thick cloud of fog containing suspended drops of the insecticide.

Vector bionomics: The branch of biology that studies the behavior of a species with regard to the environment and its interrelationships and organization.

Vector competence: Capacity of the arthropod to be infected with the pathogen and, in turn, capacity of the pathogen to multiply within the arthropod in order to be subsequently transmitted.

Vector ecology: The study of time and space distribution of vectors, their habitat, environmental factors, and interactions with other species.

Vector-borne disease: Infectious diseases transmitted by mosquitos, bedbugs, fleas, flies, or ticks that act as vectors of different pathogens, either protozoans (*Trypanosoma, Leishmania, Plasmodium*), viruses (*Flavivirus, Alphavirus*, etc.), bacteria (*Rickettsia*, among others), or filariae (*Onchocerca, Mansonella, Wuchereria,* etc.).

Vectorial capacity: Effectiveness of pathogen transmission by a species of insects already proven to be competent vectors.

Vulnerability analysis: Study of areas with the greatest risk factors for transmission of the disease.

West Nile Virus: Virus of the genus *Flavivirus* (family *Flaviviridae*) that causes acute nervous system disease in humans. Birds and mosquitoes participate in the transmission cycle. Horses, monkeys, and other mammals can also be infected. The principal vectors are mosquitoes of the genus *Culex*.

Yellow fever: An infectious disease caused by the *Flavivirus* genus (family *Flaviviridae*). In the Americas, two transmission cycles are known: the urban cycle (human-mosquito-human transmission), whose principal vector is the ***Aedes aegypti*** mosquito; and the jungle (sylvatic) cycle in which mosquito species (*Haemagogus* spp. and *Sabethes* spp.) act as different vectors and primates (monkeys) participate as hosts, amplifying the virus during the viremia phase.

Zika: An infection caused by an arbovirus of the genus *Flavivirus* (family *Flaviviridae*), phylogenetically very close to other viruses, such as dengue, yellow fever, Japanese encephalitis, and West Nile Virus. It is transmitted by mosquitoes, mainly of the genus *Aedes*. A few cases of sexual and vertical transmission (mother to child) have been documented, as has transmission by blood transfusion.

Preface

Integrated vector management (IVM) is defined as "a rational decision-making process to optimize the use of resources for vector control," which enhances the effectiveness and efficiency of national and subnational vector control programs. This strategy provides program managers with long-term control methods that are sustainable and environmentally appropriate, making it possible to reduce dependence on insecticides and protect the population from vector-borne diseases (VBDs).

The purpose of this document is to provide a manual for professionals at the operational, technical, and managerial levels so that they can properly apply the IVM strategy to control or eliminate the main vectors of arboviral disease (dengue, Zika, chikungunya, yellow fever), malaria, and neglected infectious diseases (Chagas disease, leishmaniasis, filariasis, etc.). It seeks to offer the technical details needed to plan, implement, supervise, evaluate, and subsequently validate the IVM methodology.

This document is based on a Pan American Health Organization (PAHO) mandate set forth in 2008 (resolution CD48.R8, document CD48/13) and it specifically complements a series of World Health Organization (WHO) guidance documents published in 2012: Handbook for Integrated Vector Management,[1] Monitoring & Evaluation: Indicators for integrated vector management,[2] Guidance on policy-making for integrated vector management,[3] and Core structure for training curricula on integrated vector management.[4]

In addition, as part of preparation of the document, a working group was established of people in charge of vector control programs at the national, subnational, and municipal levels, and of researchers from some Latin America and Caribbean research institutions. This group met in Belize City from 13-16 March 2018 to discuss, review, and propose a version of the Handbook tailored to the Region.

The goal of IVM is to help manage or eliminate VBDs by making vector control more efficient, cost-effective, ecological, sustainable, and culturally acceptable. IVM seeks to help vector control programs take advantage of available scientific data

1 World Health Organization. *Handbook for integrated vector management.* Geneva: WHO; 2012.
2 World Health Organization. *Monitoring & Evaluation: Indicators for integrated vector management.* Geneva: WHO; 2012.
3 World Health Organization. *Guidance on policy-making for integrated vector management.* Geneva: WHO; 2012.
4 World Health Organization. *Core structure for training curricula on integrated vector management.* Geneva: WHO; 2012.

(epidemiological, entomological, and local determinants of disease, among others) to design and implement interventions with intersectoral participation. When relevant and feasible, such interventions should impact more than one VBD.

In September 2018 the 56th Directing Council of PAHO approved the Plan of Action on Entomology and Vector Control 2018-2023 (resolution CD56.R2, document CD56/11). It provides an important framework for countries' commitment, makes vector control a renewed priority, and takes into account the fundamentals of IVM, including budgeting. It is hoped that countries will consult this strategic handbook as they strive to achieve the targets of that Plan of Action.

1. Background

This document compiles the recommendations made by the World Health Organization (WHO) and the Pan American Health Organization (PAHO) to help professionals in charge of vector control programs in Latin America and the Caribbean at the national, subnational, and local level update their knowledge in order to make evidence-based decisions on the most appropriate control measures for each specific situation.

IVM can be used for surveillance and control or for elimination of VBDs and can help reduce the development of insecticide resistance through the rational use of these products.

This document provides instructions for fulfillment of the 2008 PAHO mandate set forth in CD 48/13 (Integrated Vector Management). It specifically complements a series of WHO guidance documents published in 2012: Handbook for Integrated Vector Management,[5] Monitoring & Evaluation: Indicators for integrated vector management,[6] Guidance on policy-making for integrated vector management,[7] and Core structure for training curricula on integrated vector management.[8]

The methodology followed in the preparation of this document applied the best available evidence on IVM, considering the situations of countries and the principle scenarios of VBD transmission.

We hope that this handbook can be reproduced and easily used, and that its messages are clear and help apply IVM as efficiently as possible in the respective regions. The Annexes share the experiences of some countries of the Americas in the use of IVM.

1.1. Situation analysis of vector-borne diseases in the Americas

Around one billion people live in the Region of the Americas, which represents 13% of the world's population. This Region has the most urbanized population in the world (over 80%) (1), a percentage that is virtually the same in North America (82%) as in Latin America and the Caribbean (80%). Also, three of the world's six megalopolises

5 World Health Organization. *Handbook for integrated vector management.* Geneva: WHO; 2012.
6 World Health Organization. *Monitoring & Evaluation: Indicators for integrated vector management*. Geneva: WHO; 2012.
7 World Health Organization. *Guidance on policy-making for integrated vector management*. Geneva: WHO; 2012.
8 World Health Organization. *Core structure for training curricula on integrated vector management*. Geneva: WHO; 2012.

are in the Americas (Mexico City, New York, and São Paulo), each with nearly 20 million inhabitants (1).

VBDs are common in both densely populated regions and in peri-urban and rural areas of Latin America and the Caribbean. These infectious diseases are transmitted by mosquitoes, bedbugs, fleas, flies, and ticks. These animals act as vectors of various pathogens, either protozoans (*Trypanosoma, Leishmania, Plasmodium*), viruses (*Flavivirus, Alphavirus,* etc.), bacteria (*Rickettsia*, etc.), or filariae (*Onchocerca, Mansonella, Wuchereria,* etc.).

VBDs contribute significantly to the global morbidity burden, particularly impacting communities in developing countries. In the Americas there is a high burden of these diseases, several of which present endemo-epidemically in different geographical areas. They cause school absenteeism, worsen poverty, increase health costs, and overload health systems, while undermining general economic productivity (2-4).

The main VBDs affecting the populations of the Americas are: dengue, Zika, chikungunya, malaria, leishmaniasis (cutaneous, mucocutaneous, and visceral), Chagas disease, onchocerciasis, and lymphatic filariasis, and to a lesser extent, yellow fever and West Nile Virus (Table 1).

The distribution and intensity of VBDs is determined by a complex and dynamic interaction of biological, geographical, and environmental conditions that delimit the area of transmission in rural, peri-urban, or urban settings. The interrelationship between bio-environmental processes and social, economic, political, and cultural processes determines the likelihood of transmission and whether it is endemic, emerging, reemerging, or epidemic (5).

Malaria and the congenital and neurological syndromes caused by Zika virus pose serious risks, especially to women of childbearing age, pregnant women, and fetuses/neonates. Therefore, protecting vulnerable women from mosquito bites should be an important part of vector control efforts.

PAHO estimates that 145 million people in 21 countries of the Region live in areas at risk for malaria, with *Anopheles darlingi* as the principal vector. Argentina is currently in the process of certifying the elimination of malaria transmission and Paraguay was recently certified as malaria-free. Furthermore, Belize, Costa Rica, Ecuador, El Salvador, Mexico, and Suriname are close to eliminating the disease. Coordinated bilateral efforts are currently underway to put an end to malaria transmission in Haiti and the Dominican Republic. However, the expansion of gold mining—without the capacity for diagnosis, environmental management, vector control, or malaria prophylaxis and treatment—has produced local epidemics in the Guyana Shield, various countries throughout Central America, the Pacific coast of Colombia, various municipalities of Brazil, and in Venezuela (4).

Table 1. Distribution of VBDs in the Americas, 2013-2018

Country	Dengue	Chikungunya	Zika	Yellow fever	Malaria	Chagas disease	Cutaneous Leish.	Visceral Leish.	Onchocerciasis	Plague	Lynphatic filariasis	Schistosomiasis
Brazil	●	●	●	●	●	●	●	●	●	●	●	●
Ecuador	●	●	●	●	●	●	●			●		
Venezuela	●	●	●	●	●	●	●	●	●			●
Bolivia	●	●	●	●	●	●	●	●		●		
Guyana	●	●	●	●	●	●	●				●	
Peru	●	●	●	●	●	●	●			●		
Suriname	●	●	●	●	●	●	●					●
Argentina	●	●	●	●		●	●	●				
Colombia	●	●	●	●	●	●	●	●				
French Guiana	●	●	●	●	●	●	●					
Guatemala	●	●	●		●	●	●	●	●			
Mexico	●	●	●		●	●	●	●				
Panama	●	●	●	●	●	●	●					
Paraguay	●	●	●	●		●	●	●				
Costa Rica	●	●	●		●	●	●	●				
Dominican Republic	●	●	●		●		●				●	
El Salvador	●	●	●		●	●	●	●				
Honduras	●	●	●		●	●	●	●				
Nicaragua	●	●	●		●	●	●	●				
Belize	●	●	●		●	●						
Haiti	●	●	●		●						●	
Saint Lucia	●	●	●									●
Trinidad and Tobago	●	●	●	●								
United States	●	●	●							●		
Anguilla	●	●	●									
Antigua and Barbuda	●	●	●									●
Aruba	●	●	●									
Bahamas	●	●	●									
Barbados	●	●	●									
Bonaire, St. Eustachius	●	●	●									
Cayman Islands	●	●	●									
Curaçao	●	●	●									
Dominica	●	●	●									
Grenada	●	●	●									
Guadeloupe	●	●	●									●
Jamaica	●	●	●									
Martinique	●	●	●									●
Puerto Rico	●	●	●									●
Saint Barthélémy	●	●	●									
Saint Martin	●	●	●									
Saint Vincent	●	●	●									
Saint Martin (Hol.)	●	●	●									
Turks and Caicos Islands	●	●	●									
Virgin Islands of USA	●	●	●									
Bermuda	●	●										
British Virgin Islands	●	●										
Cuba	●		●									
Montserrat	●	●										●
Saint Kitts and Nevis	●	●										
Uruguay	●					●		●				
Chile						●						

* *Not all presently transmitted VBDs in the Americas are included.*
Leish.= Leishmaniasis
Source: PAHO/WHO

In the last three decades, dengue in the Region of the Americas has been characterized by recurring epidemic cycles of 3-5 years, and cases have been on the rise since 2000. Existing evidence indicates that transmission has spread to new geographical areas, such as the southern United States, and the *Aedes aegypti* vector has been found at higher altitudes in some Andean cities and towns. *Ae. albopictus* is another dengue vector that has spread in the Region (6).

Chikungunya virus and Zika virus appeared in the Region in the 2013-2014 and 2015-2016 periods, respectively. Infections caused by these viruses have been associated with cases of Guillain-Barré syndrome (7). As was previously pointed out, Zika virus poses a serious risk for pregnant women and children born with the infection. This highlights the need for good coordination among maternal and child health services and vector control programs.

Yellow fever is a reemerging and potentially epidemic mosquito-borne disease. Its prevention and control are based on vaccination of at-risk populations and rapid detection and treatment of cases. However, the sylvatic outbreaks that have occurred in Brazil since 2017 (8) highlight the need to strengthen surveillance of zoonotic yellow fever in nonhuman primates to monitor presence of the virus in *Haemagogus* and *Sabethes* mosquitoes involved in the sylvatic transmission cycle, and to eliminate *Ae. aegypti* populations in at-risk cities through effective vector control methods. Together, these measures can prevent urban transmission.

Vectors continue to be the principal mechanism for spreading the parasite that causes Chagas disease. Nearly six million people of the Region of the Americas, particularly families that live in substandard housing and some indigenous communities, are still chronic sufferers of this disease. Congenital transmission also remains a big problem. Food and beverages contaminated with Chagas disease vectors continue to cause local outbreaks of acute disease (9).

Leishmaniasis is another vector-borne parasitic disease (*Lutzomyia* spp.) whose incidence is increasing. It constitutes a significant health problem in the Region: every year some 55,000 cases of cutaneous and mucocutaneous leishmaniasis are reported, along with 3,500 cases in the visceral form. Leishmaniasis is more prevalent in vulnerable rural and peri-urban communities (10).

Unplanned urbanization and the immigration of settlers into forest habitats, such as agricultural or timber workers, have been associated with local outbreaks of Chagas disease and leishmaniasis.

In recent decades, progress has been made in the elimination of three other vector-borne parasitic diseases in the Region (onchocerciasis, lymphatic filariasis, and schistosomiasis), through preventive pharmacotherapy with antiparasitic drugs and the occasional use of vector control techniques. Onchocerciasis is currently only transmitted in the Yanomami indigenous area along the border between Brazil and Venezuela, while lymphatic filariasis has been almost eliminated from Brazil and is limited to a few foci in Guyana, Haiti, and the Dominican Republic. Similarly, active schistosomiasis transmission is limited to a few foci in Brazil, Suriname, and Venezuela (11).

Up-to-date information on the number of cases and distribution of the main VBDs in the Americas can be found on the official PAHO website: www.paho.org.

1.2. Context of vector control programs in the Americas

Historically, some initiatives led by WHO have promoted malaria and dengue control strategies. In the 1950s, with the availability of insecticides such as dichloro-diphenyl-trichloroethane (DDT) and synthetic drugs, as well as the results of some successful experiences, campaigns to eliminate *Ae. aegypti* and malaria met with varying results (12, 13). However, insecticide resistance caused the malaria elimination campaigns to fail in several countries (14).

Between 1950 and 1970, anti-malarial efforts succeeded in eliminating *Ae. aegypti* and, at least initially, preventing the re-urbanization of yellow fever in most countries of the Americas, although these results were not sustained over time (5). The initial success of insecticide-based vector control, which had a positive impact on public health, caused environmental management and other alternative methods to be neglected or even forgotten. Starting in the 1970s and 1980s, the effectiveness of these programs declined due to various economic, administrative, operational, and even biological issues, with resistance beginning to appear as the behavior of vector species began to change. All this caused a weakening of institutional action in different countries of the Region.

In the 1990s, a strategy of "Integrated and Selective Vector Management" (14) was attempted. This was based on a combination of control measures aimed at specific disease vectors but could not be consolidated due to different aspects related to program structures.

With the dawn of the new millennium, IVM was proposed, based on a more flexible, rational, and comprehensive approach which simultaneously considered control of the main insect vectors in endemic places, different control methodologies and strategies, and intersectoral action. However, in most countries of the Region progress has been slow due to the existence of operational barriers that hinder IVM's full incorporation into program routines (15).

The greatest obstacles to sustained application of this operational strategy have been problems specific to these diseases and structural deficiencies in the control programs.

Below are some examples of these problems in the context of malaria.

Specific gaps for malaria vector control:

- The main malaria vector control interventions—indoor residual spraying (IRS) and long-lasting insecticide treated nets (LLINs)—provide insufficient coverage. There are populations that could benefit from these interventions that are not currently covered.
- In some scenarios IRS and LLINs are being applied, but the operations do not comply with the recommended guidelines (quality of the interventions).
- Some countries use conventional interventions to reduce vector density, such as spatial application of insecticides, rather than the recommended interventions for malaria (IRS and LLINs). Spatial applications may use more resources and operating capacity than other actions (including diagnosis and treatment).
- In some countries, larva is controlled with larvicides or other measures rather than the main recommended interventions for malaria vector control.

Structural gaps in malaria (that may be common to arboviral diseases and Chagas disease):

- Limited entomological evidence to guide control operations; the need to develop an entomology network with systematic and standardized actions.
- Deficiencies in the stratification and management of information to prioritize interventions.
- Weaknesses in human resources trained in vector control operations; absence of a public policy on human resources for vector control.
- Problems in procurement processes for insecticides, LLINs, and vector control equipment.
- Absence of organized and evidence-based intersectoral management.

Further gaps include approaches that focus on each disease separately, the disjointedness of policies to manage school, home, and work environments, and a lack of coordination with other programs (15).

In view of the mixed results of vector control programs at local and regional levels in the various countries and regions of the Americas, in 2008 PAHO/WHO approved CD48/13 on *Integrated Vector Management: A Comprehensive Response to Vector-borne Diseases* (16). In response to the described failings, it proposed a new approach. This handbook seeks to adapt that initiative to the unique features of the Americas with respect to the most prevalent VBDs in the Region.

2. Scope and objectives

This document is aimed at decision-makers (entomologists and technical personnel) in local, regional, and national vector control programs, as well as professionals working in epidemiological surveillance. Its purpose is to compile clear and concise information on the relevant aspects of IVM (environmental, physical, mechanical, chemical, biological, and ecological vector control strategies and insecticide resistance, among others) to facilitate proper decision-making by inter- and intra-sectoral teams.

3. General considerations on integrated vector management

IVM is based on the lessons learned from integrated pest management (IPM) in the agricultural sector, which generated methodologies such as population monitoring, the threshold for action, and mechanical, biological, and microbiological pest control, while optimizing and streamlining the use of resources and control mechanisms.

IVM is defined as "a rational decision-making process to optimize the use of resources for vector control" (15). It seeks to improve the effectiveness and efficiency of national vector control programs to provide countries with long-term control methods that are sustainable and environmentally appropriate, making it possible to reduce dependence on insecticides and protect the population from the most prevalent VBDs.

VBDs such as dengue continue to be a serious public health problem in the Region. Epidemics have increased in severity (6), new arboviral diseases have emerged, and old arboviral diseases such as yellow fever have reemerged, with urban cases recorded for the first time in more than 50 years (17). *Ae. aegypti* populations continue to pose a threat and the introduction and spread of *Ae. albopictus* has opened new opportunities for arbovirus transmission.

For this reason, implementation of IVM requires the adaptation of institutions, appropriate regulatory frameworks, decision-making criteria, and procedures that can be applied at lower operating levels. It also requires decision-making skills that can facilitate intersectoral action and the establishment of sustainable vector control measures with health-based goals (15).

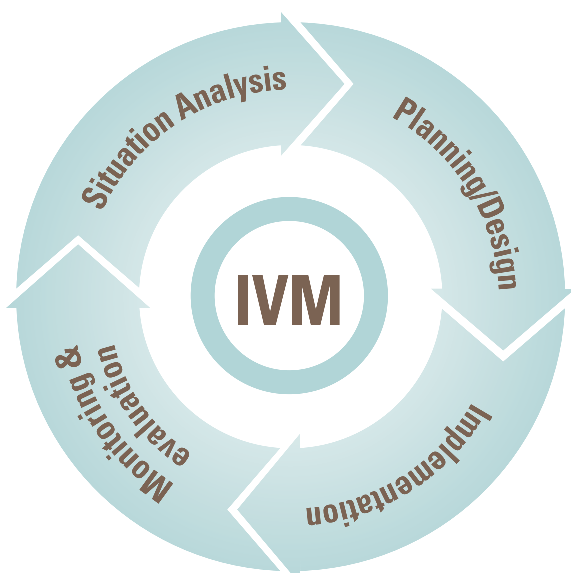
In addition, climate change and increased flooding and droughts, combined with a deficient piped water supply in many urban areas in the Americas, encourage people to store water at home, thereby increasing the risk for mosquito-borne epidemics. Increased average local temperatures and greater variation in regional rainfall facilitates vector reproduction and the transmission of parasites and virus. This could alter the distribution and incidence of VBDs over time and space (18).

A more mobile population and migration caused by political and economic instability facilitate the spread of VBDs. New diseases are introduced in areas where vector populations are not controlled, while massive influxes of susceptible people are coming to unplanned urban areas. Strengthening current control programs is therefore fundamental to protect against these risks. IVM provides an opportunity to address these changes effectively in an intersectoral context as part of a broader public health management plan (15).

IVM is characterized by evidence-based decision-making and may consist of different tools targeting a single VBD, or one or more tools used comprehensively against more than one VBD.

In view of all this, IVM is conceived as a flexible management system that can adapt to changing local conditions, following cyclical processes with multiple rounds of situation analysis, planning, design, execution, monitoring, and evaluation, among other elements (Figure 1).

Figure 1. IVM flow chart and some of its elements



IVM involves the following cyclical processes:

Situation analysis. We must know the distribution of VBDs and the vectors that transmit them in order to correctly plan control measures and prioritize resources. Disease can be assessed on two scales:

1) Large-scale analysis (national jurisdiction) and stratification by municipalities, provinces, departments, or states (according to the country). In this case the analysis consists of preparing endemicity maps, epidemiological data at the provincial level, and vector distribution. Programs may classify provinces, parishes, departments, or states according to the presence of VBDs, incidence, vector species, and vector ecology.

2) Local-level analysis (neighborhood, housing development, footpath, etc.) and stratification to include VBD microepidemiology, epidemiological data, environmental information, and population determinants. After the local analysis, one might consider targeting transmission areas, then proceed to characterize each area, and finally determine the interventions to carry out according to area of priority.

Planning and design. Depending on the interventions to be implemented, there are various chemical and non-chemical vector control tools that may be useful in controlling both adults and larvae or nymphs. It is important to select vector control methods for their effectiveness with respect to the epidemiological parameters (prevalence and incidence of infection or disease), although evidence of their effectiveness against vectors may be useful in some circumstances.

However, when choosing control methods, other factors should be considered, since some control methods are less effective in given environments or ecological areas. These factors are:

- characteristics of the vector species (breeding, feeding, and resting sites, main activity times, insecticide resistance, etc.);
- human and environmental safety, availability, and cost-effectiveness;
- community acceptance and participation;
- logistical requirements for implementing the intervention.

Other factors to be considered are, for example: best time for the intervention, areas in which it will be carried out, entities that will participate in the application, and monitoring and evaluation.

Aspects to consider in the areas of execution are the target populations of the intervention, geographical size, and the goals of vector control (control or elimination). On the other hand, although the health sector bears primary responsibility for IVM, it is important to involve different sectors (public and private), as well as the community.

Implementation. First of all, it is advisable to use interventions whose effectiveness is well established; these should be adapted to the entomological, social, and behavioral parameters of the place.

Periodic and regular entomological surveillance must be conducted throughout the IVM program, although the objectives and parameters to be measured may change depending on the status of the program and the vectors. The main entomological parameter to be measured is vector density (adults and/or larva-like stages), although others are also important, particularly insecticide susceptibility.

Vector surveillance may be done by the entomology team alone or in tandem with community participation after some training (this has been effective for triatomine surveillance). The intervention unit must be defined (block, footpath, etc.) as well as the unit of evaluation (breeding site, house, etc.). Furthermore, there must be checks and evaluations prior to the intervention. When there are sentinel or pilot sites, it is important to consider factors such as endemicity of the disease, ecological areas, accessibility of the intervention site, and the use of insecticides in the area.

Monitoring and evaluation. Clear indicators should be established for monitoring the success of the program by measuring them with time scales and verifiable data sources for each indicator. Indicators can be specific to a disease or intervention, for example: number of LLINs distributed and effect on the burden of disease. A sound data management system must be established to record information on the indicators; its findings should be shared regularly. External evaluators should be in charge of monitoring and evaluating the program to avoid any conflicts of interests. Furthermore, if possible, this evaluation should include the participation of other social and community entities (15).

4. Elements of the integrated vector management strategy

Implementation of IVM does not require new structures, but rather proper integration and coordination of existing structures. To this end, WHO points out five main elements of the IVM strategy (see Table 2):

1) integrated approach;
2) evidence-based decision-making;
3) intrasectoral and intersectoral collaboration;
4) advocacy, social mobilization, and legislation;
5) capacity building.

Table 2. Key elements for application of the IVM strategy (adapted from the WHO Handbook for Integrated Vector Management, 2012 [15])

	Element	Description	Requirements
1	Integrated approach	Addressing several diseases by combining different control tools. Application of both chemical and non-chemical control methods. Integration with other disease control methods, such as vaccines and drugs.	Information system for VBD surveillance (cases and vectors) and control methods used. Collegial body within the health sector that periodically analyzes the health situation on the basis of evidence. Ratio of VBDs in the country, by region. Identification of regions with locations that have more than one VBD. Inventory of types of control methods, by country and region. Plan to incorporate new control technologies.

2	Evidence-based decision-making	Adaptation of strategies and interventions to local vector ecology and to the epidemiology of the disease, guided by operational research and subject to routine monitoring and evaluation.	Identify evidence to justify the actions taken Capacity to carry out operational studies for IVM.
3	Intrasectoral and intersectoral collaboration	Collaboration within the health sector and with other public and private sectors. Planning and decision-making at the most basic local levels. Inclusion of the community in decision-making.	Collegial body that includes public health and other public and private sectors to periodically analyze the health situation based on evidence. Technical Advisory Groups to support evidence-based decision-making. Identification of the most local level with authority to make operational decisions based in local conditions.
4	Advocacy, social mobilization, and legislation	Promotion and embedding of IVM principles in the design of policies at the ministry, and in the most relevant agencies and civil society. Establishment or strengthening of regulatory and legislative controls for public health. Engagement and empowerment of the community, which enhances sustainability.	Are there any health promotion and mass communications programs available to promote the principles of IVM? What is the legal framework associated with IVM? Which measures have been applied? Is there a map of social actors? If there is, do they participate in IVM?
5	Capacity building	Availability of infrastructure and financial and human resources at the central and local level. Training and education in accordance with the IVM curriculum.	Survey of human, physical, and financial resources available for IVM. Registry of training available at the central and local levels. Diagnosis of training needs at the central and local levels. Training and continuing education plan.

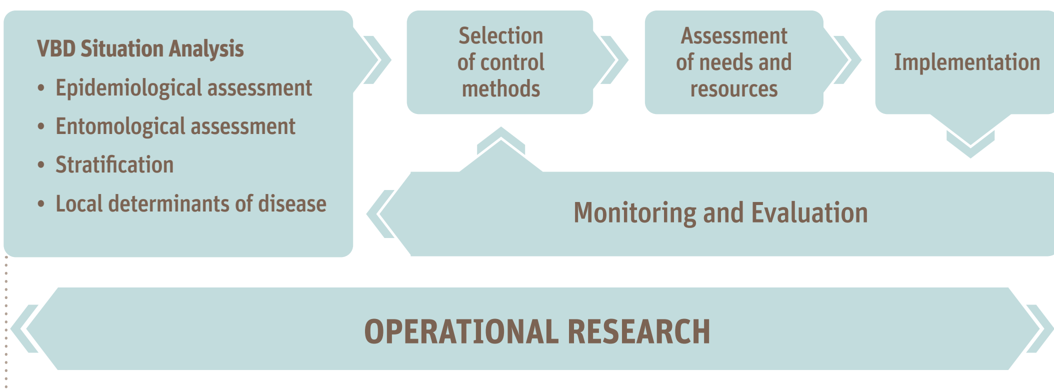
4.1. Integrated approach

IVM consists of applying various vector control methods that have proven to be effective when used alone or in combination with others. Multiple methods may be used against a single disease, while one or more methods can be applied to several diseases. These methods may be chemical or non-chemical. And IVM can be complemented with vaccines, mass drug administration, or diagnosis and treatment, to achieve integrated disease control.

Because a single vector (such as *Ae. aegypti*) can transmit more than one disease, IVM can be used to control the many diseases (in this case dengue, chikungunya and Zika) acting through that species. Some interventions (e.g., mosquito nets, LLINs) are effective against several vector species, making them effective in vector control both for malaria and leishmaniasis.

An integrated approach is comprised of several activities that should be carried out cyclically (Figure 2). Operational research should be carried out for each activity to identify any obstacles that might limit the intervention.

Figure 2. Activities that comprise an integrated approach to IVM

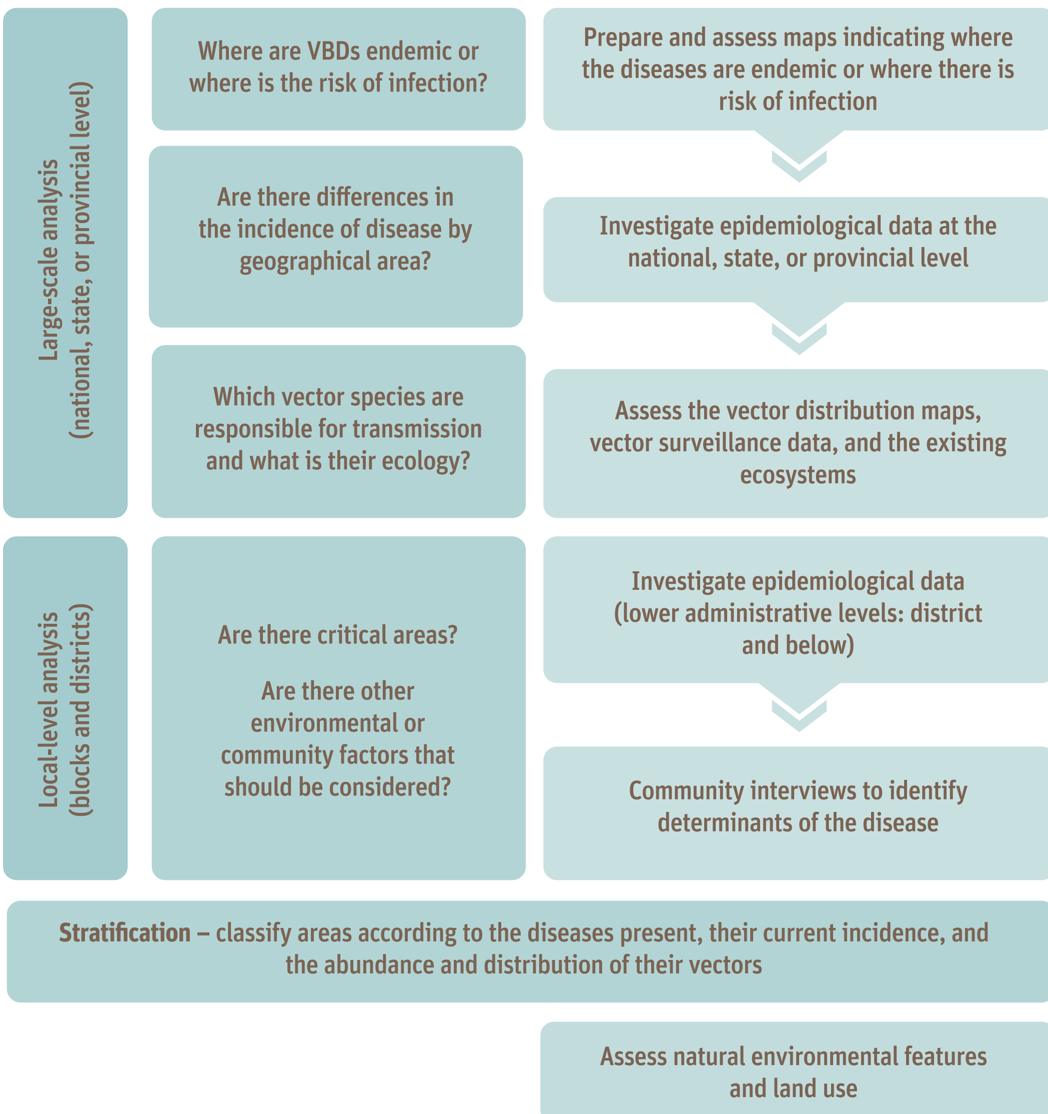


4.1.1. Situation analysis of vector-borne diseases (VBD)

Insofar as possible, before implementing IVM a joint assessment should first be conducted of the epidemiological and entomological information and of the local determinants of the most prevalent VBDs. This will make it possible to prepare stratified disease maps and determine the priority intervention areas.

For the situation analysis, it is essential to have support both within and outside the health sector and to include community representatives in decision-making. Some key elements to be included in the situation analysis are illustrated in Figure 3.

Figure 3. Key elements to include in the situation analysis



The main elements to be used for the situation analysis are described below.

4.1.1.1. Epidemiological assessment

Epidemiological assessment is the first step toward determining the burden of disease or diseases in the communities under study. It is necessary to determine where disease transmission is most intense in order to target resources there. It is essential to use the epidemiological surveillance systems of each country, as they provide information related to the spatial distribution and the temporal dynamics of VBDs. This facilitates decision-making and is important for monitoring and evaluation.

The burden of disease can be measured based on data for incidence, prevalence, and mortality, which can be complemented with lost days of work or school. In order to interpret them correctly in situations where they are not yet standardized by program, disease data must be known, such as incubation period, chronic or asymptomatic forms of infection, reservoirs, other forms of transmission such as mother-to-child, etc.

4.1.1.2. Entomological assessment

For IVM, it is essential to correctly to determine which vector species are present in certain habitats and regions and when they can be expected to increase in abundance and activity. Entomological surveillance systems in each country provide information on the spatial-temporal distribution of vector species.

According to WHO (19), before implementing a control strategy, the following issues should be considered (with the support of experts or academics, as needed):

- Which species are expected to be present according to the types of ecosystems? *This assumes knowledge of the bionomics and ecology of the species.*

- Are the species considered to be vectors actually responsible for transmitting the disease? *This assumes knowledge of vector competence and vectorial capacity. Vector competence is the capacity of the insect to be infected and the capacity of the pathogen to multiply inside the insect in order to be subsequently transmitted. Vectorial capacity refers to the effectiveness of pathogen transmission by species of insects already proven to be competent vectors; it includes variables such as abundance, longevity, survival, a preference for human beings or other reservoirs, and habits related to transmission (frequency of bites in the case of salivary transmission or pathogen regurgitation, and frequency of defecation in the case of fecal transmission).*

- Where and at what time of year do vector breeding sites proliferate, or is there greater abundance of the vector in the transmitting stages?
- When and where do vectors bite and rest? *This assumes knowledge of circadian variations (peak biting times of day or night) and whether hematophagous feeding and rest take place within or around the domicile area.*
- Are the species of vectors susceptible or resistant to the insecticides used in the control programs?
- What are the principal or the most productive breeding sites? *Important information for targeting actions.*

A series of entomological indices has traditionally been used for the entomological monitoring of vector presence and abundance in localities. Table 3 presents the most commonly used indices for vectors of the main VBDs. Figure 4 presents an entomological surveillance method using ovitraps.

These entomological indices can also be useful for monitoring and evaluating intervention strategies. But there should be consistence between the control measure used and the index. For example, if the control method used was social intervention for the elimination of *Ae. aegypti* breeding sites, an indicator such as the container index should be selected.

Table 3. Principal entomological indices of the disease-transmitting vectors *Aedes, Anopheles, Culex, Lutzomyia,* and triatomines (20-23)

Stage	Method	Entomological index	Calculation	*Aedes*	*Anopheles*	*Culex*	*Lutzomyia*	Triatomines
Egg	Ovitrap	Positivity Index	Number of ovitraps with eggs/total ovitraps × 100	×				
		Ovitrap Density Index	Total of eggs ovitraps with eggs/total positive ovitraps × 100	×				
Larva	Active search	Container Index	Number of containers with larvae/total containers × 100	×				
		Dwelling index	Number of dwellings with containers with larvae/total of dwellings inspected × 100	×				
		Breteau Index	Number of containers with larvae/total of dwellings inspected × 100	×				
		Index of potential containers	Number of potential containers + Number of containers with larvae/total of dwellings inspected × 100	×				
		No. of larvae per ladle (ladle method)	Number of ladles positive/ Total number of ladles		×			
Nymph	Active / passive search	Colonization Index	Total of dwellings with nymphs/total dwellings inspected × 100					×
Pupa	Active search	Pupas Index	Number of pupas/ total dwellings inspected × 100	×				
		Index of pupas per area	Number of pupas/area inspected	×				
		Index of pupas per person	Number of pupas/ Number of people in the inspected dwellings	×				

Stage	Method	Entomological index	Calculation	*Aedes*	*Anopheles*	*Culex*	*Lutzomyia*	Triatomines
Adult	Active search	Index of adults	Number of dwellings with adult mosquitoes/ total of dwellings inspected × 100	×		×		
		Index of dwellings with female mosquitoes	Number of dwellings with female mosquitoes/total of dwellings inspected × 100	×				
		Index of adult mosquito density	Number of female mosquitoes/Number of dwellings with female mosquitoes × 100	×				
	Human attractant	Bite/landing* rate	Number of mosquitoes/ person/hour × 100*	×	×			
	Sticky trap	Index of adults per trap	Number of mosquitoes/ total of traps × 100	×			×	
	BG trap	Index of adults per trap	Number of mosquitoes/ total of traps × 100	×				
	Pregnant female trap	Index of adults per trap	Number of mosquitoes/ total of traps × 100	×				
	CDC trap	Index of adults per trap	Number of mosquitoes/ total of traps × 100	×	×	×	×	
	Shannon trap	Index of adults per trap	Number of mosquitoes/ total of traps × 100	×	×	×	×	
	Active search	Infestation index	Number of dwellings infested with triatomines/total of dwellings inspected × 100					×

*According to ethical criteria: Achee NL, Youngblood L, Bangs MJ, *et al.* Considerations for the use of human participants in vector biology research: a tool for investigators and regulators. *Vector Borne Zoonotic Dis* 2015; 15: 89-102.

Figure 4. Ovitraps for the monitoring of *Ae. aegypti*

Source: Ministry of Health ofCampo Grande, Brazil, ArboAlvo Project (a, b). Ministry of Health of Medellin, Colombia (c).

4.1.1.3. Stratification

The stratification process is required for IVM because it facilitates good decision making on where to place control resources. However, since the risk of the disease is not uniform over space and time, it is important to determine the causes of these variations. Stratification is the classification of areas according to the intensity and risk of transmission, as well as the abundance of vectors, to determine which control approaches are needed. In the case of malaria, for example, stratification is based on an analysis of receptivity and vulnerability. Geographic information systems (GIS) can be used to generate layered maps indicating areas with the greatest prevalence of disease.

Some spatial factors are strongly associated with the incidence of disease—such as vector density, topography and altitude, rainfall, ecosystems, and other social factors. These favor increased VBD incidence, as does a lack of planning in home construction and in water storage needs. Each scale must be analyzed separately, considering human occupancy, the presence and density of vectors, and the operating capacity of the local health team.

4.1.1.4. Local determinants of disease

The epidemiology of VBDs is complex and depends on several local factors. Factors that affect the spread of VBDs are the determinants of disease. It is important to understand all these determinants in order to take appropriate action to mitigate risk.

The determinants of disease can be divided into four interacting categories:

- Determinants related to the pathogens, e.g. the serotypes of dengue virus, *Plasmodium* and *Leishmania* species, or the DTU (discrete typing units) of *Trypanosoma cruzi*.
- Determinants related to the vectors: dominant species for a region.
- Determinants related to human activities, such as cultural, behavioral, and political factors that affect transmission.
- Determinants related to the environment.

VBD control programs primarily affect two categories of determinants: pathogens and vectors. But the goal of IVM is to address all the critical determinants whenever possible. If there is no action on the environmental and human determinants, the vectors will continue to proliferate, and communities will remain at risk. Thus, after the epidemiological and entomological assessment, there should be an analysis of the environmental and social determinants, in accordance with the results of interviews and prior knowledge of the disease. This will yield appropriate stratification and situation analysis to move to the next stages, such as selection of the local control methods that evidence indicates will be the most effective. As with all the previous topics, this information can be complemented with requests for data from experts and academics.

4.1.2. Selection of the control methods

Control methods can be environmental, mechanical, biological, or chemical. To ensure selection of the most suitable control measures, it is necessary to weigh the advantages and disadvantages of the methods in the local context, along with community acceptance. Table 4 lists the main control methods available and their application to various vectors.

Table 4. Principal measures used to control the disease-transmitting vectors *Aedes, Anopheles, Culex, Lutzomyia*, and triatomines (24-29)

Control measures					*Aedes*	*Anopheles*	*Culex*	*Lutzomyia*	Triatomines
Environmental control									
Environmental improvements	Housing improvements				×	×	×	×	×
	Collection of waste and other materials				×	×	×	×	×
	Improved sewerage				×	×	×		
Drinking water supply					×	×	×		
Urban planning					×	×	×	×	×
Mechanical/physical control									
Approaches to reduce density or increase vector mortality	Elimination of vector breeding sites	Washing			×		×		
		Covering	Covers		×		×		
			Screens		×		×		
		Drainage			×	×	×		
		Fill-in			×		×		
		Waste disposal			×				
Approaches to reduce human/ vector contact	Mosquito nets				×	×	×	×	×
	Door and window screens				×	×	×	×	×
	Suitable clothing				×	×	×	×	
Biological control									
Natural enemies					×	×	×	×	×
Biological larvicides					×	×	×		
Entomopathogenic fungi									×
Chemical control									
Approaches to reduce density/ increase vector mortality	Adulticides	Focal intervention	Spraying inside homes and ancillary buildings	Residual spraying		×		×	×
				Thermal spraying	×				
				Fogger					×
		Perifocal intervention	Extradomiciliary spraying	Ultra-low volume spraying	×				
	Larvicides	Chemical insecticides			×	×	×		
		Growth regulators			×				

Approaches to reduce human/ vector contact	Impregnated mosquito nets	LLINs	×	×	×	×	×
		Traditional nets	×	×	×	×	×
	Personal repellents		×	×	×	×	
	Insecticide impregnated net		×	×	×	×	×
	Insecticide impregnated curtains		×	×	×	×	×
New technologies							
Release of mosquitoes with endosymbiotic bacteria			×				
Release of transgenic mosquitoes			×	×			
Release of irradiated mosquitoes			×	×			

When taking chemical measures, it is necessary to have information on insecticide resistance. Periodic monitoring of adulticide and larvicide resistance according to the WHO guidelines is recommended, as well as periodic quality control checks on application methods. It should be stressed that surveillance is a fundamental component of insecticide resistance management programs, since it provides basic information for early detection of resistance. This makes it possible to plan alternative control measures through proper selection of insecticides. Familiarity with resistance mechanisms in vector populations helps when selecting insecticides.

When a vector population is known to be resistant to traditional insecticides, the main recommendation is not to increase the dose or frequency of application, but to consider using another insecticide with a different action mechanism.

It is recommended that products be rotated to avoid insecticide resistance; *i.e.*, use two or more types of insecticides with different action mechanisms and alternate them periodically. Also, different insecticides may be used in different areas of a locality.

New technologies should be considered complementary, not as substitutes of already existing control methods, as their epidemiological impact has not yet been verified.

4.1.3. Assessment of needs and resources

Once the most appropriate control methods for the local situation have been selected, it is important to take stock of available financial, human, and technical resources and determine what additional minimum resources are needed. This inventory should include potential funders to support the activities. Partnerships and collaboration with other local programs or public services should be considered, in order to coordinate activities and avoid duplication of efforts. Potential sources of funding include national vector control programs, municipalities, districts, and other public or private actors.

The amount and type of resources needed depends on the diseases and vectors targeted by the intervention. For example, for species primarily found in farming and ranching areas, close collaboration with the agricultural sector is required. For vectors that breed in peridomestic environments, a strong component of community participation is required.

The method selected for vector control also affects the kinds of resources needed. For example, indoor residual spraying requires trained operators working under supervision, which means proper programming and major financial and logistical support.

Depending on the determinants of disease identified and the IVM strategies selected, the health sector may need to get involved, with contributions from healthcare services, other vector programs, immunization, maternal and child health, primary care, etc., in addition to other governmental sectors (environment, infrastructure, education, armed forces) and the private sector (human and veterinary health, tourism, transportation, mass media, etc.).

Local requirements for training and strengthening should be identified. It is also important to strengthen the roles and training of people in the community, in the health sector and, if appropriate, in the agricultural sector, who could benefit from short courses on vector biology and ecology and control methods. The training and experience of agricultural workers in integrated pest management is an important resource.

In the case of malaria, for example, several indicators should be considered when selecting interventions (30):

- technical determinants: full walls in dwellings, endophilic and endophagic *Anopheles* species, groups of dwellings, vector insecticide sensitivity, population density, etc.;
- operational determinants: number of formally trained personnel, sustainability of coverage higher than 80%, social acceptance of the interventions, capacity of the entomology team to characterize breeding sites and monitor larval density, breeding sites susceptible to intervention, conducting complete cycles, evaluations of entomological efficacy, etc.

4.1.4. Implementation

Local implementation of the strategy can begin after conducting a situation analysis, defining the priority areas of intervention, selecting the most appropriate control methods, and determining the resources needed. It is imperative to first identify the activities, roles, and responsibilities of the intervention team. It is also essential that stakeholders in various sectors and community representatives participate in this step, to ensure the sustainability of the control strategies.

Additionally, prior to implementation, the objectives and timetable for implementation and use of resources should be established. Insofar as possible, control measures should address several vectors or VBDs if they occur simultaneously. Section 5 gives step by step details for implementation of the IVM strategy.

4.1.5. Monitoring and evaluation

It is important to carry out periodic monitoring and evaluation of the strategy's implementation (process) and impact (outcome). A monitoring schedule should be followed for each planned activity, to allow for timely correction of any deviations that are detected. For evaluation, the outcomes and expected impact should be considered and a series of indicators should be established for each area evaluated. If possible, there should be benchmark values for IVM performance in each intervention area.

Monitoring and evaluation should be adjusted to local conditions and the intervention level (regional, national, subnational, local, etc.).

Below is a description of indicators that may serve as benchmarks for each element of IVM. They are taken from a sample of indicators in the PAHO Plan of Action on Entomology and Vector Control 2018-2023, which can be used Region-wide (31).

Table 5. Indicators for the different elements of IVM

Elements	Process indicator
Integrated approach	Number of countries and territories that have established a task force for multisectoral engagement in vector control (including vector control during emergencies/outbreaks) that has convened in the past 12 months and developed a national vector control work plan
	Number of countries and territories with vector control programs using data and information (e.g., temperature, rainfall, climate, environment, potable water, sanitation and waste management, infrastructure and housing) from various sources for integrated decision-making within the vector control programs
Evidence-based decision-making	Number of countries and territories that have established or strengthened their entomological surveillance system and database in accordance with PAHO/WHO guidelines and/or recommendations
	Number of countries and territories that have established or strengthened a system for the monitoring and management of vector resistance to insecticides used in public health, in accordance with PAHO/WHO guidelines and/or recommendations
Intrasectoral and intersectoral collaboration	Number of countries and territories that have national or territorial plans or programs for water and sanitation improvement, housing improvement, and/or urban planning that include entomological risk as a factor for prioritizing actions and conducting assessment and studies.
Advocacy, social mobilization, and legislation	Number of countries and territories in which the health authorities have prepared plans or agreements for effective community participation, engagement, and mobilization at the national, regional, and local level (including local health services) with sustainable commitments in vector control
Capacity building	Number of countries and territories that have concluded or updated their existing vector control needs assessment (work force, entomology, and vector control capacity and structure) through a consultative process within the past 24 months, in accordance with PAHO/WHO guidelines and/or recommendations
	Number of countries and territories with staff from national health authorities and/or their supporting institutions trained in entomology, vector control, and IVM, in alignment with the national vector control needs assessment
	Number of countries and territories that have used a national or regional institution or network to conduct a training or education program (degree/diploma/certificate) that included entomology, vector control, and IVM in the past 24 months

Impact indicators should refer to changes in the outcomes of epidemiological surveillance in the short, medium, and long term. They should secondarily refer to changes in entomological surveillance outcomes.

Impact indicators should also complement the process indicators that are usually part of programs and are reported periodically regarding resources used and activities carried out during a time period, as well as instrument quality control (quality of equipment, supplies and staff procedures), that are also subject to periodic evaluation.

4.2. Evidence-based decision-making

The selection and implementation of control methods should be based on knowledge of local vector ecology, insecticide resistance in the vector population, local determinants of disease, and the epidemiological situation. The community's acceptance of the intervention measures should also be confirmed.

IVM programs should also be accompanied by monitoring and evaluation of the strategy's impact on vectors and diseases. Operational research priorities should be set, and studies should be conducted that yield information relevant to the program.

All this information must be analyzed as a whole. This will facilitate the best decision-making, with the objective of the interventions established beforehand.

Evidence-based decision-making for IVM takes place almost every step of the way, especially in the selection criteria for the control strategy and the periodic analysis of outcomes. This makes it possible to improve the effectiveness of actions, which can be adapted to situations that evolve over time. Collaboration within the health sector and with other sectors, including academia, can facilitate this (see information below on the situation room).

4.3. Intersectoral and intrasectoral collaboration

IVM should be a collaborative endeavor in which the health sector and other sectors, such as the ministries of agriculture, education, and housing, local governments, community groups, and nongovernmental organizations (NGOs) all work together.

If there are different vector control programs or health programs not directly related to vectors that mobilize the community (e.g., immunizations, lactation), it is important to coordinate and integrate these activities to make efficient use of resources and avoid overburdening the community.

The health sector has traditionally been in charge of vector control programs, although other governmental agencies share responsibility for certain control methods and in certain specific regions. For example, environmental management in farming areas, road construction, mining, and peri-urban areas are directed and administered by the ministries of agriculture and of the environment and by local governments (state, provincial, departmental). In addition, in economic development areas such as plantations, mines, and hotel complexes, the private sector is responsible, under the supervision of the ministry of health.

In all the scenarios described above, it is advisable to have a situation room in which to evaluate epidemiological events of interest, with the participation of representatives of the community and of the aforementioned sectors.

Figure 5. An example of intersectoral collaboration for housing improvement in areas endemic for Chagas disease

Source: Carlota Monroy collection, University of San Carlos (USAC), Guatemala. Photo by Belter Alcántara, Applied Entomology Laboratory (LENAP-USAC)

4.4. Advocacy, legislation, and social mobilization

IVM should be efficiently communicated by promoting and integrating the concept into the policies of the most relevant ministries, organizations, and civil society. Engaging and empowering communities to enhance the sustainability of IVM should be one of the objectives of the program. Administrative procedures and legislative controls for public health should be established or strengthened, to determine whether the regulatory framework is suitable to the IVM strategies proposed for each administrative level. If not, the necessary changes must be made.

Advocacy work is also necessary to achieve political commitment, help secure the resources needed for the intervention, and place this item on the work agendas in the different sectors. Through community activism and lobbying, some of these interventions can be sustainable.

Figure 6. Tire recycling, specifically mandated by the Ministry of the Environment of Brazil, National Council of Environment (Resolution 416 of 2009)

Source: Bank of images - SUCEN/SP

4.5. Capacity building

IVM relies on the skills and capacity of personnel at different levels. Therefore, it should be accompanied by continuing education to improve and maintain the knowledge and skills of personnel at the national, departmental, and local levels.

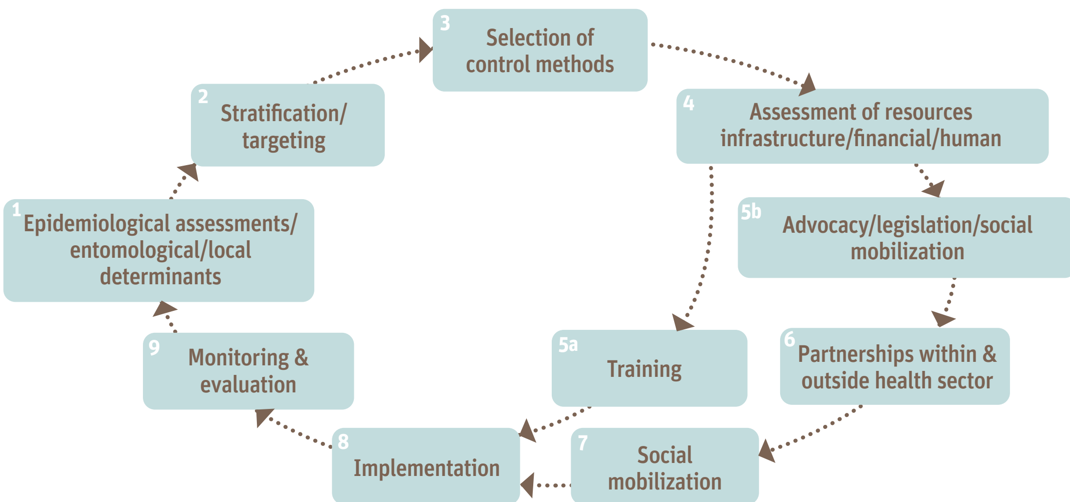
Capacity building is a great challenge for IVM programs since it entails a significant financial investment in the training of staff linked to the program. The hope is that human resources who receive training will have job stability and will remain in the institutions responsible for the program.

As previously stated, determining the needs for training and continuing education is an essential element of planning for different timeframes.

5. An example of integrated vector management implementation at the local level

Below is an example of the sequence for IVM implementation at the local level (Figure 7). This is merely an example: IVM programs should be tailored to specific scenarios and local conditions.

Figure 7. Flow chart for IVM implementation at the local level



5.1. Situation analysis and characterization of the principal vector-borne diseases and their local vectors

A working group should be set up to analyze information available on the area, list all the VBDs present, and select priority diseases for intervention. Once the VBDs are selected, an inventory will be prepared for each vector species, along with the vector's distribution, abundance, and insecticide resistance.

It must be determined whether there are priority population subgroups for the VBDs present in the area, and whether they require special interventions. It is fundamental to involve the community in these decisions.

The high-risk geographical areas for VBDs should be mapped out according to epidemiological and entomological indicators, taking into account timing, coverage, periodicity, and the resources needed for control.

Risk assessment can be more precise if indicators such as the following are included:

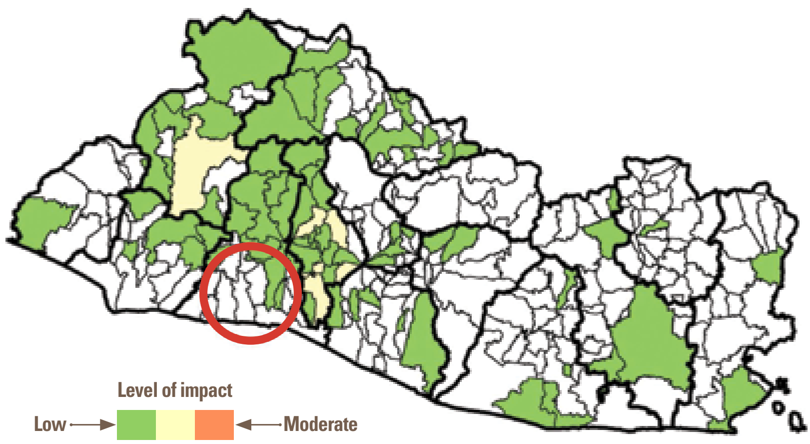
- temperature, rainfall, and relative humidity;
- social organization and community participation;
- coverage of household piped water supply;
- waste collection.

Figure 8. Coordinated vector control working group in the municipality of Belo Horizonte (Brazil)

Source: Fabiano Geraldo Pimenta Júnior collection

Figure 9. An example of epidemiological and entomological analysis of dengue, chikungunya, and Zika in El Salvador, 2018

Stratification of municipalities based on epidemiological and entomological criteria for arboviruses (dengue, chikungunya, and Zika), El Salvador, October 2018



Alert level	#
Severely impacted municipality	0
Moderately impacted municipality	6
Lightly impacted municipality	72
Municipalities not impacted	184

Epidemiological and entomological criteria used for each of the 262 municipalities

Standardized morbidity ratio (SMR) for suspected dengue cases (95% CI)
SMR of suspected chikungunya cases (95% CI)
SMR of suspected Zika cases (95% CI)
SMR of confirmed dengue cases (95% CI)
SMR of confirmed serious dengue cases (95% CI)
SMR larvae in dwelling
Percentage of dwelling with no intervention
Population density

Source: Ministry of Health of El Salvador

5.2. Stratification

First, the areas suitable for intervention must be selected, based on local dynamics for the transmission of each VBD. IVM interventions should be targeted in time and space, for different kinds of epidemiological scenarios: routine control, elimination, outbreak response, etc.

It should be kept in mind that critical areas of the main VBDs may be in high transmission areas or may appear in scattered foci when transmission drops off substantially. For this reason, the situation room should periodically analyze the situation and the results of IVM to decide whether the initial stratification needs to be modified (Figure 7, steps 9 to 1 again).

Geolocation and geographic information systems can be used to guide IVM activities. Control programs can use their ties to scientific institutions to access more complex GIS systems to identify clusters of cases or vectors or critical areas in time and space. Identifying these areas may be useful when planning control activities.

Figure 10. Identifying blocks with clusters of mosquitos positive for Zika virus and determining vector control interventions in the municipality of Boca del Río, Veracruz (Mexico)

Source: Images from Azael Che Mendoza.

5.3. Selection of control methods

The purpose of IVM is to optimize the use of various resources for vector control. For this reason, different measures for control or elimination of the vector—both chemical and non-chemical—should be considered. Furthermore, if different vectors or VBDs coexist in a single area, it is recommended to use strategies that can attack all of them at the same time.

From the list of possible interventions in an area (i.e. those that have real potential for implementation), those with the most evidence of success should be selected; or failing this, those that enjoy expert consensus. The best choice is evidence-based interventions that can control vectors for more than one disease in the intervention area. When deciding on a control measure, it is also important to assess the insecticide resistances of the vectors.

Once the vector control interventions are chosen, a quick inventory must be done for each intervention to determine its requirements in terms of human resources, critical supplies, machinery, equipment, and vehicles, as well as costs to ensure technical quality, timeliness, coverage, and periodicity.

The choice of control methods should be based on information including epidemiological, entomological, and other decision-making data so that priorities can be set (for areas and/or risk periods), specific or combined interventions can be carried out, and the population can be alerted, and also to allow greater participation by other sectors that are important for the sustainability of the control measures.

Table 4 presents the principal measures used in IVM. Because it is advisable to give due consideration to community acceptance of the control measures, the community should be involved in selecting them.

5.4. Resource assessment

The installed capacity for the intervention in the local setting must be determined, as well as any adverse factors that may hinder the operation. It is also necessary to determine the control measures available in the area (physical, chemical, biological, and environmental), and to ensure that there are sufficient trained personnel, critical inputs, required machinery and equipment, and a structure for planning, monitoring, supervision, and evaluation.

5.5. Advocacy, legislation, and social mobilization

IVM implementation starts with planning. Then, health sector institutions make their contributions, followed by other related sectors working in the public or private sphere (city government, social development, education, tourism, local industries, etc.).

Within these partnerships, a group of leaders needs to mobilize resources to implement IVM. This group will also set the agenda for meetings with other sectors and with the community.

In IVM, community participation is, by definition, a goal that should be achieved through health promotion and communication. Ideally, community participation should be reflected in the following achievements:

- VBDs are recognized as a priority;
- medical care is timely;
- planning is participatory;
- the control measures undertaken by the health sector are accepted and supported;
- the community collaborates in activities to protect families and individuals.

Figure 11. Community engagement and empowerment workshop, Bi-national project to eliminate malaria on the Hispaniola island (Haiti and Dominican Republic)

Source: PAHO/WHO

5.6. Training

First of all, the skills and abilities of the operational personnel must be assessed. This will determine the IVM training program to be followed (insecticide and equipment handling, biosafety, community engagement strategies, etc.). It is essential to provide continuous training and to ensure that the acquired skills are maintained. Attention must also be paid to specific training in management/administration and in how to record and analyze results at the local level.

Figure 12. Technical materials developed by countries in the Region

Source: Ministry of Public Health and Social Assistance (Dominican Republic); Ministry of Public Health and Social Welfare (Paraguay); Ministry of Public Health and Social Assistance (Guatemala).

5.7. Implementation

IVM must be implemented by a multidisciplinary team with expertise in the different components of the control plan. Social communications should be adjusted for the different stages of the plan: importance of VBDs, invitation to express opinions on what to include in the plan, publicizing the general plan, description of areas in which community participation is sought, benefits of the plan, evaluation of the plan, recognition of community participation, opportunities for engagement, etc.

The operators should be in charge of implementing the plan, following the guidelines established by the multidisciplinary team in the working group.

5.8. Monitoring and evaluation

The IVM program should be monitored on an ongoing basis, so that timely adjustments can be made if things deviate from the original plan. In addition, for a proper evaluation, there should be indicators for each activity, in order to keep the results aligned with the program's objectives. The results of the evaluation will determine the next steps to follow in the situation analysis, in order to continue the IVM cycle.

6. Operational research

According to WHO and USAID (32), operational research is the systematic application of research techniques to decision-making to achieve specific results. Hence, operational research should be geared to the priority needs of a program, generating a body of knowledge to customize strategies and interventions. This information is most useful for decision-makers, who can use it to improve program operations.

Operational research can be a continuous process with five basic steps:

1. Identify the problem and diagnose it
2. Select a strategy
3. Experiment with strategies and evaluate them
4. Disseminate information
5. Use the information in decision-making

This process is designed to enhance efficiency, effectiveness, and the quality of the services provided, as well as the availability, access, and acceptance of the services users want (Figure 13).

Figure 13. Basic steps in operational research

Among the features that distinguish operational research from other types of research are the following:

1) It addresses specific problems in specific programs, rather than general health issues;
2) It follows systematic procedures of qualitative and quantitative data collection, to compile evidence that supports decision-making;

3) It identifies a problem to investigate, designs an experiment, carries it out, analyzes it, and interprets the results with a view to improving the interventions;

4) It is only satisfactory if the results can be used to make decisions about the program; that is, mere publication is not a valid indicator in this type of research.

There are many potentially effective products for disease control that have had very limited impact on the burden of disease (20). Below is a non-exhaustive list of some examples of operational research:

- studies on vector ecology
- evaluation of insecticide resistance
- efficacy, effectiveness, and performance of current methods
- efficacy, effectiveness, and performance of new vector control measures

Following are some examples of specific operational research initiatives in Latin America and the Caribbean, whose results have been useful for improving the effectiveness of control programs:

- In Brazil, 12 years of monitoring insecticide resistance confirmed high levels of resistance, which was decisive in the Ministry of Health switching from temephos to another group of insecticides recommended by WHO (33).
- In Guatemala, a study to evaluate the effect of impregnated mosquito nets on malaria vectors led to a recommendation to use impregnated nets before the rainy season arrived. The findings showed that education was needed to convince the population not to wash the mosquito nets during malaria transmission season, from June to October (34).
- Regarding Chagas disease and the spread of strictly household vectors: technical fundamentals and experience acquired with the species *Rhodnius prolixus* (in Central America, Colombia, and Venezuela) and *Triatoma infestans* (in the Southern Cone) indicate that transmission can be interrupted and that complete elimination can be achieved in the short or medium term with systematic chemical control (21).

7. Final considerations

IVM implementation signals a paradigm shift for VBD control programs in the Americas. Its objective is to promote greater impact and sustainability, and to make control interventions more effective and durable than traditional programs.

IVM poses organizational and operating capacity challenges for the Region's current control programs, but these must be adapted before, during, and after the introduction of IVM.

To implement IVM programs in the Americas, the following fundamental aspects should be taken into account:

- use a variety of data sources (epidemiological, entomological, environmental, sociodemographic, etc.) for stratification;
- include community members and representatives of non-health sectors in the situation room working group to ensure proper decision-making;
- use a variety of control strategies when conducting IVM, leaving the use of chemical products as a last resort;
- conduct studies on local determinants of disease and on insecticide resistance in the most relevant VBD vectors.

8. Bibliography

1. United Nations Development Program. Human Development Report for Latin America 2013-2014. Citizen Security with a Human Face: Evidence and proposals for Latin America. New York: UNDP; 2013.

2. Global Burden of Disease Collaborative Network. Global Burden of Disease Study 2010 (GBD 2010) Results by Cause 1990-2010. Seattle, United States: Institute for Health Metrics and Evaluation (IHME), 2012.

3. Cucunubá Z, Nouvellet P, Conteh L, et al. Modelling historical changes in the force-of-infection of Chagas disease to inform control and elimination programmes: application in Colombia. *BMJ Global Health* 2017; 2: e000345.

4. Pan American Health Organization. Plan of Action for Malaria Elimination 2016-2020. 55th Directing Council of PAHO, 68th session of the WHO Regional Committee for the Americas; Washington, D.C., USA, 2016 Sep 26-30. Washington, D.C.: PAHO; 2016 (Document CD55/13).

5. Padilla JD, Pardo RH, Molina J. Manejo integrado de los riesgos ambientales y el control de vectores: una nueva propuesta para la prevención sostenible y el control oportuno de las enfermedades transmitidas por vectores. *Biomedica* 2017; 37 (2): 7-11.

6. Dick OB, San Martín JL, Montoya RH, et al. The history of dengue outbreaks in the Americas. *Am J Trop Med Hyg* 2012; 87 (4): 584-593.

7. Weaver SC, Charlier C, Vasilakis N, et al. Zika, chikungunya, and other emerging vector-borne viral diseases. *Annu Rev Med* 2018; 69 (1): 395-408.

8. Pan American Health Organization. Epidemiological Update: Yellow Fever. 20 March 2018. Washington, D.C.: PAHO/WHO; 2018.

9. Henao Martínez A, Kolborn K, Parra Henao G. Overcoming research barriers in Chagas disease — designing effective implementation science. *Parasitol Res* 2017; 116 (1): 35-44.

10. Pan American Health Organization. Leishmaniasis: Epidemiological Report of the Americas. Washington, D.C.: PAHO/WHO; 2015.

11. Lammie PJ, Lindo JF, Secor WE, et al. Eliminating lymphatic filariasis, onchocerciasis, and schistosomiasis from the Americas: breaking a historical legacy of slavery. *PLoS Negl Trop Dis* 2007; 1 (2): e71.

12. Pan American Health Organization. Informe de la campaña de erradicación de *Aedes aegypti* en las Américas. Publication No. 48. Washington, D.C.: PAHO; 1960. pp. 8-10.

13. Epelboin Y, Chaney SC, Guidez A, et al. Successes and failures of sixty years of vector control in French Guiana: what is the next step? *Mem Inst Oswaldo Cruz* 2018; 113 (5): e170398.

14. Pan American Health Organization. Control selectivo de vectores de malaria: guía para el nivel local de los sistemas de salud. Washington, D.C.: PAHO; 1995.

15. World Health Organization. Handbook for integrated vector management. Geneva: WHO; 2012.

16. Pan American Health Organization. Definition of integrated vector management (position paper on integrated vector management - document HTM/NTD/VEM). Washington, D.C.: PAHO; 2008.

17. P an American Health Organization. Situation of Yellow Fever in the Americas; 1960-2008. CE142 Technical Report. 2008.

18. Kraemer MU, Sinka ME, Duda KA, et al. The global distribution of the arbovirus vectors *Aedes aegypti* and *Ae. albopictus*. *eLife* 2015; 4: e08347.

19. World Health Organization. Position Statement on Integrated Vector Management (document WHO/HTM/NTD/VEM/2008.2). Geneva: WHO; 2008.

20. Special Programme on Research and Training in Tropical Diseases. Implementation Research Toolkit. Geneva: WHO; 2014.

21. Silveira AC. Transmisión vectorial de *Trypanosoma cruzi* y su control. In: Pan American Health Organization and Inter-American Development Bank. Programa regional para el control de la enfermedad de Chagas en América Latina. Iniciativa de bienes públicos regionales. PAHO/IDB: 2010.

22. Bowman LR, Runge-Ranzinger S, McCall PJ. Assessing the relationship between vector indices and dengue transmission: a systematic review of the evidence. *PLoS Negl Trop Dis* 2014; 8 (5): e2848.

23. World Health Organization. Control of the leishmaniases: report of a meeting of the WHO Expert Committee on the Control of Leishmaniases, Geneva, 2010 Mar 22-26 (WHO technical report series; no. 949). Geneva: WHO; 2010.

24. Rozendaal JA (ed). Vector control: methods for use by individuals and communities. Geneva: WHO; 1997.

25. Pan American Health Organization. State of the art in the Prevention and Control of Dengue in the Americas. Meeting Report (28-29 May, 2014, Washington, DC). Washington, D.C.: PAHO; 2014.

26. World Health Organization. Control of Chagas Disease. Second report of the WHO Expert Committee (WHO technical report series; no. 905). Geneva: WHO; 2002.

27. World Health Organization. WHO recommendations for achieving universal coverage with long-lasting insecticidal nets in malaria control (September 2013 - revised March 2014). Geneva: WHO; 2014.

28. World Health Organization. Larval source management: a supplementary measure for malaria vector control: an operational manual. Geneva: WHO; 2013.

29. Courtenay O, Gillingwater K, Gomes PA, et al. Deltamethrin-impregnated bednets reduce human landing rates of sandfly vector *Lutzomyia longipalpis* in Amazon households. *Med Vet Entomol* 2007; 21 (2): 168-176.

30. Centers for Disease Control and Prevention. Malaria — Great Exuma, Bahamas, May – June 2006. MMWR 2006; 55 (37): 1013-1016.

31. Pan American Health Organization. Plan of Action on Entomology and Vector Control 2018-2023. 56th Directing Council of PAHO, 70th Session of the Regional Committee of WHO for the Americas; Washington, D.C., USA, 23-27 September 2018. Washington, D.C.: PAHO; 2018 (Resolution CD56.R2).

32. United Nations Children's Fund, United States Agency for International Development, World Health Organization, Special Programme on Research and Training in Tropical Diseases, UNAIDS. Marco para la investigación operativa y ejecución dentro de los programas de salud y control de enfermedades. Geneva: WHO; 2008.

33. Chediak MG, Pimenta FG, Coelho GE, et al. Spatial and temporal country-wide survey of temephos resistance in Brazilian populations of *Aedes aegypti*. *Mem Inst Oswaldo Cruz* 2016; 111 (5): 311-321.

34. Richards FO, Zea Flores R, Sexton JD, et al. Efectos de los mosquiteros impregnados con permetrina sobre los vectores de la malaria en el norte de Guatemala. *Bol Oficina Sanit Panam* 1994; 117 (1): 1-11.

9. Annex

Some experiences with IVM implementation in the Americas

1. Cutaneous leishmaniasis in French Guiana, 1983-1986

Alert context: The annual incidence of cutaneous leishmaniasis (CL) in French Guiana was 0.25% between 1976 and 1983 and mainly affected young men who were in contact with the sylvatic cycle (deforestation, mining, military training, hunting). However, during that same period, incidence was 3.8% in the village of Cacao.

Situation analysis: ***Cases:*** *a)* Until 1983, there had had been 123 cases of CL with no differences between the sexes or age groups. There was an annual census and individual records on diagnosis and treatment at the only dispensary in Cacao; *b)* A cumulative spatial grouping of the cases was done, toward the western outskirts of the village. ***Vectors:*** *Lutzomyia umbratilis* infected with *Leishmania guyanensis* were captured in Cacao proper and, in greater abundance, in the forest environment, where there was a sylvatic reservoir in *Choloepus didactylus* (two-toed sloths). ***Local background:*** Cacao was founded in 1977, 80 km from Cayenne, on the Comté river after the deforestation of a 9-hectare area, which was settled by some 700 Hmong refugees from Laos, a country non-endemic for CL. Two forested areas remain next to the new village: a 12-hectare patch to the west and an area of gallery forest to the southeast. ***Integrated analysis:*** Hypothesis of peridomestic transmission from overflow of the sylvatic cycle and proximity of dwellings to the jungle.

Vector control strategy—method and application: ***Objectives:*** *a)* To reduce the number of cases of CL in Cacao. *b)* To eliminate peridomestic vector populations in Cacao. ***Methodology:*** *Vector control during the period of least abundance: a)* a 400-meter mechanical barrier: elimination of the western jungle patch; *b)* Chemical mitigation: daily application during the month of deforestation in the deforested area (to protect workers and prevent spreading to the village) and in Cacao (peridomestic colonies). *Community awareness campaign:* Information on the epidemiology of CL and the objectives and methodology of the strategy. *Clinical surveillance:* Four months among deforesters and three years among Cacao residents. *Entomological surveillance:* In 50-meter wide corridors parallel to the western border, standardized capture was done in a randomly selected dwelling (community volunteers). *Study of reservoirs:* Edge observation with bait traps. *Basics:* Information on the behavior of Cacao residents, vector ecology and dispersion area, seasonality of cases and vectors, and CL incubation period. ***Needs and resources:*** *a)* Sectoral coordination of care, research, and vector control (Office de la Recherche Scientifique et Technique Outre-Mer, Institute Pasteur de Cayenne, malaria control), municipal health team, community; *b)* Human resources: three deforestation machine operators, 10 woodcutters, five members of the malaria control service, and two scientists. ***Indicators:*** Number of human cases during three transmission seasons, vector abundance index, and presence of reservoirs before the intervention and at 0, 6, 12, and 18 months following it.

Monitoring and evaluation: *a)* No case of CL among the deforestation workers; *b)* In Cacao, there were seven cases the first year (six in young men), one case the second year in the gallery forest, and no case the third year. In other localities of the department, there was regular incidence of 77-79 cases/year; *c)* Abundance index of *L. umbratilis:* at the beginning, the ratio between the jungle patch and the village of Cacao was 14.3:1; after deforestation, the patch declined 110-fold, while in town it increased 20%, then gradually declined. After 18 months no vectors were detected in town or in the jungle patch (during peak vector season). There were no infected vectors. On the southeastern border where there was no intervention, abundance maintained its annual pattern; *d)* Five months after the intervention, sloths, opossums, and rodents were observed in the residual jungle; one year later, there were no tree-dwelling reservoirs close to the village of Cacao.

IVM basics: Stratification according to the distribution of cases and vectors. Combined strategy of mechanical and chemical actions where there was the greatest evidence at the time, based on the local context and knowledge of the vector ecology and epidemiology of the disease, with proper planning of monitoring and evaluation. Integration of intra- and intersectoral work with community participation.

Figure 1. Map of the village of Cacao and surrounding forests (inset, location of French Guiana)

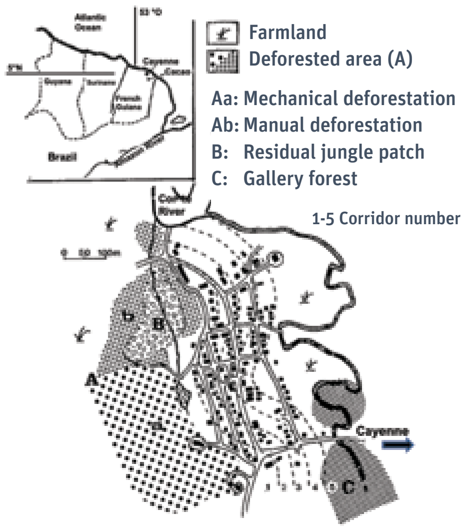


Image from June 2019

Source: Adapted from Esterre P, Chippaux JP, Lefait JF, Dedet JP. Évaluation d'un programme de lutte contre la leishmaniose cutanée dans un village forestier de Guyane française. *Bull World Health Organ* 1986; 64 (4): 559-565.

2. Chagas disease: Southern Cone Initiative, subregional scale

Alert context: In the 1990s, studies of seroprevalence and burden of disease showed that Chagas disease continued to be a serious public health problem in the Southern Cone countries. Scientific evidence and the experience of the programs, some of which had more than 40 years of field operations, made it possible to attempt a technically feasible, evidence-based, and socially acceptable control strategy. The countries of this region had recently returned to democracy and were both sensitive to social issues and politically cooperative. This made it possible to implement a coordinated and economically sustainable strategy.

Situation analysis: The epidemiological situation, level of organization of national programs, background, and control results were all heterogeneous among and within the Southern Cone countries. The countries with more developed programs had information on vector surveillance at the level of locality and residence, as well as seroprevalence and incidence of acute cases on different subnational scales. This made it possible to stratify risk, prioritize interventions, and plan resources. In the countries with less developed programs, it was feasible to reproduce the strategies used by the first group, according to local modalities. Distribution of infection was considered an indicator of vector risk in clustered spatial groups, taking into account limitations related to the time between subclinical infection and mother-to-child transmission, although the focal level was taken into account for acute vector-borne cases (and in the recent outbreaks of oral Chagas disease).

Vector control strategy–method and application:

Objectives: *a)* To interrupt vector-borne transmission by the principal vector in the region: *Triatoma infestans; b)* To avoid transfusion transmission (other forms of non-vector transmission are not described in this section).

Implementation: In July 1991, the Ministers of Health of Argentina, Bolivia, Brazil, Chile, Paraguay, and Uruguay (later Peru, by invitation), together with PAHO (technical secretariat) under the Southern Cone Initiative (INCOSUR), created an intergovernmental commission to prepare and implement a subregional plan for the elimination of *T. infestans*. During technical meetings they agreed upon a strategy, standardized the methodology, indicators, and information systems, and identified training and logistical coordination needs. Joint annual critical analysis and monitoring meetings were held.

Basics: Knowledge of *Tri. infestans* domiciliary and peridomiciliary ecology. This species has been introduced in many of the endemic areas and has a long life cycle; toxicity of pyrethroids; no recorded resistances. Information on expected impact of the strategy from cost-effectiveness models and pilot studies of interventions with temporal continuity and spatial contiguity. Effective treatment during recent infections and younger age groups. Furthermore, the transmission cycle is related to inequitable distribution of wealth, which causes structural problems (poor housing quality, overcrowding, inadequate access to health services) that exceed the capacity of health systems and require multisectoral initiatives. Social and cultural issues should also be considered, such as community organizing, risk perceptions, practices in and around the home, socioeconomic status, personal agency, and migration.

Methodology: *Vector control:* Initial chemical intervention with pyrethroids against household populations of triatomines in two selective cycles of the domiciliary-peridomiciliary area, in infested localities, six months to one year apart, and control of focal re-infestation. Mechanical intervention (depending on the jurisdiction), reducing vector resting places in the dwelling. *Vector surveillance:* Initial and functional periodicity (consistent with vector cycle and risk of active or passive reinfestation), by program personnel (person-hours) and, where possible, through community engagement (to identify the vector, report it, know who to report to and what to expect, and receive a response in proper time and form). *Cases:* Seroprevalence studies, monitoring of acute cases and appropriate treatment. *Evaluation:* According to standardized methodologies and indicators, evaluations of performance and outcomes in selected localities, through personnel shared between countries and jurisdictions. *Inter- and intrasectoral activities:* Integration of other areas of government and the private sector to improve housing, engage the community in surveillance and in housing improvements for health, raising awareness in the health care system. *Activities among countries:* Training of field agents and horizontal cooperation for bilateral interventions in border areas.

Needs and resources: Calculated according to the programmatic needs of countries and jurisdictions, geographical survey, housing census and census data, and identification of local resources for permanent surveillance. Need for training and performance evaluation (international and national), workshops, handbooks, and procedures manuals.

Indicators: By locality and accrued on the scale of first and second subnational jurisdiction. *Process indicators:* Operational ones (e.g., number of dwellings treated, visited for surveillance, etc.) and consumption of inputs. Entomological indicators on presence and abundance, by species and domestic unit site and transmission indicators: seroprevalence in younger age groups (initial, monitoring, and outcome).

Monitoring and evaluation: Between 1991 and 2012, the initiative held 19 annual meetings. At the last one, the interruption of vector-borne transmission of *T. cruzi* by *T. infestans* was certified through international assessments in Uruguay, Chile, the non-Amazon part of Brazil, and in seven provinces of Argentina. There was a significant reduction throughout the entire Southern Cone. In almost all of the countries, housing improvement plans were implemented and legislation was enacted to address other modes of transmission. The experience of each country was capitalized by exchanging knowledge and creating other subregional initiatives with the Amazon countries (AMCHA),[9] the Andean countries (IPA),[10] and the Central American countries (IPCA).[11] Complementary impacts included strengthening of the existing evidence, promoting the search for more effective alternatives, strengthened local capacity, reduced vector density, and reduced likelihood of passive dispersion. On the other hand, the limitations and risks of the consolidation stage were exposed, such as a loss of sustainable surveillance activities due to the paradox of success leading to the prioritization of resources for other emergencies, and the relative increase in other forms of transmission, of extra-domiciliary vector populations, and of vector populations below the sensitivity threshold of surveillance methods.

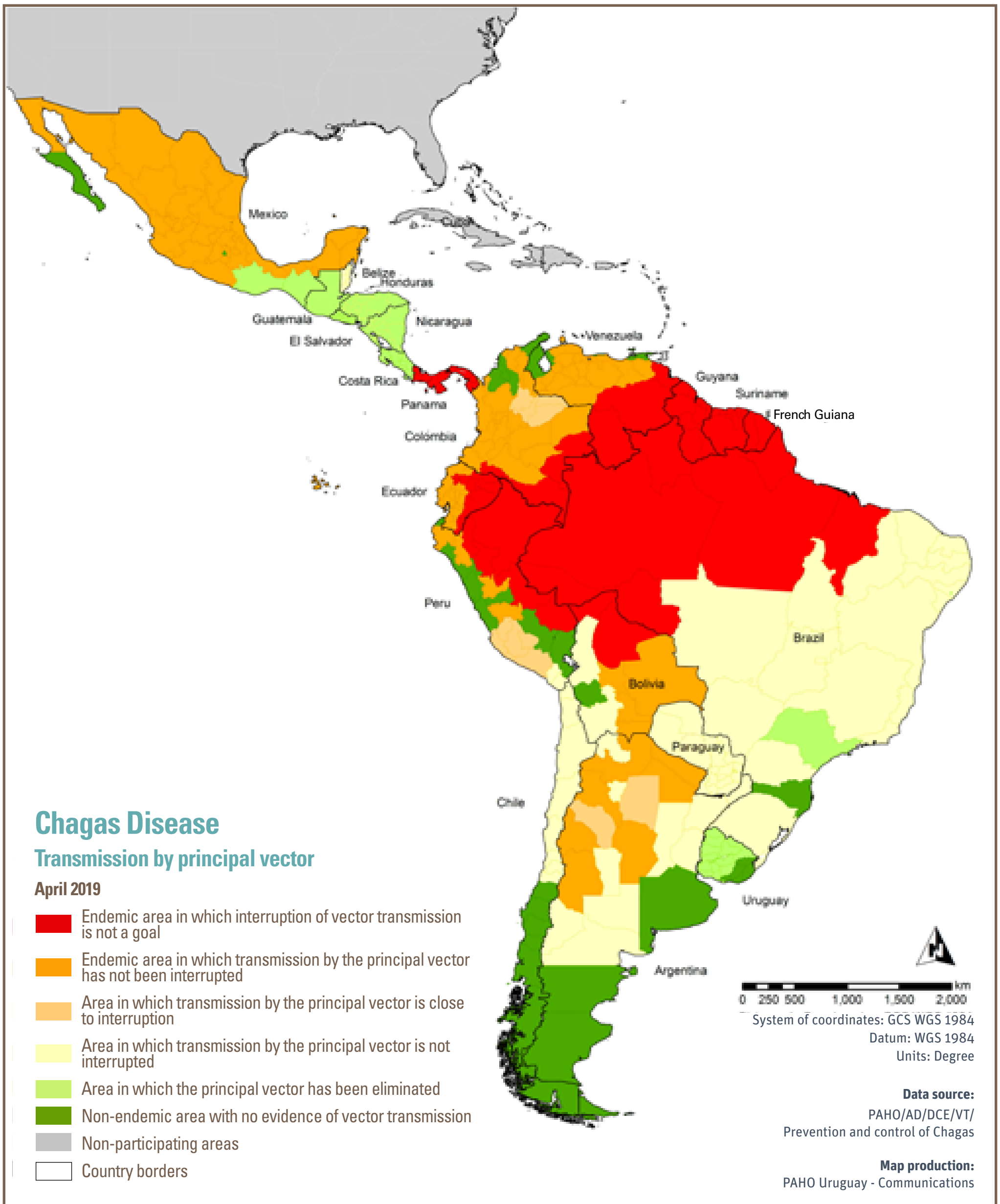
IVM basics: Stratification according to the distribution of vectors and cases. The strategy used methods for which there was the most evidence at the time, based on the context and knowledge of vector ecology and epidemiology of the disease, with proper planning of the evaluation and subregional monitoring to allow for periodic reprogramming. Integration of intra- and intersectoral work with local resources and community participation.

9 Iniciativa de los Países Amazónicos para la Vigilancia y el Control de la Enfermedad de Chagas (AMCHA) [Initiative of the Amazon Countries for the Surveillance and Control of Chagas disease (AMCHA)].

10 Iniciativa de los Países Andinos de Control de la Transmisión Vectorial y Transfusional de la Enfermedad de Chagas (IPA) [Initiative of the Andean Countries for the Control of Vector-borne and Transfusion Transmission of Chagas Disease (IPA)].

11 Iniciativa de los Países de América Central para el Control de la Transmisón Vectorial, Transfusional y la Atención Médica de la Enfermedad de Chagas (IPCA) [Initiative of the Countries of Central America for Control of Vector-borne and Transfusion Transmission of Chagas Disease and Medical Care (IPCA)].

Figure 2. Map with stratification of the risk of transmission of Chagas disease in the Americas, 2019



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3. Haiti/Dominican Republic Binational Strategy for the Control and Elimination of Malaria: the experience of Ouanaminthe-Dajabón

Context and situation: Hispaniola (home to the sovereign States of Haiti and the Dominican Republic) is the only Caribbean island with malaria transmission.

In 2007, nearly 33,000 confirmed cases and 200 deaths were reported on the island (total population 20 million). Haiti accounted for 90% of the cases.

Situation analysis: The Global Fund to Fight AIDS, Tuberculosis, and Malaria awarded sizable grants to Haiti and the Dominican Republic to fight malaria during the 2009-2013 period.

With the support of PAHO/WHO and financial assistance from the Carter Center, since October 2008 the two countries have been conducting a pilot project in the border area of Ouanaminthe (Haiti) and Dajabón (Dominican Republic).

Vector control strategy method and implementation: This pilot project tapped into the experience and institutional capacity of the Ministry of Public Health of Haiti and its National Malaria Control Program (PNCM), as well as the Ministry of Public Health of the Dominican Republic and its National Center for the Control of Tropical Diseases (CENCET). The project applies a comprehensive package of interventions, including:

- rapid diagnostic tests;
- weekly review of surveillance by the binational team to monitor data quality;
- joint efforts to map the transmission area and vector control measures (indoor residual spraying (IRS), treatment and elimination of breeding sites, and insecticide impregnated bed nets (LLINs));
- evaluation of the interventions and entomological strategies;
- social mobilization.

In the social sphere, community workers do active case-finding and use a social communication strategy including radio shows and megaphones to continuously disseminate messages about prevention measures (proper use and care of LLINs, acceptance of IRS, and elimination of breeding sites), the symptoms of the disease, adherence to antimalarial treatment, etc.

In 2012, the Haitian PNCM distributed almost three million LLINs throughout the country. In Dajabón more than 15,000 mosquito nets have been distributed since 2014, covering almost the entire at-risk population.

The antimalarial programs of both countries received technical assistance to train staff in laboratory microscopy and entomology. Training focuses on various tasks, including data collection, data quality control, mapping of breeding sites, epidemiological surveillance with stratification of populations according to risk, and vector control. With support from the Malaria Zero Alliance, entomology personnel are trained in IRS.

Monitoring and evaluation: The success of this pilot project lies in the joint strategy of these two provinces, which facilitated a new binational approach for malaria control and elimination. The outcome has been excellent: the positivity rate in the area fell from 3.5% in 2012 to 0.3% in 2016. The project took first place in the 2017 Malaria Champions competition (tying with another project in Brazil).

IVM basics: Combined strategy that uses different methods of surveillance (risk stratification, active and passive case-finding) and control (rapid diagnosis, mosquito nets, IRS) according to the context and knowledge of vector ecology and epidemiology of the disease; an integrated approach with the participation of different institutions in planning, training of personnel, and the identification of human, material, and financial resources; integration of intra- and intersectoral work with local resources and community participation.

Figure 3. Surveillance, control, and community mobilization activities in the malaria elimination project along the border of Haiti/Dominican Republic (Ouanaminthe-Dajabón), 2017

Source: PAHO/WHO.

4. Control of *Aedes aegypti* breeding sites through the "Recycle for Your Own Good" program in the Mexican city of Mérida

Context: Studies conducted in Mérida through a collaborative effort of the Autonomous University of Yucatán and the Yucatán Health Services (SSY) found that the most productive breeding sites (with the largest number of pupas that produce adult mosquitoes) were "cans and buckets" and "various small plastic objects" (associated with cooking and washing), which the population considers useful. It was believed that targeting control on the cans and buckets alone could reduce the *Ae. aegypti* pupa populations by more than 50%.

Situational analysis: *Ae. aegypti* breeds in water stored in different containers around human dwellings. Actions to reduce immature populations (eggs, larvae, and pupas) tend to rely on chemical control of breeding sites that cannot be removed, as well as the elimination of disposable containers, through various health promotion and community participation strategies.

Integrated analysis: Traditional breeding site reduction and elimination strategies, and the use of larvicides, clearly have had little effect. For this reason, it was decided that the fight against the dengue vector should be strengthened through organized community participation to promote recycling and the elimination of containers that the population considers useful but are the biggest breeding sites.

Vector control strategy—method and application: In 2013, the Government of Yucatán launched the "RxB" program (*"Recicla por tu Bienestar"* ["recycle for your own good"]) through the SSY, in coordination with the ministries of Social Development, Urban Development, the Environment, and Public Education, with the participation of the municipalities. The program originated in the experience of two other programs carried out by the city of Curitiba (Brazil) during the 1990s for the collection of household garbage (*"Lixo que não é lixo"*[12] and "*Compra do lixo*"[13]). These initiatives promoted recycling in supermarkets, where recyclable material collection centers were installed, with an incentive system (free bus tickets and vouchers for the purchase of goods, including groceries) in exchange for each bag of recyclables. In 2011, the RxB program was established in the state of Quintana Roo under the name "Reciclando basura por alimentos" [*Recycling trash into food*], in order to promote a culture of recycling by exchanging large volumes of reusable food containers from the

12 Portuguese for "trash that's not trash."
13 Portuguese for "trash for sale."

basic food basket, to support health and family budgets. After this experience, the Government of Yucatán introduced RxB as a multisectoral program within its "Dengue-free Yucatán" campaign, coordinated through different municipalities, ministries, and public and private institutions.

Objective: Significantly reduce important *Ae. aegypti* breeding sites in containers the population considers useful, where traditional strategies have not worked, and promote recycling at the same time.

Methodology: RxB: A public awareness campaign to encourage the separation of unused household solid waste. In exchange for recycling, points or credit is issued for each kilogram and type of recyclable turned in. These can be exchanged for basic grocery items, electronic devices, and sports equipment (Figure 4). The strategy has been implemented every week since February 2013 in neighborhoods with high entomological and epidemiological risk, according to the assessment carried out by SSY. *Entomological surveillance:* Impact on breeding site presence and abundance of *Ae. aegypti*, comparing samples taken before and after the intervention, breeding site typing surveys, and pupae counts.

Needs and resources: Research, intersectoral coordination of care, vector control, municipality, community.

Monitoring and evaluation: Individual assessments of the RxB program have shown a significant reduction in the number of positive containers (relative risk [RR] = 0.33; $p < 0.05$) and dwelling positivity for *Ae. aegypti* (odds ratio [OR] = 0.41). The impact of the buckets is significantly reduced, both in number of positives (RRI = 0.34; $p < 0.05$) and in positive presence in dwellings (OR = 0.44; $p < 0.05$). RxB's success in controlling both productive and unused *Ae. aegypti* breeding sites in Mérida (Yucatán, Mexico) suggests that this strategy should be a best practice for countries where dengue is endemic. It is a good example of integrated vector control, particularly regarding evidence-based decision-making, advocacy, social mobilization, and collaboration of the health sector with other sectors such as environment, social development, education, and industry.

IVM basics: Integrated approach with the involvement of different institutions in planning activities; integration of intra- and intersectoral work with local resources and community participation. Entomological assessment with knowledge of vector ecology to identify the best control method.

Figure 4. Activities of the "Recycle for Your Own Good" program in different neighborhoods of the city of Mérida (Yucatán, Mexico), 2013

Source: Jorge Alfredo Palacios Vargas.

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